Analysis of Responses to the Call for Evidence for Biomass Strategy on the Role of Biomass in Achieving Net Zero

This summary report was commissioned by the Department for Business, Energy and Industrial Strategy (BEIS).

Table of Contents

Executive Summary

From April 2021 to June 2021, the Department for Business Energy and Industrial Strategy held a call for evidence to inform the development of the upcoming biomass strategy. In total, 144 responses were received and analysed. The call for evidence was divided into four chapters focusing on supply, end uses, sustainability and accounting, and innovation. The key findings and recommendations by chapter are provided below. Response rates by chapter varied, but included a broad range of stakeholder groups, as displayed in Figure 1.

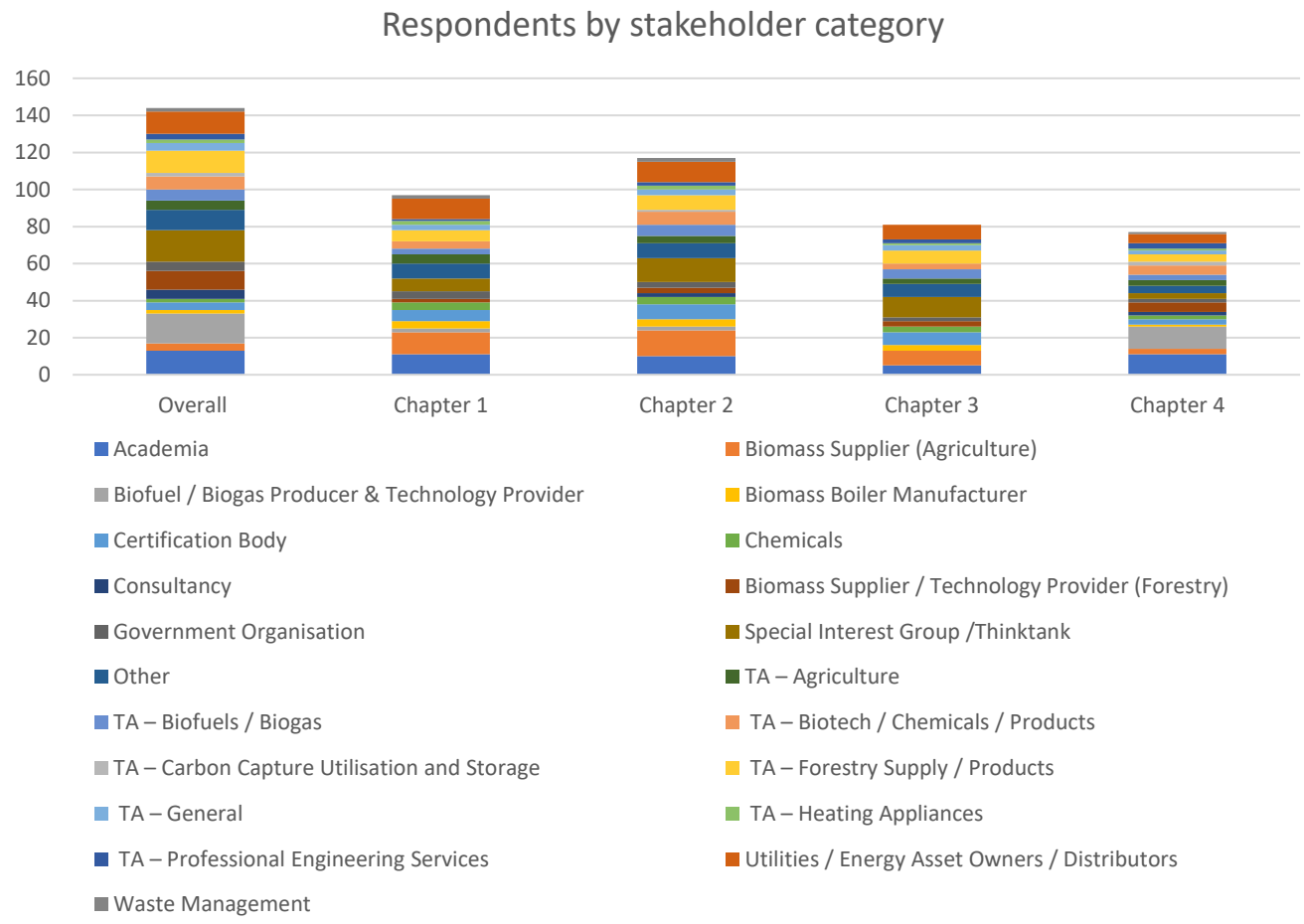

Figure 1 - Respondents categorised by stakeholder type[1]

[1] Note: category names shortened, i.e. TA refers to Trade association / representative Group.

SUPPLY

Chapter 1 of the call for evidence explored the variety of biomass feedstock types from domestic and international sources and sought information on the potential size and makeup of domestic biomass resource from different sources, as well as on the current and potential future costs of these biomass resources. Overall, 97 responses were submitted for the Questions in chapter 1.

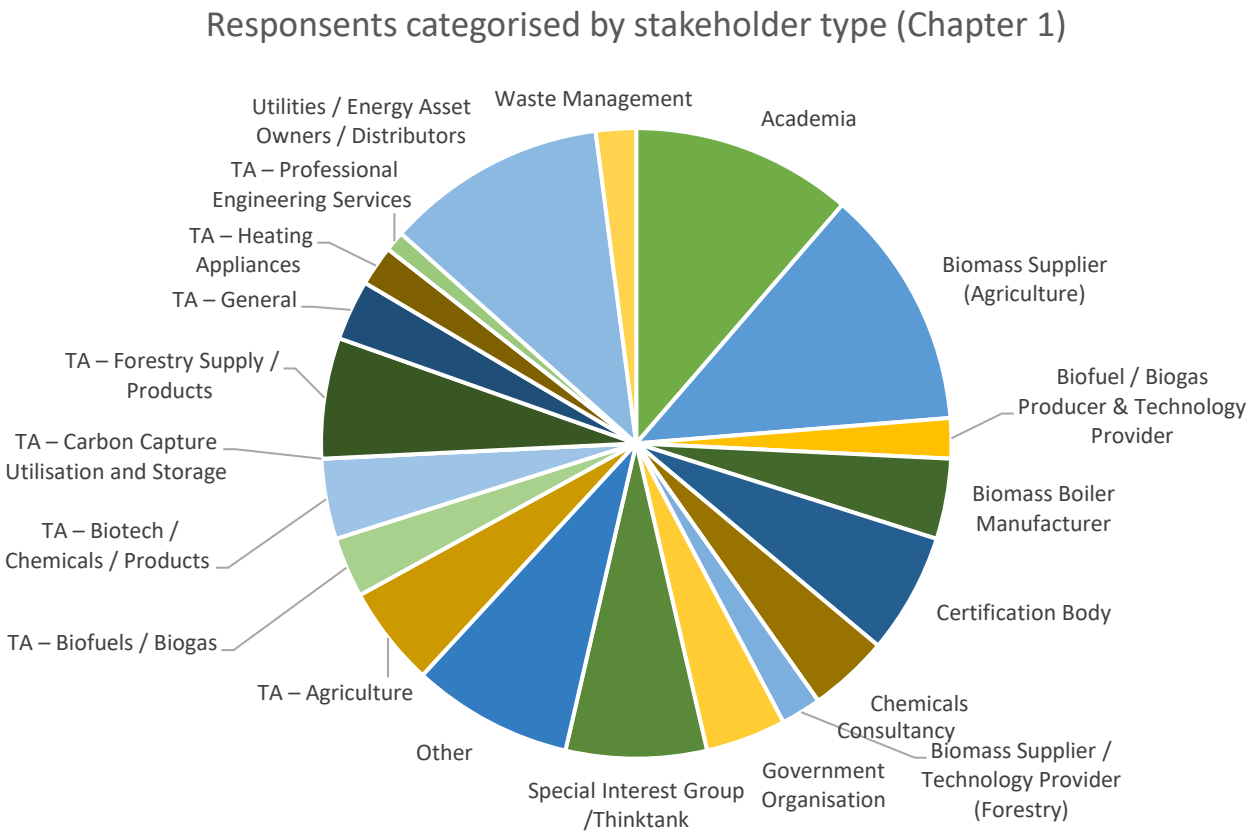

Figure 2 - Stakeholders categories for respondents - Chapter 1[2]

Analysis of the responses suggested a lack of publicly available data on UK biomass resources and as a result the questions were not adequately answered to enable a full picture to be developed. Respondents noted the difficulty in projecting how the overall UK biomass resources might change by 2050 due to a perceived lack of clear government policy, strategy, and financial investment within the industry. This lack of perceived long-term direction is seen as preventing the biomass industry from being able to plan and invest with confidence. There were three main biomass resources discussed: waste, energy crops, and forestry.

[2] Note: category names shortened, i.e. TA refers to Trade association / representative Group.

Underutilized waste resources

There was agreement that the UK has significantly underutilised waste resources (food waste, agricultural waste, manufacturing waste and livestock waste etc) which could be exploited. It was suggested that improvements to waste stream management and supply chains could ensure that waste feedstocks are better utilised. Additional investment may be needed to enhance waste supply chains supporting better reclamation of biomass feedstocks from waste and new rules for the collection of food waste from households. Improvements to local recycling infrastructure may be needed to ensure that the value is captured, and the feedstock used most effectively. Using waste was thought to reduce waste sent to landfill and avoids displacing food, feed, or virgin timber, which reduces possible conflicts with existing biomass and land uses.

Although, there is a need to ensure that waste is used locally to avoid emissions associated with transportation. With established end-uses for all grades of waste wood and the market expecting to grow, there is an opportunity to use this feedstock effectively. Respondents noted that the market for waste wood within the UK is relatively stable, therefore the cost of waste wood is not expected to rise above inflation despite some market growth. However, there were suggestions that the removal of the red diesel allowance in 2022 could negatively impact the cost of waste wood resources. The overall positive impact and cost associated with using waste wood, i.e. diverting it from landfill and the low processing emissions, was considered to outweigh any negative impacts (air quality concerns: harmful contaminants and Particulate Matter (PMs)).

Forestry biomass

Over half of respondents (evenly split across stakeholder groups) to this chapter stated that the forestry sector in the UK is expected to grow and the stock is underutilised. The increased use of UK forestry as a source of energy is expected to have positive environmental impacts according to some respondents. It is important to note that the UK currently relies heavily on imported wood for its timber and biomass needs in addition to domestic supply. Some respondents (mostly within Academia) are strongly opposed to the importing of biomass and commented that importing from Europe and the USA increases carbon dioxide (CO_2) emissions associated with its use, however others supported the UK increasing the amount of imported biomass into the UK or noted that the amount would inevitably rise towards 2050.

Respondents noted that there could be a need to increase pellet capacity in the UK but there is a reluctance to invest. There are a high number of unmanaged woodlands in the UK, which could contribute towards the UK's biomass resources, therefore a priority should be to increase the amount of forestry covered by "Woodland Management Plans" and avoid policies that encourage removal of tree cover. It was recommended that the government should also encourage the delivery of

continuous cover forestry to minimise greenhouse gas emissions (GHG) and protect air quality, water quality, soil health, and biodiversity. There is evidence that forestry biomass supply costs increased in recent years, in line with increasing biomass combustion capacity around the UK, and there is an expectation that the cost of UK timber will continue to rise. This could encourage greater forest cover and replanting which could increase the UK's carbon sink.

Energy crops

A clear role for energy crops (short rotation coppice, hemp, miscanthus etc) was identified, with 88% of respondents to this chapter stating that energy crops have the potential for growth or are currently underutilised. Energy crops could be the most cost-effective option for biomass deployment, but significant investment is needed. Land rental fees and harvesting account for the highest proportion of production costs[3]. It was suggested that this opportunity could be realised by incentivising farmers to convert land to growing wholly energy crops or to add them into their crop rotation to deliver a wider variety of crops, enhancing biodiversity.

The main benefits of utilising energy crops were summarised as the potential to improve soil quality, biodiversity, reduce flooding and being an efficient use of land compared to alternatives. Concerns were raised around negative environmental impacts, specifically a decline in native and local varieties of crops. In addition, algae and seaweed were highlighted as a potential area for growth, however respondents struggled to provide reliable data on the current or future availability of the UK's algae and seaweed resources.

Industrial applications of biomass

Biomass opportunities for industrial use and manufacturing were also highlighted in responses to questions in Chapter 1. An increased reliance on biofuels was noted and it was suggested that this could provide access to potentially highly skilled roles in industrial biotechnology in regional areas, forestry management, transportation, system installation and maintenance. The potential for existing supply chains and refineries from fossil fuel industries to be re-deployed as bio-refineries was raised as an opportunity. Gasification of waste was also noted by one respondent to be a possible route to decarbonise difficult sectors such as transport. There is potential for producing BioLPG using the gasification of sustainable wastes and it was suggested that dedicated bio-refineries could provide significant volumes of fuel.

[3] Ricardo's AEA's (2017) Biomass Feedstock Availability, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597387/Biomass_feedstock_availability_final_report_for_publication.pdf

Risks and benefits

A common theme in responses to question in this chapter was that the production of domestic biomass could have positive impacts on air quality, water quality, soil health, flood risk and biodiversity as well as contributing towards carbon emission reduction.

In addition, it was suggested that biomass could play a key role in the rural circular economy where biomass plants located close to the source of a rural feedstock can support skilled rural employment and green economic growth. Respondents noted that integrating bioenergy systems as part of agricultural and/or forest activities can add significant co-benefits to landowners, employees, and local communities.

However, respondents suggested that industry and government do not currently measure and recognise these benefits when considering areas for investment, policy intervention and market growth and as such, there is a need to more accurately account for these benefits. Lifecycle Assessments (LCAs) could be used across the biomass sector, but at present there is not an industry best practice methodology and the data available is not deemed reliable or comparable. Respondents acknowledged that bioresources are complex and evolving so there is a need to ensure that any approach is flexible and that it covers the whole value chain.

Common themes around key challenges and barriers to increasing biomass supply included a lack of certainty around the Government's overall policy and strategy regarding biomass, a lack of / reduction in incentives, a lack of investment in infrastructure (transportation, processing plants etc.), insufficient research and development funding for new technologies or "novel" forms of biomass. In addition, a need to enhance public perceptions and drive demand for biomass was highlighted.

END USES OF BIOMASS

Chapter 2 explored the various end-uses and applications that biomass can be used for, and where and how biomass use could be prioritised to best deliver our net zero target. This chapter also sought information on how the deployment of Bioenergy with Carbon Capture and Storage (BECCS) could be supported as well as the air quality implications associated with biomass deployment. Overall, 117 responses were submitted for the questions in chapter 2 (Figure 3).

A range of end uses were valued by respondents, though our findings indicate that some are seen as a greater priority than others as shown in Figure 4. Whilst information on support by end use has been captured in the categories identified in the question 8 (heat, electricity, transport, agriculture, industry, and chemicals and materials), it should be noted that many respondents referred to biomass in its holistic sense as opposed to specifying sources.

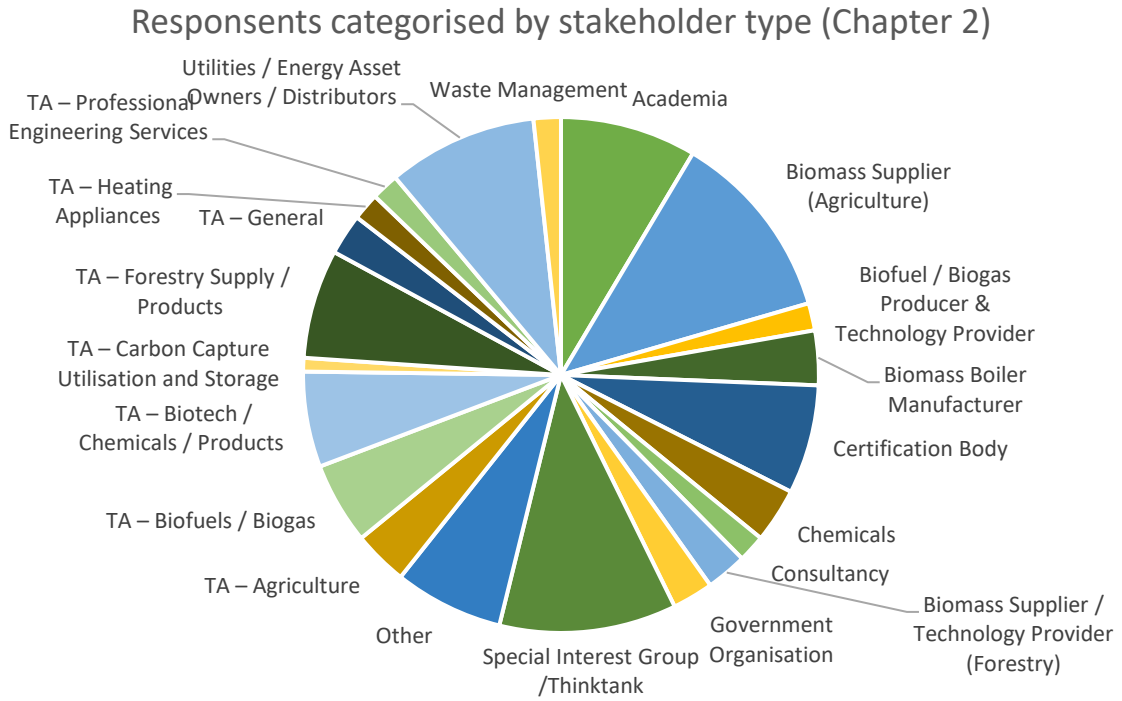

Figure 3 - Stakeholders categories for respondents - Chapter 2[4]

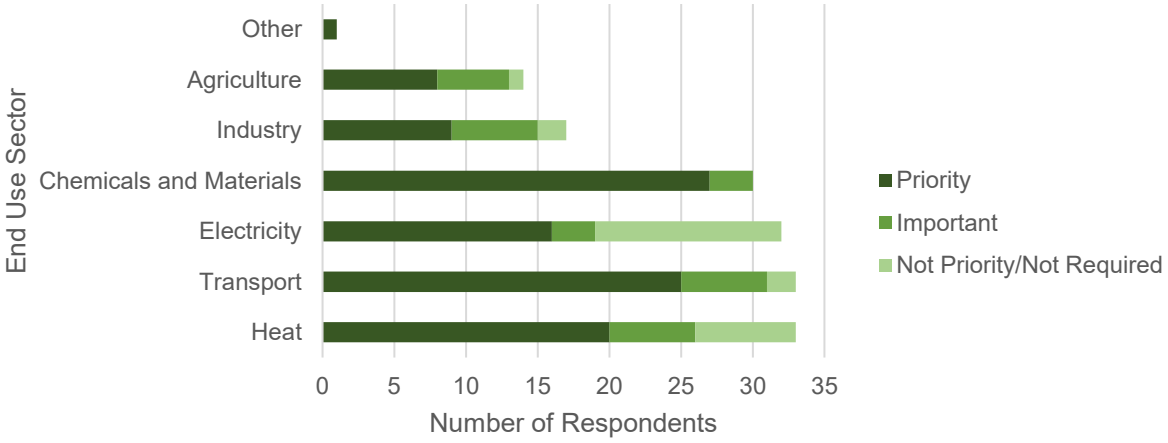

Figure 4 – Priority end uses for biomass - Question 9

Heat

44% of question respondents indicated that some form of biomass could be valuable in supporting the decarbonisation of heat. 100% of respondents in the categories 'Biomass Boiler Manufacturers', 'Government Organisations' and 'Trade Association / Representative Group – Heating Appliances' who responded to question eight indicated that biomass has a role to play in heat.

[4] Note: category names shortened, i.e. TA refers to Trade association / representative Group.

29% of those who supported biomass in heating referred to rural and/or off-gas grid areas and 24% referred to hard to treat properties. By contrast, 7% indicated that some or all sources of biomass were not required in all or certain heating applications. Those who did not support some or all sources of biomass in certain or all heating applications were from the following respondent categories: 'Academia', 'Non- Profit Research Organisation / Special Interest Group / Think Tank' and 'Trade Association – Forestry Supply Products'. The focus of respondents in the category 'Trade Association – Forestry Supply Products' was on the use of biomass for materials such as wood-based panels

Concerns raised in relation to biomass usage for heating included limited availability, existence of alternative technologies, air quality implications and carbon emissions.

Transport

Regarding transport, 41% of respondents indicated biomass could play a role. Those who supported biomass in transport were from a range of respondent types including, but not limited to: 'Government Organisations', 'Biofuel/Biogas Producers & Technology Providers' and 'Trade Associations / Representative Groups - Biofuels / Biogas' Those who did not support some or all biomass sources in transport were from the following respondent categories: 'Academia', Non – profit organisation/ Special Interest Group / ThinkTank' and 'Trade Association / Representative Group – General'.

Liquid biofuels, biohydrogen and biogas were proposed as potential energy vectors and hydrogenation, anaerobic digestion (AD), gasification, alkaline thermal treatment, pure pyrolysis and the Fischer-Tropsch process were highlighted as technologies which could be utilised. Several feedstocks which could be used for transport were identified including waste such as Municipal Solid Waste (MSW) and food waste; and agricultural sources such as wheat and sugar beet.

It was suggested that biomass should be used to tackle harder to decarbonise applications such as Heavy Goods Vehicles (HGVs), aviation, shipping and in some cases rail where diesel drive trains are in operation. However, it was indicated by some that with competition for biomass expected to increase, future policies should be carefully designed to prioritise biomass usage for certain transport applications (e.g. where there is high decarbonisation potential or few limited alternatives). Moreover, the availability of alternative technologies was highlighted as a barrier to deployment. A recurring theme across all end uses was the need to consider the sustainability of sources and accounting for the carbon intensity of the fuel.

Electricity

39% of question respondents indicated that some form of biomass could be valuable in supporting the decarbonisation of electricity. 100% of respondents in the following categories who responded to question eight indicated that biomass has a role to play in electricity: 'Biomass Supplier (Agriculture)'

and ‘Waste Management’. By contrast 11% indicated that some or all sources of biomass were not required in all or certain electricity applications. Those who did not support some or all biomass in electricity were from a range of respondent types including but not limited to[5]: ‘Consultancies’, ‘Government Organisations’ and ‘Non-profit organisations/ Special Interest Groups/ ThinkTanks’.

The role of biomass in delivering negative emissions alongside electricity and providing balancing capabilities was highlighted. Whilst respondents saw a role for BECCS, five respondents said it was preferable to produce hydrogen from biomass given hydrogen has good energy storage and seasonal balancing capabilities. Those who did not support some or all sources of biomass in electricity highlighted that there is a declining carbon benefit of biomass as the grid decarbonises. They also stressed a need for a full life cycle emissions assessment of BECCS, improved sustainability of biomass sources and identified the cost, air quality implications, procurement, delivery, and storage as challenges to deployment.

Chemicals and materials

A common theme in this chapter was around the opportunities to utilise biomass across the chemicals and materials sector. 34% of question respondents suggested that biomass could be used to produce plastics and packaging, alternative construction materials, cement manufacture, metal production, replacement of fossil fuels in lubricants, food, pharmaceuticals, cosmetics, textiles, and agrochemicals. 100% of respondents in the following categories who responded to question eight supported the use of biomass in Chemicals and Materials: ‘Biomass Supplier (Agriculture)’, ‘Chemicals’, ‘Trade Association / Representative Group – General’.

Industry

26% of question respondents indicated that some form of biomass could be valuable in supporting the decarbonisation of industry. Respondents noted the role for biomass in the industrial sector to provide space heating, process heating (in particular for hard to decarbonise processes, e.g. steel, cement), bio-CO_2 production, scrubbing systems, food and drink, pharmaceuticals and non-metallic mineral production. Those who supported biomass in industry were from a range of respondent types including, but not limited to: ’Biofuel/ Biogas Producer & Technology Provider’, ‘Trade Association / Representative Group (Biotech / Chemicals / Products)’, ‘Utilities/ Energy Asset Owners/ Distributors’.

[5] These categories have been selected for reference here as they are the top three categories in terms of the proportion of respondents who indicated this view as a percentage of the number within the respondent category who responded to the Question as a whole. Unless indicated otherwise, this is used throughout the remainder of this chapter. Where different categories have equal percentages, those categories with the top three percentage values have been cited.

Agriculture

Agricultural uses were proposed by 22% of question respondents. Those who supported biomass in agriculture were from a range of respondent types including, but not limited to: 'Biomass Supplier (Agriculture)', 'Trade Association / Representative Group (Agriculture)' and 'Waste Management'.

End uses cited included soil restoration and regeneration, animal bedding and feed, the creation of on-farm energy and to act as an alternative source of income for farmers. Respondents highlighted a role for biomass (including BioLPG and biogas from AD/pyrolysis) to produce on farm energy and heat. Moreover, it was recommended that biomass should be used to protect wildlife, deliver land stabilisation, reduce carbon emissions, support rural economic growth and food production.

Priority use framework

To drive greater use of biomass across these end uses, respondents identified several existing frameworks to prioritise biomass deployment, alongside a range of different principles that should guide prioritisation. Respondents saw that a range of policy mechanisms would be required to support biomass deployment, including extension of existing policies. Financial incentives were proposed as the most popular mechanism to encourage and enable deployment. Regulation was also recommended by some respondents with the importance of targets, obligations and product regulatory frameworks including carbon foot-printing also recommended.

Not all respondents supported the principle of prioritisation by end-use, with ten respondents indicating that existing policy was distorting the market and that support should be removed across certain areas.

Looking at air quality specifically, respondents tended to highlight how biomass should be used as opposed to specifying end uses where deployment should be avoided all together. When referring to how biomass should be used, respondents discussed mitigation tools that should be employed including, but not limited to, regulation and enforcement and the need for full consideration of air quality impact in project/policy evaluation. Where information on where biomass should be used was provided, it has been captured. This included introducing further limits on the use of biomass in urban areas, for example.

Risks and barriers

To gain feedback on the current policy landscape, the call for evidence sought views on policy gaps or barriers. Themes around policy gaps centred around the non-domestic RHI (Renewable Heat Incentive), the Renewables Obligation (RO) contract, and Renewable Transport Fuel Obligation (RTFO). Commonly referred barriers were uncertainty and lack of guarantee in the carbon neutrality,

supply availability, cost of BECCS deployment, and complexity of land occupation and building of infrastructure.

In addition, numerous respondents suggested that the lack of clear and consistent definition of biomass is a challenge. Whilst policy gaps, risks and barriers were captured in separate categories, in some instances they were found to be highly interlinked with clear connections between the different policy gaps, risks and barriers identified. For example, some barriers that are multifaceted are complex to mitigate ultimately presenting risks to the market across a range of issues.

In addition to the above barriers, frequently stated risks included issues surrounding pollution, negative environmental impacts, and market system concerns. Air pollution was discussed at length in response to question 14, with a particular focus on heating and agriculture. Regulation was highlighted as the most popular mitigation tool. Proposals included introducing restrictions on geographical deployment based on population density, improving installation standards, requiring better public information, emissions limits, regulated storage practices, expanding environmental permitting, mandating emissions monitoring via planning, and introduction of penalties for non-compliance.

Whilst there were proposals to improve current controls in relation to air quality, many respondents expressed a view that existing controls are sufficient. For example, respondents emphasised that biomass boilers are already highly regulated from fuel quality to emissions reporting. It should also be noted that where respondents did support policy to protect air quality from the impact of biomass deployment, multiple respondents suggested that air quality should be addressed through emissions legislation as opposed to via the biomass strategy.

SUSTAINABILITY AND ACCOUNTING FOR EMISSIONS

Chapter 3 addressed the sustainability criteria around biomass supply and use, and also welcomed views on approaches for accounting for full life cycle emissions. Overall, 81 responses were received for chapter 3.

The analysis suggests mixed views on whether the existing sustainability criteria are sufficient. There was a lack of evidence provided by respondents on how to improve the sustainability criteria to ensure biomass from all sources supports wider climate, environmental and societal goals. Many who stated that the current criteria were not sufficient failed to provide evidence of how the criteria could be improved.

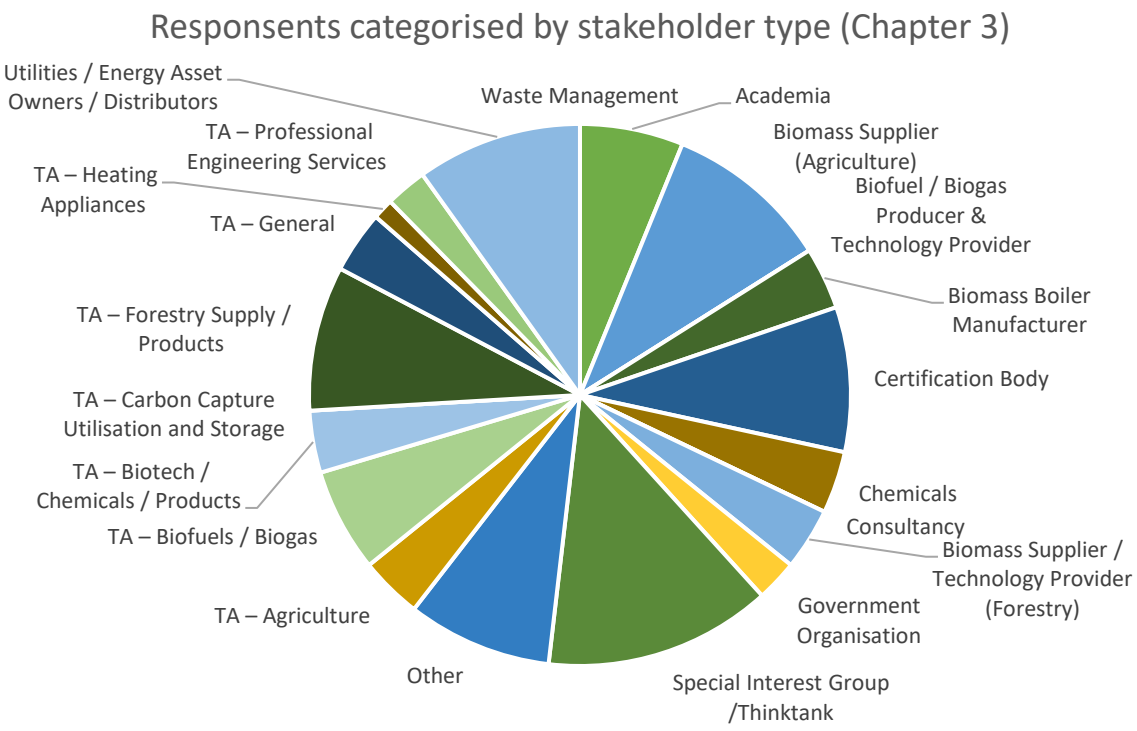

Figure 5 - Stakeholders categories for respondents - Chapter 3[6]

Sustainability criteria

Those who agreed that the current UK criteria was sufficient highlighted that it has evolved over time to become comprehensive, therefore indicating that the UK does not need to make immediate changes. However, it was noted that the scientific evidence needs to be regularly reviewed alongside industry evidence to improve and develop new legislation / sustainability criteria.

It was suggested that the UK has been able to balance sustainability compliance without making the UK an unattractive market for biomass supply. Concerns were raised in relation to carbon accounting standards and Carbon Capture and Storage (CCS) practices. A need to improve LCA methodologies was highlighted to ensure that the full value chain is captured and the need to incorporate the latest research and new research in the future was noted. Overall, participants who suggested improvements recommended a widening of the sustainability criteria so that it included non-GHG indicators as climate, environmental, and societal goals, and in particular net zero.

[6] Note: category names shortened, i.e. TA refers to Trade association / representative Group.

Sustainability monitoring and reporting

Considering monitoring and reporting specifically, respondents highlighted that there are currently inconsistencies in the sustainability monitoring and reporting requirements for domestic biomass with numerous schemes currently available. It was suggested that the requirements were fragmented and that there does not appear to be any sharing of the data across different schemes, organisations and regulatory or government departments. Concerns were raised in relation to the governance of existing schemes which could impact impartiality. From an international perspective, respondents welcomed the UK's approach which mitigates more risks than the EU Renewable Energy Directive (EU RED) and cautioned against introducing overly restrictive regulations.

The availability of data was a key discussion point with larger biomass organisations indicating that they had access to vast amounts of sustainability data and that more granular detail could be reported upon. However, this was caveated by the need to substantiate the benefit of providing this information. Some respondents noted that the current evidence requirements under existing schemes was deemed to need some improvement but there is a risk that increasing requirements could create administrative burden and impact competitiveness. It was suggested that a government review of the data that is being collected by biomass suppliers would be beneficial to aid discussions on regulatory requirements. This review may indicate that the appropriate datasets already exist and could be utilised more effectively. There were calls to share more data across the industry and regulators. As noted previously, respondents advocated for a standardised LCA for biomass which would allow emissions to be compared on a level playing field. They also called for increased auditing across the supply chain to mitigate negative impacts.

Some alternative mechanisms were suggested by respondents to ensure sustainability independence of current incentive schemes. Cross-sector legislation was proposed as key to unlocking more sustainable supply, encouraging utilisation, and driving uptake of sustainability measures in biomass. This included reference to LCAs, fuel registers and standardised carbon footprint labelling. Concerns were raised regarding smaller organisations, and it was advised that additional support may be needed to overcome some of the barriers to entry. There was agreement that the purpose of voluntary schemes should be to raise the standard of sustainability in supply chains and provide a means to self-report and administer policy. However, there were mixed views on the extent to which voluntary schemes should be used, with some advocating extending them and others raising concerns around the ability to fulfil their roles without bias.

International governance

Internationally, the UK has an important role to play in driving global governance of sustainability in biomass. It was suggested by numerous respondents that the UK is one of the leaders in biomass

sustainability and should seek to improve the global governance frameworks as a major consumer of biomass materials. Respondents highlighted inconsistencies across international technical standards and a lack of parity between domestic and international biofuel sources. Forest governance was identified as a key area of concern with a need for international governments to increase protections on forests, including an end to clear-felling, deforestation and land-use insufficiencies which leads to a declining biodiversity of plants and wildlife.

LCAs and Carbon accounting

It was suggested that improved full LCAs could support sustainable practices, but it is important that the methodology covers multiple aspects of sustainability such as land-use change and wildlife protection. Respondents argued that biomass cannot be considered carbon neutral as there are other emissions that are released into the atmosphere from the harvesting, drying and transportation of biomass. Therefore, respondents suggested that the whole supply chain including harvesting, processing, drying and transportation of the biomass should be taken into account. Only 4% of respondents were satisfied with the current state of lifecycle emissions accounting.

There was an overwhelming consensus from respondents that there is a lack of sufficient policy and standards in relation to lifecycle emissions and that LCAs are not suitably utilised in carbon pricing, UK Emissions Trading Scheme (UKETS), and other accounting measures. The inconsistencies in carbon pricing across geographies was highlighted as a challenge and some suggested that the price was not high enough. Concerns were raised around double counting of emissions throughout the supply chain. It was argued that reporting of negative emissions for internationally traded bioenergy feedstocks could become complicated and opaque with the introduction of BECCS.

There were mixed views regarding the role of BECCS with concerns raised around the cost of implementation, technology readiness and efficacy. However, many also argued that there were insufficient economic incentives for investment and thus intervention may be needed to enable greater deployment. There are likely to be challenges with emissions reporting and some respondents suggested that the scope of this needs careful consideration.

INNOVATION

Chapter 4 explored the role of innovation and sought evidence on how innovation could bring down costs and reduce barriers to deploying technologies, or improving the way current, more mature technologies operate. There were 77 responses to the questions in chapter 4.

A clear commonality across most responses was the need to support multiple technology types to deliver a range of end uses. The approach taken should resist any temptation to pursue preferential outcomes and instead allow market dynamics to let the best suited technologies develop.

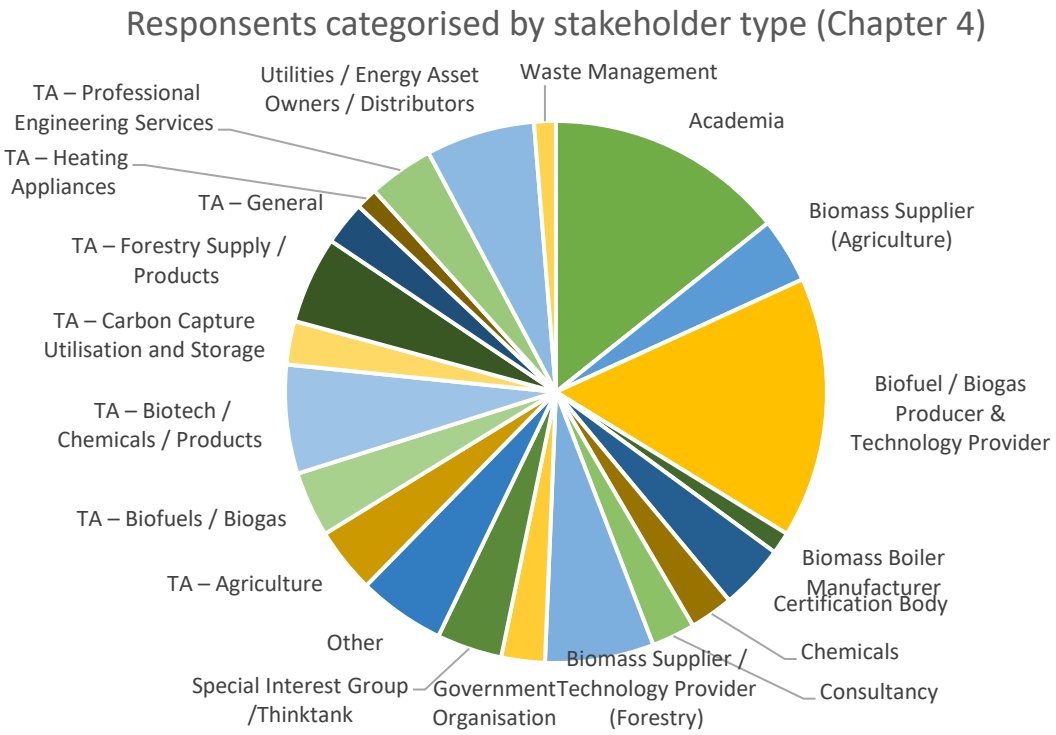

Figure 6 - Stakeholders categories for respondents - Chapter 4[7]

Waste processing technologies (ACTs and AD)

Waste processing technologies such as gasification, pyrolysis and AD were the most commonly identified solutions to deliver the priority end uses of biomass. Multiple benefits were highlighted, e.g. providing a sustainable energy source, soil amelioration and decarbonising hard to treat sectors. These technologies were deemed to be scalable and at an advanced stage of development, however, more could be done to promote these technologies. Securing finance on these maturing technologies was said to be challenging.

BECCS

BECCS was also considered a key technology; it was suggested that using BECCS can help fully capture the benefits from negative emissions to further fuel the thermal chemical processing technologies. Furthermore, BECCS could address challenges faced when using some of the more embryonic technologies by being used concurrently. However, as with waste processing technologies, the need for greater government investment and support in relation to BECCS was highlighted by numerous respondents. Furthermore, some concerns were raised regarding the readiness of the

technology. It was suggested that the lack of clear policy and incentives around BECCS puts future investment at risk and will ultimately constrain investment. Improved stakeholder engagement alongside supportive policy could encourage greater uptake.

Industrial biotechnology

The use of biomass in industrial technologies was also recognised as having the capability to deliver priority end uses. Respondents identified the UK's leading global position in bioscience as a catalyst for further development in industrial biotechnology. However, further research and innovation will be needed to unlock this potential and make them cost and performance competitive against the established fossil-based technologies and products. Additionally, biofuels were also identified as a solution to decarbonising a range of sectors. The solution was deemed relatively low cost and with various applications including converting natural gas furnaces to low carbon fuels.

Risks and Barriers

Increasing the deployment of advanced technologies will come with a number of barriers and risks. Financial constraints were identified including the need for investment, high costs of deployment and a lack of incentives to encourage uptake. A need for clear government regulation and action was mentioned as a lack of government action could restrict innovation according to some respondents. However, it was noted that stagnant policy and existing technologies were also barriers to adoption. An important challenge which will need to be considered is the availability and quality of feedstocks as respondents raised concerns around the heterogeneity of feedstocks. Finally, existing infrastructure could limit innovation or make the deployment of advanced technologies more challenging as adaptation will be required.

Regional innovation potential

The UK is well placed to support technical innovation and scale up feedstock supply chains with biomass likely to be deployed across all nations. England, Scotland, and Wales all have individual, specific strengths. Key regions identified in England include the South-West, South-East, Midlands, and the North of England due to innovation and academic capabilities, high feedstock potential, and industrial clusters in these areas. Scotland was identified as a hub for biomass feedstock supply scale-up and technology innovation because it is the lead in wood pellet production, has highest demand for biomass heating, and a breadth of businesses working in bioenergy. Academic expertise in Wales was identified as a key strength alongside major forestry areas which could be expanded to support biomass supply. Northern Ireland and Jersey were also highlighted as potential areas for growth.

Rural regions were identified as logical areas to focus on scaling up feedstock supply chains as end uses are likely to be in these locations. It was suggested that a focus on rural development will support local job development and economic growth. Respondents identified urban and industrialised areas as potential regions of the UK for technological innovation and feedstock supply chain improvements. Moreover, urban areas are likely to have largescale waste streams that could be utilised as a feedstock.

Introduction

This report presents analysis of responses to a public call for evidence on the Biomass Strategy. The call for evidence ran between 20th April 2021 and 15th June 2021. The call for evidence asked 26 open Questions and requested the submission of supplementary evidence.

The consultation documents are available on the UK Government website at: https://www.gov.uk/government/consultations/role-of-biomass-in-achieving-net-zero-call-for-evidence

BACKGROUND

The call for evidence aimed to strengthen the Government's evidence base around biomass and will contribute to a review of the potential for biomass to support the UK's net zero target. The call for evidence invited views on:

- availability of sustainable biomass from domestic and international sources
- potential end uses to support our net zero target in the context of availability of sustainable biomass feedstocks
- the sustainability of the supply chain and opportunities for strengthening existing criteria
- accounting of GHG emissions from biomass use
- BECCS technology and its potential applications to deliver negative emissions
- opportunities for innovation to support wider deployment of technologies with potential to support the net zero target.

The information provided by stakeholders in this Call for Evidence will support a review of the amount of sustainable biomass available to the UK, and how this resource could be best utilised across the economy and in different end-uses, considering existing and future demand, to support the net zero target. The Call for Evidence will also inform an assessment of the UK's current biomass sustainability

standards, already some of the world's most stringent, to see where and how they could be improved even further. This assessment considers the risks and opportunities provided by biomass in delivering our wider environmental targets, including on biodiversity, air quality and water. This Call for Evidence will also inform BEIS' considerations on the role of BECCS in reducing GHG emissions across the economy, and if and how the technology could be deployed.

NUMBER AND PROFILE OF RESPONDENTS

In total 144 respondents made a submission to the call for evidence. Respondents have been allocated to one of twelve respondent groups by the analysis team at Gemserv. A breakdown of the number of responses received by each respondent type is set out in Table 1 below.

Table 1 - Responses received by respondent type to call for evidence

Respondent type	Total number of respondents
Academia	13
Biomass Supplier (Agriculture)	4
Biofuel / Biogas Producer & Technology Provider	16
Biomass Boiler Manufacturer	2
Certification Body	4
Chemicals	2
Consultancy	5
Biomass Supplier / Technology Provider (Forestry)	10
Government Organisation	5
Non-profit organisation / Special Interest Group / ThinkTank	17
Other	11
Trade Association / Representative Group – Agriculture	5
Trade Association / Representative Group – Biofuels / Biogas	6
Trade Association / Representative Group – Biotech / Chemicals / Products	7
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	2

Respondent type	Total number of respondents
Trade Association / Representative Group – Forestry Supply / Products	12
Trade Association / Representative Group – General	4
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	3
Utilities / Energy Asset Owners / Distributors	12
Waste Management	2
Total	**144**

NATURE OF THE RESPONSES

There was diversity across the type, length and focus of the responses received. Over half responses (55%) were submitted via the Citizens Space portal. These tended to focus on responding to the specific Questions posed in the call for evidence documentation. 65 responses were submitted via email which responded to the specific Questions. However, 13 respondents did not respond directly to the Questions and instead submitted comments in the form of a statement, letter, or short report. To ensure that this data was captured, these responses were analysed under the most relevant consultation Question.

Most respondents provided detailed answers to the Questions with some providing very extensive responses. These longer responses were often technical and organisation specific containing detailed augmentation for specific uses or feedstocks. They often contained high quality evidence which went beyond the Questions asked in the call for evidence. This analysis reviewed all of these submissions including supplementary evidence. It should be noted that these detailed responses and technical papers were reviewed alongside the most relevant consultation Question, however it was not possible to delve into them in detail for this report.

ANALYSIS AND REPORTING

This report provides a Question-by-Question analysis of the responses received and has been developed to give an overview of the evidence, commentary, recommendations, and views presented across the 144 responses. It should be noted that as this is a public consultation, the responses may

not be representative of the whole population with many of the respondents having a vested interest in the outcome of the call for evidence or subject area.

The report summarises the frequency of comments made and an indication of the stakeholder types making specific points. Whilst viewpoints have been grouped where possible, many comments were made by a small number of respondents and as such should be considered in this light. This means that the statements within the report may not be representative of wider public opinion. Where multiple respondents have raised the same points, this has been highlighted.

Many of the responses to the call for evidence were from groups of organisations or individuals. For these, the response has been analysed as a single submission and thus counted as one in the categorisation exercises.

In general, direct quotes have not been used in the analysis and instead some original wording with editing or paraphrasing is used. Throughout the analysis, responses have been categorised and summarised to allow a high volume of data to be reviewed. Where specific examples are given or suggestions made, this may be quoted. All responses have been analysed as submitted thus, further research, fact checking, or reference reviews have not been undertaken as part of the analysis.

Chapter 1: Supply

INTRODUCTION

Chapter 1 explored the variety of biomass feedstock types from domestic and international sources and sought information on the potential size and makeup of domestic biomass resource from different sources as well as on the current and potential future costs of these biomass resources. In addition, it invited evidence on the environmental, climate, and land use considerations associated with the different feedstocks. It also asked for information on any opportunities, risks, benefits, and trade-offs of increasing domestic production. The Questions welcomed views on imports of biomass and the risks and opportunities that might arise from increasing imports and any barriers that might apply.

POTENTIAL SIZE, LOCATION MAKEUP

Question 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?

97 respondents answered Question two equating to 67% of all respondents. The Table below summarises the respondent types for this Question.

Table 2 - Respondents categorised by respondent type for Question 2

Respondent type	Total number of respondents
Academia	11
Biofuel / Biogas Producer & Technology Provider	12
Biomass Boiler Manufacturer	2
Biomass Supplier (Agriculture)	4
Biomass Supplier / Technology Provider (Forestry)	6

Certification Body	4
Chemicals	0
Consultancy	2
Government Organisation	4
Non-profit organisation / Special Interest Group / ThinkTank	7
Other	8
Trade Association / Representative Group – Agriculture	5
Trade Association / Representative Group – Biofuels / Biogas	3
Trade Association / Representative Group – Biotech / Chemicals / Products	4
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	6
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	1
Utilities / Energy Asset Owners / Distributors	11
Waste Management	2

Total	**97**

Generally, respondents have found it difficult to provide reliable statistics regarding either the "current" or the "potential" size of the biomass resource within the UK. A common note from respondents for Question two is that there **isn't enough publicly available data on UK biomass resources** to adequately answer the Question. Respondents noted the difficulty in projecting how the overall UK biomass resources might change by 2050 due to **a perceived lack of clear government policy, strategy, and financial investment within the industry**. However, two respondents quoted Ricardo's UK and Global Bioenergy Resource Model, 2017[8] suggesting that, the role of bioenergy in the UK economy could grow sustainably by a factor of more than 2.5 times by 2032. The total domestic resource for 2032 is estimated to be between 580 and 672 PJ; made up of the waste, forestry, and agricultural sectors, including perennial energy crops like Miscanthus and Short Rotation Coppice (SRC) willow. Please note that Ricardo's study excluded "novel" feedstocks such as algae etc.

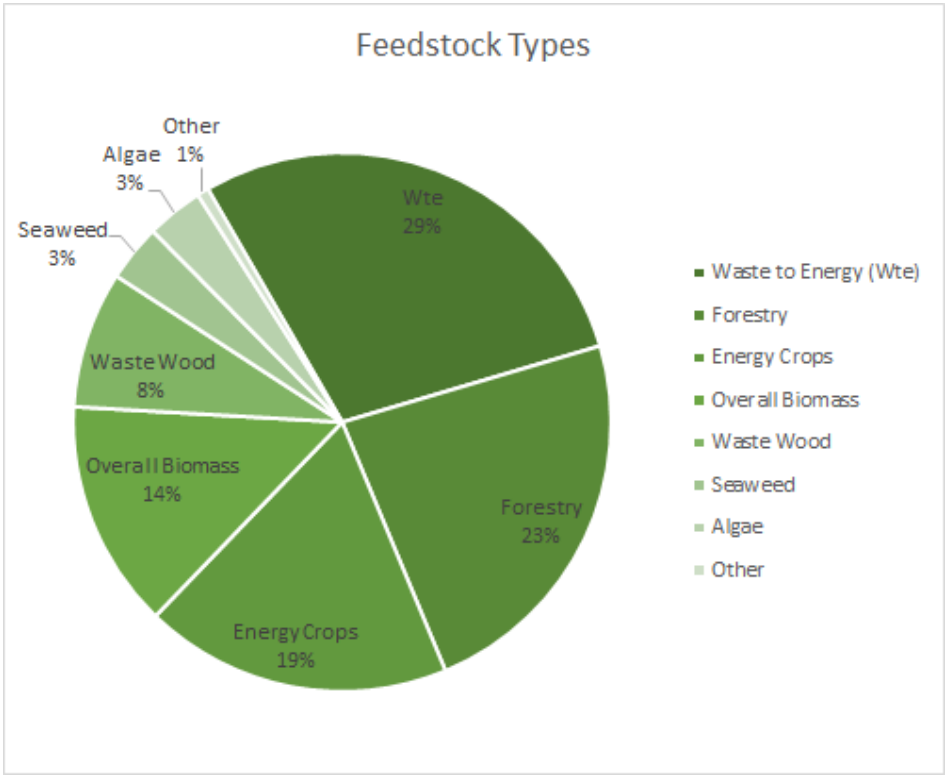

Figure 7 – percentage of feedstock types mentioned by respondents for Question two.

[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597387/Biomass_feedstock_availability_final_report_for_publication.pdf

Biomass resource from the waste sector (agricultural, household, etc)

42% of respondents to Question 2 specifically provided comments on waste feedstock supply, with **78% suggesting that waste biomass has the potential for growth or is underutilised**. Respondents who focused on waste agreed that the UK has significantly underutilised waste resources, and this should be a key focus area for expansion. The Anaerobic Digestion and Bioresources Association (ADBA) response [9] provided indications of current industrial capacity and estimates regarding potential UK waste resources (see Tables 3 and 4):

Table 3 – ADBA's estimate on the current industry capacity for AD

Type of waste	Farm waste (FW)	Industrial residues (ILW and ISW)	Crops (C)	Food waste (FDW)	Residual waste (RW) (organic fraction)	Sewage Sludge (SS)	Other
Current industry feedstock capacity (Million tonnes)	3.5	6.6	3	3.3	1.2	24	0.1

In addition, the ADBA provided the estimates below regarding potential UK waste resources:

Table 4 – ADBA's estimated of UK waste resources

Type of waste	Household food waste	Hospitality and food services (HaFS)	Retail industry	Manufacturing and industry food waste	Pre-farm gate food waste	Livestock wastes (manures and slurries)
Potential estimated resource (Million tonnes)	6.6	1.1	0.3	1.5	3.6	90

The most common recommendation from respondents was the **need to improve waste streams and supply chains through better policy**. Respondents commented that Local Authorities (LA) need to be encouraged to segregate waste properly, and that without aligned LA recycling practises, expansion and uptake of waste derived fuels could be hindered.

[9] 2020 - Anaerobic Digestion and Bioresources Association The Role of Biomass in Achieving Net Zero Call for Evidence

Biomass resource from waste wood

12% of respondents to Question 2 specifically provided comments on Waste Wood. **There were mixed views on whether the supply of waste wood could increase.** 33% of these respondents suggesting that waste wood has the potential for growth and is underutilised, however 66% of respondents disagreed noting that waste wood resources will not increase significantly. Generally, respondents including the Wood Recyclers Association (WRA), the Wood Panel Industries Federation (WPIF) and RWE Renewables (RWE) agreed that there are currently around 4.5 million tonnes per annum of waste wood available within the UK[10]. Stobart Energy suggested that the market supply and demand is broadly balanced with established end-uses for all grades of waste wood, with the RWE suggested that the UK's structure of compliance leads to higher quality waste wood being recycled into animal bedding or particle board (1.5mt) with the remainder being utilised by waste incinerators

Notably, the WRA and the WPIF have theorised that the **current available resource could in fact reduce by 2050**, or at least remain at current levels. In contrast, one respondent (Talbott's Biomass Energy Systems Ltd) expects the **waste wood market to grow along with the UK's manufacturing and construction sector**. It was also noted by the WRA and several biomass producers and suppliers that the current Environment Agency (EA) and Scottish Environment Protection Agency (SEPA) compliance structures regarding the supply and burning of waste wood often leads to waste wood being use for animal bedding or other uses, but not for energy.

The below Table was provided by the WPIF in their supporting evidence which gives demand estimates for the UK waste wood market.

Table 5 – WPIF's UK Waste Wood Market 2019 with Forecast for 2021 -2022

Sector	2019 (000 Tonnes)	2021-22 (000s Tonnes)
Wood Based Panels	984	982
Large Scale Biomass	2390	3371
Animal Bedding, surfaces	320	391
Export	190	313
Small Scale biomass	100	100
Alternative fuels/reuse	200	402
Total Demand	**4184**	**5559**

[10] Forestry Commission (2020) Forestry Statistics 2020, https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/

Sustainable domestic biomass resource from the forestry sector

34% of respondents to Question 2 specifically provided comments on the available supply of biomass from the forestry sector with 58% of these suggesting that **forestry has the potential for growth or is underutilised**. 26% of respondents who provided comments on the available supply of biomass from the forestry sector stated that the UK forestry resources for biomass will expand (or should not) with the remainder providing no clear position.

Most respondents evidenced their answers on the current size of the UK's available forestry biomass resource by citing the 2020 Forestry Commission Statistics[11] which stated there were 1.39 million hectares of certified woodland in the UK, out of a total 3.2 million hectares of woodland in the UK. Based on this statistic regarding uncertified woodlands**, a recurring theme was the number of unmanaged woodlands which could contribute towards the UK's biomass resources**.

Respondents suggested that **a priority should be to increase the amount of forestry covered by "Woodland Management Plans"**. Four respondents (including the Biomass suppliers List (BSL)) noted that it will be necessary to convert existing farmland to managed woodlands to meet expected future demand without further increasing imports of timber and fuels (wood pellets etc). However, respondents that were partially in favour of increasing planting of energy crops, and those concerned around food security, disagreed with this approach.

Regarding the potential UK forestry resources and targets to increase these, several respondents pointed towards the 2020 Forestry Commission Statistics[12] data to illustrate that while significant quantities of roundwood are harvested in the UK annually (10.8 million m^3 in 2019), **far greater quantities are imported** (49.9 million m^3 in 2019). This shows that the UK therefore relies heavily on imported wood for its timber and biomass needs. This data provides a baseline for the UK's current demand and suggests that **there is a market for UK forestry resource expansion**.

Most respondents found it difficult to provide an estimate on the UK's potential future sustainable forestry resource, however Calor did provide the below projected forestry resource by 2030 (based on research by the S2biom project)[13]. **This data suggests a decline in resource** which aligns with 26% of respondent views.

[11] Forestry Commission (2020) Forestry Statistics 2020, https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/
[12] Forestry Commission (2020) Forestry Statistics 2020, https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/
[13] https://www.s2biom.eu/

Table 6 – Calor Gas projections for the UK Sustainable Forestry Resource

	2012	2020	2030
Forestry resource (projections)	14566 (kt)	14300 (kt)	14111 (kt)

Sustainable domestic biomass resource from Energy Crops - (SRC, Hemp, Miscanthus, etc)

27% of respondents to Question two specifically provided comments on the supply of energy crops with 88% clearly stating that **energy crops have the potential for growth or is underutilised**.

Generally, respondents stated that due to the relatively low CO_2 emissions and quick growth rates attributed to energy crops that **the UK should look to expand this resource and market**. It was suggested that this could be achieved by incentivising farmers to convert land to growing wholly energy crops or to add them into their crop rotation. According to the ADBA response, the UK currently processes 3.7Mt of crops such as maize, grass, rye, and sugar beet for energy use (in 2019) with just 1.6% of UK arable land being used specifically for all bioenergy crops. The National Farmers Union (NFU) estimates that up to 40Mt of bioenergy crops can be produced each year from one million hectares of land in rotation per annum. Three respondents quoted research by Ricardo[14] which found that a significant part the UK's biomass resources (8-15% of the UK potential resource) will need to come from the development of energy crops on up to 350,000 ha of land.

The below Table (based of research by the S2biom project) [15] shows the projected growth of energy crops and grassland. It suggests a significant increase in energy crops between 2012 and 2020 and projected growth to 2030. However, grasslands feedstock is expected to grow more slowly.

Table 7 - Calor Gas projections for the UK Sustainable Energy Crop Resource

Feedstock Type	2012 (kt)	2020 (kt)	2030 (kt)
Energy Crops	141	3513	4336
Grassland	26903	26913	26919

[14] Ricardo's AEA's (2017) Biomass Feedstock Availability, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597387/Biomass_feedstock_availability_final_report_for_publication.pdf
[15] https://www.s2biom.eu/

Sustainable domestic biomass resource from other sectors

Responses tended to focus on waste, forestry and agricultural sectors, however other biomass feedstocks were highlighted. Of the other biomass feedstocks mentioned by respondents, 5% of respondents to Question 2 specifically provided comments on the supply and potential of algae, with 80% of those believing that **algae has the potential for growth or is underutilised**. Overall, respondents struggled to provide reliable data on the current available UK algae resource. It was noted that without clarity on Government policy regarding algae, along with significant investment, it was difficult to predict how much the UK could be produce in the future. A common theme however was that algae has massive potential particularly for carbon capture. For example, The University of Sheffield stated that "1kg of algae biomass can fix 2kg CO_2, however they stated that their research to support this claim is pending publication.

In addition, 5% of respondents also mentioned the potential of seaweed with 80% believing that further research and investment is warranted. As like comments regarding algae, **respondents found it difficult to predict the future potential seaweed could offer the UK** overall biomass resource.

CURRENT AND POTENTIAL FUTURE COSTS

Question 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?

94 respondents answered Question three equating to 65% of all respondents. The Table below summarises the respondent types for this Question.

Table 8 - Respondents categorised by respondent type for Question three

Respondent type	Total number of respondents
Academia	11
Biofuel / Biogas Producer & Technology Provider	12
Biomass Boiler Manufacturer	2
Biomass Supplier (Agriculture)	4
Biomass Supplier / Technology Provider (Forestry)	5

Respondent type	Total number of respondents
Certification Body	4
Chemicals	0
Consultancy	1
Government Organisation	3
Non-profit organisation / Special Interest Group / ThinkTank	9
Other	8
Trade Association / Representative Group – Agriculture	4
Trade Association / Representative Group – Biofuels / Biogas	3
Trade Association / Representative Group – Biotech / Chemicals / Products	5
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	5
Trade Association / Representative Group – General	4
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	3
Utilities / Energy Asset Owners / Distributors	7
Waste Management	2
Total	94

Overall, respondents **focused their answers heavily on the positive environmental and land use impacts relating to the supply and utilisation of feedstocks** and tended to make broader

assumptions on the current and potential future costs of supply. Each feedstock category is explored in more detail below with positive and negative impacts summarised.

Waste (Agricultural, Household, etc)

57% of respondents to Question 3, and who focused their response on waste feedstocks, agreed that the **key environmental impacts of using waste as a feedstock are positive**. Using waste was thought to **reduce waste sent to land fill and avoids displacing food, feed or wood production** which reduces possible conflicts with existing biomass and land uses. Seven respondents specifically commented on **the need to improve supply and waste processing chains in order to maximise the effectiveness of wastes as a feedstock**. There was also a clear recommendation to ensure that the transport of waste remains localised (respondents cited a radius of 30 miles) to ensure that GHG emissions are kept to a minimum.

Regarding the costs associated with the use of BioWaste, as the main production costs have already been built into the original "use" of the material, **the main increase in costs is associated with improving industry infrastructure to facilitate better use of BioWaste**. With investment in infrastructure improvements, waste can be used as a feedstock effectively from an existing resource. Additionally, the investment in this infrastructure and associated industry built around local BioWaste supply chains would support the development of rural economies.

Waste wood

Respondents noted that as the GHG emissions and costs associated with the production and use of waste wood are captured by its original use. Therefore, **the cost of utilising the feedstock should be minimal**, with the majority of the costs and GHG emissions associated with utilising waste wood being grading the "quality of waste wood", along with the associated transport and processing costs of converting this recycled wood into fuel. **The overall positive impact and cost associated with using waste wood was considered to outweigh any negative impacts**. The benefits of waste wood include, further resources being diverted from landfill, the low processing emissions, and transport costs being comparable to alternative feedstocks.

Respondents stated that the market for waste wood within the UK is relatively stable and suggested that they **do not expect the costs or demand of waste wood to significantly rise**. However, it was noted by two biomass suppliers that they expect their processing costs to rise by approximately 10% due to the removal of the red diesel allowance in April 2022.

It should be noted that several "Non-profit organisations" raised **concerns regarding air quality, particularly in built up areas**. In their view, waste wood can contain harmful contaminants and **burning waste wood can emit harmful Particulate Matter (PM)**. This risk was also noted by some

trade associations and biomass suppliers, however, most stated that the current EA regulations are sufficient to mitigate this risk.

Forestry

Overall, **respondents suggested that with sustainable management of UK woodlands, the increased use of UK forestry as a source of energy will have positive environmental impacts**. It was noted that the **government should avoid any policies which encourage excessive removal of tree cover** and instead target alternative biomass from degraded or underutilised land. The government should also encourage the delivery of continuous cover forestry to minimise GHG emissions and protect air quality, water quality, soil health, and biodiversity.

14 respondents noted the **need to improve the UK's overall woodland management** with respondents stating that increasing the percentage of woodlands covered by approved woodland management plans should be a priority. It was suggested that this could be achieved through improved training and advice regarding good forestry practices.

Five respondents commented that they have **seen forestry biomass supply costs increase in recent years,** in line with increasing biomass combustion capacity around the UK (associated with the RHI and Renewable Obligation Certificates (ROC) incentives), and these respondents also expect costs of UK timber to continue to rise. However, respondents did not give an indication of the scale of this increase. It was proposed that this increase in costs could have a positive impact as it incentivises new forest resources and re-planting of forests, which increases the UK carbon sink, biodiversity, and overall woodland stock.

Energy Crops

27% of respondents to Question 3, who focused their response on energy crops specifically and argued that **increased utilisation of energy crops could have the most beneficial impact environmentally**. Seven respondents suggested that **energy crops could be the most cost-effective option for biomass deployment but cautioned that the sector would need significant investment**. The main benefits were summarised as the potential to improve soil quality, biodiversity, reduce flooding and being more of an efficient use of land compared to alternatives. It was highlighted that the quick growth rate associated with energy crops is an advantage over other biomass feedstock types (mainly forestry). In addition, energy crops can provide landowners with another revenue stream as part of their options for crop rotation.

An important resource which was cited by numerous respondents was Ricardo's - Sustainable Bioenergy Feedstocks Feasibility Study[16]. This was particularly well referenced when discussing the cost associated with producing perennial energy crops such as SRC and Miscanthus. Ricardo's study suggested that the largest costs of supplying both SRC and Miscanthus are land rental fees, requirements for higher rates of return and harvesting. Harvesting accounted for around half the overall production costs due to the recurrent nature of the cost. Another major contributor to cost of supply was planting and planting material, which accounted for just under a third of the costs for Miscanthus and around a quarter of the costs for SRC.

ACCOUNTING FOR OTHER (NON-GHG) BENEFITS

Question 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)?

75 respondents answered Question four equating to 52% of all respondents. The Table below summarises the respondent types for this Question.

Table 9 - Breakdown of Respondents by Organisation Type for Question Four

Respondent type	Total number of respondents
Academia	9
Biofuel / Biogas Producer & Technology Provider	8
Biomass Boiler Manufacturer	1
Biomass Supplier (Agriculture)	4
Biomass Supplier / Technology Provider (Forestry)	3
Certification Body	3
Chemicals	0
Consultancy	2
Government Organisation	4
Non-profit organisation / Special Interest Group / ThinkTank	7

[16] Ricardo's AEA's (2017) Biomass Feedstock Availability, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597387/Biomass_feedstock_availability_final_report_for_publication.pdf

Respondent type	Total number of respondents
Other	7
Trade Association / Representative Group – Agriculture	3
Trade Association / Representative Group – Biofuels / Biogas	2
Trade Association / Representative Group – Biotech / Chemicals / Products	4
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	3
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	3
Utilities / Energy Asset Owners / Distributors	7
Waste Management	0
Total	**75**

Overall, **most respondents stated that increasing the UK's production of domestic biomass would have positive impacts on air quality, water quality, soil health, flooding risk and biodiversity**. A recurring concern was the need to more accurately account for the benefits. Respondents suggested that **industry and government do not currently measure and recognise these benefits when considering areas for investment, policy intervention and market growth**.

In terms of overall length and details of the responses to section one, responses to Question four tended to be the shortest and with the least supporting evidence provided.

Lifecycle Assessments (LCA)

A consistent recommendation from respondents to Question four was the need to improve "full" LCAs across the biomass sector. **It was generally agreed that there is not an industry "best practice" to follow**. It was proposed that improving the methodology and policy regarding the use of LCAs would provide more reliable data on the indirect benefits of biomass. Whilst there was acknowledgement that there is a well-developed methodology governed by ISO standards for LCA, it

can be challenging to apply these within a bioresource context due to the complex nature of biological systems. Moreover, as **best practices are yet to be established for auditing the environmental impacts of biotransformation processes**, there is inconsistency and challenges in applying attributional LCA techniques to biotechnologies. LCA needs be extended to assess value chain impacts and dependencies on natural capital as part of making bio-economies more circular. This could be complemented by conceptual techno-economic analysis, using cost-benefit analysis, cost-effectiveness, and risk assessment methods to aid with option appraisal.

Air Quality

21% of respondents to Question 4 commented on air quality with 18% specifically highlighting that **increasing access and production of domestic biomass will enhance air quality overall**. This was due the assumption that increasing access and production of domestic biomass will result in increased planting rates of woodlands and energy crops etc.

It was noted that as modern biomass boilers are generally installed **in sparsely populated areas, the impact on air quality is likely to be minimal**. However, some of the environmental charities expressed concern stating that even well-maintained boilers will produce more pollution than similar gas systems. Responses to Question 4 were comparable to those received for Question three with **NGOs raising concerns regarding the domestic burning of waste wood and "wet" wood with a particular emphasis on air quality**. One respondent also raised concerns regarding high levels of harmful PMs in wood smoke, which falls within the PM 2.5 category which is deemed a serious public health risk.

Soil and Crop Health

20% of respondents again stated that expansion of the UK biomass industry would have **positive effects on the soil and crop health**[17]. Respondents noted the benefit of adding further energy crops to farms crop rotation schedule as the key benefit for soil and crop health.

Biodiversity

17% of respondents noted that **expansion of forestry and agricultural biomass industries would ultimately have positive effects on biodiversity.** 4% of respondents disagreeed stating that expansion could have negative effects, while the remainder did not comment on biodiversity. Of those respondents who noted that biodiversity would be enhanced, it should be noted that this was under the assumption that re-planting rates and better woodland management practises would be adopted, in addition to a wider variety of crops being put into rotation. However, it was noted that use of heavy machinery for felling trees can also affect soil biodiversity, while growing crops in sensitive locations

[17] Future Biogas Response: Role of Biomass in Achieving Net Zero: Call for Evidence

can impact migratory bird routes, and the planting of biomass such as sugarcane and maize (used in AD) has been shown to significantly increase levels of soil erosion and infertility[18].

Flooding

14% of respondents to Question 4 specifically commented that **increasing our access and production of domestic biomass would reduce flooding risk**. This was particularly noted by respondents focusing on SRC highlighting that there is strong evidence that SRC provides flood prevention services due to its root structure. In addition, respondents highlighted that good woodland management can also aid flood prevention. However, Environmental charities disagreed pointing to harmful clear-felling practices that can affect water filtration and natural flood defences

Challenges or concerns raised

Three respondents to Question four mentioned that **the government should look to both punish and reward practices which cause environmental degradation and benefits respectively**. It was suggested that this could promote emissions reduction, encourage sustainable land-use and support biodiversity. Examples were provided in relation to sustainability governance frameworks which was seen as a regulatory stick to drive better practices and incentives such as rewarding organisations which follow good land use or environmental practices associated with cultivating feedstock.

DOMESTIC BIOMASS

Question 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

86 respondents answered Question five equating to **62% of all respondents**. The Table below summarises the respondent types for this Question.

Table 10 - Breakdown of Respondents by Organisation Type for Question Five

Respondent type	Total number of respondents
Academia	9
Biofuel / Biogas Producer & Technology Provider	13
Biomass Boiler Manufacturer	2
Biomass Supplier (Agriculture)	4

[18] Soil Association (Jun 2015). Runaway maize: subsidies soil destruction.

Respondent type	Total number of respondents
Biomass Supplier / Technology Provider (Forestry)	7
Certification Body	3
Chemicals	0
Consultancy	2
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	5
Other	6
Trade Association / Representative Group – Agriculture	5
Trade Association / Representative Group – Biofuels / Biogas	5
Trade Association / Representative Group – Biotech / Chemicals / Products	4
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	4
Trade Association / Representative Group – General	2
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	3
Utilities / Energy Asset Owners / Distributors	7
Waste Management	1
Total	**86**

Overall, respondents agreed that the **production of biomass and increasing the UK's domestic market does support rural employment/economy, farm diversification, circular economy, industrial opportunities**, along with positive wider environmental benefits.

Circular Economy

50% of respondents to Question 5 spoke of the **positive effect and role biomass does and will play in the rural circular economy** where biomass plants located close to the source of a rural feedstock can support skilled rural employment and green economic growth. A key theme mentioned was, integrating bioenergy systems as part of agricultural and/or forest activities, which can add significant co-benefits to landowners, employees, and local communities. **Biomass sourcing, production and utilisation can support diversification of agricultural/forest activities and create additional income** from biomass-based activities, thus creating jobs and building capacity. Provision of biomass for localised energy generation will also provide green skills/opportunities and support economic growth.

In addition, respondents noted that **waste and by-products represent a vast resource that is currently underutilised and could power a circularised bioeconomy.** The potential for refining MSW to create zero-waste urban systems was noted. AD was highlighted for its ability to play a part in the promotion of a circular economy approach in the food sector.

Industrial Opportunities

An increased reliance on biofuels was noted and it was suggested that **this could provide access to potentially highly skilled roles** in industrial biotechnology in regional areas, forestry management, transportation, system installation and maintenance. Existing supply chains and refineries from fossil fuel industries could be re-deployed as bio-refineries. Activities to support this transition could include **re-training of workforces from the fossil fuel industries** that will need to transition toward renewable and potentially bioenergy solutions. Respondents also commented that regional bioprocessing could be supported by centralised final processing, providing jobs and development in both rural regions and industrial clusters.

Respondents also pointed towards a study conducted by E4tech for Sustainable Aviation[19] which showed that by 2035, SAF (Sustainable Aviation Fuel) facilities could be built across the UK, generating an annual Gross Value Added (GVA) of £929m, creating 6,500 jobs and saving 3.6 million tonnes CO_2eq. per annum when fully operational.

Gasification of waste was also noted by one respondent to be a possible route to decarbonise difficult sectors such as transport. There is potential for producing BioLPG using the gasification of sustainable wastes and it was suggested that dedicated bio-refineries could provide significant volumes of fuel. It was also noted that urban farms and breweries may also present different

[19] https://www.e4tech.com/resources/108-sustainable-aviation-fuels-potential-for-the-uk-aviation-industry.php?filter=year%3A2014

economic opportunities across the supply chain, however further research into the viability of urban opportunities is required as they will need different solutions to their rural counterparts.

Rural Employment

Another consistent non-GHG benefit raised by respondents to Question 4 is **the positive impact expansion and investment would have on rural economies**. Drax Group referenced Analysis by ADAS UK[20] for the ETI36 on job opportunities from the domestic bioenergy market. This research estimates that by 2055, there will be ~5,600 FTE in the Solid Recovered Fuel sector, 1,300 FTE in the SRC sector and 2,200 FTE in the Miscanthus sector. After accounting for the fact that agri-crop-related jobs are seasonal, up to 17,900 individual job opportunities are created across the year in 2055, with between 4,300 and 16,700 individuals needed at any one time. Of the 17,900 individual opportunities estimated to be created by the bioenergy sector in 2055, 31% are expected to be specialist contractors, 25% offsite specialists (plant breeders/agronomists), 23% casual labour, 18% farmers and the remainder logistics experts (lorry drivers).

Wider Environmental Benefits

Further environmental benefits that were raised in this Question included:

- The potential for hemp to restore brownfield sites, Military of Defence/Defence infrastructure organisation sites, quarries, and former landfill sites
- The need to promote farming practises and feedstock types (such SRC) that do not require significant water, heavy industrial machinery, fertilisers to both harvest and convert into fuel.
- Increased production and use of biomass could help decarbonise sectors like agriculture while producing fuel for heat or electricity
- Development of district-based heating systems could help decarbonise rural areas
- Land management for biomass could be considered as an intervention under the Environmental Land Management Schemes (ELMS) to promote environmental benefits.

Challenges or concerns raised

One respondent noted that biomass policy should not promote the production of energy crops that have **negative environmental impacts** and native and local varieties should always be considered first as standard practise and as part of a complete LCAs.

[20] RELB: Job Implications of Establishing a bioenergy market, Wynn S et al 2016. Available here: https://www.eti.co.uk/library/adas-relb-job-implications-of-establishing-a-bioenergy-market

There is an opportunity to align across different uses of biomass. It was suggested that **all biomass feedstocks should be subject to the same standards regardless of use**, otherwise there is a risk that biomass use will be favoured by less-regulated sectors of the economy which could reduce the beneficial sustainability outcomes.

One respondent raised the **importance of consultation with local landowners and communities to ensure suitable net-zero pathways for the region** and determining correct usage pathways for biomass. Doing so would allow regional authorities or efforts to reap the highest benefits from additional production of biomass by identifying the **most suitable uses of biomass** and ensuring that these are prioritised to **meet the regions decarbonisation requirements**.

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

88 respondents answered Question six equating to **61% of all respondents**. The Table below summarises the respondent types for this Question.

Table 11 - Breakdown of Respondents by Organisation Type for Question Six

Respondent type	Total number of respondents
Academia	8
Biofuel / Biogas Producer & Technology Provider	12
Biomass Boiler Manufacturer	2
Biomass Supplier (Agriculture)	4
Biomass Supplier / Technology Provider (Forestry)	6
Certification Body	3
Chemicals	0
Consultancy	3
Government Organisation	1
Non-profit organisation / Special Interest Group / ThinkTank	6
Other	7
Trade Association / Representative Group – Agriculture	4

Respondent type	Total number of respondents
Trade Association / Representative Group – Biofuels / Biogas	4
Trade Association / Representative Group – Biotech / Chemicals / Products	4
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	7
Trade Association / Representative Group – General	4
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	2
Utilities / Energy Asset Owners / Distributors	8
Waste Management	1
Total	**88**

Overall, respondents to Questions six stated that the main challenges and barriers to increasing our domestic supply of sustainable biomass are a perceived lack of consistent government policy, uncertainty surrounding finances and incentives, demand uncertainties, and public perception.

Government policy

26% of all responses expressed **concerns over a lack of certainty around the Government's overall policy and strategy regarding biomass**. This lack of perceived long-term direction is seen as **preventing the biomass industry from being able to plan and invest with confidence**. Without clear government strategy which provides sufficient confidence in the market, farmers will be hesitant to devote land to producing energy crops, which will hinder the scaling up of domestic biomass supply. In addition, respondents commented that **stepping up the reclamation of biomass feedstocks from waste would require new rules for the collection of food waste from households, and improvements to local recycling infrastructure**. Furthermore, utilisation of food waste for AD or composting would require LAs to provide separate food waste collections, additionally diverting this waste stream away from landfill into the biomass feedstock supply chain.

Finance and Incentives

31% of all respondents to Question 6 stated the **main challenges or barriers to the expansion of the UK's domestic supply of sustainable biomass are economic in nature**. A consistent theme across respondents was lack of, or reduction of incentives, relating to both the growth and usage of biomass, with the removal of the RHI being the most common incentive mentioned.

Another consistent economic theme was the overall lack of investment in infrastructure (transport, processing plants etc), along with lack of research and development funding in new technology and "novel" forms of biomass (Hemp, algae etc). Respondents were concerned that without a clearly published strategy regarding targeted investment for new technologies, financial support for potential schemes encouraging the allocation of land for production of biomass along with providing industry and consumers with incentives which support diversification and adaptation of biomass, that the biomass sector would struggle to expand meaningfully to contribute towards Net Zero.

It was also noted by three respondents that farmers require long term, guaranteed contracts offering a price that is competitive with cereal crops for ventures to be economically viable. Without long-term guarantees, farmers are unlikely to diversify their crop base and be able to properly adopt biomass as a viable commercial option, either into crop rotation or as a sole crop.

Public Demand, Perception and Education

21% of respondent to Question 6 stated that the **public need encouragement to move from fossil fuels,** which, often as the incumbent fuel, is seen as the easy option. The perceived "expense" of switching from relatively cheap-to-consume fossil fuels, for which the appropriate appliances are already available, presents a barrier for further uptake in domestic biomass systems. Some have also noted that the demand for domestic forestry and other biomass resources may decline as **there is currently no comparative domestic replacement to the Non-Domestic Renewable Heat Incentive (NDRHI).** It was also suggested that negative public perception of UK woodland being used for wood fuels must be changed, by educating and reassuring the public that due to rapid planting rates, our woodland cover is increasing.

Wider industry barriers and challenges

Further industry barriers and challenges raised in this Question included:

- Land availability for forestry, and planning constraints on forestry being planted on agricultural land,
- Competition of biomass with livestock and food crops, wildlife, and broader economic, environmental, and social demands

- Ensuring biomass end uses are aligned, and not depriving its use elsewhere, including reuse in construction, or recycling for use in long term storage, wood-based products such as wood-based panels (e.g. chipboard)
- Competition from other renewable heating technologies and options, particularly small domestic options such as Heat Pumps
- Delivery and access issues for domestic boilers and sufficient domestic space to store fuel (in particular wood pellets)
- The Covid 19 pandemic and the associated economic impact for businesses along with work restrictions/policy
- The cost of compliance, regulation (waste permits etc) and associated industry certifications becoming increasingly expensive.

IMPORTS OF BIOMASS

Question 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?

78 respondents answered Question seven equating to **56% of all respondents**. The Table below summarises the respondent types for this Question.

Table 12 - Breakdown of Respondents by Organisation Type for Question Seven

Respondent type	Total number of respondents
Academia	9
Biofuel / Biogas Producer & Technology Provider	8
Biomass Boiler Manufacturer	1
Biomass Supplier (Agriculture)	3
Biomass Supplier / Technology Provider (Forestry)	8
Certification Body	3
Chemicals	0
Consultancy	3
Government Organisation	1

Respondent type	Total number of respondents
Non-profit organisation / Special Interest Group / ThinkTank	7
Other	7
Trade Association / Representative Group – Agriculture	3
Trade Association / Representative Group – Biofuels / Biogas	2
Trade Association / Representative Group – Biotech / Chemicals / Products	2
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group – Forestry Supply / Products	6
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	2
Utilities / Energy Asset Owners / Distributors	7
Waste Management	0
Total	**78**

Current and Future Imported Resources and Locations

27% of respondents to Question 7 stated they either supported the UK **increasing the amount of imported Biomass into the UK** or commented that the amount would **inevitably rise towards 2050**. With 23% either suggested that **the UK should look to decrease importing biomass** or should stop completely. 50% of respondents provided no clear opinion whether they support or are against the importation of biomass, however a key theme across respondents for Question 7 was that **the UK is currently highly reliant on imported biomass resources**. In particular, the dependence on imports of wood pellets was highlighted. Some respondents were strongly opposed to the importing of biomass and have commented **that importing from Europe and the USA increases CO_2 emissions associated with its use**. It should be noted that almost all respondents focused their responses on the available imported "woody" biomass fuels and there was almost no mention of importing other feedstock types.

Respondents who expressed support for increasing the level of imported biomass into the UK were primarily biomass suppliers, trade associations (which included several North American forestry and

pellets associations) and international certification bodies heavily involved in the international biomass market.

Overall, respondents supportive of imported biomass recommended that **ongoing and short-to-medium term increases in the importation of biomass is necessary** to enable UK growth trajectory of bioenergy towards the 2050 net zero targets. These respondents were also of the view that **importing biomass is sustainable and cost effective** (although as noted later within challenge and concern raised by respondents to Question seven, further regulation has been recommended).

Several respondents pointed to the Forestry Commission's statistics [21] which showed that in 2016 the **UK was the second largest importer of forestry products**. According to figures by the UK Pellet Council (UKPC)[22], between 2015 and 2019 the quantity of imported pellets traded in the UK had increased by a factor of 25. The UKPC also estimated that the UK uses ~600,000 tonnes of A1 grade pellets each year, of which approximately 250,000 tonnes is produced from four UK plants and 350,000 tonnes is imported from Europe, predominantly from the Baltics and the Iberian Peninsula. While the UKPC suggested **there is the potential to increase the domestic pellet production** by up to 100% (using sawmill residues and forestry by-product), they noted that this is unlikely given industry reluctance to invest in UK pellet mills. However, UKPC and several other respondents proposed that even if the UK were to increase its own production of wood fuels to meet current and expected future demand, the levels of imported biomass fuel would continue to rise, due to increasing expected demand.

Drax, which many respondents pointed out as the largest single importer of biomass fuel, stated that in 2020, they imported just over seven million tonnes of woody-biomass. 80% of their feedstock supply come from the Southeast of North America, with a further 13% from the Baltics and the remainder from Portugal, other EU countries, and Brazil. Drax specifically mentioned that the USA has a "*tremendous forest resource, with over 1.1 million square km of forest land - 110 million hectares or 271 million acres*". The USA was consistently mentioned by other respondents as having the greatest potential sustainable resources of biomass. This is mainly because the USA has advanced forest industries, strong regulation, and robust sustainability standards which makes it likely to continue to make up a large percentage of the imported biomass into the UK. It should be noted that three of the trade associations who responded to Question 7 are USA based industry associations.

[21] Forestry Commission (2018) https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2018/international-forestry/world-trade-in-forest-products/

[22] UK production and trade of ENplus pellets. https://docs.google.com/spreadsheets/d/1kurKaRNJuQWfw-fyt-P8skK2_AdjLmPptpQdQximF84/pubchart?oid=1411692576&format=interactive

Opposition to Importing Biomass

Respondents opposed to importing biomass tended to be responding on behalf of NGOs, within the Academia Sector, and some Trade Associations. The respondents who favoured Waste, Energy Crops, and other biomass feedstocks and who are opposed to importing biomass to meet the UK needs, were of the view that **increasing the amount of imported biomass would ultimately suppress expansion of the UK market** and that the industry and Government should look to phase out importing biomass and invest in native resources which have the potential to allow the UK to be largely self-sufficient.

It was also noted by respondents opposed to importing biomass wood fuels that the **NDRHI subsidy has distorted international markets for biomass** and Questioned the sustainability and carbon emissions associated with the production and shipping of biomass particularly from Eastern Europe and the USA. They noted that, importing biomass fuel such as chip and pellets from these locations is ultimately counterproductive as the carbon saving are debatable and could be damaging to biodiversity in these regions. In addition, **some Questioned our reliance on imported fuels and its risk to national energy security** and pointed out that other UK feedstock streams such as waste could significantly reduce our reliance on imported biomass. The World Wildlife Fund (WWF) Risky Business report[23] made reference to support concerns regarding CO_2 and biodiversity imported biomass fuel.

Challenges or Concerns Raised

A consistent risk noted by respondents either in favour of increasing imports or from those who are projecting imports will inevitably increase are **issues regarding consistency of the supply chain, both economically (price of fuel) and the availability of supply**. In addition, it was also noted that there is a risk that the growing demand for biomass worldwide may erode the UK's 'first-mover' advantage as an importer over time, which in turn could drive up costs.

The need to increase sustainability and legal requirements for the import of wood fuels into the UK was also raised by four respondents. It was noted that the BSL's recent updated requirement that only imported timber/products which hold FSC, PEFC or Sustainable Biomass Program (SBP) certification, if the timber has originated from countries with a Confor risk rating of under a 100, could be explored as a baseline requirement for all imported timber to be use for as fuel.

[23] RSPB/WWF Risky Business report. Available online: https://www.wwf.org.uk/riskybusiness

Chapter 2: End use of biomass

Chapter 2 explored the various end-uses and applications that biomass can be used for. It invited evidence on the **role and potential of different biomass feedstock types** to support the decarbonisation of different areas, such as agriculture, chemicals and materials, transport, and power, and asked **which areas are best suited for priority applications** in the short and long term as well as the **policy gaps and wider barriers that need to be overcome** to realise their potential. In addition, it sought information on how the deployment of BECCS could be supported, how biomass use could be prioritised to best deliver our net zero target, and whether and how the Government could target sustainable biomass use towards the highest priority application.

A range of end uses were valued by respondents, though our findings indicate that some are seen as a greater priority than others. Many respondents referred to biomass in its holistic sense opposed to specifying sources, however, where sources were specified, this information has been captured. Several existing frameworks were identified to prioritise biomass deployment, alongside a range of different principles that should guide prioritisation. Policy gaps, risks and barriers impacting deployment were also identified. Respondents saw that a range of policy mechanisms would be required to support biomass deployment, including extension of existing policies. However, in contrast to this, there were some respondents who noted that existing policy was distorting the market and that support should be removed. Looking at air quality specifically, respondents highlighted how biomass should be used as opposed to specifying end uses where deployment should be avoided all together, however, where this information was provided, it has been captured.

ROLE FOR BIOMASS

Question 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)

117 respondents answered Question eight equating to 84% of all respondents (please note this includes those who did not answer specific Questions but who provided information relevant to this Question that was captured here and does not include duplicate responses). The Table below summarises the respondent types for this Question.

Table 13 – Breakdown of Respondents by Organisation Type for Question Eight

Respondent type	Total number of respondents
Academia	10
Biofuel/ Biogas Producer & Technology Provider	14
Biomass Boiler Manufacturers	2
Biomass Supplier (Agriculture)	4
Biomass Supplier/ Technology Provider (Forestry)	8
Certification Body	4
Chemicals	2
Consultancy	3
Government Organisation	3
Non-profit organisation / Special Interest Group / ThinkTank	13
Other	8
Trade Association / Representative Group - Agriculture	4
Trade Association / Representative Group - Biofuels / Biogas	6
Trade Association / Representative Group - Biotech / Chemicals / Products	7
Trade Association / Representative Group - Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group – Forestry Supply / Products	8
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	2
Utilities/ Energy Asset Owners/ Distributors	11
Waste Management	2
Total	**117**

The responses to Question eight were relatively detailed with many respondents citing multiple end-uses and providing a detailed justification of their viewpoint, with evidence provided in many cases. Not all respondents specified a source and as such, analysis has been conducted across all sources, with a detailed focus on specific sources undertaken separately. Many respondents referred to specific technologies within each end-use category and where possible, this information has been captured.

It should be highlighted that some respondents explicitly indicated that biomass was not required within a certain sector, with some not commenting at all Analysis of responses to this Question has been divided into each end-use category, with individual context regarding the specific biomass sources provided under each of these sub-headings.

It is important to note that not all respondents supported the principle of prioritisation by end-use. Further information on this has been provided under the 'Challenges or Concerns Raised' subheading in this section. It may be valuable to refer to Figure 8 below which was submitted to the Call for Evidence by multiple respondents and indicates the global consumption of biomass and wastes by end-use in 2015.

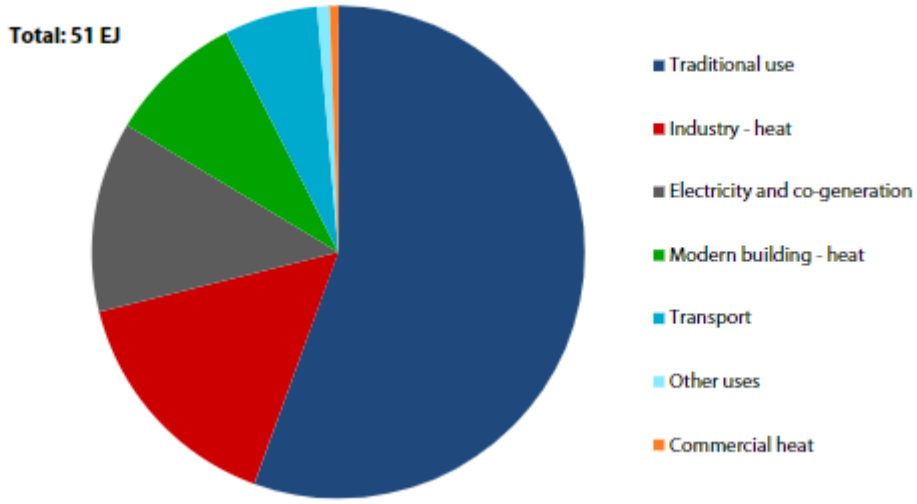

Figure 8 - Global Consumption of Biomass and Wastes by End – Use in 2015[24]

[24] CCC. Biomass in a Low Carbon Economy. Available At: https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/

Heat

Looking across all biomass sources, 44% of respondents to this Question indicated that some form of biomass could be valuable in supporting the decarbonisation of heat, whilst 7% indicated that some or all sources of biomass were not required.

Respondent Categories of Interest

100% of respondents in the below categories who responded to Question eight indicated that biomass has a role to play in heat.

- Biomass Boiler Manufacturers.
- Government Organisations
- Trade Association / Representative Group – Heating Appliances

Respondents saw biomass as having a key role to play as an alternative source of heat to traditional fossil fuel heating. Some saw biomass as important specifically in **rural, off gas grid areas and hard to treat properties**, and in particular at a small to medium scale, whilst others saw the potential for **biogas to be blended into the gas distribution system**. In addition to this, **district heating** was also referenced as a key opportunity for biomass. Some respondents simply referred to the role of biomass in decarbonising heat more generally (further information has been provided below). It should be noted that 12 respondents referred to industrial heat, however, these responses have been captured within the 'industry' section.

29% of those who supported biomass in heating referred to rural and/or off gas grid areas and 24% referred to hard to treat properties. These factors are inextricably linked, with one respondent citing that around 2 million dwellings in the UK are not connected to mains gas and are in rural areas and that 70% of the least energy efficient housing (those rated F/G) are off gas grid.

At least ten respondents referred to the **need to transition away from the high carbon emissions associated with fossil fuels in off gas grid properties (such as heating oil and coal).** The complexities associated with installing alternative technologies, such as heat pumps in harder to treat properties, were also highlighted. When considering heat pump installations, the following key concerns were raised:

- The **poor fabric efficiency** of old buildings (particularly those with solid walls) and the complexities and costs associated with insulating these.

- The **difficulties associated with listed buildings** including aesthetic considerations associated with preparatory work (e.g. insulation) and the heat pump itself.
- The **need for heat emitter replacement** when installing a heat pump.
- The **potential need for grid reinforcement** with increasing electrification of other sectors including transport.

Reference was made to the Government's own research which indicates that around 20% of off gas grid fossil fuel homes are not currently suitable for low temperature heat pumps and are better suited to high temperature heating[25]. Though there was a suggestion that when accounting for technology costs, rather than what would be technically feasible, the size of the 'hard to treat' sector could be over double this.

Several different forms of biomass heating were referenced by respondents including biomass boilers, the use of biomass sources to supply local Combined Heat and Power (CHP), and bio–Liquefied Petroleum Gas (bioLPG) which can be used as a drop in fuel for any LPG boiler. There was also extensive discussion around the role of processed biogas (e.g. biomethane) and injection of biogas into the national gas grid. It was suggested that biogas can be produced from a range of biomass sources including terrestrial seaweed, sugar beet pulp and waste. It was noted that biogas can be injected into the national gas grid to support decarbonisation. Respondents highlighted that as biomethane is chemically identical to fossil fuel natural gas, it is compatible with all existing gas infrastructure from transmission via the gas grid to combustion within domestic boilers.

There were a range of technologies referenced in relation to biogas production including, but not limited to AD, alkaline thermal treatment, and electrolysis and pyrolysis. In their response, ADBA estimated that industry could produce 54.5 TWh of biomethane per year – enough to heat 4.5 million homes and that with further efforts, an additional 21.8 TWh, heating a further 1.8 million homes could be possible. There was also a discussion around the development of heat networks connected to biomass power plants and CHP to enable local housing or industry to use the heat from power generation or heat networks with a biomass heat source. Looking at CHP, it was suggested by ADBA that most biogas currently produced is being fed into CHP engines (~60% of all biogas produced). Those who referenced heat networks provided limited data regarding the potential scale of this solution but did provide insight about where this may be a valuable solution, referring to locations with pre-existing heat networks including Birmingham and Sheffield as well as the potential in the Tees Valley. Respondents also referred to the role biomass could play in hybrid heating systems. In

[25]BEIS. (2020). Future Support for Low Carbon Heat. Available At: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/888736/future-support-for-low-carbon-heat-consultation.pdf

particular, where biomass systems are combined with heat pumps to alleviate the pressures associated with widespread electrification during periods of cold weather. Reference was also made to non-domestic buildings off the gas grid and the role biomass could play in decarbonising heat in commercial buildings as well as schools, hospitals, leisure centres and greenhouses.

The below Figure was provided by the Renewable Energy Association (REA) and highlights the potential growth in bioenergy for heat production. It indicates an increase in biomass use in heat networks and biomethane production specifically with a decline in unmanaged domestic wood heating.

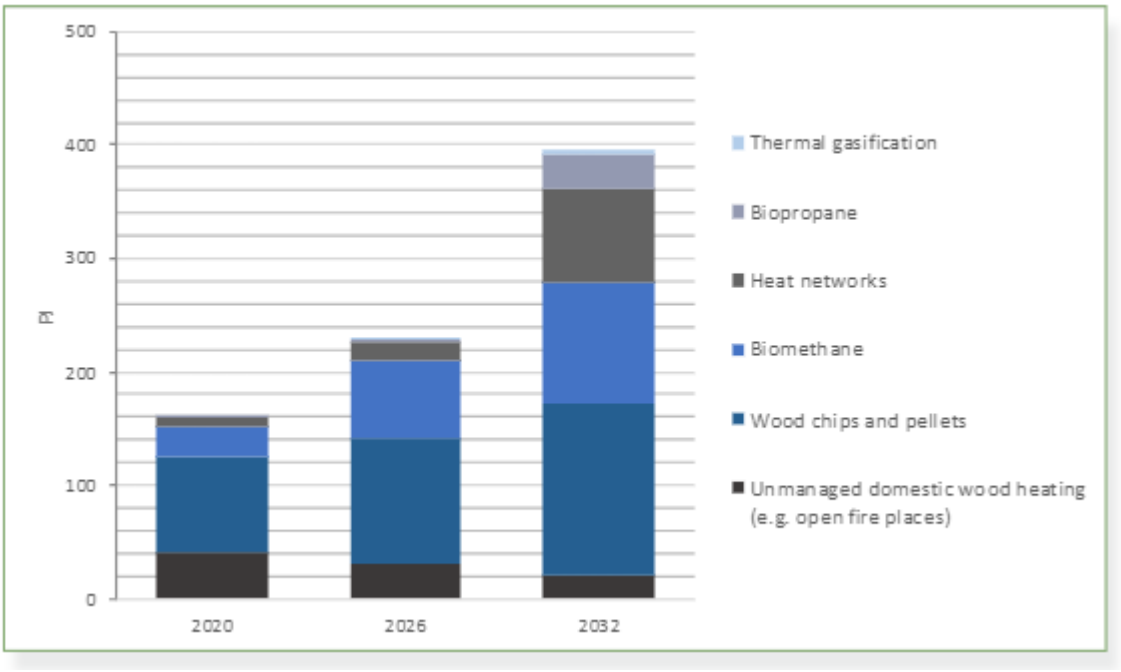

Figure 9 - Potential Growth in Bioenergy for Heat Production[26]

Information on the cost of different biomass options for heating were provided, compared to fossil fuel counterfactuals as well as other low carbon alternatives such as heat pumps. However, **beyond cost, there was reference to the importance of the consumer and consumer choice**, with indication that a range of other factors are important for consumers when considering a heating system. These included:

- The ability for consumers to use the heating system whenever they like.
- The importance of heating the home up quickly.

[26] REA. Bioenergy Strategy. Available At: https://www.bioenergy-strategy.com/publications

- The importance of system familiarity.

Whilst some cited that biomass systems would be easier for consumers to use compared to other low carbon alternatives, others suggested certain systems could be more complex. There was an indication that vulnerable households may struggle to handle pellets and logs and the on-going cleaning required associated with traditional biomass boilers. In relation to consumer choice, respondents cited the importance of Government supporting a range of technologies in the route to net zero to ensure consumers have different options available to them.

(Certain Sources Of) Biomass Not Required

For those who didn't support the role of biomass in heating or only supported it in limited circumstances, a range of reasons was cited including:

- The **limited availability of biomass sources** and in particular forestry feedstocks.
- The **existence of alternative technologies** such as heat pumps powered by low carbon electricity from sources such as wind, solar PV, and nuclear and green hydrogen.
- The **air quality implications associated with biomass combustion** (PM2.5 and NO_2) and the public health impacts associated with poor air quality. There was indication that new restrictions on the sale of wet wood were not sufficient to mitigate this risk and that there is a need to consider local air pollutants and GHGs holistically in a 'one atmosphere' approach to achieve zero air emissions, with reference made to the Climate Change Committee's recognition that any outcome which reduces or removes GHG emissions at the expense of air quality would be unacceptable.
- The **CO_2 emissions associated with biomass and specifically forestry biomass combustion** were also highlighted. It was noted that biomass feedstocks can only feasibly contribute towards decarbonisation where the CO_2 emissions from burning would have occurred anyway within a very short timeframe or where emissions will be taken up again by plant regrowth within a short space of time. Reference was made to the IPBES/IPCC report on biodiversity and climate (see extract below).

IPBES/IPCC Report on Biodiversity and Climate[27]

"Actions undertaken for climate change mitigation by enhancing ecosystem carbon sinks through biomass, planting large areas of forests or crops for biomass energy, may have other important consequences for the climate system. It is important that the full climate consequences of land-based climate mitigation actions, in both the short and long-term are considered when evaluating their contribution. These consequences include effects mediated by changes in non-CO_2 GHG emissions, reflectivity of the surface to solar radiation (albedo), evapotranspiration, and the concentration of aerosols in the atmosphere, as well as indirect land-use change arising from large forest-area or bioenergy cropland expansion."

It was highlighted that decisions need to be made now, with indication that **failure to send clear signals to consumers and industry regarding the role of biomass in heat (and across other sectors) going forward could result in an ever-increasing legacy problem.**

Respondent Categories of Interest

Those who did not support some or all sources of biomass in certain or all heating applications were from the following respondent organisations:

- Academia
- Non- Profit Research Organisation / Special Interest Group / Think Tank
- Trade Association – Forestry Supply Products N.B – The focus of these responses was on the use of biomass for materials such as wood-based panels

Electricity

Looking across all biomass sources, 38% of respondents to this Question indicated that some form of biomass could be valuable in supporting the decarbonisation of electricity, whilst 11% indicated that some or all sources of biomass were not required.

Respondent Categories of Interest

100% of respondents in the below categories who responded to Question eight indicated that biomass has a role to play in electricity:

- Biomass Supplier (Agriculture)
- Waste Management

[27] IPBES and IPCC. Biodiversity and Climate Change: Workshop Report. Available At: https://ipbes.net/sites/default/files/2021-06/20210609_workshop_report_embargo_3pm_CEST_10_june_0.pdf

Of those who supported the use of biomass in electricity generation, several referred to the role of biomass in **delivering negative emissions electricity** (via Bioenergy Carbon Capture and Storage (BECCS)) as an opportunity to **not only decarbonise electricity generation to be used in other sectors (e.g. heat and transport) but also to enable negative emissions in support of harder to abate sectors.** It was also noted that the captured CO_2 may be used to provide reliable 'anchor' volumes to enable the successful deployment of early CO_2 transport and storage networks. The importance of ensuring BECCS is cost effective and provides genuine negative / carbon neutral emissions, whilst avoiding wider adverse environmental impacts was highlighted by respondents.

Respondents who highlighted BECCS as a use for biomass, made specific reference to perennial crops such as Miscanthus and SRC given the ability to grow these crops at scale and their ability to outperform other biomass sources[28]. Reference was also made to forestry sources, with specific mention of the IPCC's Special Report on Climate Change and Land which noted the importance of sustainable forest management that can also yield products including bioenergy, with almost all scenarios to prevent warming above 1.5 °C including a combination of bioenergy, carbon capture, and reforestation and afforestation which can be supported by woody biomass[29].

Respondents often highlighted **specific technologies to support the decarbonisation of electricity**. For example, at least 10 respondents noted the importance of utilising CHP which is associated with higher efficiencies than solely electricity generation. It was suggested heat could be used in a variety of end uses including to heat buildings via heat networks. Other technologies referenced included alkaline thermal treatment, as well as incineration and pure pyrolysis. In relation to these technologies, there appeared to be a particular focus on using waste (including food waste, MSW and sewage sludge) with respondents noting that waste derived biomass could play an important role. It was suggested that waste was preferable to other sources in some of the above technologies.

Six respondents specifically cited the important role biomass could play in **supporting intermittent generation** by responding to grid deficits from intermittent renewable sources such as solar PV and wind. Some suggested that biomass could play this role directly, given its inherent in-built storage. It was noted that liquid biomethane, for example, could be used to fuel generator sets situated at solar PV and wind farms using National Grid connections and/or positioned at high-capacity access points in the grid which could even be combined with Liquid Air Energy Storage (LAES) technologies. It was also recognised that biomass power generation is itself dispatchable.

[28] CCC. Sixth Carbon Budget: Methodology Report. Available At: https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-Methodology-Report.pdf (Figure B7.5)
[29] IPCC. (2019). Special Report: Climate Change and Land. Available At: https://www.ipcc.ch/srccl/

By contrast, five respondents suggested that using biomass to produce hydrogen would be preferable given hydrogen has good energy storage and seasonal balancing capabilities. Moreover, hydrogen can be combusted in existing gas turbines in the short term while locking in a future pathway to 100% hydrogen-fuelled power generation. It was also suggested that the AD industry could support in providing flexibility to the grid by absorbing excess electricity to produce green hydrogen via electrolysis, which could then be fed into an AD digester to produce biomethane to be stored in the gas grid and used during periods where demand exceeds supply.

The below Figure was provided by the REA which shows the potential growth in bioenergy for electricity production out to 2032. It is important to note, that this Figure may not represent the viewpoints of all respondents.

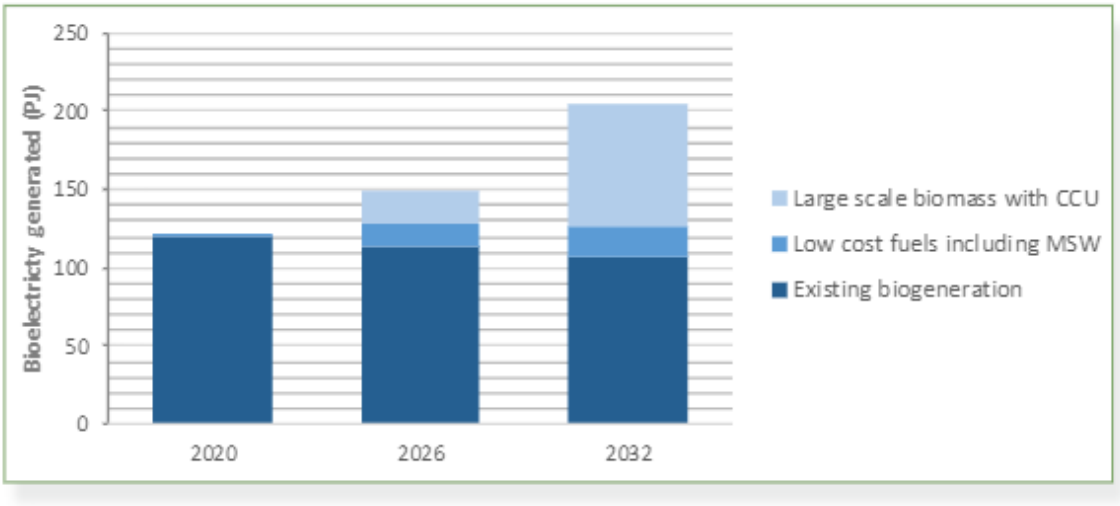

Figure 10 - Potential Growth in Bioenergy for Electricity Production[30]

(Certain Sources Of) Biomass Not Required

There were however challenges raised to the use of biomass in the decarbonisation of electricity. Some of the key challenges raised have been outlined below:

- Potentially **declining carbon benefit of biomass as the grid decarbonises** as biomass technologies are not as low carbon as alternative technologies (such as nuclear, wind and solar PV alongside battery storage).

- The fact that **the carbon benefit of biomass technologies needs to be further understood**, with reference to a report by UCL which stated that the full life cycle emissions

[30] REA. Bioenergy Strategy. Available At: https://www.bioenergy-strategy.com/publications

of BECCS could often be far from zero and could in fact be as high as 40-80% of the captured CO_2, due to various factors associated with the supply chain[31]. Forestry feedstocks and the CO_2 emissions associated with biomass and specifically forestry biomass combustion were highlighted as concerns. A respondent noted that biomass feedstocks can only feasibly contribute towards decarbonisation where the CO_2 emissions from burning would have occurred anyway within a very short timeframe or will be taken up again by plant regrowth within a short space of time.

- **The sustainability of biomass sources** in relation to the indirect land use change and biodiversity impacts of agricultural sources and deforestation.
- **The cost of biomass technologies** was also cited as a barrier to uptake.
- **Challenges with biomass fuel procurement, delivery and storage** were raised, with specific reference to forestry sources. In relation to storage, it was noted that dust from wood chips can create a hazard, as well as the ability of wood chips to self-ignite, or spontaneously combust when stored for long periods of time.
- The **air quality impact associated with biomass technologies** and the implications this can have for health were stated and these concerns have been discussed further in the analysis of responses to Question 14.
- **Specific technical challenges** associated with certain biomass technologies were also raised.

Respondent Categories of Interest

Those who did not support some or all biomass in electricity were from a range of respondent types including but not limited to[32]:

- Consultancies
- Government Organisations

[31] UCL Institute for Sustainable Resources. The Role of Bioenergy with Carbon Capture and Storage in the UK's Net Zero Pathway. Available At: https://www.ucl.ac.uk/bartlett/sustainable/sites/bartlett/files/ecf_beccs_final_report.pdf

[32] These categories have been selected for reference here as they are the top three categories in terms of the proportion of respondents who indicated this view as a percentage of the number within the respondent category who responded to the Question as a whole. Unless indicated otherwise, this is used throughout the remainder of this chapter. Where different categories have equal percentages, those categories with the top three percentage values have been cited.

- Non-profit organisations/ Special Interest Groups/ ThinkTanks

Transport

41% of respondents to this Question indicated that some form of biomass could be valuable in supporting the decarbonisation of transport, whilst 3% indicated that some or all sources of biomass were not required.

Respondent Categories of Interest

Those who supported biomass in transport were from a range of respondent types including, but not limited to:

- Government Organisations (100% of government organisations who responded to Question eight).
- Biofuel/Biogas Producers & Technology Providers/Trade Associations / Representative Groups - Biofuels / Biogas

Across transport, **several energy vectors were referenced** including liquid biofuels, biohydrogen, & biogas. **Multiple technologies were also referenced** including hydrogenation, AD, gasification, alkaline thermal treatment, pure pyrolysis and the Fischer-Tropsch process. In relation to the use of biomass in transport, the below Figure was provided by the REA. It is important to note, that this may not represent the viewpoints of all respondents.

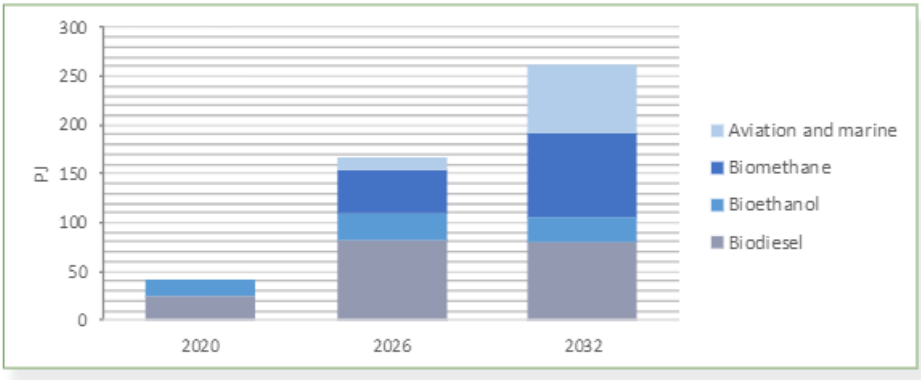

Figure 11 - Potential Growth in Bioenergy for Transport[33]

Feedstocks for transport that were highlighted by respondents included waste such as MSW and food waste; and agricultural sources such as wheat and sugar beet. It was noted that technologies for

[33] REA. Bioenergy Strategy. Available At: https://www.bioenergy-strategy.com/publications

advanced biofuels are under development around the world with many technologies to turn non-food organic waste into transportation fuels currently being developed.

Of those who supported the role of biomass in transport, many referred to harder to decarbonise applications including HGVs, aviation, shipping and in some cases rail where diesel drive trains are in operation. Some referred to the role of biomass in cars in the short term. Other forms of transport identified included forklift trucks and tractors. It was noted that **transport has seen a slow decline in emissions and the importance of supporting the decarbonisation of this sector was highlighted**, particularly in areas where other options are not well established.

It was indicated that with competition for biomass expected to increase, future policies should be carefully designed to **prioritise biomass usage for transport applications for which there are few alternative abatement options to 2050**. Similarly, the supply and demand of biofuels across different transport sectors was referenced as important for consideration. For example, it was suggested by one respondent that a mandate for biofuels in aviation for example, should be structured so that it incentivises biofuels in the sector in the short term and helps transition biofuels from road transport to aviation in the medium to long term.

Reference was made to Department for Transport statistics which reveal that UK biofuel supply achieves average GHG savings of 82% compared to fossil fuels[34] and that for the period 2018-19, biofuels in the UK saved approximately 2 million tonnes of GHG emissions, equivalent to removing more than one million cars from the road[35].

Cars (Short Term)

It was suggested by four respondents that there would be a **role for biofuels in fuelling legacy internal combustion engines in the short term**, particularly in the delivery of biomethane for the E10 mandate. It was however suggested this use would decline in the long term with the rise of Electric Vehicles and the focus would shift to some of the harder to decarbonise forms of transport.

On E10, it was noted that although biofuels are in widespread use today in blends with petrol and diesel, typically at 5-10% by volume, there is a lot of discussion around an E20 petrol grade. It was highlighted that it is perfectly feasible to increase the bio-content of petrol well beyond the ethanol blend limit as any ‘excess’ ethanol can be converted to full EN228 bio-gasolines. It was the respondents view that this is an area that is not being researched aggressively enough.

[34] Department for Transport. Renewable Fuel Statistics 2020: Fourth Provisional Report. Available At: https://www.gov.uk/government/statistics/renewable-fuel-statistics-2020-fourth-provisional-report/renewable-fuel-statistics-2020-fourth-provisional-report
[35] Zemo Partnership. The Renewable Fuels Guide. Available At: https://www.zemo.org.uk/assets/reports/ZEMO_Renewable_Fuels_Guide%20_2021.pdf

Heavy Goods Vehicles (HGVs)

35% of those who supported biomass in transport specifically cited HGVs as a key area. It was noted that for long haul HGVs, the lack of technology readiness for low carbon options is one of the main challenges for the sector to deliver net zero emissions. It was suggested that key benefit of biofuels in the space is that they **can be blended with existing fuels such as gasoline, natural gas and diesel and used in today's engines and existing infrastructure**, offering practical and cost-efficient solutions for reducing emissions.

Specific examples were cited, for example reference was made to both CNG and LNG and their growing use for HGVs in the UK freight sector. Reference was also made to biomethane as a drop in fuel for natural gas vehicles; with approximately 600 HGVs currently operating on biomethane in the UK. There was acknowledgement of the role of biomethane ahead of a future hydrogen solution to deliver greater emissions savings compared to solely focusing on zero emission options, as emissions saved today are more than emissions saved later. It was noted that delaying the switch to biomethane today and waiting for a zero-emission solution could severely limit carbon savings.

Aviation

There appeared to be **particular reference to the role of biomass in the production of SAF**, with 50% of those who supported the role of biomass in transport citing aviation as a key end use. It was noted that all modelled scenarios in the National Grid Future Energy Scenarios assume bioenergy will be crucial to the production of SAF[36] and that bio-aviation fuel has the significant benefit of being compatible with existing aviation engines when combined with traditional kerosene. Reference was made to the Climate Change Committee's 6th Carbon Budget which highlights the role of SAF in decarbonising aviation, with potentially 17% of jet fuel consumed in 2050 in the UK coming from biofuels[37]. It was suggested that the key to creating demand for SAF in aviation is through a SAF mandate, which should be ambitious but consistent with the pace of building out supply capabilities and infrastructure, and be ramped up over time, as the production scales up.

In terms of the availability of alternative technologies for aviation, it was noted that the most optimistic view of accelerating the introduction of electric, hybrid and zero-emissions (hydrogen) aircraft in the

[36] National Grid ESO. Future Energy Scenarios. Available At: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents
[37] CCC. The Sixth Carbon Budget – The UK's Path to Net Zero. Available At: https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

2035-2040 timeframe would reduce the expected 2050 emissions of CO_2 by 42%, which would be insufficient to offset the expected increase of worldwide air traffic, let alone getting to net zero[38].

Whilst it is possible in principle to produce synthetic liquid fuels made from renewable electricity and CO_2 from a point source or Direct Air Capture (DAC) (Renewable Fuels of Non – Biological Origin) which can act as drop-in fuels, the manufacture of such liquid fuels requires a significant number of energy intensive processes. This provides an important context for calibrating the ongoing importance of biofuels in transportation sectors that are hard to electrify.

There was specific reference made to analysis on the aviation sector conducted by Green Alliance which suggests that limiting growth in demand will be an essential starting point for the sector to reach net zero by 2050, even allowing for substantial use of GHG removals to balance off residual emissions[39]. It was suggested that where it is necessary to develop and deploy liquid SAF for long haul flights, this should focus on synthetic fuels combining carbon captured form the air with hydrogen using renewable energy, rather than on those produced using biomass.

Shipping

23% of those who supported the role of biomass in transport cited shipping as a key end use. Respondents noted that alternative fuels such as ammonia, hydrogen and methanol require substantial changes to engines, fuel systems and fuel storage, and that vessels may require very different layout to address safety concerns when using such fuels. Given the long lifetime of marine vessels and the costs associated with conversion of existing vessels to new fuels, it was suggested that drop-in fuel solutions will be required with biofuels being the primary option.

(Certain Sources Of) Biomass Not Required

Of those who did not support biomass deployment, a range of reasons were cited. These included:

- **The existence of alternative technologies** (e.g. electrification, green hydrogen, and synthetic fuels) and the role that shifting to public transport and active travel could play in decarbonising the sector.

- The **sustainability of certain sources of biomass**, with reference made to the impact that use of food and bioenergy crops has had on food prices and the displacement of food

[38] Air Transport Action Group. Balancing Growth in Connectivity with a Comprehensive Global Air Transport Response to the Climate Emergency. Available At: https://aviationbenefits.org/media/167187/w2050_full.pdf
[39] Green Alliance. The Flight Path to Net Zero. Available At: https://green-alliance.org.uk/resources/The_flight_path_to_net_zero.pdf

production in the past. In relation to waste, there is a risk that policy to encourage use could create perverse incentives and dampening much needed efforts to reduce waste.

- **Concern around carbon emissions associated with certain sources of biomass** was also observed. For example, there was reference to the GHG emissions associated with fertiliser use for bioenergy crop production.

Respondent Categories of Interest

Those who did not support some or all biomass sources in transport were from the following respondent categories:

- Academia
- Non – profit organisation/ Special Interest Group / ThinkTank
- Trade Association / Representative Group - General

Agriculture

Looking across all biomass sources, 22% of respondents to this Question indicated that some form of biomass could be valuable in supporting the decarbonisation of agriculture, whilst 1% explicitly indicated that all or certain sources of biomass were not required.

Respondent Categories of Interest

Those who supported biomass in agriculture were from a range of respondent types including, but not limited to:

- Biomass Supplier (Agriculture)
- Trade Association / Representative Group (Agriculture)
- Waste Management

Of those who noted biomass had a role to play in decarbonising agriculture, **a range of end uses were cited** including soil restoration and regeneration, animal bedding and feed, the creation of on-farm energy and to act as an alternative source of income for farmers. The NFU referenced their paper on achieving net zero (see extract below):

It is perhaps interesting to highlight that the National Farmers Union (NFU) have set an ambitious goal of reaching net zero GHG emissions across the whole of agriculture in England and Wales by 2040. The NFU's assessment indicates that net zero can only be delivered if the sector acts across a range of internationally recognised inventories with multiple measures that fall under three broad headings:

- Improving farming's productive efficiency.
- Improving land management and changing land use to capture more carbon.
- Boosting renewable energy and the wider bioeconomy.

NFU: Achieving Net Zero, Farming's 2040 Goal[40]

Soil Restoration and Regeneration

13 respondents identified soil restoration and regeneration as a key end use of biomass to support degraded arable farmland and improve fertility whilst reducing the use of mineral fertilisers. Specific techniques noted included the application of digestate from AD and biochar from pyrolysis as well as the use of certain biomass crops as rotation crops such as Miscanthus and hemp by increasing soil carbon through their extensive root systems and low requirement for nitrogenous fertilisers. In addition to this, the role of seaweed as a fertiliser was highlighted.

It was indicated that using these techniques to improve soil quality can help to increase crop production by increasing soil organic carbon and soil microbial activity as well as providing a source of nitrogen and phosphorous that crops can use. Respondents highlighted that digestates have the additional benefit of displacing carbon intensive nitrogenous fertilisers and ultimately improving water quality by reducing the risk of leaching of organic nitrogen and phosphorus into groundwater, compared to if commercial fertiliser is used.

A further benefit identified was improving soil quality to sequester carbon, reduce the risk of soil erosion and improve the water holding capacity of soil to protect against drought.

Animal Bedding and Feed

Four respondents indicated that biomass has a role to play as an animal feed, with emerging sources of biomass referenced such as terrestrial seaweed which can support in the avoidance of fugitive methane emissions from livestock farming. The role that biomass, including crop residues can play in providing animal bedding was highlighted by two respondents.

[40] NFU. Achieving Net Zero: Farming's 2040 Goal. Available At: https://www.nfuonline.com/nfu-online/business/regulation/achieving-net-zero-farmings-2040-goal/

On Farm Energy

Six respondents referred to the role of biomass (including BioLPG and biogas from AD/pyrolysis) to produce on farm energy and heat. It was remarked that many on-farm operations such as **powering field machinery, water pumping, drying, heating, and cooling** are currently heavily on high-carbon fossil fuels such as oil and diesel. It was also suggested that electrification and hydrogen could be costly and unpractical for rural off-grid farmers and agri-businesses.

Alternative Source of Income

It was highlighted that given the decline of meat and dairy consumption and the need for this to decline further in future, **agricultural sources of biomass such as bioenergy crops (e.g. Miscanthus and hemp) could play a role in replacing these sources of income for farmers.** Respondents stressed that a market and sufficient demand is required to enable this.

Across this sub-section as a whole, agricultural waste (e.g. animal slurries and crop residues) was commonly referred to in this section. It was noted that using waste biomass from the agricultural sector can reduce GHG emissions associated with waste decomposition in landfill/ the field. Looking at crop residues specifically, respondents recommended that a cost-benefit assessment should be done to ensure the use of residues would not lead to greater benefits elsewhere (e.g. being ploughed back into the soil).

(Certain Sources Of) Biomass Not Required

Respondents who did not support the role of some or all sources of biomass in agriculture specifically focused on forestry feedstocks only. They raised concerns around the sustainability of forestry feedstocks and the impact of forestry feedstock use on carbon emissions.

Respondent Categories of Interest

Those who did not support some or all biomass sources in agriculture were from the respondent category ‘Non – Profit Organisations/ Special Interest Groups / ThinkTanks’.

Industry

Looking across all biomass sources, **26% of Question respondents indicated that some form of biomass could be valuable in supporting the decarbonisation of industry**, whilst 3% indicated that some or all sources of biomass were not required in some or all industrial applications.

Respondent Categories of Interest

Those who supported biomass in industry were from a range of respondent types including, but not limited to:

- Biofuel/ Biogas Producer & Technology Provider
- Trade Association / Representative Group (Biotech / Chemicals / Products)
- Utilities/ Energy Asset Owners/ Distributors

Heating

One of the most significant themes (noted by at least 15 respondents) was the **role biomass could play in decarbonising industrial heat (including space, process, and water heating).**

- **Space Heating:** There was indication that biomass could play a role in heating industrial buildings such as warehouses and large distribution centres. Reference was made to a range of energy vectors including biomethane and bio – LPG.
- **Process Heating**: It was suggested that sources of biomass could be used directly in biomass boilers or kilns/furnaces as an industrial fuel to provide process heat or via CHP with CCS with the benefit of providing electricity (for powering pumps, compressors, refrigeration, lighting etc.) and serving as negative emissions. It was also suggested that biomethane could play a role in decarbonising industrial heat.

Other

10 respondents referred to the role of biomass in decarbonising industry more generally across a range of areas beyond heat including electricity generation, for example. Another area discussed was the role bio-CO_2, could play in industrial processes that use CO_2 such as the manufacture of food and drink. It was suggested that the existing AD infrastructure could fully supply industry with renewable CO_2 and that bio – CO_2 is particularly beneficial as its release is carbon neutral.

The potential role of biomass in scrubbing systems was also referenced. It was advocated that there is potential to use sources such as algae to feast on CO_2 and nutrients such as Nitrogen and Phosphorous recovered from waste streams.

A range of industries were referenced as potential users of biomass. Some respondents however suggested that biomass should be reserved for the hardest to decarbonise industries such as iron and steel production, and others proposed that biomass has a key role to play in a range

of different sectors such as food and drink manufacturing, pharmaceuticals, and non-metallic mineral production (e.g. cement).

(Certain Sources Of) Biomass Not Required

It should be noted that of those who did not support the role of some or all sources of biomass in industry, this largely concerned forestry feedstocks only, with respondents noting the **concerns around the sustainability of forestry feedstocks and the impact of forestry feedstock use on carbon emissions.** There was some discussion around the role of hydrogen in decarbonising industry, with suggestion that hydrogen derived from electrolysis, for example, would be preferable in some instances. However, the cost and availability of hydrogen were challenged by other respondents.

Respondent Categories of Interest

Those who did not support the use of some or all sources of biomass in all or certain applications within industry were from the following respondent categories:

- Non – profit organisation / Special Interest Group / ThinkTank
- Trade Association / Representative Group - Biofuels / Biogas (who focused on industries heavily reliant on hydrogen as a feedstock who have other viable routes to acquiring low carbon hydrogen).

Chemicals and Materials

Looking across all biomass sources, 34% of Question respondents indicated that some form of biomass could be valuable in supporting the decarbonisation of chemicals and materials, whilst 2% indicated that some or all sources of biomass were not required.

Respondent Categories of Interest

100% of respondents in the below categories who responded to Question eight supported the use of biomass in Chemicals and Materials:

- Biomass Supplier (Agriculture)
- Chemicals
- Trade Association / Representative Group – General

There was a focus on the fact that chemicals and materials cannot be decarbonised as they are fundamentally carbon-based compounds, indicating the need for alternative, renewable

sources of carbon, such as biomass to be used as an alternative to fossil fuel feedstocks, such as crude oil and natural gas.

It was indicated that many **high value chemicals and useful polymers can be directly extracted from biomass** but that beyond this, the conversion of biomass via a range of different processes (e.g. chemical, thermal, or biological) can yield a range of high value chemicals. It was noted that using biomass in the production of materials has the additional benefit of sequestering carbon in a stable chemical product.

Many saw a significant role for biomass as an alternative feedstock (31 respondents) for the manufacture of chemicals and as an alternative material (6 respondents). Some of the end uses highlighted have been outlined below:

- **Plastics and Packaging**: Some saw a role for biomass in the development of plastic substitutes or as an alternative feedstock for plastic production, whilst others cited the role of manufactured wood-based panel products in packaging. It was noted that ethanol can be converted to ethylene and polyethylene plastics.

- **Alternative Construction Material**: The role of wood as a construction material was highlighted as an alternative to concrete. It was indicated that the use of wood in construction could cut UK emissions from construction by a total of 28MtCO_2e during the course of the fifth carbon budget (between 2027 and 2032)[41].

- **Cement Manufacture:** There is role for waste biomass in cement manufacture. Respondents indicated that the use of biogas to replace natural gas could reduce emissions by around 200ktCO_2 per year.

- **Metal Production**: It was indicated that biomass can be used for phytomining.

- **Piezoelectric Materials**: It was suggested that cellulose can generate power from compression via the piezoelectric effect.

- **Other Products Dependent Upon Fossil Fuel Feedstocks**: Respondents referred to the role of biomass in decarbonising the production of other products dependent on fossil fuel feedstocks including lubricants, food, pharmaceuticals, cosmetics, textiles, and agrochemical products. An alternative perspective on BECCS was provided by one respondent here. They discussed the production of ethanol, which can be used as an energy vector or platform

[41] Green Alliance. Less in More Out. Available At: https://green-alliance.org.uk/less_in_more_out.php

chemical from corn via sugar fermentation which has been proven to be an effective way of capturing and sequestering CO_2 for either storage or utilisation[42].

Respondents referenced a range of existing projects in the 'chemicals and materials' space including, but not limited to:

- Whisky co-product projects led by IBioIC with Zero Waste Scotland, MiAlgae, BioPower Technologies and Horizon Proteins[43].
- Large scale facilities in Braskem in Brazil where sugarcane bioethanol is converted to bio-ethylene for use in sustainable polyethylene and PET production by companies such as Coca-Cola[44].
- A large scale bioethylene oxide plant in the US where corn ethanol is used to produce sustainable surfactants for companies such as Unilever[45].

Respondents also provided reference to studies in the space. For example, one respondent provided reference to a study which has shown that a biobased alternative to fossil fuel derived Poly – Vinyl Chloride (PVC) can offer up to 90% GHG savings compared to fossil fuel derived PVC[46]. Another provided reference to a study on the potential production of methane and chemicals using AD[47]. A further respondent provided reference to a roadmap for the UK concrete and cement industry[48].

(Certain Sources Of) Biomass Not Required

Of those who did not fully support the use of some or all sources biomass in materials and chemicals, a range of reasons were **cited. Concerns were raised about forestry feedstocks in particular.**

[42] Governors' Biofuels Coalition. (2021). Successful Completion of Illinois Basin - Decatur CCS Project; CO_2 From Ethanol Plant. Available At: https://www.governorsbiofuelscoalition.org/successful-completion-of-illinois-basin-decatur-ccs-project-co2-from-ethanol-plant/
[43] IBioIC. Whisky Industry and Biotech Innovators Collaborate to Find New Sustainable Solutions. Available At: https://www.ibioic.com/news-database/whisky-industry-and-biotech-innovators-collaborate-to-find-new-sustainable-solutions
[44] Breaskem. I'm Green Bio – Based. Available At: https://www.braskem.com/imgreen/bio-based-en
[45] Croda. Accelerating Our Sustainable Future. Available At: https://www.crodapersonalcare.com/en-gb/our-brands/croda/eco-range
[46] Inovyn. Inovyn Launches Worlds First Commercially Available Grade of Bio Attributed PVC. Available At: https://www.inovyn.com/news/inovyn-launches-worlds-first-commercially-available-grade-of-bio-attributed-pvc/
[47] D. Dionisi, I. Bolaji, D. Nabbanda and I. M. Silva. Calculation of The Potential Production of Methane and Chemicals Using Anaerobic Digestion. Biofuels, Bioproducts and Biorefining. vol. 12, no. 5, pp. 788-801. Available At: https://abdn.pure.elsevier.com/en/publications/calculation-of-the-potential-production-of-methane-and-chemicals-
[48] MPA. UK Concrete and Cement Industry Roadmap to Beyond Net Zero. Available At: https://www.thisisukconcrete.co.uk/TIC/media/root/Perspectives/MPA-UKC-Roadmap-to-Beyond-Net-Zero_October-2020.pdf

One respondent cautioning the need to consider the full carbon lifecycle when considering the role of woody biomass as a substitute for manufacturing construction materials such as concrete and steel and others cautioning wider **concerns surrounding carbon emissions and sustainability** in relation to forestry feedstocks. Concerns were also raised regarding biomass feedstocks more widely, with respondents noting the **importance of balancing competing demands on land for food, fibre, and afforestation alongside biomass**. The **importance of research into new biomass products such as novel plastics was also emphasised.**

Respondent Categories of Interest

Those who did not support biomass for chemical and material production, were from the respondent category 'Non-profit organisation / Special Interest Group / ThinkTank'.

Other

13% of Question respondents referred to 'other' end uses. Other benefits noted included the role of **biomass in wildlife protection, land stabilisation and carbon reduction as well as supporting the attainment of wider government priorities such as levelling up and job creation**. It was also suggested that biomass has a role to play in **food production in the non-traditional sense** such as via the extraction of protein from insects grown on food waste or omega 3 oils from microalgae.

Challenges or Concerns Raised

Some of the commentary provided on challenges and concerns is outlined below:

- **Biomass should be targeted towards applications that do not result in emissions of CO_2**, or to which CCS technology can be employed, as opposed to being targeted towards end uses.

- The UK government should adopt a **principles-based approach**, which recognises the need for BECCS and efficient biomass technologies but does not intervene in the marketplace by imposing new regulations.

- Biomass should be used in a manner which m**aximises the decarbonisation and energy value of the resource**, irrespective of the end use.

- It was recommended that **"saving" biomass for use in hard to convert industries is a form of market manipulation and not a sustainable policy**. Another respondent added that they did not support attempts to create an overly-prescriptive hierarchy of best use and choose 'winners and losers'. It was highlighted that overly prescriptive regulations disrupt the

function of the market and prevent biomass producers from fully participating in established supply chains, which could have a range of negative outcomes.

- It was also highlighted that **simply stating single best uses for different biomass feedstocks should be treated with caution.**

There was some discussion concerning **end-uses which may change over time**. For example, certain end uses may be more appropriate in the short term and others more appropriate in the long term. sectors. Whilst this is not necessarily reflective of the views of all respondents, it highlights that changes may occur. The Figure below from the CCC provides an indication of how end uses may change in certain sectors.

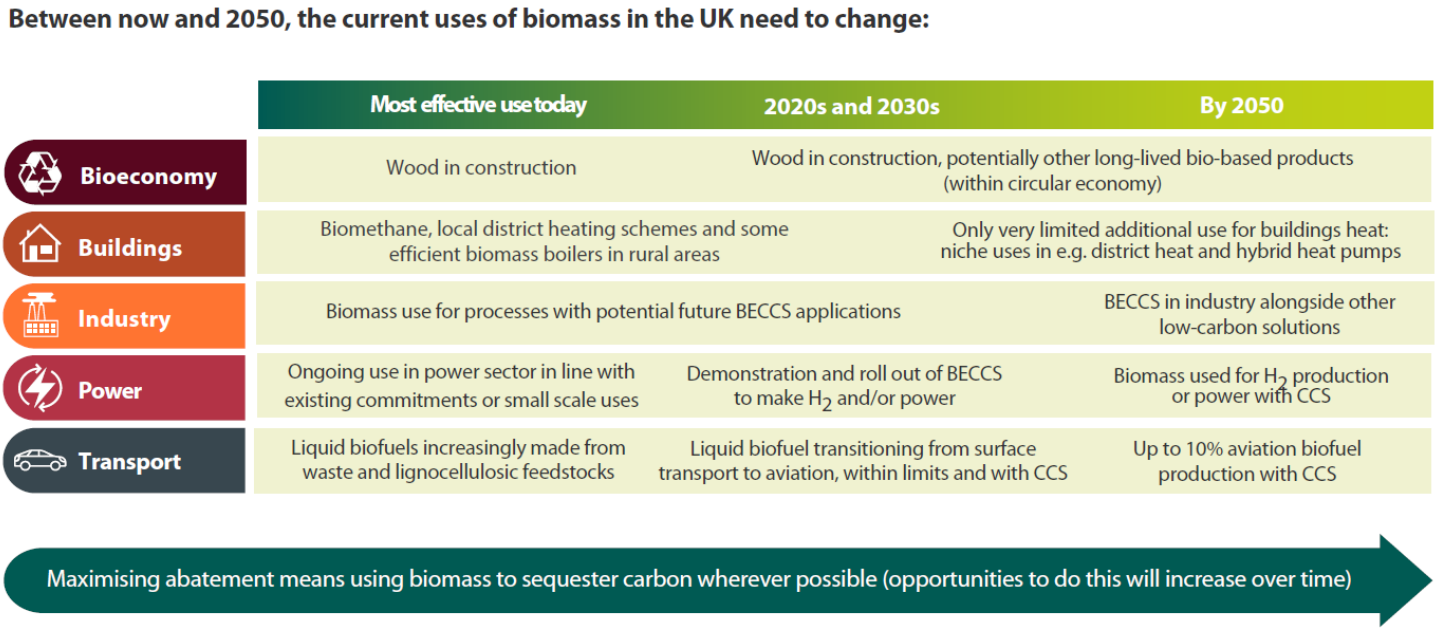

Figure 12 - Changing Uses of Biomass Over Time (Source: Climate Change Committee)[49]

Gaps in the Evidence Base

Given the fact that **many respondents did not specify end uses associated with each biomass source**, this could be considered a remaining gap in the evidence base. That being said, there was a view from some that assigning certain biomass feedstocks to particular end-uses is not an appropriate strategy in any case. In addition to this wider gap, some respondents identified specific areas where further research was required in response to Question 8. These areas included:

[49] CCC. Biomass in a Low Carbon Economy. Available At: https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/

- The potential for increasing the bio-content of petrol well beyond the ethanol blend limit via the conversion of 'excess' ethanol to full EN228 bio-gasolines.
- The importance of research into new biomass products, such as novel plastics.
- The need for better assessment of lifecycle carbon impacts of biomass as part of broader research required to understand the environmental positives and negatives associated with biomass deployment in certain areas (e.g. plastics).

PRIORITISATION OF APPLICATIONS

Question 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.

101 respondents answered Question nine equating to 73% of all respondents (please note this includes those who did not answer specific Questions but who provided information relevant to this Question that was captured here and does not include duplicate responses). The Table below summarises the respondent types for this Question.

Table 14 - Breakdown of Respondents by Organisation Type for Question Nine

Respondent type	Total number of respondents
Academia	9
Biofuel/ Biogas Producer & Technology Provider	13
Biomass Boiler Manufacturers	2
Biomass Supplier (Agriculture)	3
Biomass Supplier/ Technology Provider (Forestry)	8
Certification Body	2
Chemicals	2
Consultancy	3
Government Organisation	4
Non-profit organisation / Special Interest Group / ThinkTank	7
Other	7

Respondent type	Total number of respondents
Trade Association / Representative Group - Agriculture	3
Trade Association / Representative Group - Biofuels / Biogas	5
Trade Association / Representative Group - Biotech / Chemicals / Products	7
Trade Association / Representative Group - Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group – Forestry Supply / Products	7
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	3
Utilities/ Energy Asset Owners/ Distributors	10
Waste Management	0
Total	**101**

The responses were variable in length, with many citing similar reasoning in their responses to Question eight and nine. Responses have been categorised into those who noted that biomass was a priority, that it was important, that it was not important/ those who indicated biomass was not required (see Figure 13). It should be highlighted that as categories were not provided for respondents to select from in the call for evidence, categorisation has been determined based upon the written responses provided. Whilst information on this has been captured, it is important to recognise that those who did not refer to a specific end-use may have also held the view that biomass was not required in this sector. However, this could not be assumed.

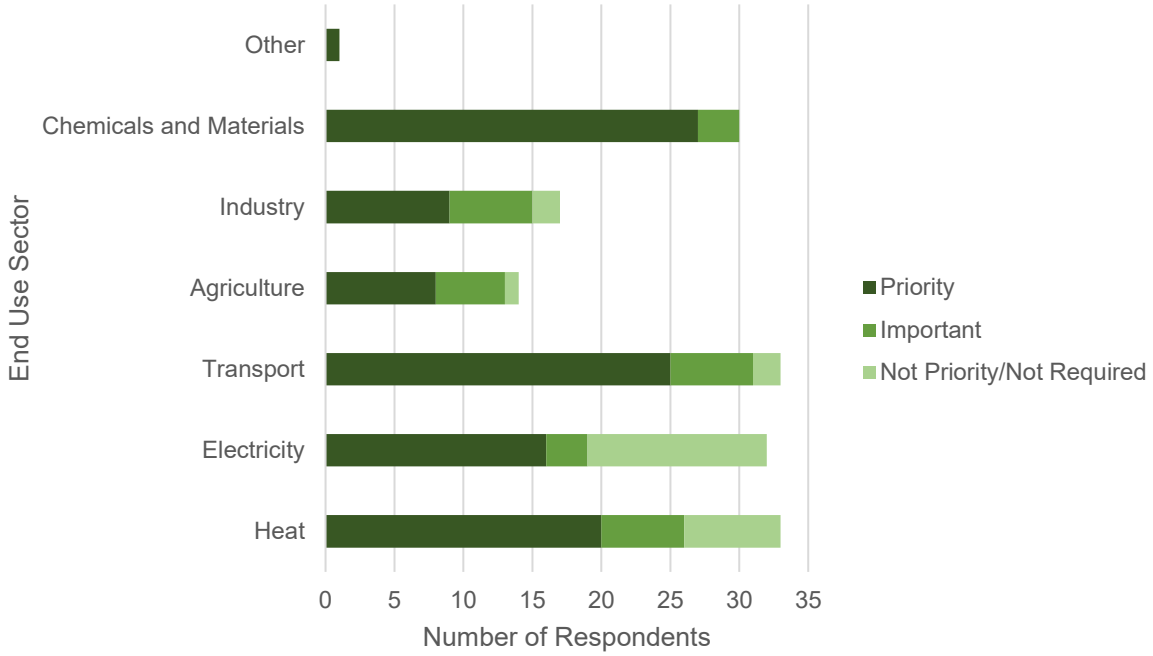

Figure 13 -Prioritisation by End Use Sector

The analysis of this Question has been divided by end use sector, with commentary on biomass source contained under each sector sub-heading. As highlighted in the analysis of responses to Question eight, not all supported prioritisation of biomass by end use. This is discussed further under the sub-heading 'challenges or concerns raised'.

Heat

26% of Question respondents indicated that heat was a priority or important end use sector for biomass, with 16 specific references within this group to a biomass source (either agricultural, forestry, waste or other) of which forestry (including waste wood) was most cited (nine specific references within this group).

Many of the technologies and end-uses referenced, as well as the reasoning behind these proposals were the same as those discussed in Question eight and therefore further information hasn't been captured here. There was a particular focus on the **prioritisation of community use and prioritisation on the basis of human needs.** For example, in relation to forestry sources, it was noted that priority could be given to encourage the use of biomass wood waste at source, and for waste, the option to use community waste in a closed loop system was cited.

Respondents cited the importance of **considering the role of biomass in the short term separately to the long term.** It was suggested that biomass could play a role up to 2050, for example, by which

point there may be a greater role for other energy vectors such as hydrogen. Related to this, there was indication from one respondent that opportunities in heat could be divided into three groups:

- Immediate Opportunities
- Development Opportunities
- Strategic Opportunities

There was **reference to the international environment** and that consideration should be given to the approach being taken in other countries including Germany, France, and Austria. One respondent noted that whilst the UK leads bioenergy sector development, the role of biomass in decarbonisation of heat is increasing in countries such as Germany, France and Austria who all expect heat applications with bioenergy to grow and play an increasingly important role in decarbonising the heat sector alongside other non-biomass solutions.

On the other hand, 6% of Question respondents indicated that heat was not a priority end use for biomass, or it was not required for the decarbonisation of heat. For those who did not support biomass deployment, similar reasoning was provided as was provided in Question eight and therefore detail has not been provided here. It was noted by some respondents that **prioritisation should be on the basis of decarbonisation potential and where there are no alternative technologies available and that on this basis, heat was not a priority end use sector.** The principles that respondents suggested should be used to determine priority end uses are further outlined in the analysis of responses to Question 10.

Electricity

A total of 19% of Question respondents indicated that electricity was a priority or important end use sector for biomass, with seven specific references within this group to a biomass source (either agricultural, forestry or waste or other) of which agricultural biomass was most commonly cited. A total of 12% of Question respondents indicated that electricity was not a priority end use for biomass/ biomass was not required for the decarbonisation of electricity.

Many of the technologies and end-uses referenced, as well as the reasoning behind these proposals were the same as those discussed in Question eight and therefore further information hasn't been captured here. There was **some commentary in relation to BECCS** and that priority should be given to applications for biomass where it can be used with CCUS, given reports that the UK is unlikely to reach net zero without Negative Emissions Technologies (NETs).[50]

[50] Climate Change Committee. Net Zero – The UK's Contribution to Stopping Global Warming. Available At: https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

As above, there was also a discussion around short term versus long term priorities, with indication that prior to the wider scale deployment of hydrogen and other technologies such as wind, solar and nuclear, there was a particular role for biomass.

Transport

31% respondents indicated that transport was a priority or important end use sector for biomass, with eight specific references within this group to a biomass source (either agricultural, forestry or waste or other) of which waste was most commonly cited (19% of Question respondents who supported biomass in transport).

Many of the technologies and end-uses referenced, as well as the reasoning behind these proposals were the same as those discussed in Question eight and therefore further information hasn't been captured here. Respondents referred to the fact that biomass use within transport could be targeted towards hard to decarbonise areas and where alternative technologies are not available. Prioritisation principles are further considered in analysis of responses to Question 10. One respondent provided the below diagram outlining the potential role of biomass in certain areas of the transport sector. Figure 14 was provided by United Kingdom Petroleum Industry Association (UKPIA) and provides an indication of some potential areas where biomass could be deployed, however, it was submitted by one respondent and may not be representative of all respondents' viewpoints.

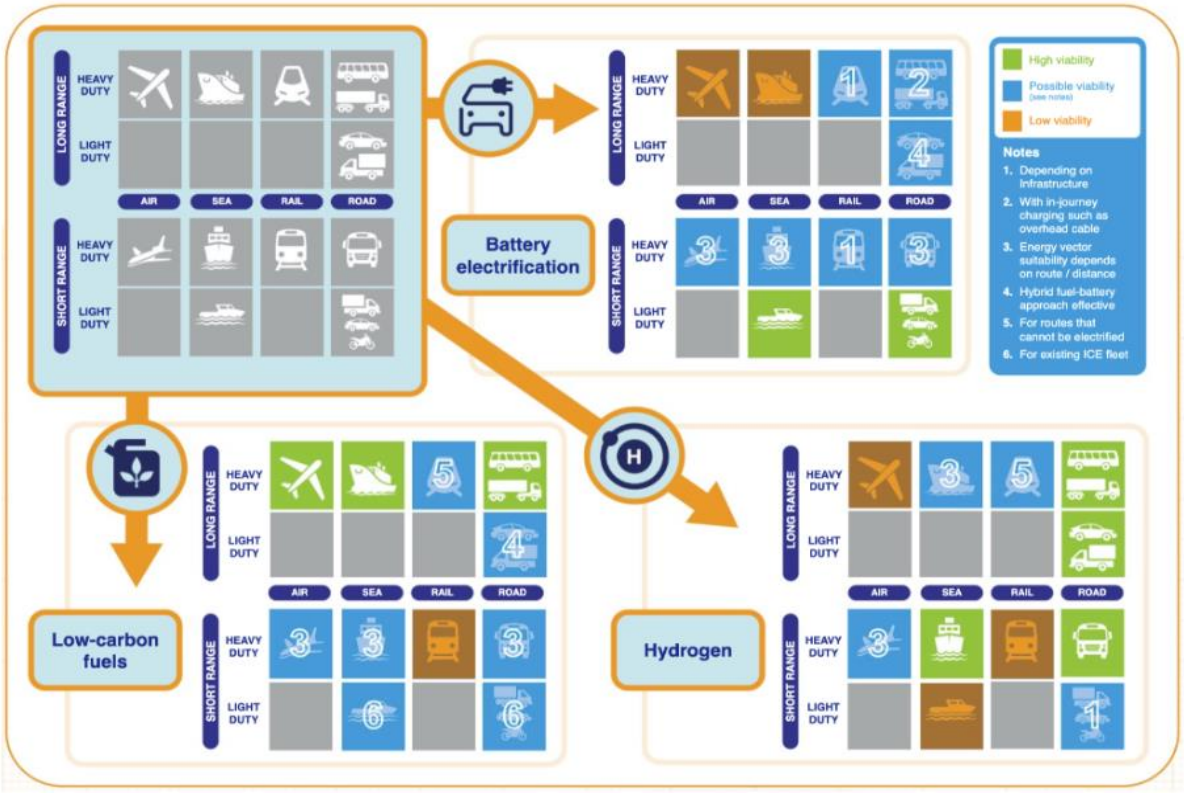

Figure 14 – Potential Energy Vector Suitability for Transport Modes. Source: UKPIA[51]

As above, respondents highlighted a need to consider the **timing of prioritisation**, with indication that prior to the wider scale availability of hydrogen and improvements to battery technology, biomass can play a key role in different areas of the transport sector.

There was also reference to the importance of NETs and the role transport could play in maximising the potential for BECCS in two ways:

a. Building infrastructure for fuel supply and manufacturing and use in which BECCS can ultimately be deployed.

b. Production of carbon negative biofuels like drop-in refinery fuels and bio-hydrogen where the supply chain involves CCUS.

Only 2% of Question respondents indicated that transport was not a priority end use for biomass/ biomass was not required for the decarbonisation of transport. Those who noted transport should not be a priority end use sector for biomass noted concerns around the fact biofuels do not lock in carbon long term given that CO_2 is released during combustion, alongside other emissions that are likely to

[51] UKPIA. The Future of Mobility in the UK. Available At: https://online.flippingbook.com/view/609189063/

occur during the lifecycle. Moreover, concerns around air quality were raised, and the existence of alternative technologies such as Electric Vehicles highlighted as an alternative technology that can enable air pollutants caused by vehicles to rapidly disappear.

Agriculture

13% of Question respondents indicated that agriculture was a priority or important end use sector for biomass, with a proportion specifically citing a biomass source (either agricultural, waste (including agricultural waste or other).

Many of the technologies and end-uses presented as opportunities for agriculture, as well as the reasoning behind these proposals were the same as those discussed in Question eight and therefore further information hasn't been captured here. There were some **differing views regarding the prioritisation of biomass within agriculture**, with one respondent suggesting applications such as soil restoration should be prioritised over on farm energy and another suggesting that on farm energy should be prioritised, for example. Once again, there was some discussion around short term versus long term priorities, with the potential role of hydrogen as an energy vector in future. Only 1% of Question respondents indicated that agriculture was not a priority end use for biomass/ biomass was not required for the decarbonisation of agriculture. In the case where biomass was not supported, the existence of alternative technologies such as wind and solar PV and hydropower was cited.

Industry

15% of Question respondents indicated that industry was a priority or important end use sector for biomass, with respondents specifically citing a biomass source (either agricultural, forestry, waste or other). Many of the technologies and end-uses referenced were the same as those discussed in Question eight and therefore haven't been captured in detail here.

In addition to the information provided and presented in Question eight, there was some discussion around short versus long term priorities regarding biomass use within industry. For example, one respondent suggested that in the near term, industrial sites with pre-existing storage and handling facilities could use biofuels and that longer term, biomass could play a more focused role in dispersed industrial sites without access to hydrogen and CO_2 pipelines.

Once again, there was reference to the fact prioritisation should be on the basis of decarbonisation potential and in areas where there are no alternative technologies available, and that on this basis, biomass had a role to play in decarbonising industry (see analysis of responses to Question 10 for further information). There was also reference to the fact priority applications for biomass should be where it can be used with Carbon Capture Utilisation and Storage (CCUS). Hydrogen was also referenced here though it was indicated that a key role of biomass is in fact in hydrogen production (as covered in Question eight), particularly from gasification of waste, which has a range of benefits.

Only 2% of Question respondent indicated that industry was not a priority end use for biomass/ biomass was not required for the decarbonisation of industry. Of those who did not see industry as a priority area for biomass deployment, reasons cited included the existence of alternative technologies such as wind, solar and hydropower and the negative impacts associated with the use of biomass at scale.

Chemicals and Materials

32% of Question respondents indicated that chemicals and materials was a priority or important end use sector for biomass, with a proportion of respondents specifically citing a biomass source (either agricultural, forestry, waste or other).

Many of the technologies and end-uses referenced, as well as the reasoning behind these proposals were the same as those discussed in Question eight and therefore further information hasn't been captured here. As in many of the above sectors, there was reference to the fact prioritisation should be on the basis of decarbonisation potential and in areas where alternative technologies are not available and that on this basis, biomass had a role to play in decarbonising chemicals and materials. Principles for prioritisation are discussed in further detail in the analysis of Question 10. There was also reference to the need to prioritise applications for biomass where it can be used with CCUS.

Reference was made to the **benefit of long-term carbon storage in certain chemicals and materials, with respondents quantifying the negative emissions potential associated with certain end uses of biomass in the chemical and materials space**, based upon an LCA. Two respondents referred to an LCA of Linear Low-Density Polyethylene (LLDPE) from UK cultivation of wheat grain and sugar beet, which shows that the sequestration of biogenic carbon within the plastic results in negative emissions of 1043kg CO_2eq and 1372kg CO_2eq per tonne of LLDPE respectively (when allocation by mass is used as the basis for the LCA)[52].

Reference was also made to the work by Spierling et al. who estimated that substituting 65.8% of the world's conventional plastics with bio-based plastics would avoid 241–316 Mio.t less CO_2-eq. per year, approximately 20% of global GHG emissions associated the lifecycle of plastics[53]. Another respondent provided a Table of the carbon footprint associated with traditional plastic products and bio-attributed plastic products (see Annex 1).

However, **other respondents highlighted uncertainty with calculating the carbon savings that could be achieved by transitioning to a bio-based chemicals and materials sector**. These respondents emphasised that it is critical to not only consider the carbon intensity of the biomass

[52] North Energy Associates, 2009
[53] Spierling et al. (2018), Bio-based plastics – A review of environmental, social, and economic impact assessment, Journal of Cleaner Production, 185, 476-491.

production pathway and the carbon intensity of the incumbent, but how the carbon storage in the product changes over time. It was highlighted that the permanency of the carbon sequestration is also difficult to predict because it varies not just by the chemical or material made, but the application it is used for and the potential for recycling. It was however highlighted that further research is being undertaken in this space by the Supergen Bioenergy Hub and others in the sector.

As in Question eight there were multiple references to carbon being required for chemical production and that this is a core reason for prioritising biomass in chemical and material manufacturing. It was suggested that there may be alternative ways of moving away from the use of carbon containing fuel sources in other sectors.

Other

The role of biomass in supporting CO_2 removal was identified across a number of responses to this Question. It was noted that one of the priority applications of biomass should be to provide CO_2 removal. It was suggested that many of the current uses of biomass in the UK can quickly and effectively be decarbonised using CCUS in the 2020s and early 2030s, which can help drive the UK towards GHG emissions reduction targets.

Challenges or concerns raised

Not all respondents supported the idea of targeting biomass sources to specific end-uses. Some of the commentary provided on this point, beyond what has already been captured in Question eight has been outlined below:

- It was noted that it is **difficult to prioritise by end use**, as different applications may be appropriate in different instances.
- It was suggested that instead of prioritising by end-use, **sustainable biomass feedstocks should be prioritised for applications where there is no temporal, financially viable, or sustainable alternative, with consideration also given to the feedstock**. The principles that could be used to guide prioritisation have been further discussed in analysis of responses to Question 10.
- It was also suggested that priority applications for biomass should be **where it can be used with CCUS.**

Gaps in the evidence base

Many respondents did not specify specific end uses associated with each biomass source. As such, this could be considered a remaining gap in the evidence base. In addition to this wider gap, some respondents identified specific areas where further research was required in response to Question

nine. As highlighted in response to Question eight, the need for **better assessment of lifecycle carbon impacts of biomass was cited.** However, here some specific areas for consideration were cited in relation to determining the carbon savings that could be achieved by transitioning to a bio-based chemicals and materials sector:

- The carbon intensity of the biomass production pathway.
- The carbon intensity of the incumbent.
- How the carbon storage in the product changes over time.
- The permanency of the carbon sequestration, given that this varies by the chemical or material made, the application it is used for and the potential for material recycling/reuse.

Question 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?

93 respondents answered Question 10 equating to 67 % of all respondents (please note this includes those who did not answer specific Questions but who provided information relevant to this Question that was captured here and does not include duplicate responses). The Table below summarises the respondent types for this Question.

Table 15 - Breakdown of Respondents by Organisation Type for Question 10

Respondent type	Total number of respondents
Academia	9
Biofuel/ Biogas Producer & Technology Provider	10
Biomass Boiler Manufacturers	1
Biomass Supplier (Agriculture)	2
Biomass Supplier/ Technology Provider (Forestry)	7
Certification Body	3
Chemicals	0
Consultancy	2
Government Organisation	4

Respondent type	Total number of respondents
Non-profit organisation / Special Interest Group / ThinkTank	8
Other	4
Trade Association / Representative Group - Agriculture	5
Trade Association / Representative Group - Biofuels / Biogas	5
Trade Association / Representative Group - Biotech / Chemicals / Products	7
Trade Association / Representative Group - Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group – Forestry Supply / Products	7
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	2
Trade Association / Representative Group – Professional Engineering Services	3
Utilities/ Energy Asset Owners/ Distributors	9
Waste Management	1
Total	**93**

The level of detail provided in Question 10 was variable, with some respondents referring to one single framework or principle and others referring to several different frameworks and principles, providing detail on why certain frameworks and/or principles are important and, in some instances, how they should be applied.

Whilst **some respondents referred to well established frameworks, many instead referred to a range of different principles that should be used to guide decision making.** The frameworks discussed in response to Question 10 have been captured in Figure 15. It is worth noting that where respondents referred to specific principles as opposed to a well-established framework, this has been captured in the category ‘Other Form of Decision-Making Framework’. A separate analysis of the different principles was subsequently carried out and the principles discussed in response to Question 10 are displayed in Figure 15, with an indication of how many respondents supported each principle.

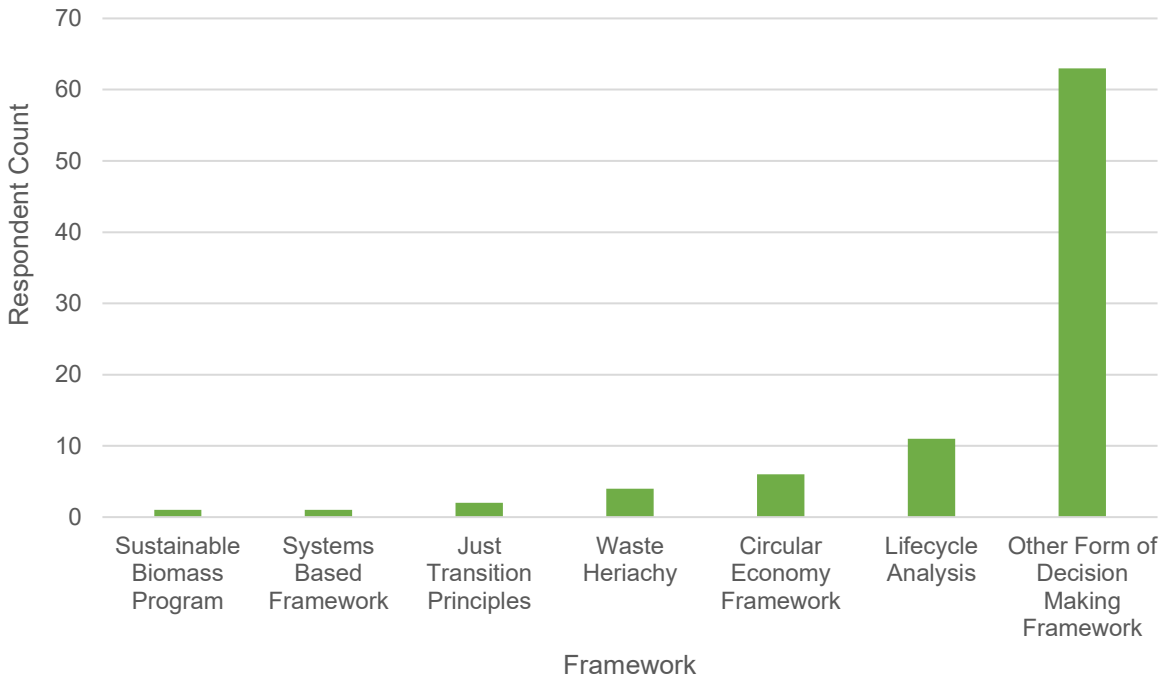

Figure 15 - The Frameworks Cited by Respondents to Question 10

Further detail on each of the above-named frameworks has been provided below. It should be noted that not all respondents supported the idea of using frameworks to determine priority end-uses. This has been discussed further in the 'Challenges and Concerns' subheading within this section.

Frameworks

Framework 1: Sustainable Biomass Framework

One respondent noted that **frameworks already exist to ensure forests are not over-used or over-harvested for the bioenergy sector.** Biomass producers often sit at the end of the value chain thus ensuring the lowest value wood goes towards bioenergy production. Alongside market forces which assign the highest price to products that store carbon over the long term, a combination of US and UK law sustainability criteria and industry certifications ensure that sustainable biomass sourcing does not cause undue burden on the forest resource. Specific reference was made to the SBP, an independent, not-for-profit voluntary certification scheme, which ensures sustainable woody biomass production by preventing sourcing from: lands that will not be replanted, lands that have been converted away from high-carbon stock, and areas where harvesting practices are detrimental to the long-term productivity of the forest, among other requirements.

Framework 2: Systems Based Framework

One respondent noted the role for a **system-based framework that aligns with other related policies seeking multiple benefits and a case-by-case assessment of the use of biomass.** They suggested that this should acknowledge the business case and existence of alternative technologies (discussed further within the principles section).

Framework 3: Just Transition Principles

There was indication from two respondents that just transition principles may offer a framework for determining the priority end-uses of biomass. This could be particularly relevant when identifying points at which biomass may offer economic and employment opportunities for sectors and places that may not have an alternative pathway to transition away from carbon-intensive activity.

Framework 4: Waste Hierarchy

Four respondents highlighted that a waste hierarchy could be used as a framework to determine the priority end-uses of biomass. It was noted that waste streams should be treated in accordance with the waste hierarchy which **prioritises prevention, reuse and recycling above energy recovery and prioritises the above action via disposal in landfill**. Specific reference was made to the food and drink waste hierarchy which states that food waste prevention and animal feed should be prioritised over sending food waste to AD. It was however caveated by respondents that some specific types of low-grade biomass are not suitable for all technologies due to their composition and therefore a careful scoping and prioritisation mechanism should be in place. Nonetheless, respondents agreed that where possible the waste hierarchy should be prioritised.

Framework 5: Circular Economy Framework

Six references were made to the Circular Economy Framework. It was proposed that the key focus should be on **incentivising circularity**. Respondents suggested that foundational principles of the circular economy should be adopted (and adapted if required):

- Design out waste and pollution.
- Key products and materials in use.
- Regenerate natural systems.

Framework 6: Life Cycle Analysis

11 respondents indicated that a **full LCA would be a valuable way of determining priority end-uses of biomass.** It was indicated that this should be standardised across the industry. Within this, consideration of the source of biomass is critical. It was caveated that Government should carefully

consider how it can robustly quantify the impact of biomass use, without disincentivising uptake through creating administrative complexity. Respondents emphasised the need to compare the overall lifecycle impact to alternatives. It was suggested that in considering a full LCA, carbon storage should be recognised.

Principles

Where respondents indicated principles as opposed to a well-established framework, their responses have been captured as 'other form of decision-making framework' and the principles presented in Figure 16, with detailed information provided. Analysis by respondent type has been conducted for the top five principles.

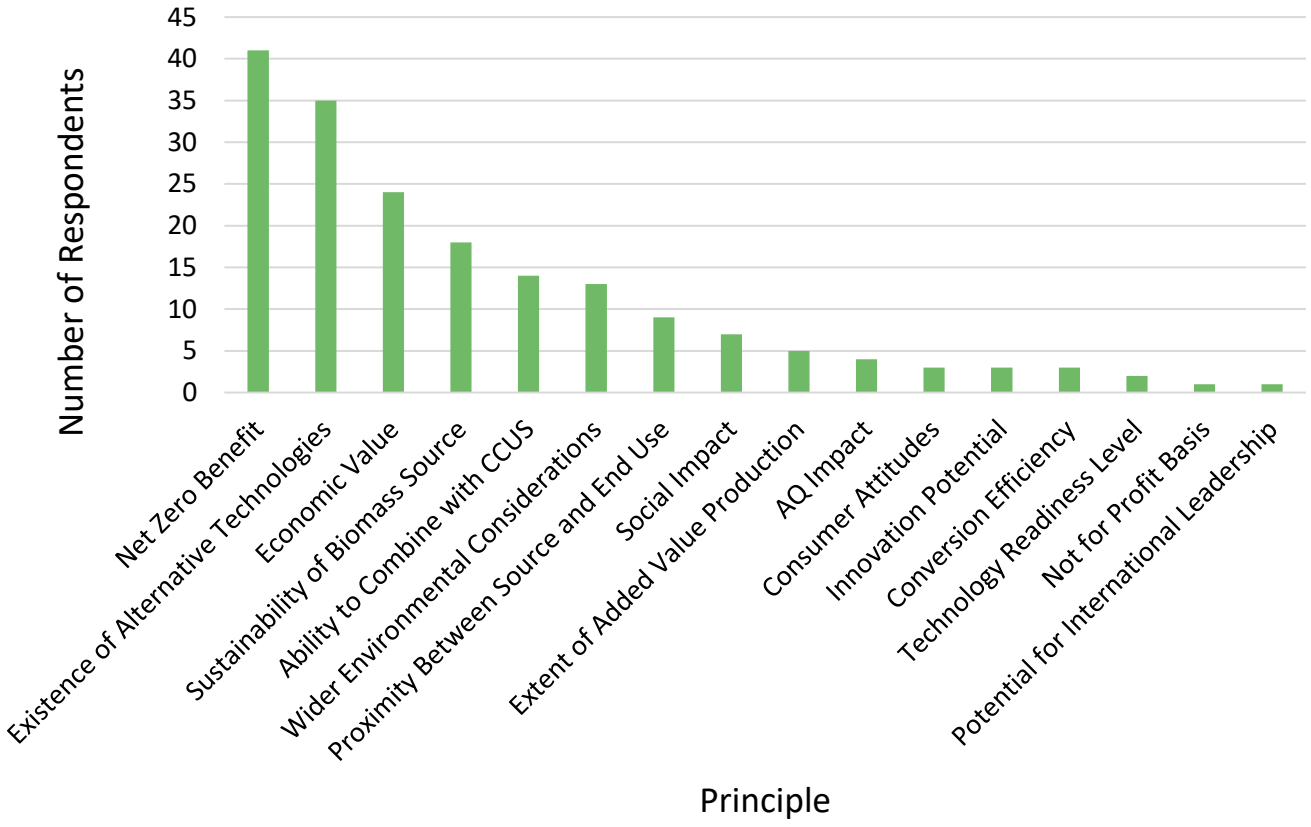

Figure 16 - The Principles Cited by Respondents to Question 10

Principle 1: Net Zero Benefit

41 respondents indicated that net zero benefit would be critical to determining priority end uses for biomass. It was however remarked that the **criteria for the calculation of net zero benefit needs**

reviewing. Respondents raised concerns about **inconsistencies and uncertainty across the supply chain** (e.g. where the product/process chain starts and finishes as well as flaws in carbon assumptions) which would impact the creation of an industry standard and the need for recognition for all key elements within the supply chain was highlighted.

Some respondents went beyond net zero benefit, indicating that biomass should be prioritised when it **does not result in increased emissions or where it results in negative emissions** (it is worth highlighting that 'ability to combine with CCUS' was captured as a separate category.) One respondent summarised their views noting that "a policy that rewards verified GHG savings or removals is preferable to a policy attempting to restrict biomass supply to specific end uses."

Respondent Categories of Interest

Those in support of the use of net zero benefit as a principle to guide prioritisation were from a range of respondent types including, but not limited to:

- Trade Association / Representative Group - Carbon Capture Utilisation and Storage (100% of respondents from this category who responded to Question 10 cited net zero benefit)
- Trade Association / Representative Group – General (100% of respondents from this category who responded to Question 10 cited net zero benefit)
- Biofuel/ Biogas Producer & Technology Provider

Principle 2: Existence of Alternative Technologies

35 respondents highlighted the need to consider the **availability / existence of alternative technologies**. It was suggested that priority should be given to sectors where there are **limited low carbon options available or where the low carbon options available are not appropriate for certain areas of the sector.** Specific examples in a range of end use sectors were provided but this information has largely been captured in analysis of responses to Question eight and nine. Examples included heat for older, domestic off gas grid properties, where heat pumps may not be appropriate/ financially viable and aviation where there are current few decarbonisation options.

The **cost** of alternative technologies was also referenced as an important factor for consideration here, alongside the **Technology Readiness Level (TRL).** It was highlighted that the situation may evolve. One respondent said that "there are clear phases during which different objectives should be prioritised, driven by the operational availability of different types of technology."

Respondent Categories of Interest

Those who cited ‘existence of alternative technologies’ as a principle to guide prioritisation were from a range of respondent types including, but not limited to:

- Trade Association / Representative Group
    - Carbon Capture Utilisation and Storage (100% of respondents from this category who responded to Question 10 cited existence of alternative technologies)
    - General
    - Professional Engineering Services
- Government Organisation
- Biofuel/ Biogas Producer & Technology Provider
- Certification Body

Principle 3: Economic Value

There was a strong indication that economic value should be considered as a principle, with 24 respondents alluding to the need to consider economic value. This is likely to include **job creation, the competitive advantage and GVA that products/processes could bring, and the value products and processes contribute to GDP**, as well as the potential benefit of **diversification of revenue streams**. Economic value on a smaller scale was also highlighted, with reference to the economic benefits that could be provided to rural economies and particularly farmers, for example. Economic impact associated with the displacement of alternative uses should also be considered. It was suggested by some that a cost-benefit analysis should be conducted, relative to other technologies.

Respondent Categories of Interest

Those who cited ‘economic value’ as a principle to guide prioritisation were from a range of respondent types including, but not limited to:

- Trade Association / Representative Group
    - Carbon Capture Utilisation and Storage (100% of respondents from this category who responded to Question 10 cited existence of alternative technologies)

- Biotech / Chemicals / Products
- Other

Principle 4: Sustainability of Biomass Source

18 respondents referred to the sustainability of the biomass source as an important factor that should be considered when determining the priority end uses of biomass. It was noted that the **UK needs strong sustainability standards enforced for biomass produced both in the UK and overseas.** There was reference to 'sustainability' encompassing many different factors including the impact on local communities, the local environment and wider carbon impacts.

It was recommended that further research is needed to map the sustainable uses for different categories of biomass so specific resource pathways can be prioritised. Respondents stressed the need for strong, consistent, and equivalent sustainability criteria across all markets to deliver a harmonised market and a level playing field for all participants. There was a call for certainty on these requirements to ensure a stable market. Examples were provided surrounding specific biomass sources:

- **Forestry**: There was indication that where there is competing demand for woody biomass, priority should be given to material use in the first instance. It was noted that this can help to extend the carbon cycle and mitigate climate change. It was indicated by one respondent that woody biomass should be considered as a 'transition' fuel, and that it should be phased out. Concern was raised regarding the fact nearly half of all biomass imports into the UK energy market come from whole trees[54].
- **Agricultural**: It was noted that determining where biomass should be used should start with the common agreement that food and feed are of primary importance.
- **Waste**: There were concerns raised that when something is economically incentivised for burning, it encourages unsustainable production as there is a lack of 'added value' opportunities. Incentivising the use of food waste as a fuel was presented as an example which is likely to give an economic incentive to wasting food. It was noted that biomass as a resource for energy should not compete with wider resource efficiency objectives such as the conservation of natural resources and the efficient use of biomass for crucial uses such as rebuilding soil carbon.

[54] Drax PLC. Drax Group Annual Report and Accounts 2020. Available At: https://www.drax.com/wp-content/uploads/2021/03/Drax_AR2020.pdf

Respondent Categories of Interest

Those who cited ‘sustainability of biomass source’ as a principle to guide prioritisation were from a range of respondent types including, but not limited to:

- Trade Association / Representative Group
    - Agriculture
    - General
- Non – profit organisation / Special Interest Group / ThinkTank
- Utilities / Energy Asset Owners / Distributors

Principle 5: Ability to Combine With CCUS

Linked to the importance of considering the net zero benefit of different technologies, it was noted by 14 respondents that ability to combine with CCUS should be a key factor in determining priority end uses of biomass. They argued that this could **help to ensure the greatest decarbonisation benefits are achieved** and reward outcomes that contribute to net zero in a technology and feedstock-agnostic manner.

Respondent Categories of Interest

Those who cited ‘ability to combine with CCUS’ as a principle to guide prioritisation were from a range of respondent types including, but not limited to:

- Trade Association / Representative Group
    - Carbon Capture Utilisation and Storage
    - General
- Utilities / Energy Asset Owners / Distributors

Principle 6: Wider Environmental Considerations

13 references were made to the importance of considering wider environmental risks and benefits when determining the priority end uses of biomass. Environmental considerations referenced included the **importance of flood mitigation, wildfire management, biodiversity improvements, waste management and the provision of other ecosystem services**. Respondents acknowledged that

biomass use can have both positive and negative implications which need to be considered. For example, one respondent suggested that biomass feedstocks with significant implications on biodiversity should not be used, however it was clear from submissions that there are significant benefits too which need to be reflected. Within this, the importance of promoting regenerative practices was highlighted by multiple respondents.

Principle 7: Proximity Between Source and End Use

Nine respondents referred to the importance of considering proximity between source and end use. The importance of prioritising locally sourced biomass to encourage the utilisation of biomass at or close to source was highlighted. Respondents suggested that **avoiding long distance transportation and minimising transport miles is important in avoiding unnecessary emissions**.

Principle 8: Social Impact

Social impacts were referenced by seven respondents. When prioritising end uses, it was suggested that consideration should be given to the **social impact of biomass use including job creation and social wellbeing**, particularly for rural communities as well as contribution to the **levelling up agenda.**

Principle 9: Extent of Added Value Production

Five respondents indicated the importance of considering the extent of added value production when determining priority end uses of biomass. Reference was made, for example, to the **use of waste to create high value products** such as aviation fuel, as well as creating additional CO_2 removals, if CCUS is used.

Principle 10: Air Quality Impact

The importance of considering air quality impacts was cited by four respondents, with reference made to a zoning approach to protect cities and urban areas from poor air quality.

Principle 11: Consumer Attitudes

The importance of considering **consumer choice** as part of any future framework was noted by three respondents. For example, it was highlighted that consumers expect to have choice in relation to heat decarbonisation options for their homes.

Principle 12: Innovation Potential

The potential for innovation and supporting technological advancement were highlighted as important factors for consideration by three respondents. It was noted that creating frameworks that incentivise and promote innovation will ensure progress.

Principle 13: Conversion Efficiency

Conversion efficiency was raised as an important factor for consideration by three respondents, with one respondent indicating that "it is important that as a feedstock, biomass is used efficiently." Another cited the importance of maximising value extraction from biomass.

Principle 14: Technology Readiness Level

Two respondents cited that consideration of the technology maturity should be considered. One respondent suggested that the government should look to support high TRL technologies in the near term to maximise decarbonisation potential, and in doing so, help to grow the biomass supply chain and support development of other biomass technologies.

Principle 15: Not for Profit Basis

One respondent cited the importance of considering biomass end uses on a not-for-profit basis.

Principle 16: Potential for International Leadership

The potential for international leadership was cited as a consideration by one respondent who highlighted that the UK has an opportunity to be an international leader in net zero biomass through:

- Establishing a replicable cross economy, investable biomass, and Greenhouse Gas Removal (GGR) business model(s).
- Accelerating the deployment of net zero uses of biomass.
- Providing export opportunities in net zero biomass use (such as BECCS skills and knowledge) to help decarbonise other nations.

Challenges or concerns raised

Not all respondents supported the implementation of frameworks and/or principles to guide decision making. One respondent explicitly highlighted that creating an overly prescriptive hierarchy of best use and choosing 'winners and losers' would not be an effective policy and that "this type of regulation would be unprecedented in raw materials supply chains and would represent an overreach

of government." Another respondent highlighted that "overly-prescriptive regulations disrupt the function of the market".

In relation to forestry sources of biomass specifically, it was stated that frameworks already exist to ensure forests are not over-used and over-harvested for the bioenergy sector. It was considered that the natural cascading force in the market already ensures that only lower value wood goes towards bioenergy production.

Gaps in the evidence base

A clear gap was identified in relation to utilising an LCA as a decision-making framework/ net zero benefit as a principle to guide decision making. It was suggested that further research is required including:

- Research by Government into how it can robustly quantify the impact of biomass use, without disincentivising uptake through creating administrative complexity. Key considerations include:
    - Ability to compare overall life cycle impact to alternatives.
    - Recognition of carbon storage.
- A review of the criteria for calculation of net zero benefit to set out an industry standard and reduce uncertainties in key areas including:
    - How different segments of the supply chain are defined and attributed to different actors.
    - Assumptions in carbon factors.

INCENTIVISING DEPLOYMENT

Question 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?

76 respondents answered Question 11 equating to 55% of all respondents. The Table below summarises the respondent types for this Question.

Table 16 - Breakdown of Respondents by Organisation Type for Question 11

Respondent type	Total number of respondents
Academia	10
Biofuel/Biogas Producer & Technology Provider	13
Biogas Boiler Manufacturer	0
Biomass Supplier (Agriculture)	3
Biomass Supplier/Technology Provider (Forestry)	3
Certification Body	2
Chemicals	1
Consultancy	3
Government Organisation	3
Non-profit Organisation / Special Interest Group / ThinkTank	10
Other	7
Trade Association / Representative Group - Agriculture	2
Trade Association / Representative Group – Biofuels/Biogas	3
Trade Association / Representative Group – Biotech	3
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group – Forest Supply / Products	2
Trade Association / Representative Group – General	2

Respondent type	Total number of respondents
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	2
Utilities / Energy Asset Owners / Distributors	8
Waste Management	2
Total	**76**

All respondents answered the first part of the Question regarding specific arrangements needed to incentivise deployment of BECCS. These responses, although in depth, did not compare the different incentives required for BECCS with other GGR and CCUS technologies. While priority sectors and specific end-use were not identified directly in the responses, some respondents did distinguish sectors along the supply chain where support is needed.

In terms of the quality of responses, some respondents went into depth conveying specific financial incentives, analysing policies, and proposing areas where research and development is needed. However, most respondents reported at high level and identified the type of incentives and arrangements needed but not specifically how they would like this to be addressed.

The most common arrangements reported were Financial Incentives, R&D, and Other Policies (see Figure 17). Responses which related to Global Outlook and Technology Deployment were detailed. This Question encouraged respondents to also outline their concerns associated with BECCS. Some of these respondents specifically **highlighted that they did not want to see incentives for BECCS, justifying this by outlining the key challenges and concerns associated with BECCS.** Overall, the common themes observed across the various key arrangements were concerns of uncertainty in carbon reduction potential of BECCS, supply availability and quality, cost of deployment, and technology readiness.

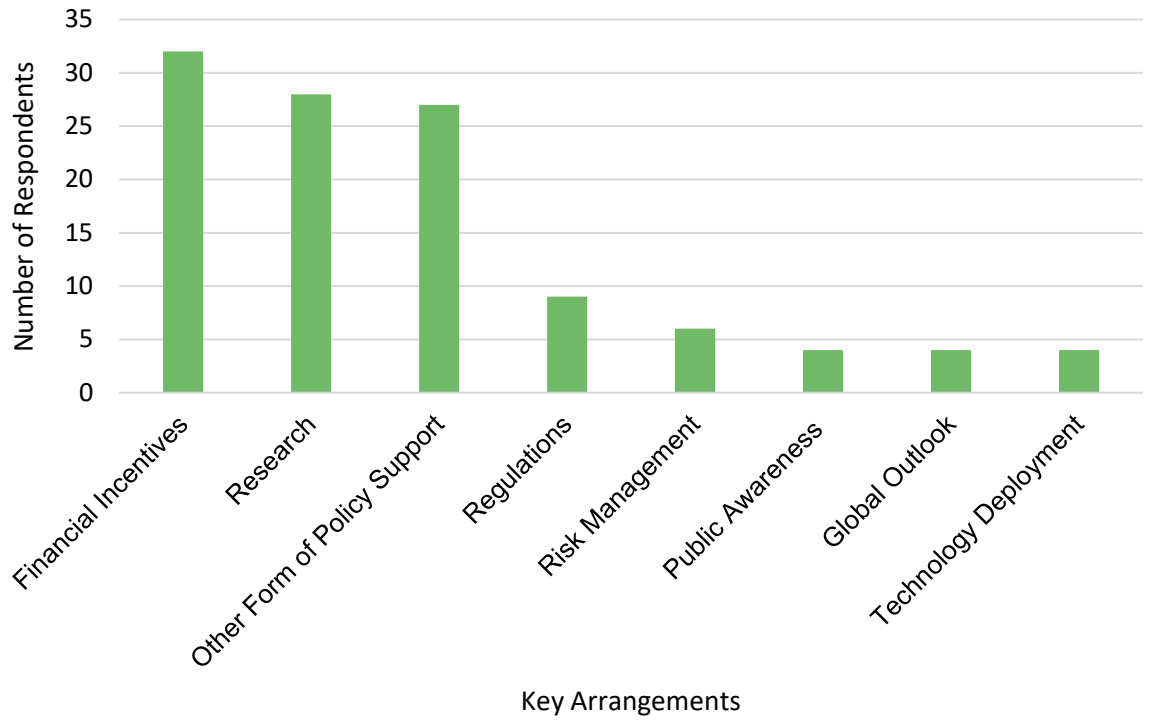

Figure 17 - Key Arrangements for Incentivising BECCS

Financial Incentives

33 respondents highlighted financial incentives as needed to support deployment. However, most of these financial mechanisms were coupled with other policies proposals, R&D requests, or concerns, which are outlined under the subheading 'challenges or concerns raised' within this section. The **commonly reported market mechanisms were carbon pricing and carbon credits.** Respondents highlighted that there needs to be more financial support and incentives for suppliers such as farmers to support BECCS. Some respondents also referred to financial incentives needed for upstream sectors to support technology deployment. Separately, traded offsets and financial incentives for carbon sequestration were also reported as key to enabling sectors to not only support BECCS but also enable them to step away from carbon emitting practices.

Research

The second most reported arrangement after financial incentives was research. Four respondents highlighted that LCAs were needed to fully understand the impacts of biomass supply, processing, and its end-use. Some respondents indicated that more research was required to assess the compatibility of BECCS within the ecosystem, taking into consideration current and future technologies. In addition, respondents vocalised that research on forecast and risk assessment is needed to design BECCS so that it is also flexible to respond to technological advancement. These respondents indicated that a LCA and further research should not be conducted as a general

umbrella for BECCS but rather done on a project-by-project basis as impacts can differ significantly depending on source and end-use.

Other Form of Policy support

Seven respondents alluded to incentives without addressing a particular mechanism. Transparency for ensuring investor confidence was highlighted as crucial as a mechanism to encourage more investment, both financial and in terms of resources. Whilst some respondents referred to long term policies and business models specific to BECCS application to be important in deployment, others specified further detail. One respondent noted that the outcome of ELMS will be significant to BECCS deployment, another respondent stated that combining GGR policy and CCUS policies together would help bring guarantee to the BECCS market. A respondent highlight that it is important to create a sustainable and verifiable GGR market and to develop a standardisation of GGR methodologies.

Respondents reported that **increased education is needed surrounding the benefits of BECCS** to encourage more suppliers into the BECCS supply chain. They indicated their belief that there is currently low public awareness and that communication to upstream sectors would incentivise key actors, such as farmers to engage. It was noted that this education needs to be coupled with support to de-risk suppliers and guarantee financial benefit through policies and schemes.

Regulations

A respondent highlighted that legislation is key for BECCS deployment. They specified that legislation is needed to de-risk the production of hemp for farmers to then incentivise them to grow these crops for BECCS. A respondent from Academia answered that legislation is needed to ensure transparency and traceability of sources to make sure that the BECCS sources are also sustainable. Another respondent said that regulations are required to control the use of supply as biomass is not finite.

Risk Management

Two respondents highlighted the need for risk management. One respondent from the Academia sector said that Global Outlook (expanded below) is needed to de-risk supply of biomass. They noted that due to biomass resource distribution, BECCS functions optimally in large scales and so global supply chain support and international participation is needed. Another respondent from the Utilities sector identified risk management as a necessary arrangement due to BECCS not being fully mature in its technology and for the cost.

Public Awareness

One respondent said that public awareness and increasing education of the benefits of biomass and BECCS is necessary to encourage deployment.

Global Outlook

Four respondents specified the need for **international collaboration and a consistent framework**. This ask was often linked to accounting and efficiency. One respondent noted that the UK needs to take advantage of the existing supply chain and imports of biomass sources to increase efficiency rather than to create a new biomass resource. Multiple respondents highlighted that international carbon accounting is needed to monitor and track rates of sequestration / negative carbon emissions. They indicated that this needs international support, participation, and standardised frameworks.

Technology Deployment

Technology deployment was listed as an important factor by six respondents. However, the current low rates of guarantee and high costs caused concern with respondents highlighting the importance of technology deployment to drive the growth of BECCS. Two respondents who considered technology deployment as key also stated that this should be combined with nature-based solutions or proposed other mechanisms to unlock co-benefits.

Challenges or concerns raised

Whilst a range of interventions were highlighted to support deployment of BECCS, many respondents coupled them with concerns. Some of the key concerns raised have been documented below:

- **BECCS can become a carbon emitter**, with the risk of disadvantaging the UK and the local area's net zero goals.
- **Deployment of BECCS can be incompatible with the surrounding ecosystem**, causing risks of biodiversity loss and forest degradation.
- BECCS processing and biomass supply require land use change which **can contribute to land grab.**
- Multiple respondents indicated that the **UK's definition of biomass should be expanded** to include biochar and sugar.
- Respondents noted that the transition to biomass technology could produce emissions in the process due to the **lack of current infrastructure suitable for BECCS** deployment.
- The **production of biomass supply is often not sustainable**. One response from the NGO sector highlighted that the UK, as one of the least forested nations, currently rely their sources on imports from North America and other regions for wood and biomass for energy. They explained that according to Dogwood Alliance's research on the US forests and climate energy[55], these forests where the wood pellets are sourced from in North America are not

[55] Dogwood Alliance Research Paper on US Forests and Climate Emergency. Available at: https://s3.amazonaws.com/media.dogwoodalliance.org/wp-content/uploads/2017/03/The-Great-American-Stand-Report.pdf

sustainably managed. It was suggested that, although the end-use may have carbon reduction benefits, without the sustainability of sourcing biomass in the first instance, it is only carbon neutral at best.

- Whilst BECCS may be cost efficient short term compared to other CCUS tech, **BECCS has shorter lifespan of assets** which is exacerbated by biomass being a finite resource which is not currently abundant.
- As carbon capture technologies focus on carbon removal rather than carbon reduction, respondents noted that these technologies **could enable fossil fuel companies to continue their practices and prevent them from being accountable** for their emissions.
- Technological limitations (such as cost).
- Uncertainty of successful development.
- Incompatibility with current technology.
- Attention on BECCS risks causing disadvantages to other CCUS technologies.

Alternative Solutions

Seven respondents highlighted alternatives to replace and/or supplement BECCS technology. Some of the key suggestions documented have been outlined below:

- Multiple respondents reported that **other alternatives of carbon mitigation** such as habitat restoration, regenerative farming and afforestation **are more holistically beneficial**. It was noted that these alternatives focus on co-benefits and multiple functions which seeks to support the surrounding ecosystems.
- One respondent from the 'Other' sector addressed the issue of carbon emissions from BECCS noting that other forms of CCUS should be considered to reduce carbon emissions with more confidence. They noted that, in addition to nature-inspired solutions for GHG sequestration by soil, **Biorefinery for Carbon Capture and Storage (BRECCS)** should be considered instead of traditional BECCS as under BRECCS products retain carbon for the longest duration possible. They explained that as only 5-10% of the biomass is needed for CCS[56], bioenergy projects alone should not be incentivised. This respondent highlighted that these alternative methods of CCUS have social and environmental benefits beyond biomass energy.
- One respondent reported a range of novel CCUS techniques to produce valuable products including acetic acid, formic acids and other chemicals and materials. Reference was also made to the role algae can play in sequestering CO_2.
- Multiple respondents reported that BRECCS should be considered instead.

[56] Studies referenced include: Sadhukhan, J., Ng, K.S., Hernandez, E.M. 2014. Biorefineries and Chemical Processes: Design, Integration and Sustainability Analysis. Wiley, Chichester. Available at: DOI:10.1002/9781118698129

Gaps in the Evidence Base

Given many respondents did not compare the different incentives required for BECCS with other GGR and CCUS technologies, this could be considered a remaining gap in the evidence base. As noted previously, respondents also indicated that more research is required to assess the compatibility of BECCS with the ecosystem, current and future technologies. It was also suggested that **research on forecast and risk assessment is needed to design BECCS so that it is also flexible and can adapt to technological advancement**. However, as highlighted above, respondents indicated that research is required on a project-by-project basis in recognition of the differences between individual projects.

Question 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?

90 respondents answered Question 12 equating to 65% of all respondents (please note this includes those who did not answer specific Questions but who provided information relevant to this Question that was captured here and does not include duplicate responses). The Table below summarises the respondent types for this Question.

Table 17 - Breakdown of Respondents by Organisation Type for Question 12

Respondent type	Total number of respondents
Academia	10
Biofuel / Biogas Producer & Technology Provider	10
Biomass Boiler Manufacturers	2
Biomass Supplier (Agriculture)	4
Biomass Supplier / Technology Provider (Forestry)	6
Certification Body	3
Chemicals	2
Consultancy	2
Government Organisation	0
Non-profit organisation / Special Interest Group / ThinkTank	7

Respondent type	Total number of respondents
Other	8
Trade Association / Representative Group – Agriculture	5
Trade Association / Representative Group - Biofuels / Biogas	4
Trade Association / Representative Group - Biotech / Chemicals / Products	6
Trade Association / Representative Group - Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group - Forestry Supply / Products	6
Trade Association / Representative Group - General	1
Trade Association / Representative Group - Heating Appliances	2
Trade Association / Representative Group - Professional Engineering Services	3
Utilities / Energy Asset Owners / Distributors	8
Waste Management	0
Total	**90**

The level of detail provided in relation to Question twelve varied with some respondents providing a detailed insight into the different policy mechanisms that could be used to incentivise the use of biomass and target available resource towards the highest priority applications and others simply stating the type of policy mechanism.

It should be highlighted that not all respondents were in favour of policy support for biomass. Further information on this has been documented in the ‘Reduce Policy Support’ subheading within this section.

Responses have been categorised as per Figure 18 and further detail on each of these categories has been provided below. For the top five policy categories raised, an analysis by respondent type has been conducted.

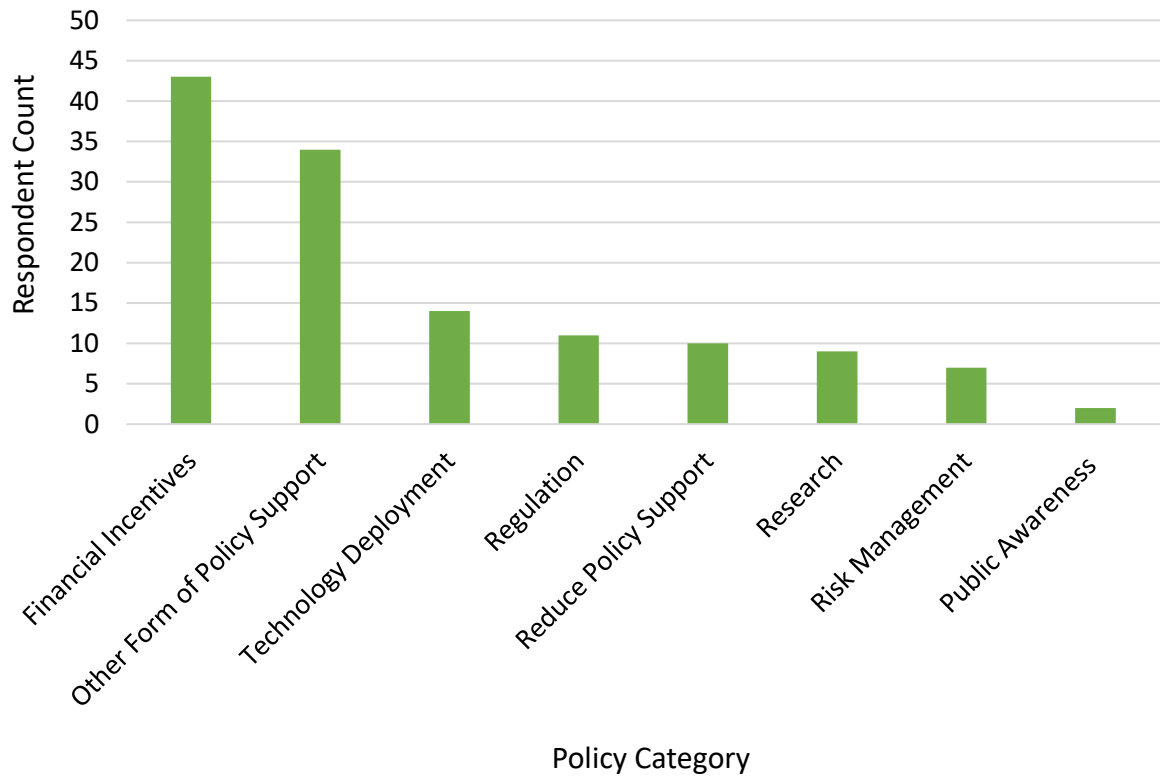

Figure 18 – The Categories of Policy Support Cited by Respondents in Response to Question 12

Financial Incentives

A total of 43 respondents referred to some form of financial incentive as a mechanism to incentivise biomass deployment. **A range of different financial instruments were referenced, and these have been divided into supply incentives and demand incentives**. It should be noted that **with regard to balancing supply and demand incentives, the picture was relatively unclear**, with many respondents simply stating that both supply and demand incentives were required.

There was indication from some respondents that supply incentives should be favoured, as by focusing on supply incentives Government can more easily control the impacts of biomass supply, whereas demand incentives require monitoring of the supply chain which is more complex. It was noted that incentives for new sources of supply could be based upon encouraging end users to share risk with growers, resulting in more robust supply chains. By contrast, others noted that demand incentives may ensure the cost competitiveness of the supply.

Supply Side Financial Incentives

A range of supply side financial incentives were suggested by respondents. These have been outlined below:

- Agricultural and forestry planting schemes for energy.
- Promotion of crops as an alternative source of income for farmers seeing a decline in meat and dairy demand.
- Rewarding natural capital benefits of energy crop cultivation.
- Carbon incentives for growers, with the importance of fairness noted between woodland creation incentives and perennial crop incentives.
- Six year low/interest free establishment loans, repayable in years three, four, five and six for growers to plant the maximum area available rather than the maximum they can afford on a self-funding basis.
- Supply side incentives, including grants.
- It was indicated that supply contractors would perhaps be allied to capital grant funding. The importance of ensuring incentives offer reliable, long lasting, and appropriate funding to support good practices, beyond the simple switch of land use to ensure enhanced soil health, carbon balance, biodiversity, ecosystem services, livelihoods etc. was noted. There was also reference to the ELMS which one respondent indicated "will be crucial in incentivising farmers to increase bioenergy production." However, one respondent suggested that there was greater opportunity to use ELMS to encourage supply of domestic biomass it was noted that "at present, except for trees (and to a degree peatland although the lowland peat task force has yet to report) there is little incentive for sectors such as agriculture to develop long-term capture and removal strategies."

Demand Incentives

A range of end-use financial incentives were suggested by respondents. These have been outlined below:

- Expansion and amendment of existing instruments to support biomass deployment, with reference to the following:
    - ROCs.
        - It was noted that a scheme similar to the ROC but renamed Renewable Biomass Credits could be valuable. It was suggested that this could potentially be paid per tonne for the use of sustainable biomass, or "dark green" double value carbon credits based on the sequestered levels of carbon.
    - Contracts for Difference (CfD).
    - Feed-in Tariffs (FiT).
    - Reinstation of RHI for small and medium boilers.

  - Amendment of the Green Gas Support Scheme to support AD plant-produced biogas.
  - Increased funding under the Clean Heat Grant (now referred to as the Boiler Upgrade Grant) to incentivise low carbon technology uptake.
  - Expansion of the Clean Heat Grant (now referred to as the Boiler Upgrade Grant) to cover biogas combustion and larger heating systems above 45 kW.
  - End to subsidies for fossil fuel use with low VAT rates – gradual increase from 5% to 20% over next five years to raise £2-3bn to help fund renewable energy projects.
  - A 50% capex grant for rural off-gas homes.
  - Business rate credits for industrial biomass usage and conversion.
- A range of other incentives primarily targeting the non-domestic sectors were referenced including:
  - Incentives for directly fired biomass operations (which would be particularly valuable for cement and lime manufacturers).
  - Incentives for biochar usage within agriculture.
  - Other forms of grants and subsidies to cover the partial cost of equipment purchase and installation.
    - Specific sectors highlighted included the non-domestic sector given the closure of the non-domestic RHI and the fact that under the IETF investment is spread thinly between technologies and industrial processes across the country.
  - A subsidy or tax break for using sustainably produced biomass products rather than fossil fuel derived materials (going beyond existing mechanisms such as the RTFO).
  - Continued support for electricity generation using biomass, particularly via BECCS.
- Extensive detail on the idea of an economy wide carbon tax/application of a carbon price was provided and these ideas have been discussed in further detail below:
  - Over 10respondents highlighted the role a carbon tax on fossil fuels could play in driving fossil fuel users towards finding alternative uses.
  - It was noted that a priority tax could be introduced where end users that are deemed to take a higher priority will pay higher tax on high carbon producing fuels, making biomass more attractive as an alternative.
  - Another idea suggested in this space was a climate change repair cost or tax in which these higher polluters pay. This can in turn be used specifically to reduce carbon going forward, e.g. planting more forests etc.

  - It was suggested that a carbon tax should be accompanied by duties on embedded carbon at borders.
  - It was indicated that carbon taxation could be increased year on year in every Budget.
  - It was suggested that carbon taxation could also be combined with ending fossil fuel subsidisation by increasing VAT rates over the next five years, with the extra funds reinvested into renewable energy projects.
  - The importance of a fully costed carbon pricing system that considers social and environmental costs was noted.
  - There was indication that an economy wider carbon price applied to all sectors, with a cross sectoral cap and trade system would reward products and energy vectors with lower carbon footprints. It was noted that such an approach would ensure that low carbon technologies such as biomass are deployed in sectors with the greatest need.
- A suggestion was also received whereby the Government should determine a mechanism for biomass and waste streams to be directed to biofuels and chemicals production plans/projects, as opposed to conventional disposal/treatment routes. They added that the Government should ensure that innovative sustainable biofuels/chemicals projects receive their fair share of the available domestic waste and biomass. It was noted that this could be via additional subsidies which could be used to offer lower gate fees to the consumers/LAs.
- It was also proposed that Government should increase the level of support via guaranteed mechanisms and funding for novel biomass projects to enable financing to be obtained and technology risk issues minimised.

Those who cited ‘financial incentives’ as a key mechanism to support biomass deployment were from a range of organisation types including, but not limited to:

- Trade Association / Representative Group – General (100% of respondents from this category who responded to Question 12 cited financial incentives)
- Biomass Supplier (Agriculture)
- Biomass Supplier/ Technology Provider (Forestry)

Other Form of Policy Support

Supportive Policy Framework

Eight respondents referred to the importance of a supportive policy framework. Respondents cited the importance of a **consistent, long-term approach to policies**. A respondent added that consistency will be key for industry stability and will help keep the UK as an attractive market for

sustainable biomass exports. It was noted that changes and inconsistencies to policies could negatively impact investor confidence which would in turn directly impact the UK's net-zero objectives. There was agreement with this sentiment across several responses. There were calls for a co-ordinated national plan for the use of biomass, led by Government and supported by industry and academia.

There was a call for **strong, consistent, and equivalent sustainability criteria** applied across all sectors to ensure a harmonised market. There were similar calls for a strong carbon methodology, as alluded to in responses to Question 10. There were also references to the importance of clear and consistent definitions across the sector such as clear definitions for waste.

Respondents noted the importance of wider policy support to enable biomass deployment. Some of the specific issues cited have been outlined below:

- One respondent commented that wider policy support was needed in order to address current licencing issues which are impacting the growth of certain biomass feedstocks such as hemp.
- Another added that support was required to address concerns over availability and supply.

Promoting Sector Wide Communication

There was a call for **greater engagement from the end user community** in terms of what they want the biomass sector to produce. Specifically, it was noted that there should be defined list of chemicals, materials, and other biobased products that researchers and technology providers should concentrate on. It was noted that this needs to be driven by Government to get buy in from industry.

There was discussion around a **sector-led approach to building an economy-wide carbon policy framework** to accelerate the transition to net zero. It was noted that this could be done via three separate policy categories:

- **Sectoral Carbon Policies** – The implementation of tailored sectoral carbon policies covering all major emitting sectors, with incentives and / or mandates progressively strengthened to drive required pace (as previously highlighted).
- **Packages of Complementary Policies** – The implementation of complementary policy packages to support carbon policies (e.g. innovation support or access to finance), as well as addressing key sectoral barriers to change (e.g. transitional or distributional impacts).
- **Linking Sectoral Carbon Policies** – The introduction of trading and validated carbon credit mechanisms and the linking of sectoral policies with carbon markets to enable an integrated economy wide framework of incentives.

Protecting and Growing the Market

The **importance of market harmonisation was cited**. There was also a discussion surrounding the role of the Government in protecting and growing the market for biomass products.

It was noted that Government must **protect the market against creating a new incumbency where all biomass resource is deployed via one technology**, whilst supporting on the demand side by helping to create a market for certain products, irrespective of the technology from which they were produced. Importantly, not all supported market intervention, with respondents highlighting the potential role of a free market in feedstocks utilising existing CEN/ISO standards. If combined with appropriate mechanisms such as a carbon tax, it was thought that intervention would not be needed.

To overcome supply and demand challenges, one respondent recommended a Bioresource Brokerage Service which could be rolled out as an exercise to provide greater visibility to the market regarding supply and demand. It was suggested that by developing and maintaining an online platform for a trial period, this could allow by-products to be visible to end users to manufacture high value products – a bioresource materials marketplace.

Linked to overcoming demand challenges, it was noted that government could introduce targets for the deployment of GGRs including biomass-end use technologies such as BECCS as an opportunity to give industry and suppliers an understanding on the potential market size and opportunities.

Respondent Categories of Interest

100% of respondents in the below categories who responded to Question 12 referred to ‘other form of policy support’:

- Consultancy
- Trade Association / Representative Group - Carbon Capture Utilisation and Storage
- Trade Association / Representative Group – General

Technology Deployment

14 respondents cited the importance of encouraging technology deployment. A range of proposals were outlined:

- A cross technology-readiness level programme of support to encourage innovation and support novel products already in the market.
- Investment to support deployment of new technologies, with specific examples provided below:

  - Deployment of integrated biorefinery technology that embeds process integration methodologies and principles which can respond to changing supply demand conditions, while offering economic feasibility and life cycle sustainability.
  - Demonstration facilities, grant funding and loans guarantees to stimulate the biochemicals with CCS industry to speed up and de-risk commercialisation.
  - Financing of projects targeting novel biomass pre-treatment technologies.

Of the respondents who suggested that the Government can better incentivise biomass usage through the deployment of technologies, there was a general view **that existing, more well-established technologies should still be supported**, deployed, and developed. It was suggested that "further innovation is needed alongside a focus on mobilisation of existing feedstocks and use of current technologies" and "it is also important to ensure continuity for existing projects and allow these projects to grow and adapt as circumstances change."

From a holistic view, the consultation has proved that there is not a one size fits all solution and that many different technologies are required.

Respondent Categories of Interest

Respondents citing 'technology deployment' as a key mechanism to support the biomass sector were from a range of organisation ties including, but not limited to:

- Trade Association / Representative Group
  - General
  - Biotech / Chemicals / Products
- Biomass Boiler Manufacturers

Regulation

11 respondents referred to the role of regulation. Options suggested included:

- Mandatory renewable content targets, however, it was noted that through regular reviews, mandates should be ramped up systematically over time, as the global production scales up and commercialises. Specific examples were proposed:
  - A dedicated SAF mandate.
  - Renewable content targets for products from the chemical and material sector.
  - Continuation of mandates for low carbon products such as through the RTFO.
- Obligations to stimulate the supply side such as specific obligations on segregated food waste collection.
- Product regulatory frameworks, with specific examples cited including:

    - Product regulatory frameworks based on LCA.
    - Obligations on biodegradable products.
    - Standardised carbon footprint labelling system on all consumer goods.
- Mandatory market share for selected biomass applications.

It should be noted that **not all respondents supported regulation**. One respondent stated, "regulations that restrict or prioritise the use of biomass for specific fractions/uses could lead to less efficient conversion of biomass into products, thereby reducing the potential mitigation of emissions from each tonne of biomass feedstock."

Respondent Categories of Interest

Respondents citing 'regulation' as a key mechanism to support the biomass sector were from a range of organisation ties including, but not limited to:

- Chemicals
- Trade Association / Representative Group - Biofuels / Biogas
- Utilities/ Energy Asset Owners/ Distributors

Reduce Policy Support

Whilst many respondents recognised a need for policy support, 10 respondents challenged proposals to increase policy support with a general consensus from these respondents that existing policies, and in particular tariff-based mechanisms (e.g. RHI) are skewing the market. Ten respondents referred to the need to reduce policy support in certain areas.

Some argued for Government to take a more **considered approach when constructing incentives**. This relates to the need for government incentives to focus on the delivery of a range of environmental, social, and economic benefits. It was proposed that **a holistic approach would incentivise and push bioenergy sectors to invest in innovation across a range of solutions**, rather than focus on specific end-uses. It was also suggested that Government should not have a role in deciding how biomass is used; it was argued that such decisions should be driven by market.

Others indicated that certain mechanisms, such as tariff-based mechanisms should be removed entirely. Respondents suggested that all existing subsidies should be redirected into "genuinely non-emitting" and renewable alternatives (solar and wind etc.). Those that held this view indicated that these changes should be made as soon as possible.

From an environmental perspective, concerns were raised in relation to policies driving unintended consequences. A respondent stated that existing policies and their relevant subsidies are, in some cases, having a negative impact on the climate. They have resulted in widespread deforestation

which has a direct impact on wildlife and communities living in and around the surrounding areas. Another agreed with a specific focus on heating options, noting that heating options which produce CO_2 and are proven contributors to poor air quality such as biomass should not receive financial or market incentives. They added that "when we are facing a climate emergency and trying to tackle poor air quality, expanding biomass burning does not seem the best approach and needs to be used carefully and with caution". Another suggested that Government should not have a role in deciding how biomass is used; it was argued that such decisions should be driven by market.

Respondent Categories of Interest

Respondents who called for a reduction in policy support for some or all sources of biomass within certain applications were from a range of organisation types including, but not limited to:

- Trade Association / Representative Group – Forestry Supply / Products
- Non-profit organisation / Special Interest Group / ThinkTank
- Certification Body

Risk Management

Respondents highlighted the need for **improved risk mitigation**. In particular, there was a role identified for the government to provide support to reduce risk for industry and investors. The development of new and emerging technologies was seen as an area where this could be beneficial to enable greater investment and provide confidence.

Public Awareness

Increasing public awareness and consumer engagement was cited as an important means of supporting the deployment of biomass. It was noted that **ensuring consumers are informed on the role of biomass in decarbonising the UK and how their choices may support increased use of sustainable biomass** was important given its cross sectoral applications. Another suggestion within this space was that Government should encourage the pooling of resources or a wider sense of community sharing to encourage uptake.

Gaps in the Evidence Base

There is a need for additional clarity with regard to balancing supply and demand incentives. Responses indicated that the picture was relatively unclear for stakeholders and therefore this may be considered an ongoing gap in the evidence base.

There were specific calls from respondents regarding the importance of research to support the development of new and emerging technologies. Additionally, there was indication that a key gap in the evidence base is a defined list of chemicals, materials, and other biobased products that

researchers and technology providers should concentrate on. It was noted that this needs to be driven by Government to get buy in from industry.

RISKS OR BARRIERS TO DEPLOYMENT

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

97 respondents answered Question 13 equating to 70% of all respondents. The Table below summarises the respondent types for this Question.

Table 18 - Breakdown of Respondents by Organisation Type for Question 13

Respondent type	Total number of respondents
Academia	10
Biofuel/Biogas Producer & Technology Provider	12
Biomass Boiler Manufacturers	2
Biomass Supplier (Agriculture)	4
Biomass Supplier/Technology Provider (Forestry)	6
Certification Body	3
Chemicals	1
Consultancy	2
Government Organisation	3
Non-profit Organisation / Special Interest Group / ThinkTank	10
Other	7
Trade Association / Representative Group - Agriculture	4
Trade Association / Representative Group – Biofuels/Biogas	6
Trade Association / Representative Group – Biotech	6
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	1

Trade Association / Representative Group – Forest Supply / Products	4
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	2
Utilities / Energy Asset Owners / Distributors	9
Waste Management	2
Total	**97**

The quality of responses for this Question was high and detailed. While some respondents did not expand on their broader points, most responses frequently included detailed paragraphs. 56 of the respondents answered in relation to policy gaps with repeated reference to policies and schemes albeit, with different recommendations. 43 respondents commented on the barriers and 19 on risks.

Whilst **more respondents focused on policy gaps, referring directly to specific policies such as the non-domestic RHI, the RO contract, and RTFO, the reported barriers supplement these answers with reasons why policy gaps are an issue.** Commonly referenced barriers included uncertainty and lack of guarantee in the carbon neutrality, supply availability, cost of BECCS deployment, and complexity of land occupation and building of infrastructure. A further barrier that was repeatedly noted and which is not conveyed through policy gaps is the definition of biomass. **Many respondents indicated that the UK's definition of biomass does not include many feedstocks** such as sugar and products such as biochar. Frequently stated risks included issues surrounding pollution, negative environmental impacts, and the risks that the introduction of new technology can bring to the market.

It is important to highlight that **policy gaps, risks and barriers can in some instances be highly linked** and whilst responses have been divided into the above categories for the purposes of this analysis, there are clear connections between the different policy gaps, risks and barriers identified. For example, some barriers that are multifaceted are complex to mitigate ultimately present risks to the market across a range of issues.

In terms of commonalities within sectors, air quality concerns were raised by three respondents from the NGO sector out of a total of eight respondents who raised air quality concerns. The other respondents who identified this specific concern were Government Organisations, Utilities, Biomass Suppliers, and those classified as Other. The respondents who highlighted the need for support and

incentives for suppliers were mostly Trade Associations. Out of 21 responses which focused on policies, 7 responses were from Trade Associations.

Policy gaps

Consistent Financial Support and Long-Term Policies

- 29 respondents mentioned lack of or uncertain financial support as a policy gap. The specific policies that were named were the non-domestic RHI, the RO contract and RTFO.
    - Four respondents raised concerns over the RO contract ending in 2027 for existing biomass power sites. They stated that a transitional period after 2027 is necessary and there needs to be more clarity on policies for these biomass generators after this contract.
    - Respondents noted that a continuation of the non-domestic RHI is needed to make sure that the policy changes don't adversely impact the biomass supply chain.
    - Four respondents raised the RTFO as a key policy where a review is required. One respondent highlighted that increased ambition is needed for RTFO. Another respondent commented that it currently drives BioLPG towards transport, noting concerns that they would like to see support for BioLPG deployment in heating. Another respondent highlighted that the existing and planned sub-schemes such as development fuels target and recycled carbon fuel are helpful. Two respondents highlighted that the crop cap in RTFO limits deployment of most crop derived fuels.

- One respondent indicated that ELMS is needed to address the agro-forestry gap to reward both energy crops and agro-forestry developments.

Technol*ogy Neutral Policy Support*

Multiple respondents referred to the importance of **technology neutral support in reference to BECCS**, highlighting the need for policies that would not disadvantage other CCUS technologies. As BECCS is still in process of development, respondents noted that it is important to introduce policies which are not technology specific.

Support for Sustainable Behaviour and Feedstocks

The importance of **supporting sustainable feedstocks** (e.g. manures) was highlighted. Respondents suggested that support is required for these alternative feedstocks because although they are more expensive to process, deployment could deliver significantly higher GHG emission benefits compared to other feedstocks. They also suggested that **historically, policies such the ROC, RHI, RIT, GGSS (Green Gas Support Scheme) and CfDs (Contract for Difference) have failed to incentivise sustainable behaviour.**

Financial Incentives for Negative Carbon Emissions

Multiple respondents highlighted that there needs to be a financial mechanism to **incentivise reductions in carbon emissions.** These respondents suggested that greater tax on fossil fuels and carbon pricing are good examples to reflect the impacts of these environmental costs. One respondent however, noted that the carbon price of the EU and UK ETS are too high for low carbon alternatives.

Standardisation

- Three respondents said that to ensure a level playing field, there needs to be robust and standardised emissions accounting. They highlighted that one of the current barriers to BECCS deployment is the lack of consistency of these accounting methods.
- Two respondents noted that this lack of standardisation is also reflected in the sustainability criteria across sectors. They highlighted that improving and aligning these metrics and criteria will help ensure that BECCS deployment is consistent across all sectors.
  - A respondent indicated that there needs to be a better trading environment for green gas certificates so that there are secure returns to producers.
  - A respondent mentioned the need for government certificates to incentivise green deployment.

Framework and Strategy

  - Five respondents addressed the need for clearer and more supportive frameworks to support deployment. One respondent specified that they would like to see frameworks for char/biochar in agriculture and other sectors. Another respondent noted the need for regulatory frameworks for investment incentives. Another respondent has said there needs to be frameworks which provide policy and regulatory certainty taken from agriculture-based policies.
  - One respondent said there needs to be an updated policy framework and another highlighted need for a carbon policy framework.
  - Two respondents wrote on the need for strategy, with one specifying the need for a bioeconomy strategy.

Supply Side Support

- Seven respondents highlighted the need for supply guarantee and support.
- One respondent said that rather than setting targets, policies should reflect the benefit of using specific types of biomass.

- Another respondent suggested that there should be more support for upstream sectors like farmers to incentivise them to report GHG emissions from land use change.
- One respondent noted that more focus is needed on biomass supply such as agricultural practices.
- Another raised apprehension regarding the uncertainty of the future global supply of pellets. One respondent highlighted that the new markets of supply are often based in countries that are increasingly and projected to be impacted by climate change. This means that the farmers in these areas are encouraged to plant biofuel crops when food is also scarce raising concerns around food versus fuel.

Risks

A **number of risks were identified in relation to the deployment of BECCS**. The **most frequently raised risk was in relation to local pollution** with 11 respondents referencing this. They reflected on negative impacts to local community health, concerns of biodiversity from land use change, and local air pollutants. The air quality impact associated with biomass deployment more widely are covered in the analysis of responses to Question 14. In addition, **carbon emissions from BECCS were highlighted with concerns raised around the long-term impact of emissions from the process**. One respondent shared concerns regarding whether biomass pyrolysis companies will be able to sell Certified Emission Reductions (CERs) on the carbon emission markets. Finally, one respondent said that the lack of stability and predictability in regulation makes it challenging for market participants to make investments in imported and domestic biomass supply.

Barriers

A number of barriers to deployment were raised by respondents. These included a **lack of space and infrastructure, an inconsistent definition of biomass, the costs associated with the transition to biomass technologies and licensing, and waste management planning.**

Changes to land use was a consistent theme throughout many responses. However, it was seen as a barrier by some with concerns raised in relation to the speed of changed required to accommodate BECCS and the associated environmental impacts if not considered appropriately. There was a worry raised that whole farm afforestation could reduce agricultural activity and food production which could increase the risk of land abandonment. This highlights the need to view land use holistically.

There is a need for a consistent definition of biomass which encompasses all feedstocks. Four respondents stated that the recognised definition of biomass currently does not include some critical feedstocks and/or products which the respondents highlighted as valuable. Three of these respondents referred to biochar here as a product which is not currently captured. Additionally, it was

requested by one respondent that the strategy should provide clear acceptance that sugar is a feedstock for energy, materials, and chemicals to encourage a biobased economy.

The cost of the transition was highlighted by two respondents, however the focus of the discussion differed. One respondent raised concerns surrounding the cost of switching infrastructure. They referred to the cost of removing tanks causing customers to be reluctant to transition to low carbon solutions. Another offered an alternative perspective, raising concerns regarding application and entry costs for licensing as a barrier preventing some suppliers from receiving these licenses which are there to incentivise suppliers.

Finally, one respondent highlighted that the Waste Management Plan for England could be improved as it is currently deemed counterproductive for the sustainability agenda. They noted that due to the limit on how many times waste wood can be recycled, there it is a need for the Waste Management Plan to acknowledge the role of waste wood recovery. The respondent indicated that this policy currently disincentivises recovery over recycling.

Gaps in the Evidence Base

Given that many respondents did not cite a specific end-use sector associated with the policy gaps, risks or barriers identified, this may be a remaining gap in the evidence base.

AIR QUALITY

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

84 respondents answered Question 14 equating to 60% of all respondents. The Table below summarises the respondent types for this Question.

Table 19 - Breakdown of Respondents by Organisation Type for Question 14

Respondent type	Total number of respondents
Academia	7
Biofuel / Biogas Producer & Technology Provider	9
Biomass Boiler Manufacturers	2
Biomass Supplier (Agriculture)	3
Biomass Supplier / Technology Provider (Forestry)	6

Respondent type	Total number of respondents
Certification Body	3
Chemicals	0
Consultancy	2
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	11
Other	8
Trade Association / Representative Group – Agriculture	3
Trade Association / Representative Group - Biofuels / Biogas	5
Trade Association / Representative Group - Biotech / Chemicals / Products	4
Trade Association / Representative Group - Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group - Forestry Supply / Products	5
Trade Association / Representative Group - General	2
Trade Association / Representative Group - Heating Appliances	2
Trade Association / Representative Group - Professional Engineering Services	3
Utilities / Energy Asset Owners / Distributors	6
Waste Management	1
Total	**84**

Broadly speaking the responses to Question 14 were less detailed than those provided in the rest of this section. Many respondents referred to **controls that should be introduced to limit the air quality impacts associated with biomass (i.e. *how* biomass should be used) as opposed to *where* biomass should be used.** However, information across both of these categories has been captured. Figure 19 displays the response categorisation for this section and the below sub-headings contain further information on each of the categories displayed. For the top five mitigation tools highlighted, analysis by respondent type has been conducted.

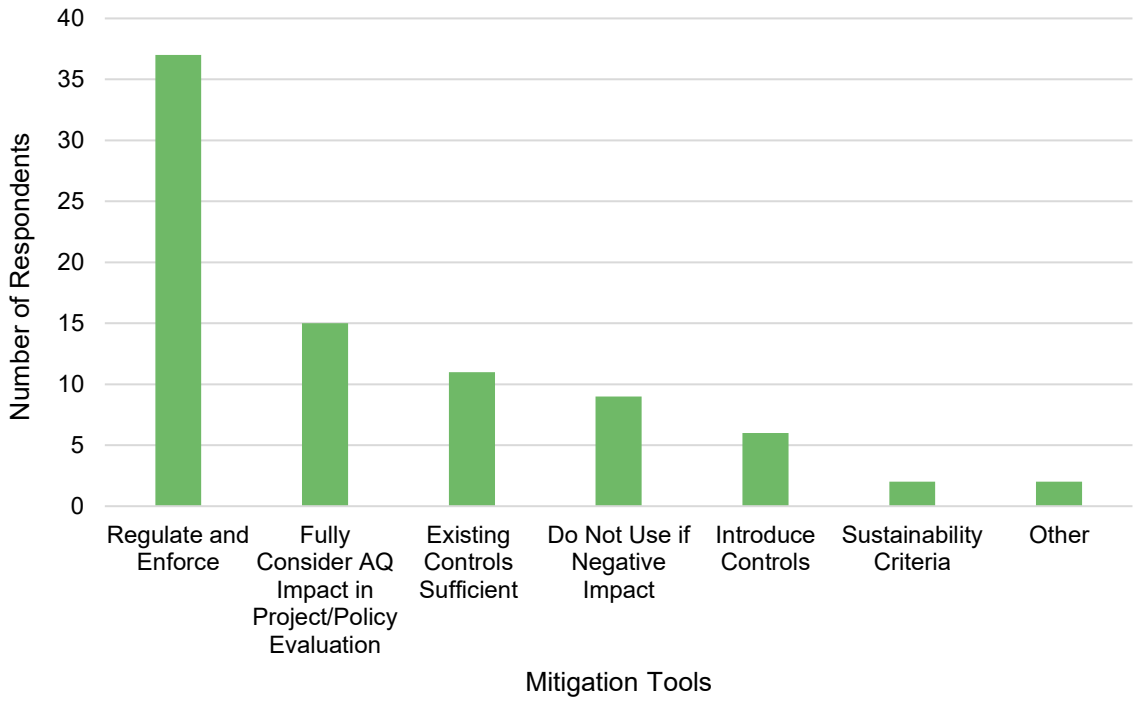

Figure 19 – Response Categorisation for Question 14

Regulate and Enforce

Introduction of regulation was the most popular mitigation tool highlighted. Of those that proposed the introduction of regulation and enforcement, 13 respondents specifically referenced heat, and 2 highlighted agriculture.

For heat, key proposals included:

- Stricter definitions on population density associated with a built-up area to further restrict non-abated biomass combustion to rural areas/ a ban if domestic biomass burning in urban areas.
- Better regulation of installation companies to ensure systems are correctly sized and set up, combined with education and training, better oversight of design proposals and independent design review.
- UK wide mandates for exempt appliances verified under the Clean Air Act that have to be designed in such a way to limit the amount of emissions produced during combustion.
- Requirement for public information on solid fuel stove operation.
- Enhanced emissions limits specified under RHI for PMs.

For agriculture, key proposals included:

- The need for well-regulated storage and low emission spreading techniques.

Where end uses were not specified, key proposals included:

- In relation to agriculture,
- Emission limits in areas of high population.

- Avoidance of applications that generate particulates and constrain operation to minimise pollutants.
- On- site emission limits.
- Introduction of biomass burning regime.
- Expansion to Environmental Permitting.
- Requirement for end use to be in close proximity to the feedstock.
- Emissions monitoring to be mandatory in planning.
- Air quality regulations set by environmental regulators across the UK, with significant fines for breach.

It should be noted that multiple respondents also suggested that air quality should be addressed through emissions legislation as opposed to via the biomass strategy. Multiple respondents indicated the importance of ensuring that where possible, Government should introduce policies that are technology neutral.

Respondent Categories of Interest

Respondents who cited 'regulate and enforce' as a mechanism to protect air quality were from a range of respondent types including, but not limited to:

- Trade Association / Representative Group
    - General (100% of respondents in this category who responded to Question 14 cited 'regulate and enforce)
    - Professional Engineering Services (100% of respondents in this category who responded to Question 14 cited 'regulate and enforce')
- Certification Body

Fully Consider Air Quality Impact in Project/Policy Evaluation

15 respondents suggested that a key means of mitigating the impact of biomass on air quality would be to fully consider air quality impact in project/policy evaluation. Concerns raised by respondents were aligned to the Clean Air Strategy 2019 Report which notes that "air pollution is the top environmental risk to human health in the UK, and the fourth greatest threat to public health after cancer, heart disease and obesity"[57].

[57] DEFRA. Clean Air Strategy 2019. Available At: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770715/clean-air-strategy-2019.pdf

Of those that proposed the need to fully consider air quality impact in project/policy evaluation, two respondents specifically referenced heat. Some of the key points raised have been outlined below:

- Specific reference was made to the burning of biomass in the indoor environment.
- It was highlighted that there is potential for fine particulates (PM 2.5) to be carried from rural to urban areas and that this should be considered.
- It was noted that according to the Air Quality Expert Group, 2017, domestic biomass boilers in the UK have a greater impact on maximum ground level PM concentrations than biomass combustion in larger power plants[58]. It was suggested that according to DEFRA, PM is the most damaging form of air pollutant in terms of damage cost per ton and damage cost of 2019 emissions[59] [60].
- It was suggested that biofuels have lower impacts on air quality and therefore their use should be considered. With reference to forestry sources, it was noted that "PM emissions from burning woody biomass can be much higher than fossil fuels, depending on the combusting technology and whether pellets are used, whereas NO_x emissions are comparable to gas and liquid fuel"[61].
- It was noted that the impact of air quality should be considered in how biomass for energy generation is expanded, considering the Government's Clean Air Strategy. It was indicated that the health effects of how and where biomass combustion is used should be carefully considered with a focus on the risks to vulnerable groups.

There was also **specific reference to electricity too**, with one respondent noting that potential air quality impacts should be carefully considered as a part of the evaluation of the use of biomass for large-scale electricity generation.

Other comments that apply more widely have been outlined below:

- It was suggested that a new Clean Air Act should be introduced as well as a requirement for Air Quality Impact Assessments where consideration should be given to NO_x and Volatile Organic Compounds (VOC) emissions.

[58] Air Quality Expert Group. 2017. The Potential Air Quality Impacts from Biomass Combustion.
[59] DEFRA (2021) Air quality Appraisal: Damage Cost Guidance.
[60] DEFRA (2021) Emissions of Air Pollutants in the UKNAEI (2018): Emission Factors by Source and Fuel.
[61] CCC. (2018). Biomass in a Low Carbon Economy. Available At: https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/

- The importance of considering not just UK residents but air quality impacts on other residents, such as those in the United States (US) given international biomass sourcing was highlighted.

    - An LCA was considered an important mechanism with respondents highlighting the need to encompass the effect of air quality and all other factors. It was suggested by one respondent that if there is a drop in air quality, this should be weighed against the benefits. It was proposed that biomass products should have a net positive impact on the environment and only be used in applications where they do so.

    - It was suggested that biomass use should be prioritised where abatement equipment exists, with strict limits on emissions to air.

    - It was indicated that further research and development is required before large scale roll out, combined with greater cross-industry standardisation.

Respondent Categories of Interest

Those who cited the importance of fully considering air quality impact were from a range of respondent categories including, but not limited to:

- Waste Management (100% of those in this category who responded to Question 14 cited this as an important factor)
- Trade Association / Representative Group - Biotech / Chemicals / Products
- Consultancy

Existing Controls Are Sufficient

It is critical to highlight that many **respondents expressed a view that existing controls are sufficient**. Respondents emphasised that biomass boilers are already highly regulated from fuel quality to emissions reporting. It was noted that this is **particularly true for medium and large-scale systems with regular recording and reporting protocols**, **as well as systems qualifying for RHI where air quality standards are in place**, with information about the product, test laboratory, tested fuel types and emissions reported on. Additionally, respondents stressed that the industry is made up of extremely technologically developed heating systems which are highly regulated. It was indicated that existing EU regulations relating to residential heat are already implemented in the UK market such as Commission Regulation (EU) 2015/1189) and Commission Regulation (EU) 2015/1185) which set minimum efficiency and maximum emissions levels for biomass heating technologies. Reference was also made to the work of BEIS in introducing mandatory fuel quality standards for biomass fuels.

It was noted that **air quality is already well regulated and enforced through Environmental Permitting** (as EU emissions standards remain in place in the UK via the Industrial Emissions Directive (above 50 MW and Medium Combustion Plant Directive (1 MW – 50 MW). It was noted that Environmental Permitting is preferable to sustainability criteria. It was highlighted that sites operating with environmental permits are required to collect data at regular intervals, depending on the substance being monitored. For most emissions this includes real-time measurements and monthly submissions. Biomass sites, whether using virgin feedstocks or waste, already have transparent data available and a high degree of regulation to ensure emissions affecting air quality are within limits. It was highlighted that attempts to implement further air quality criteria, such as trying to direct biomass locations within energy policy, could risk creating contradictions.

Other respondents referred to the UK having a mature and well understood framework of air quality regulation where emissions are highly abated, with stringent limits on emissions which are continuously monitored and reported. It was noted that all sources should continue to be regulated under that framework, with a technology neutral approach. It was also emphasised that stack heights are designed to ensure effective dispersion so that ground level concentrations are generally low relative to air quality standards and existing background concentrations.

Respondent Categories of Interest

Those who suggested that existing controls were sufficient were from a range of respondent categories including, but not limited to:

- Trade Association / Representative Group – Forestry Supply / Products
- Biomass Boiler Manufacturers
- Biomass Supplier/ Technology Provider (Forestry)

Do Not Use if Negative Impact

Nine respondents suggested that given the potential air quality impacts of biomass, it should simply not be used if there are negative impacts. Most respondents did not refer to an end-use here. It was noted that the use of biomass to derive energy was the least sustainable option in terms of air quality and that it should be phased out in place of other uses of biomass.

Key pollutants noted throughout this Question included **PM 2.5, PM 10, VOCs, SO_2, NO_x, NH_3 and CO_2.** Within this category, two respondents specifically cited PM 2.5, noting the health impacts associated with this pollutant, including respiratory problems, cancer, heart attacks and strokes. It was noted that replacing coal with biomass is not an appropriate solution to improving air quality and reducing PM 2.5 emissions with research cited stating that “the increasing role of gas and biomass and wood emissions in the health burden of PM2.5 exposure indicates that swapping one air

pollution-emitting fuel source for another is not a pathway to a healthy energy system." Respondents focusing on forestry sources of biomass noted that wood pellet production also releases unsafe air pollution, with recognition that in the U.S., pellet producing plants have been scrutinised for repeatedly evading air pollution permitting requirements or downplaying their contributions to air and water pollution.

Respondent Categories of Interest

Those who suggested that biomass should not be used where it has a negative impact were from a range of respondent categories including, but not limited to:

- Non-profit organisation / Special Interest Group / ThinkTank
- Academia
- Biomass Supplier (Agriculture)

Introduce Controls

There were several references to **controlling where technology should be deployed**. In addition, respondents referred to emissions abatement technology that could be introduced to control emissions including filter systems, CCS, mitigation technology for ammonia emissions and other Best Available Techniques (BATs).

Respondent Categories of Interest

Those who indicated that controls should be introduced to protect air quality were from a range of respondent types including, but not limited to:

- Government organisation
- Academia
- Trade Association / Representative Group - Biotech / Chemicals / Products

Sustainability Criteria

Two respondents referred to the role of sustainability criteria in shaping and encouraging the preferred end-uses of biomass.

Other

Other proposals included **considering alternative technologies and facilitating their deployment**, **considering key areas of need and consideration of the feedstock**. Moreover, the need to broaden and strengthen sustainability criteria was advised by one respondent. The importance of product certification was also highlighted as a mechanism to aid consumers, installers, and other

stakeholders to ensure air quality impacts are mitigated. Reference was made to the ClearSkies Mark[62].

Gaps in the Evidence Base

Many respondents did not specify and end-use but where they did, many referred to heat specifically. Whilst this may be due to heightened air quality concerns associated with this sector, the lack of end-use specific commentary specifically related to electricity, agriculture, transport, industry, and chemicals & materials may be seen as a remaining gap in the evidence base.

[62] Clear Skies Mark. Available At: https://www.clearskiesmark.org/

Chapter 3: Sustainability and Accounting for Emissions

Chapter 3 addressed the sustainability criteria around biomass supply and use, stakeholders were invited to provide their views about our existing sustainability criteria. They were also invited to input into the potential for amending them to ensure we support wider climate, environmental and other goals, as well as how we could improve monitoring and verification against these criteria. The consultation also asked for evidence and views on accounting for full life cycle emissions from domestic and international sources of biomass, the implications of these for carbon budgets and reporting against sustainability criteria, options for reflecting life cycle emissions of biomass in the UK's ETS, carbon pricing and our reporting standards, as well as on the options for accounting and reporting of negative emissions delivered by BECCS.

SUPPLY CHAIN SUSTAINABILITY CRITERIA

Question 15: Are our existing sustainability criteria sufficient in ensuring that biomass can deliver the greenhouse gas (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?

81 respondents answered Question 15 equating to 59% of all respondents. The Table below summarises the respondent types for this Question.

Table 20 - Breakdown of Respondents by Organisation Type for Question 15

Respondent type	Total number of respondents
Academia	5
Biofuel / Biogas Producer & Technology Provider	8
Biomass Boiler Manufacturer	0
Biomass Supplier (Agriculture)	3
Biomass Supplier / Technology Provider (Forestry)	7
Certification Body	3
Chemicals	0

Respondent type	Total number of respondents
Consultancy	3
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	11
Other	7
Trade Association / Representative Group – Agriculture	3
Trade Association / Representative Group – Biofuels / Biogas	5
Trade Association / Representative Group – Biotech / Chemicals / Products	3
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	7
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	2
Utilities / Energy Asset Owners / Distributors	8
Waste Management	0
Total	**81**

38% of the responses to this Question, shown in Figure 20 stating that 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. Another 38% of the responses to this Question stated that our existing sustainability criteria is not sufficient. A further 24% of the responses to this Question described the current sustainability criteria implementation setup but did not indicate if the criteria were sufficient. There were limited amendments suggested to ensure biomass from all sources supports wider climate, environmental and societal goals. The divide between respondents' opinions on if the criteria is sufficient is important to note.

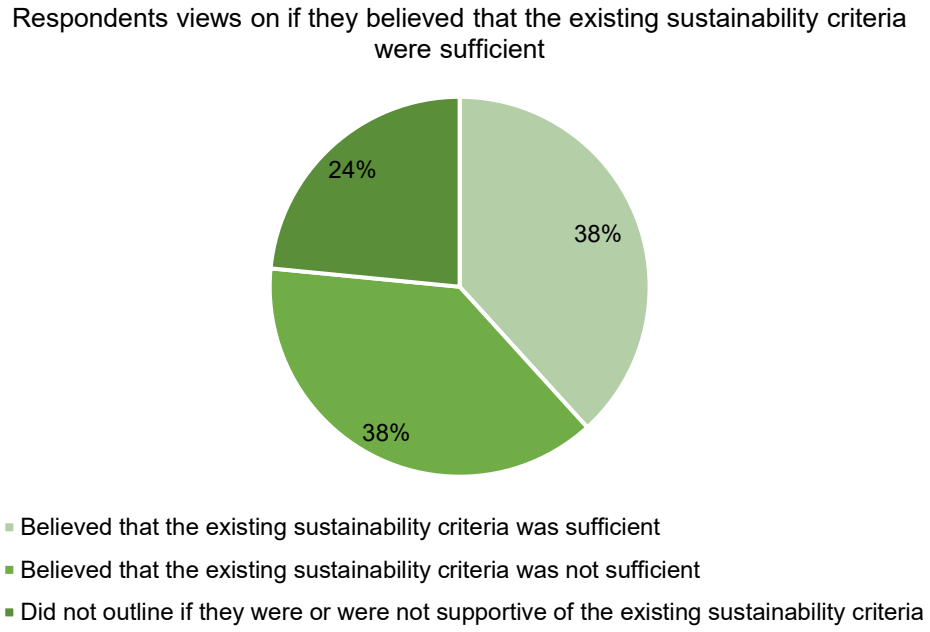

Figure 20 - Respondents views on if the existing sustainability criteria is sufficient.

There was a lack of evidence provided by respondents to ensure biomass from all sources supports wider climate, environmental and societal goals. Many who stated that the current criteria were not sufficient failed to provide evidence of how the criteria could be improved.

Existing sustainability criteria are sufficient

Overall responses that were supportive of the current sustainability criteria agreed that the current legislation allowed the UK to be seen as an attractive biomass market by other countries and companies. The approach was seen to concurrently maintain rigorous sustainability standards to ensure that biomass can deliver the GHG emission savings needed to meet net zero without wider adverse impacts, including on land use and biodiversity. Biomass suppliers also stated that this includes replanting after harvests as well as ensuring that forests remain healthy and productive while maintaining wildlife habitats, protecting soils and water quality.

Governance

38% of the responses to this Question supported the existing sustainable criteria stating that the existing criteria is fit for purpose. Biomass supplier respondents stated that the current sustainability governance is recognised as world leading and mitigates many risks. **It was suggested that the UK's current sustainability criteria goes beyond the Renewable Energy Directive II (RED II).** Respondents stated that the current UK criteria has evolved over time to become comprehensive, therefore indicating that the UK does not need to make immediate changes. However, it was noted that the UK needed to regularly review the scientific evidence as well as

industry evidence and amend the criteria as needed to ensure that it remains fit for purpose into the future. With this reviewing on a regular basis, respondents were confident that the UK would continue to have sustainability criteria which is as good or better than other countries while delivering net zero. A respondent from academia also noted that there can always be more research done on domestic and international supply chains to ensure sustainability, however, were supportive of the current criteria.

Compliance

Respondents also noted that **the UK has been able to balance sustainability compliance without making the UK an unattractive market for biomass supply**. A Biofuel / Biogas respondent mentioned that although the standards of voluntary schemes are used to verify sustainability and some GHG emissions, they do not take into account air pollution. The respondent noted that although the aim is to reduce GHG emissions, we should also factor in air pollution such as particulate emissions. It was stressed that criteria should reduce emissions at the cost of air pollution, which can be damaging to human health.

Wildlife

It was noted by a forestry respondent **that if biomass is sourced in a sustainable way it can contribute to positive outcomes for biodiversity and wildlife.** This can be achieved through forest thinning which reduces the density of trees therefore allowing for more light to reach the forest floor allowing for a natural recovery of the wildlife population in the forest by improving the quality and growth of the remaining trees and plants[63].

Existing sustainability criteria are not sufficient

38% of the responses to this Question did not support the existing sustainable criteria stating that the existing criteria are not fit for purpose. Many of the respondents noted that the UK should follow the scientific evidence base whilst amending and developing new biomass legislation

Carbon Accounting standards

There were worries that there is a **lack of clarity regarding the current carbon accounting standards and these standards are not ambitious / strong enough.** It was highlighted that carbon credits are applied to the UK even if the biomass has been grown and imported from abroad. As the material has been imported there are imbedded emissions in the transport. Respondents noted that these **transportation emissions need to be fully accounted for in the carbon accounting**

[63] Forestry Commission, 2011. Thinning Practice, A Silvicultural Guide. Available at: https://www.forestresearch.gov.uk/documents/4992/Silviculture_Thinning_Guide_v1_Jan2011.pdf

criteria. A non-profit organisation also noted that without full carbon accounting in the criteria, which included BECCS as a technology that has negative emissions, then the biomass will not be able to compete. It was suggested that without recognising these benefits, BECCS is likely to be developed further which could result in higher emissions.

CCS

Many respondents including trade associations including professional engineering services trade associations stated that **biomass should only be used when there is long term carbon capture and sequestration in place** so that the emissions from the biomass can be offset. It was highlighted that if you burn biomass, it is not absorbed into new biomass straight away, instead it takes time to be reabsorbed into new biomass and therefore carbon in the atmosphere increases when the biomass is initially burnt.

Incentive payments

A response from a consultancy also highlighted that **incentive payments do not incentivise continued sustainability improvements and reduction in GHGs.** The respondent commented that under the current systems, biomass facilities will state if the biomass is within the criteria and if it is they will receive an incentive payment. The payments that are made remain the same whether they just meet the criteria or if they have worked to reduce emissions further. Therefore, this does not encourage the industry to continually reduce their emissions once they meet the current standard. Ongoing reporting and increasing incentives to reflect continuous improvement could be considered to address this.

Preventing specific practices

Respondents also noted that **practises such as sourcing whole trees, clearcutting practices and harvesting from sensitive ecosystems should be banned.** They argued that these practices are not sustainable for long and will not help the UK to meet net zero as the practices are doing more harm to the planet than they are doing good in reducing emissions.

Amendments to ensure biomass from all sources supports wider climate, environmental and societal goals

7% of all respondents who answered Question 15 stated that **a full LCA is needed to account for all emissions from the sourcing of the biomass, transport and burning.** This assessment should use the latest research into emission values which allows for a full understanding of the carbon emissions and therefore allows for a better comparison between fuels.

A further 7% of the responses to this Question, including consultancies, non-profit organisations, and academia establishments, also stated that the **sustainability criteria need to be widened further.** They indicated that it should include other environmental impacts including non-GHG indicators such as social indicators, indicators of how healthy the wildlife population is, and water quality in the area where the biomass is sourced. The respondents have suggested that incentives could be based on the full sustainability criteria on a tapered scale. It was recommended that as more biomass suppliers meet the criteria then the criteria can become tighter so that the industry is always working towards more sustainable biomass.

A non-profit organisation respondent stated that the **sustainability criteria should be amended to exclude all feedstocks that do not provide near-term climate benefits.** They argue that feedstocks should be limited to a 'closed loop, including short-rotation woody crops or coppices on lands that are not currently in forest cover and in ways that do not compromise biodiversity. In contrast with open-loop harvest or intensification of harvest, closed-loop biomass is akin to spending carbon one has already saved'. Other respondents outlined that if the biomass was to do greater environmental harm being left where it is not harvested then it can be used. Examples of where it can do more harm is where it is likely there will be forest fires, droughts, or infestations. If it is deemed that the these are likely then they argue that it can be harvested otherwise the crop should be left in-situ.

Overall, 13% of all respondents who responded to Question 15 suggested improvements recommended a widening of the sustainability criteria so that it included non-GHG indicators such as climate, environmental, and societal goals with a particular aim to achieve net zero. Two respondents stated incentive payments could be used to continually drive industry to work towards improving the sustainability of their biomass. A number of other participants also indicated that any changes needed to align with the latest scientific research to mitigate the risk of unintended consequences.

IMPROVEMENTS

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

57 respondents answered Question 16 equating to 45% of all respondents. The Table below summarises the respondent types for this Question.

Table 21 - Breakdown of Respondents by Organisation Type for Question 16

Respondent type	Total number of respondents
Academia	5
Biofuel / Biogas Producer & Technology Provider	6
Biomass Boiler Manufacturer	1
Biomass Supplier (Agriculture)	2
Biomass Supplier / Technology Provider (Forestry)	4
Certification Body	3
Chemicals	0
Consultancy	3
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	7
Other	3
Trade Association / Representative Group – Agriculture	2
Trade Association / Representative Group – Biofuels / Biogas	3
Trade Association / Representative Group – Biotech / Chemicals / Products	4
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	3
Trade Association / Representative Group – General	1
Trade Association / Representative Group – Heating Appliances	1

Respondent type	Total number of respondents
Trade Association / Representative Group – Professional Engineering Services	0
Utilities / Energy Asset Owners / Distributors	7
Waste Management	0
Total	**57**

Responses to Question 16 were relatively strong with many providing suggestions to improve monitoring and reporting of sustainability requirements. This included implementing improvements to current monitoring reporting practices or mandating standards that currently exist in voluntary schemes across the whole industry. There were a wide range of respondent types to this Question, all providing insightful responses to aid any future improvements to the requirements.

Domestic Biomass

Respondents highlighted that there are **currently inconsistencies in the sustainability monitoring and reporting requirements for domestic biomass.** Many respondents stated that the reporting requirements across different schemes vary and do not allow for transparency. Common schemes that were mentioned were the SBP and the BSL, as shown in the Figure below. It was highlighted that the **requirements were fragmented and that there does not appear to be any sharing of the data across different schemes, organisations and regulatory or government departments.**

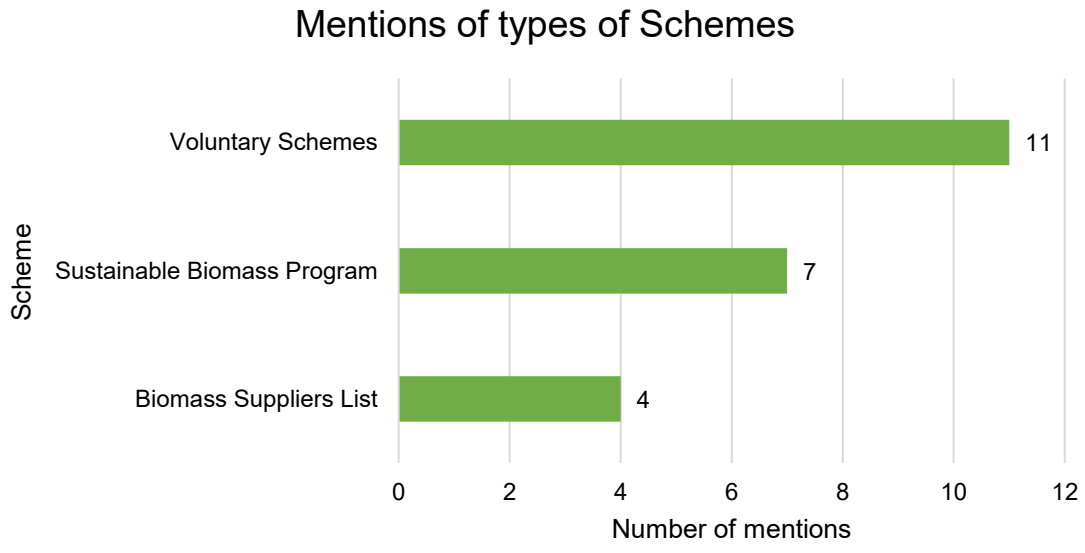

Figure 21 - Mentions of type of Schemes in Question 16

Voluntary Schemes

A certification body noted that there tends to be a low level of monitoring of suppliers in voluntary schemes and a high failure rate when suppliers are audited. There are however no statistics to available to reinforce the claims that are being made.

Respondents from non-profit organisations also suggested that current **voluntary schemes are typically overseen by industry which therefore imply that the monitoring and reporting could be flawed or not impartial as the regulations are not set by an independent panel.** Both the BSL[64] and SBP[65] have a panel made up largely of industry participants who help shape the scheme and how it is run. Respondents were concerned that this was like a self-policing approach that could lead to higher carbon emissions and loss of natural habitats.

Monitoring and reporting requirements

A couple of biomass suppliers as well as other respondents also suggested that the current monitoring and reporting requirements were not fit for purpose, in particular, **deficiencies were noted when emissions from biomass are compared to other fuels that are used for energy generation.** Respondents noted that other types of fuels do not have to account of the emissions that are created before they are burnt whereas biomass emissions normally include the emissions before being burnt which means that biomass emissions are shown as higher even if they have lower stack emissions. The approach of comparing the stack emissions of other fuels to biomass where all lifetime emissions are compared means that the respondents noted that biomass is not competing on a level playing field.

Interpretation of guidance

A government organisation respondent also commented that the guidance on compliance with the UK's sustainable criteria can be difficult to interpret and understand for industry customers. The use of differing language across the industry for the same feedstocks also leads to confusion when trying to interpret the sustainability requirements.

International Biomass

Respondents stated that **international biomass sustainability and reporting requirements do not account for variation between different countries including risk levels.** Respondents noted that there should be a tapered scale where importers of biomass from countries which are deemed to be

[64] Biomass Suppliers List. BSL Advisory Panel Members & Attendees. Available at: https://biomass-suppliers-list.service.gov.uk/Content/Documents/BSL%20Advisory%20Panel%20Public%20v2.4.pdf
[65] Sustainable Biomass Programme. Governance. Available at: https://sbp-cert.org/about-us/how-we-operate/

high risk have to provide a greater level of evidence to prove that they meet the sustainability requirements and that the material is not legally harvested with countries that are deemed to be a lower risk providing less information. Respondents noted that this would allow greater audit resources to be dedicated to the countries with a higher risk score which are more likely to not be meeting the criteria. They hypothesised that this would result in higher enforcement rates and greater quantities of sustainable biomass being imported.

Feedback on current governance structures

3% of the responses to this Question highlighted that **the current criteria are fit for purpose** as it mitigates more risks than the EU RED II criteria and therefore does not need to be updated. However, if overly restrictive regulations are introduced, it was suggested that the new regulations would not increase the sustainability of biomass in the UK market, instead this could lead to greater obstacles to compliance. It was recommended that the current regulations are drastically changed.

A further respondent noted that the current system of Ofgem placing the onus on the end user to use biomass material that is sustainably sourced and meets the compliance regulations such as BSL audited fuels works well. The respondent propsoed that the principle could be implemented into other sectors outside of the biomass sector as this has driven up sustainability standards.

Suggested improvements to the sustainability requirements

Current requirements

The larger biomass organisations indicated they hold more granular data on sustainability than is required to be reported on for their biomass. Respondents indicated that as part of an update to the sustainability monitoring and reporting requirements the data could be requested as it will allow for greater scrutiny of the sustainability of the biomass by other parties. They did also note however that it should only be requested if it is believed to be necessary to improve sustainability as it will add extra reporting costs that would have to be applied to the fuel. A general trade association agreed that a lot of data is already collected by biomass suppliers to remain compliant currently. It was suggested that a government review of the data that is being collected by biomass suppliers would be beneficial to aid discussions on regulatory requirements. This review may indicate that the appropriate datasets already exist and could be utilised more effectively.

Respondents including agriculture biomass suppliers and academia highlighted that there **need for continuous reviews of the requirements with improvements added when any gaps are identified**. A continuous review process would ensure that sustainability issues are resolved quickly, and standards updated to mitigate risks.

New requirements

Utilities and Trade Associations in the Biofuels / Biogas and the agriculture space recommended that improvements could be made by **introducing a British standard LCA which can be used for biomass as well as other fuel types.** Respondents proposed that biomass suppliers would be required to report against the standard annually to ensure that they are complying with the sustainability regulations. It was also suggested that this would mean that the emissions could be compared on a level playing field as all fuel types would be comparing the lifetime emissions of the fuels rather than just the stack emissions when the fuel is burnt or a mixture of the two being compared. A Government Organisation respondent also commented that for a LCA to be successfully implemented it is important that the GHG emissions are investigated and verified independently building on past research so that the LCA results offer an accurate and dependable comparison between fuels. A trade association in the biotech / chemicals / products space also noted that in the implementation of a LCA that the sustainability standards that are implemented need to acknowledge the human, social and economic factors and not just environmental as this could lead to wider issues within the biomass industry.

A trade association in the biotech / chemicals / products space and biomass suppliers suggested that there is a need for the industry and legislation to **develop and utilise clear and consistent definitions of materials throughout the biomass supply chain including waste biomass feedstocks** often different companies can call the same feedstock by different names. The industry is aware that currently different geographies and schemes use different definitions for materials which can lead to confusion of what the biomass feedstock is made from and how it was processed.

8% of the responses to this Question highlighted that independent audit are an important part of the monitoring and reporting sustainability requirements. Respondents advocated for more auditing across the supply chain to prevent negative impacts on nature and the wider environment due to the biomass industry by ensuring that the standards claimed by companies are met. 3% of the responses to this Question wanted to the UK align to the EU RED II certification and carry out auditing to the EU RED II standard as it would allow for information to be shared across the schemes databases.

ALTERNATIVE MECHANISMS

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

53 respondents answered Question 17 equating to 40% of all respondents. The Table below summarises the respondent types for this Question.

Table 22 – Breakdown of Respondents by Organisation Type for Question 17.

Respondent type	Total number of respondents
Academia	3
Biofuel / Biogas Producer & Technology Provider	7
Biomass Boiler Manufacturer	1
Biomass Supplier (Agriculture)	2
Biomass Supplier / Technology Provider (Forestry)	4
Certification Body	2
Chemicals	1
Consultancy	1
Government Organisation	0
Non-profit organisation / Special Interest Group / ThinkTank	7
Other	2
Trade Association / Representative Group – Agriculture	1
Trade Association / Representative Group – Biofuels / Biogas	4
Trade Association / Representative Group – Biotech / Chemicals / Products	2
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	6
Trade Association / Representative Group – General	3

Respondent type	Total number of respondents
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	0
Utilities / Energy Asset Owners / Distributors	6
Waste Management	0
Total	**53**

Responses to Question 17 were, on average, sufficiently targeted at the alternative mechanisms for ensuring biomass sustainability. The length of response was generally satisfactory and supplied views - and on occasion, practical implementation - of specific legislation or voluntary schemes in the UK and internationally.

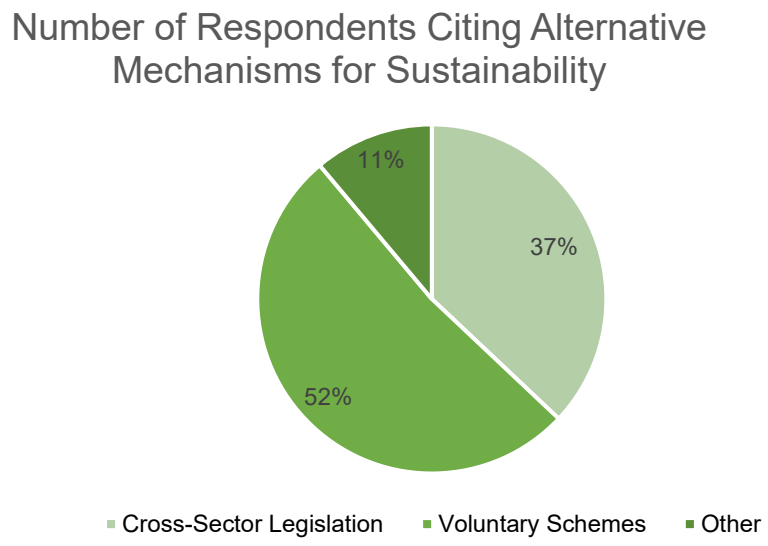

Figure 22 - Number of respondents citing alternative mechanisms for sustainability for Question 17.

Cross-sector legislation

Twenty respondents (Figure 22) indicated that **cross-sector legislation was key to unlocking more sustainable supply, encouraging utilisation, and driving uptake of sustainability measures in biomass.** Two representative groups (agriculture and biotech/chemicals/products) recommended the implementation of an LCA which is fully standardised and inclusive for SMEs and larger businesses alike to improve sustainability tracking/accounting. They pointed out practically that the LCA impact

assessment of products should be tied to both a defined standard and a Carbon Tax levy. It was suggested that this could encompass banding similar to the Environmental Permitting regime. This clear methodology and transfer of information cross-continentally will align a range of supply chains and sector end-uses with one another, creating a more cohesive and efficacious LCA model. This model could allow a multitude of products, being produced in a multitude of locations, to be fairly assessed and in a more consistent manner.

Three respondents recommended that **the government should consider the recruitment and extension of a mandated fuel register, like the BSL and/or the Sustainable Fuel Register (SFR).** Both were attested to provide useful management of the sustainability of a feedstock and fuel supply, ranging from its land-use impact, GHG emission accounting and overall sustainability. However, it was suggested that requirements should be introduced to ensure that all biofuels and feedstocks are incorporated into the BSL and SFR. This would require future expansion of the schemes and help to safeguard sustainability in as many biofuels supply chains as practicable. A respondent categorised as other and a representative group (general) suggested that retention of the Category B option, below that of Category A, plays a key role in providing an alternative route to sustainability compliance through self-reporting and bespoke assessment of evidence.

From a carbon accounting perspective, two calls were made from academia and utilities/distributor respondents to enshrine carbon intensity incentives in law and produce a carbon footprint labelling system on consumer goods. Measuring and appropriately incentivising the carbon intensity of particular feedstocks, such as the forest sector in allowing forests to grow and increase their resilience to climate change, would prevent inaction based on the placement of a carbon neutral blanket over all biomass feedstocks. Leading on from this, the academia respondent made reference to a timebound, standardised consumer products carbon footprint labelling framework that would sit on its packaging or in its product description. Not only would this enable people to make well-informed decisions based on their circumstances and requirements but would empower the consumer and create market forces based on carbon intensity that would drive innovation and supply chain sustainability.

Multiple representative groups (agriculture, biotech/chemicals/products and general) and 'other' sector respondents requested support to aid a range of businesses with a particular emphasis on SMEs. Obligations on end users to demonstrate a certain usage volume of renewable energy is commonplace in other sectors (power and road transport) and should be use more widely. However, the impact of obligations only in some sectors, dominated by larger companies, means support for the smaller business is typically side-lined. Therefore, there were calls for the implementation of SME-centric investment which would diversify the biomass portfolio and increase the speed of supply chain growth. Furthermore, the barriers to entry for SMEs were noted by several respondents; namely the cost to compete in the biomass market, the bureaucratic nature of many

schemes, and policies and certifications preventing suppliers and/or producers from taking root in the market and aligning themselves with the most apposite policy and regulation for their supply chain.

Voluntary schemes

There was a divided viewpoint amongst the 28 respondents who referenced 'voluntary schemes' (Figure *22*). There was agreement that the purpose of voluntary schemes should be to raise the standard of sustainability in supply chains and life cycles of biomass products, and provide manufacturers, suppliers, and distributors with the means to self-report and self-administer sustainable policy. However, there were differing opinions around the extent to which these schemes govern and the breadth and depth of their sphere of influence. Moreover, respondents Questioned whether they fulfil their purpose entirely without bias or skew.

Feedback given by a utilities/distributor respondent indicated engendering societal acceptance of biomass could be achieved through extension of voluntary schemes to include and minimise environmental impacts to soil, water, and air, as well as social implications. These can be developed through existing multi-stakeholder engagement and cross-sector initiatives, for example the Roundtable on Sustainable Biomaterials (RSB EU), International Sustainability and Carbon Certification (ISCC) schemes and REDcert (II & III).

Several forestry respondents recommended that the Government aligns itself with the SBP standards as it would elevate the quality and sufficiency of voluntary schemes available for UK companies. It was suggested that this could be introduced in addition to existing national legislation, enhancing various aspects of the supply chain from feedstock compliance to chain of custody and carbon balance. For example, representative groups (forestry supply/products and general), a forestry respondent and a respondent categorised as other brought to the fore BEIS' announcement of fuel quality requirements in fuel registration under the BSL. They reaffirmed the importance of closer interaction with voluntary certification schemes through the BSL, such as ENplus, GoodChips and Woodsure for providing independent auditing and certification routes. Adding finally, that the BSL effectively maps on top of certifications like SBP, Forestry Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC), Sustainable Forestry Initiative (SFI) and Forest Governance, Markets and Climate (FLEG-C).

A challenging and discordant viewpoint was shared by two NGOs respondents. **There were concerns raised about the initiation and implementation of programmes like the SBP, or GHG protocol Corporate Accounting and Reporting Standard by industry. In particular, there were anxieties about the industry overseeing these schemes from an independence perspective.** Some large corporations were named as being both involved in influencing policies and also using them, like the SBP, and as such it was suggested that these organisations were in effect self-policing

when imbedding the policies into its supply chain. There were concerns that this could potentially increase carbon emissions, natural forest loss and community harm without breaking policy.

EVIDENCE REQUIREMENTS

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

51 respondents answered Question 18 equating to 40% of all respondents. The Table below summarises the respondent types for this Question.

Table 23 23 - Breakdown of Respondents by Organisation Type for Question 18

Respondent type	Total number of respondents
Academia	4
Biofuel / Biogas Producer & Technology Provider	8
Biomass Boiler Manufacturer	1
Biomass Supplier (Agriculture)	0
Biomass Supplier / Technology Provider (Forestry)	6
Certification Body	1
Chemicals	0
Consultancy	2
Government Organisation	1
Non-profit organisation / Special Interest Group / ThinkTank	7
Other	4
Trade Association / Representative Group – Agriculture	1
Trade Association / Representative Group – Biofuels / Biogas	2
Trade Association / Representative Group – Biotech / Chemicals / Products	2
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0

Respondent type	Total number of respondents
Trade Association / Representative Group – Forestry Supply / Products	3
Trade Association / Representative Group – General	2
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	0
Utilities / Energy Asset Owners / Distributors	6
Waste Management	0
Total	**51**

The responses to Question 18 were fairly detailed. Responses commented on the additional evidence suppliers of biomass-derived energy could provide to regulators to demonstrate they meet the sustainability criteria, with many respondents providing examples of criteria that could be included from elsewhere in the world. However, few respondents provided specific feedback for heat, fuel or electricity rather including the feedback to cover all areas.

Current Evidence

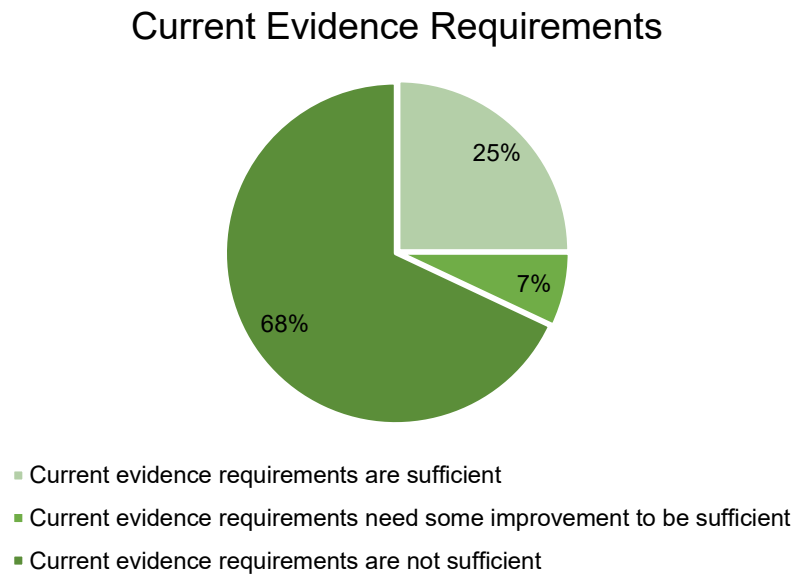

Figure 23 - Respondent views broken down by current evidence requirements

68% of the responses to this Question did not regard the current evidence requirements as sufficient. Respondents had differing views on how to improve the evidence requirements which included the use of voluntary schemes, using more detailed data that larger supplier already hold as well as changing the treatment of wate materials.

7% of the responses to this Question stated that **efforts should be made to improve existing evidence requirements so that suppliers can more easily demonstrate that they meet the criteria rather than requesting additional evidence.** It was suggested that additional evidence would put a burden on the industry. Suggestions for improvement were based on current voluntary schemes including the BSL and Criteria evidence and the sustainability data that is provided to the SBP.

3% of the responses to this Question also outlined that the current evidence is well documented in the RO scheme legislation and guidance documents. It was therefore suggested that any changes to the evidence that is requested to prove sustainability needs to take in to account new issues and scientific understanding so that the carbon emissions and sustainability claims be reliably verified.

A representative group (forestry supply/products) also stated that **currently there are very few forests that are certified sustainable globally and therefore there is a need to increase the certification globally rather than adding on additional criteria to forests which have already committed to the higher levels of sustainability.** This would mean that instead of increasing the pressure to conform and improve on the sustainability standards for all participants equally, activity is targeted towards those which have the greatest risk of not meeting the sustainability criteria. This minimises the administrative burden placed on companies by ensuring that additional requirements are appropriately targeted.

25% of the responses to this Question commented that the current evidence requirements are sufficient as such additional requirements are not needed. A representative group (forestry supply/products) stressed that additional reporting obligations would make the cost prohibitive and lead biomass unable to compete with fossil fuels.

Voluntary Schemes

Respondents, including representative bodies, certification bodies, forestry respondents and utilities/distributors, commented that there are a number of voluntary schemes including the BSL and the SBP that already collect additional evidence to demonstrate that biomass meet the sustainability criteria and that this evidence could be shared with regulators. Respondents recommended that it would be useful for the government to review the evidence that these schemes collect so that the regulators are able to understand what is currently already being provided to voluntary schemes and then decide if additional evidence would also be useful. Respondents also noted that alongside these

voluntary schemes there are other certification schemes that are also used to demonstrate sustainability which also collect evidence such as the Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC). **The respondents noted that government should evaluate if any of the information provided to these schemes would be beneficial to regulators to demonstrate that they meet the sustainability standard such as land criteria evidence.**

12% of the responses to this Question, including representative groups (biofuels/biogas and general) and utilities/distributors, highlighted that **Ofgem, through its role as the RHI administrator, already has access to a large amount of data that is used to verify if biomass being used in boilers is sustainable before RHI payments are made to participants**. It was indicated by a respondent categorised as other that there is an impression of inconsistent data sharing between BEIS and Ofgem and that if the data was shared it could be really useful to help determine future policy. This information could also be useful for other parts of the government so that they are able to evaluate the sustainability of the biomass which being used by consumers.

9% of the responses to this Question commented that the current voluntary system works for biofuels, with a biofuel/biogas respondent commenting that the regulatory compliance is effective as most suppliers need to use the schemes to be able to sell their products to consumers. As most suppliers must use the voluntary schemes, the respondents therefore argued that this improves the standard of fuel and also encourages suppliers not covered by these voluntary schemes to meet similar standards to avoid competitive disadvantage.

Additional available data

3% of the responses to this Question, including a representative group (general), utilities/distributors and forestry respondents, stated that currently **large-scale biomass suppliers and users of biomass have access to significant quantities of data on the biomass produced and used.** This data could be made available to the regulator if requested. These respondents stated that the data they hold regarding sustainability is more granular than is currently required by regulators and therefore if regulators would like access to more detailed biomass data from the large biomass suppliers, this information could be provided. The respondents did however note that they would be additional administrative barriers if they were required to provide this, and therefore they would only want to see this requested if the data was used by regulators to ensure sustainability.

Waste materials

A concern was raised in relation to waste materials and how to account for these. A representative group (biotech/chemicals/products) suggested that **used / waste biomass materials should not have to meet the sustainability criteria if it had already achieved compliance in relation to its original use.** They suggested that as long as the European Waste Catalogue (EWC) or a UK waste

carriers licence equivalent is kept then, the user should not have to meet the sustainability standards again, and this would allow for the material to have a second use as a biomass feedstock for example. They suggest that greater regulation of waste fuels would create a barrier to biomass suppliers being able to use waste materials. Increased requirements for this sector could result in more waste being sent to landfill leading to higher carbon and methane emissions.

GLOBAL GOVERNANCE

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

47 respondents answered Question 19 equating to 40% of all respondents. The Table below summarises the respondent types for this Question.

Table 24 24 - Breakdown of Respondents by Organisation Type for Question 19

Respondent type	Total number of respondents
Academia	2
Biofuel / Biogas Producer & Technology Provider	7
Biomass Boiler Manufacturer	1
Biomass Supplier (Agriculture)	2
Biomass Supplier / Technology Provider (Forestry)	5
Certification Body	2
Chemicals	0
Consultancy	2
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	5
Other	3
Trade Association / Representative Group – Agriculture	1
Trade Association / Representative Group – Biofuels / Biogas	2

Respondent type	Total number of respondents
Trade Association / Representative Group – Biotech / Chemicals / Products	1
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	3
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	0
Utilities / Energy Asset Owners / Distributors	5
Waste Management	0
Total	**47**

The responses to Question 19 were comprehensive with many responses providing a lot of detail. Many responses used examples of existing governance schemes to illustrate how the UK can help to improve the global governance of sustainability in biomass.

Respondents, including the academic sector, NGOs, utilities/distributors, and representative groups (biofuels/biogas, forestry supply/products and general), proposed that the UK had a role to play in the global governance of biomass and that currently the UK is one of the leaders in biomass sustainability. Respondents suggested that **the UK should have a leading and active role in the international community to continually drive for better sustainable criteria.**

20% of the responses to this Question advised that the global governance of biomass was fit for purpose and the respective policies related to biomass sustainability should not be amended. Utility/distributor respondents and representative groups (biofuels/biogas and general) noted there were robust frameworks such as EU RED II that are used to ensure that biomass feedstock meets strict standards.

However, the majority (80% of the responses to this Question) agreed that global governance needs to be improved and that the UK has a leading role to play in the implementation of future global governance. To ensure that the arrangements are fit for purpose, a number of recommendations were made to enhance the approach to governance of biomass globally. These are summarised below by theme:

Increased protection for forests

Many respondents, including NGOs and academia, argued that global forest governance was an area of great concern. They highlighted that the **UK should work with international governments to increase protections on forests including the end of clear-felling, deforestation and land use insufficiencies which leads to a declining biodiversity of plants and wildlife.** Many argued that the UK is a major consumer of forest biomass and therefore should play a leading role in driving up standards to ensure that the biomass material for forests is sustainable on a globally level.

Respondents, including forestry respondents, suggested that the way to improve global sustainability is to redefine what sustainability means so that there are stricter criteria for biomass suppliers to meet. They argued that the sustainability requirements do not fully account for all carbon lifecycle emissions from the material from being sourced through to burning.

Consistency across standards

10% of the responses to this Question, including consultancy and academia respondents, stated that there is an **issue with international technical standards and the parity between domestic and international biofuel sources.** These respondents noted that biomass imports were lacking a full carbon LCA where cultivation and harvesting in international countries needs to be accounted for with the transportation and shipping emissions to the country of end use also accounted for in the assessment.

10% of the responses to this Question called for the UK to improve global governance of sustainable biomass by pushing for an **international standard certification for all materials that cover all aspects of sustainability including GHG emissions, land use and wildlife protection.** There were also respondents that suggested that some of the schemes that certify sustainable biomass in the UK such as the BSL or SBP should be implemented on a global scale, or the key sustainability principles and methods of reporting implemented so that global sustainability can be achieved. There were calls from respondents such as representative groups (biofuels/biogas and general) and consultancies for standards such as EnPlus, EU RED II, SBP or Land-Use Change and Forestry (LULUCF) or similar, to be implemented on a global scale. This would ensure that all biomass has to be registered to demonstrate that it meets internationally agreed sustainability standards. Respondents argued that with a global sustainability policy then sustainability will be driven up as there are clear rules of the marketplace to operate within.

One forestry respondent suggested that the creation of an expert panel including representatives from the biomass industry and experts on decarbonisation, GHG emissions, and land use would be beneficial to support global collaboration and consistency. They argued that the group would be able

to work to drive up global sustainability standards taking in to account many different aspects of the biomass lifecycle.

Understanding the supply chain

10% of the responses to this Question proposed that a **full LCA of biomass should be carried out to accurately calculate the emissions that will be produced by the biomass.** Respondents noted that this will not only reduce the emissions that are created in processing the biomass through harvesting, drying and processes such as chipping or pelleting but also transport emissions. A greater understanding of the emission lifecycle is expected to increase deployment of more efficient, lower carbon technologies. A utilities/distributor respondent also suggested that a holistic approach to the calculation of emissions could encourage users to source biomass locally to reduce transport related emissions.

Considering land use change

Respondents, including consultancies, stated that **land-use change also needs to be taken in to account when investigating sustainability**. It was suggested that if the use of the land is changed to produce biomass, then there is a need to fully evaluate the impact of this on the local habitat. It could be considered unsustainable if habitat is lost. 10% of the responses to this Question stated that the biomass industry globally has not been protecting natural habitats and forests for wildlife. One respondent called to ban the importation of biomass from countries which are known to have a higher risk of land or biodiversity change. It was suggested that if a restriction was introduced, then the UK could work with these markets to increase their sustainability standards through the sharing of best practice to allow them access to the UK market.

LIFECYCLE EMISSIONS

Question 20: How should the full life cycle emissions of biomass be reflected in carbon pricing, UK Emissions Trading Scheme (UKETS), and within our reporting standards?

61 respondents answered Question 20 equating to 46% of all respondents. The Table below summarises the respondent types for this Question.

Table 25 25 - Breakdown of Respondents by Organisation Type for Question 20

Respondent type	Total number of respondents
Academia	3
Biofuel / Biogas Producer & Technology Provider	6

Respondent type	Total number of respondents
Biomass Boiler Manufacturer	2
Biomass Supplier (Agriculture)	5
Biomass Supplier / Technology Provider (Forestry)	2
Certification Body	2
Chemicals	1
Consultancy	1
Government Organisation	1
Non-profit organisation / Special Interest Group / ThinkTank	6
Other	4
Trade Association / Representative Group – Agriculture	1
Trade Association / Representative Group – Biofuels / Biogas	3
Trade Association / Representative Group – Biotech / Chemicals / Products	4
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group – Forestry Supply / Products	6
Trade Association / Representative Group – General	3
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	2
Utilities / Energy Asset Owners / Distributors	7
Waste Management	0
Total	**61**

The responses to Question 20 were detailed and had supporting statements that backed up the respondents' views on how the full lifecycle emissions of biomass should be reflected in carbon pricing, UKETS, and with our reporting standards.

There was an overwhelming consensus from respondents that there is a lack of sufficient policy and standards in relation to life cycle emissions and that LCAs are not suitably utilised in carbon pricing, UKETS, and other accounting measures. **Only 4% of the responses to this Question were satisfied with the current state of life cycle emission accounting.**

Carbon Pricing and Emissions Trading

There was a particular emphasis on the UKETS. However, respondents had split opinions on Zero Emission Trading System and the zero-carbon rating of biofuels. **18% of the responses to this Question called for continuous zero carbon rating on biofuels ensuring that the full carbon emission is accounted for at the land use level.** They suggested that this would help the growth of the market and stability of supply chains.

6**% of the responses to this Question were critical of the zero rating in the Emission Trading System highlighting a lack of credibility and thoroughness.** Therefore, these respondents called for the abolition of the zero rating suggesting that it has created a loophole where there are unaccounted carbon emissions related to land-use change.

Respondents presented a range of concerns and solutions to ensure that full life cycle emissions of biomass are reflected. The concerns were:

- **Carbon pricing is inconsistent between geographical locations**, e.g. it was highlighted by an academic respondent that the UK's cost per tonne of CO_2 emitted is lower than other European countries. It was noted by two NGOs that nations with a lower cost per tonne of CO_2 may be less likely to reduce their environmental impact in accordance with the Paris Climate Agreement to meet net zero.

- **The cost of the carbon deemed to not be high enough to cover the financial and health implications** of the direct carbon emissions associated with biofuel production.

- A representative group (carbon capture utilisation and storage), forestry respondents, utilities/distributor respondents and a non-profit organisation raised concerns about the **double counting of emissions from the supply chain** as they advised that biogenic emissions and forest activities are accounted for in the supply chain and should not be added into the end use emission calculations.

The recommendations were:

- Undertake a full review of the carbon pricing in the LCA.

- Incorporate an economy-wide price for biofuels which would need to be reflected in the UK's carbon accounting structures to ensure that it aligns with international prices.

- Introduce a system which allows emissions to be verified when they are transferred between jurisdictions so that the possibility of double counting could be minimised. They argued that a transparent system would help the public to be confident that carbon is being recorded accurately.

Life Cycle Analysis

29% of the responses to this Question were supportive of LCA and liked the holistic approach it offers, capturing emissions from across planting, harvesting, processing, transporting, and burning to give a full picture of the emissions that it creates.

5% of the responses to this Question highlighted that the LCA should include net carbon savings for biomass materials that would have otherwise been wasted. It was noted that these the accounting practices should acknowledge the avoided GHG emissions associated with the decomposition of the waste if it was not being repurposed.

Respondents also noted that geographical differences in environmental outcomes from biomass generation should be taken into account when importing biomass. **9% of the responses to this Question supported the inclusion of a carbon price on biomass**, however this needs to be scientifically proven and should take into consideration upstream emissions. In particular, respondents highlighted the need to account for the temporal impacts of carbon sequestration (above and below ground), carbon release, emissions from plant machinery as well as equipment and waste disposal emissions. Respondents from a certification body and a representative group (biofuels/biogas) noted that the wider scope of environmental and societal impacts such as air, soil and water quality, circular economy transition, biodiversity and ecosystem protection, energy efficiency and supporting local communities should be accounted for in the LCA.

Overall, **most participants recommended that a holistic approach to LCA needs to be introduced**. The methodology should be broad enough to capture all aspects of sustainability and not just carbon emissions. Respondents suggest that with these changes the full impact of biomass would be considered.

Of the 4% of the responses to this Question who were satisfied, most referenced the presence of international regulations and noted that these should be used as they are well-established and backed by scientific research. They stated that the Intergovernmental Panel on Climate Change (IPCC) and other leading bodies have created frameworks including the EU ETS which support the accounting of biogenic emissions. There is also an established methodology for a zero-carbon rating

for biomass at the chimney stack. Respondents suggested that other emissions such as emissions in the supply chain are accounted for throughout the supply chain and should not be double counted within feedstock / end use emissions reporting.

NEGATIVE EMISSIONS

Question 21: How should Bioenergy with Carbon Capture and Storage (BECCS) be treated for domestic and international greenhouse gas (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 CO_2 are being accounted for in different countries?

51 respondents answered Question 21 equating to 39% of all respondents. The Table below summarises the respondent types for this Question.

Table 26 26 - Breakdown of Respondents by Organisation Type for Question 21

Respondent type	Total number of respondents
Academia	4
Biofuel / Biogas Producer & Technology Provider	4
Biomass Boiler Manufacturer	2
Biomass Supplier (Agriculture)	2
Biomass Supplier / Technology Provider (Forestry)	3
Certification Body	1
Chemicals	0
Consultancy	2
Government Organisation	0
Non-profit organisation / Special Interest Group / ThinkTank	6
Other	5
Trade Association / Representative Group – Agriculture	0
Trade Association / Representative Group – Biofuels / Biogas	1

Respondent type	Total number of respondents
Trade Association / Representative Group – Biotech / Chemicals / Products	2
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group – Forestry Supply / Products	4
Trade Association / Representative Group – General	4
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	1
Utilities / Energy Asset Owners / Distributors	7
Waste Management	1
Total	**51**

Responses to Question 21 were varied. Some responses were very detailed and provided good insight on how the use of the technology should be treated in domestic and international carbon accounting and how it can impact land use. Other responses were not as detailed and did not provide a great level of detail past the respondent's initial feelings towards BECCS. Respondents also tended not to answer the second half of the Question.

BECCS Treatment for GHG emission accounting

Respondents highlighted a need for international alignment on BECCS and how it is accounted for with **3% of the responses to this Question commenting that if emission reporting was not agreed internationally then there could be double counting.**

Respondents argued that **biomass cannot be considered carbon neutral as there are other emissions that are released into the atmosphere from harvesting the biomass, drying and transportation.** Therefore, respondents, including a utility/distributor, suggested that the whole supply chain including harvesting processing, drying and transportation of the biomass should be taken into account. This should ensure a direct correlation between the various intensities of

feedstocks from differing locations when the GHG emissions associated with BECCS are calculated. Whilst some respondents concluded that BECCS is unlikely to be carbon neutral or carbon negative, it was acknowledged that it is able to bring reduced emissions as the stack emissions from burning the biomass can be considered as carbon neutral.

Other respondents, including multiple NGOs, were concerned that the **carbon accounting and reporting of negative emissions for internationally traded bioenergy feedstocks could become complicated and opaque with the introduction of BECCS.** Respondents noted that if the emissions are not accurately recorded and transparent, there is a risk that a lack of scrutiny could mean that errors are not identified and rectified. This could impact public perceptions and reduce acceptability.

A certification body and a utility/distributor commented that the costs of building and running CCS are hugely expensive in the medium-term and noted that these costs would have to be added to the fuel cost. It was also noted that the costs of implementing CCS could undermine the economic viability of projects being deployable and they had reservations that the technology would be used at scale by 2050 due to the high costs. It was suggested that **at present there are not sufficient economic incentives / drivers to adopt the technology as it currently not commercially viable.** Further respondents also **raised concerns around the effectiveness and readiness of the technology.** These respondents highlighted that currently BECCS does not remove large quantities of carbon emissions. Those who expressed concern regarding the readiness of the technology suggested that there needs to be further independent scientific research to prove that the technology can work before it is included in policy discussions.

Respondents from academia, utilities/distributors, agriculture, and a representative group (biotech/chemicals/products) noted that if the biomass is being grown by another country for the end user, then the reason that the emissions are produced when it is harvested, processed, and transported is due to the end user. The respondents therefore noted that **the end user should account for all of the emissions that are released in the production of the biomass up until the BECCS installation** as the BECCS technology makes the burning of biomass neutral at the stack.

Other respondents from the utilities/distributor sector commented that the use for BECCS is suited to the energy sector specifically to help reduce domestic GHG emissions from energy production. The use of BECCS can therefore help the UK to meet it net zero target as the carbon captured and stored should be applied to the UK. Implications of existing reporting rules on our ability to deliver negative emissions

There was a recognition that the scope of emissions reporting needs careful consideration. 7% of respondents to this Question stated that **carbon credits should be applied to the country in which**

the carbon is captured and stored in. However, it was acknowledged that emissions released during the production and transportation of biomass must also be accounted for. It was suggested that this should be captured in the end user country in which the material is being produced for. For biomass to be considered carbon neutral or even carbon negative respondents stated that the productions and transport emissions would have to also be offset, not just the stack emissions. An NGO response highlighted that BECCS by itself should not be considered 'negative emissions' as it is only capturing what is emitted at the chimney stack therefore it should only be considered 'zero emission' at chimney stack.

The complexity of the current carbon accounting rules was highlighted, and it was suggested that the introduction of BECCS and the inclusion of a negative emissions methodology could further complicate these. However, there were calls for the existing report rules to be updated and simplified to be able to incorporate negative emissions. Improving the reporting of emissions and the inclusion of negative emissions should improve transparency and improve confidence. Importantly, respondents stressed that recognising negative emissions within the existing reporting rules would be a complex task that would need to be carefully managed with robust review procedures to avoid challenge.

On the other hand, forestry respondents, a representative group (forestry supply/products), as well as utilities/distributor respondents stated that **the current accounting practises should be maintained in line with the IPCC guidelines as this ensures consistency across countries who are reporting emissions** and also reduces the chances of emissions being double counted. Respondents noted that the current rules allowed for negative emissions to be counted and had adequate controls in place to prevent any double counting. Most respondents also noted that the rules could not be changed by one country on their own, but instead international collaboration is needed so that emissions are accurately recorded across states to prevent duplication.

Chapter 4: Innovation

Chapter 4 explored the role of innovation and sought evidence on how innovation could bring down costs and reduce barriers to deploying technologies, or improving the way current, more mature technologies operate.

TECHNOLOGIES

Question 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, chapter 2), and how might these change as we reach 2050?

77 respondents answered Question 22 equating to 55.4% of all respondents. The Table below summarises the respondent types for this Question.

Table 2727 - Breakdown of Respondents by Organisation Type for Question 22

Respondent type	Total number of respondents
Academia	11
Biomass Supplier (Agriculture)	3
Biofuel / Biogas Producer & Technology Provider	12
Biomass Boiler Manufacturer	1
Certification Body	3
Chemicals	2
Consultancy	2
Biomass Supplier / Technology Provider (Forestry)	5
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	3
Other	4
Trade Association / Representative Group – Agriculture	3
Trade Association / Representative Group – Biofuels / Biogas	3

Respondent type	Total number of respondents
Trade Association / Representative Group – Biotech / Chemicals / Products	5
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	2
Trade Association / Representative Group – Forestry Supply / Products	4
Trade Association / Representative Group – General	2
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	3
Utilities / Energy Asset Owners / Distributors	5
Waste Management	1
Total	**77**

Question 22 was the most frequently answered Question in section 4. Of those responses, many stated that more than one technology that was best placed to deliver the priority end-uses along with justifications for their examples. Each mention of a technology has been recorded, as such the number of mentions exceeds the response rate for this Question.

Part 2 of Question 22 focused on how the technologies detailed might change as we reach 2050 and the carbon neutral goals associated with that date. **For the most part respondents failed to answer this part of the Question and instead focused on the technology solutions**. There are some points that have be extracted in relation to this second half of the Question, but no broader analysis of the data trends was possible.

Analysis has been undertaken in relation to the specific technologies identified. Context has been provided to explain why these technologies are best positioned to deliver the priority end uses. **Waste Processing and BECCS were the two most mentioned technologies as shown in the graph.**

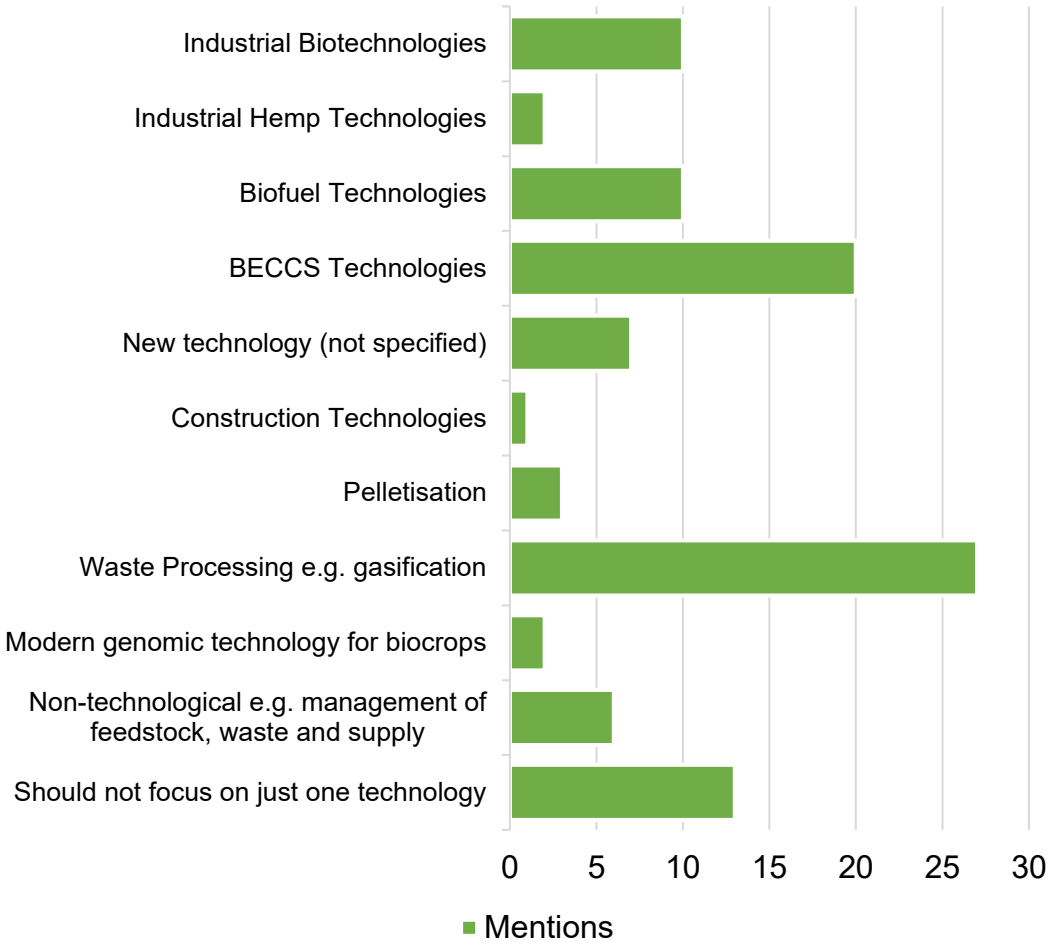

Figure 24- –Mentions of what specific technologies were identified as best positioned to deliver the priority end uses of biomass

Waste processing technologies

35% of respondents who answered the Question mentioned some form of waste processing and the technologies associated; gasification, pyrolysis, AD, and other combustion technologies.

Over 25% of the respondents from the Biofuel/Biogas stakeholder group who responded to this Question referenced thermal chemical processing technologies as being best placed to deliver the priority end uses. Furthermore, two of the three NGO respondents mentioned the different types of thermal chemical processing as well as 40% of the Utility/Distributor respondents. Below are some examples of the different types of thermal chemical processing technologies that respondents identified in their responses.

Gasification

Eleven of the respondents to this Question identified gasification specifically as one of the key technologies of strategic importance for delivering both negative emissions and using biomass to decarbonise 'hard to treat sectors'. One respondent added **that whilst gasification is not a particularly new technology, it is its 'application to existing bioenergy sectors that needs to be realised'**.

Ultimately, respondents suggested that gasification technologies **will be important in producing an array of products (e.g. heating fuels, aviation fuel, fuel for HGVs etc.) for use in priority sectors** because they can process a wide range of feedstock types. Furthermore, it was suggested that gasification technology is best positioned to deliver the priority end uses (i.e. biofuels (e.g. SAF, diesel, gasoline, etc), chemicals and hydrogen) because the **technology is already in an advanced stage of development and several projects have been deployed using biomass and waste as a feedstock already.**

Pyrolysis

Nine respondents raised pyrolysis in tandem with gasification explaining that it is a technology that should be further investigated. It was highlighted that **pyrolysis has the potential to deliver multiple benefits through generating an energy source as well as producing a soil improver and bio-based fertilizer**. Two respondents theorised that installing pyrolysis burners onto farms would enable farms already supplying solar energy to the grid to further add capacity. Additionally, the **technology is scalable** and can therefore be sited close to the source of the feedstock and/or the power demands.

Anaerobic digestion

Seven respondents also mentioned AD as a processing technology explaining that **AD used to produce biomethane is currently the best available technology with respect to achieving negative emissions in a cost-effective, financially reliable way**.

Currently, there are around **100 plants scattered throughout the UK with potential AD capabilities**. Many of these plants are used for the conversion of food or agricultural waste into valuable products, and in general AD is more suitable for wet biomass resources. Respondents explained that **innovation needs focus on 'feedstock pre-treatment to maximize gas yield, and characterisation of digestate'.**

BECCS technologies

26% of respondents to this Question mentioned BECCS technologies as being best placed to deliver priority end uses. BECCS and carbon capture technologies in general were often mentioned by

respondents in tandem with other technological examples. It is sugegsted that **using BECCS can help fully capture the benefits from negative emissions to further fuel the thermal chemical processing technologies.** Furthermore, **BECCS can ameliorate challenges faced when using some of the more embryonic technologies by being used concurrently.**

Nine respondents from the Representative Group stakeholder sector mentioned BECCS technologies as being best placed to deliver priority end uses. Similarly, a high proportion of the Utility/Distributor stakeholders (two of the five respondents) identified BECCS technologies.

Respondents explained that **by using BECCS and storage with bioenergy, vital CO_2 removals can be made which are key to achieving net zero by 2050**. The technologies that can be 'safely, efficiently and sustainably adapted to incorporate BECCS and sequester technology' were identified as being 'best positioned for continuing to access the carbon within biomass'. It remains however a technology which is not yet utilised on a commercial scale, one of the reasons for this is the **need to access large scale transportation and storage networks for captured emissions.**

Ultimately, respondents highlighed that BECCS can deliver effective GHG removal at a significant level, resulting in **a unique capability to remove carbon from the atmosphere while simultaneously providing energy, products, and other services**. However, respondents stressed that this means **prioritising support for existing large scale biomass operations**. This could be achieved by providing new policies to support ongoing use. There is a need to recognise that **BECCS is not a fully mature technology, therefore there is a need for significant investment** and there are risks associated with implementation and execution. As such, the **large-scale commercial deployment of BECCS could take a long time.**

Industrial biotechnologies

Industrial biotechnology underpins a greener means of manufacturing chemicals, consumer goods, pharmaceuticals including vaccines and antibiotics. Industrial biotechnology can additionally turn waste materials into high value products. Therefore, 13% of respondents to this Question suggested that **industrial biotechnologies is one of the best-placed technologies to deliver priority end uses**.

30% respondents to this Question from the Academia sector mentioned Industrial Biotechnologies. Furthermore, both respondents from the Government Organisation sector mentioned industrial biotechnologies as the technology best placed to deliver the priority end uses.

Respondents identified the **UK's leading global position in bioscience as a catalyst for further development in the industrial biotechnology**. One respondent suggested that as consumer product manufacturers look towards bioproducts, the UK can use these innovative existing processes.

This would turn sustainable raw materials into high value chemicals, biofuels, pharmaceuticals, and other consumer products. Another respondent hypothesised that the application of biotechnologies would continue to be supported by 'automation and machine learning, bio-foundries and bioproduction facilities'.

As with all of the technologies identified in the responses to this Question, respondents noted that **further research and innovation are needed to make them cost and performance competitive with the established fossil-based technologies and products.**

Biofuels

A further 13% of respondents to this Question indicated that biofuel technologies are best placed to deliver priority end uses identifying the use of waste biomass fuels as a key decarbonisation lever for the UK.

The respondents in favour of biofuel varied more in the sector they represented. Two of the twelve respondents from the Biofuel/Biogas sector mentioned biofuel, as did one of the two respondents from the Chemical sector. The remaining mentions of biofuel were more split amongst the respondent sectors.

Three respondents stated that **most of the natural gas furnace designs currently in operation could easily be converted to run standard biofuels**. They suggsted that this offers a **short-term and relatively easy solution to decarbonise a large proportion of emissions using existing furnace technologies**. As a technology to deliver the priority end uses detailed, it is deemed to be a **relatively low-cost solution.**

Other technologies

Over 25% of respondents stressed the need to focus on multiple technologies by either referencing multiple specific technologies in their answers or by stating that multiple technologies should be the focus without providing information on specific technologies. Nearly 17% of respondents to this Question did not specify a technology and rather explained that the approach should resist any temptation to pursue preferential outcomes, and instead allow market dynamics to let the best suited technologies develop. These respondents explained that the government has the ultimate say in the future of technological advancements in this field and they will be the ones who will need to resist the temptation to pursue preferential outcomes. They advocated that **the best solutions should emerge from technology-agnostic policies and not from government attempts to 'pick winners'**.

There was a mix of approaches outlined to deliver a technology agnostic landscape. Some respondents proposed that **existing technologies should be prioritised,** as they can be further developed rather than gambling on new technologies. Whereas other respondents recommended that

future biomass policies should encourage innovation and be designed to enable the emergence of new technologies and approaches that deliver greater benefit for the environment, society, and the economy. Generally, respondents **favoured the approach of developing the current technologies** available rather than further gambling on new technologies.

Changes as we reach 2050

Generally, the second half of the Question on how the new technologies might change as we reach 2050 was not alluded to in the responses received and therefore there is limited data available. From the little that was provided by respondents**, the consensus was that biotechnologies need the associated investments and policies to advance and attain net zero. However, as the data analysis shows, the means to realise these goals are varied and split opinion**.

Question 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?

61 respondents answered Question 23 equating to 43.9% of all respondents. The Table below summarises the respondent types for this Question.

Table 28 - Breakdown of Respondents by Organisation Type for Question 23

Respondent type	Total number of respondents
Academia	8
Biofuel / Biogas Producer & Technology Provider	11
Biomass Supplier (Agriculture)	3
Biomass Boiler Manufacturer	0
Certification Body	1
Chemicals	2
Consultancy	2
Biomass Supplier / Technology Provider (Forestry)	2
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	2

Respondent type	Total number of respondents
Other	4
Trade Association / Representative Group – Agriculture	1
Trade Association / Representative Group – Biofuels / Biogas	2
Trade Association / Representative Group – Biotech / Chemicals / Products	6
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	2
Trade Association / Representative Group – Forestry Supply / Products	3
Trade Association / Representative Group – General	2
Trade Association / Representative Group – Heating Appliances	0
Trade Association / Representative Group – Professional Engineering Services	2
Utilities / Energy Asset Owners / Distributors	5
Waste Management	1
Total	**61**

Question 23 had fewer responses than Question 22. As with Question 22, many respondents cited more than one barrier and risk that they feel hinders the deployment of advanced technologies pertaining to biomass. As before, the respondents gave justifications and reasonings for their examples of barriers and similarly, where a respondent detailed more than one technological example, their responses have been counted more than once amongst the statistical analysis.

The main barriers to deploying advanced biofuel technologies identified by respondents who answered this Question were the cost of deployment (22%), the lack of proven technology (20.7%) and the lack of government regulation (20.7%). Respondents who answered this Question also mentioned the lack of incentives (13.8%) and feedstock heterogeneity (12.6%)

As with Question 22, this Question had a second half to it that was not prominently answered. **Very few respondents mentioned the end use sectors that these barriers might affect the most.**

Analysis of this Question has been split to elaborate on the main barriers identified and to convey the main reasons respondents had for identifying those barriers as being particularly pertinent.

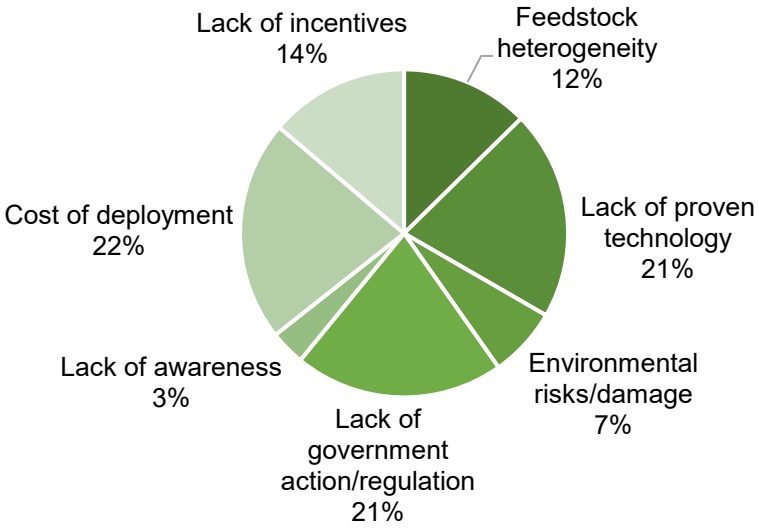

Figure 25 - Barriers and risks to increasing the deployment of advanced technologies identified by percentage

Cost

Respondents identified the cost of new technologies as the most pressing issue that would hinder deployment. Biofuel/Biogas, Representative Groups and Utility/Distributors were the stakeholder sectors that most cited the cost of deployment as a barrier.

Cost-parity with other fuels was identified as one such barrier. It is important to note that some of those who identified the cost of the fuel as a barrier conceded that it is unlikely that biofuel prices will drop sufficiently by 2050 and as such this is unlikely to drive significant uptake in its use as an alternative fuel source. Additionally, some respondents pointed towards the lack of willing investors, suggesting that the **capital requirements are currently too high whilst the returns that incentivise investment are too low**. This could also suggest a lack of certainty in the market. Furthermore, the risks for these investments are currently too high due to the largely unproven nature of the technologies. Therefore, there are **not many companies of sufficient size who are willing to fund these sorts of investments.**

Ultimately**, investments in new biomass technologies would need to be on an industrial scale**. It is anticipated that this would involve significant infrastructural costs in the UK for investors and the government. Respondents advised that this could explain why implementation, research and investment of these new technologies has been limited up to this point. It was suggested that this **outlook is unlikely to change given current legislation.**

Government action / regulation

Government action and regulation was a commonly mentioned barrier to the deployment of new biomass technologies. It was ranked joint-second in terms of number of mentions. The **barriers relating to government intervention varied** from saying that the government is overinvolved and hindering the market to saying that the government is not involved enough and ultimately missing the opportunities for technological advancements to be implemented. **61% of respondents who mentioned government action/regulation said there needed to be more regulation introduced.** Whereas the remaining 39% said there needed to be less or a significant change in the type of action and regulation from the government. There were also more nuanced examples of government intervention failing this sector in the past and the need for lessons to be learnt going forward so as not to be a barrier. One such example was of UK Government backed 'Advanced Conversion Technologies' (ACTs) which were underdeveloped for deployment but were hurriedly deployed due to the belief that it would lead to a succession of bioenergy projects.

Eight of the 18 Representative Groups who answered this Question mentioned government regulation as the main barrier to deployment. The remaining mentions of government regulation were split evenly without a clear correlation. However, it may be worth noting that six of the 11 Biofuel/Biogas respondents who answered this Question also indicated government action/regulation as a significant barrier.

Three respondents highlighted concerns about the government's current approach and recommended that **the government should not be giving preferential treatment to certain technological approaches** and instead allow the market to develop innovative solutions that can 'deliver on carbon reduction, renewable energy, and resource efficiency targets set by government policy'. Additionally, they said that **'regulatory barriers are not agile enough to respond to the trial and implementation of new technologies.'** Furthermore, one respondent stated that the 'regulatory landscape is not currently fit for purpose and is potentially **stifling innovation** in the UK, especially with respect to biological wastes and by-products'.

Another three respondents proposed that **government intervention is required to support the growth of the sector** and it is important that the UK Government 'takes a long-term bio-based markets perspective that provides both intent and a policy/incentive framework that enables private capital to be deployed'. One respondent cited the government-backed UK Guarantees Scheme as potentially being very helpful, 'if they can accept a higher level of risk than a commercial investor or lender'. They added that **bringing forward a consultation on price support would be an 'essential first step** in demonstrating to potential investors the Government's intention to address this medium-term risk and is an urgent requirement for projects to continue'.

Current technology

Many respondents highlighted that the **quality and availability of current technology are barriers**. Current technology was the joint-second most mentioned barrier. Around 50% of these respondents noted that the lack of proven technology currently in place is a key barrier to the deployment of technology going forward.

These respondents recognised the potential from current technologies however, they explained that they are **concerned about the technology's readiness levels and viewed lack of readiness as a barrier to deployment.** The development of transport and storage infrastructure and technology was mentioned as being an essential component of reducing emissions in the short and medium term. Respondents suggested that if this infrastructure and the associated technological advancements were not improved, then the negative emissions required to balance overall emissions will not be achieved.

Additionally, a couple of respondents said that **it is hard to guarantee investments for technologies that are viewed as unproven.** Generally, respondents implied that the main challenge to building current technology into future Government strategy is the fact that **it is currently unclear where the technology will work best in 'real life' and within the biomass industry**. A lack of proven examples of current technologies that can be implemented into the biomass infrastructure that can effectively reduce emissions and ultimately challenge the climate emergency was also identified.

Incentives

Four of the eleven Biofuel/Biogas respondents to this Question mentioned the lack of incentives, as did both of the respondents from the Forestry sector, showing a range of sectors are eager to see more incentives for developing and deploying new technologies as currently it is seen a barrier to further development.

One respondent explained that currently there are **no 'systematic payments or benefits for negative emissions and that existing agricultural carbon removal incentives are complex' making it difficult to develop business models that can effectively incorporate new technologies**. Most respondents agreed that there **needs to be clear incentives and support for the deployment of new technologies and effective commercialisation**. One such example was supporting graduates and post-graduates undertaking study in the sector to ensure that the needs of the industry are factored into the design and delivery of the research of new technologies. Additionally, the Clean Heat Grant (now named the Biomass Upgrade Grant) was referred to as a potential solution but respondents noted currently **there is no strong incentive for supporting sustainable biomass** and that this needs greater recognition and support.

Heterogeneity of feedstocks

The feedstock heterogeneity along with the uncertainty around the amount of available feedstock was highlighted as a barrier. Four of the eight respondents who answered this Question from the Academia sector mentioned feedstock heterogeneity as a barrier to the deployment of new technologies.

Two respondents said that it is **difficult to get long term feedstock contracts currently and that access to feedstock is an issue in itself.** One of the reasons attributed to this going forward was the available fuel catchments are not able support the feedstock requirements of a large increase in biomass feedstock demand and usage if there was a scaling up of its use. This led to two more respondents identifying the **need for an establishment of new logistics networks for feedstocks in order to effectively distribute it.** Therefore, this lack of feedstock and its distribution is a barrier to the development and deployment of new technologies.

The respondents that commented on feedstock heterogeneity stated that there **is not currently a homogenous feedstock supply with good quality assurance,** and this creates problems with 'optimisation and subsequent value capture' from the feedstock.

End use sectors

The second part of this Question, regarding the end use sectors that may be affected by the barriers to the development of biomass technologies was not really elaborated on by respondents.

Of those that did respond, the **consensus was that if the risks associated with the deployment of advanced technologies were not mitigated and the various barriers identified were not eliminated, then the effects on all sectors associated with biomass would be profound**. Respondents again justified this by saying that both inaction and misplaced action may cause drastic knock-on effects for end use sectors and the industry as a whole. From this, it could be concluded that the impacts are not sector specific and that the biomass supply chain is interconnected with technologies deployed across multiple end uses.

REGIONAL STRENGTHS

Question 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?

60 respondents answered Question 24 equating to 43.2% of all respondents. The Table below summarises the respondent types for this Question.

Table 29 - Breakdown of Respondents by Organisation Type for Question 24

Respondent type	Total number of respondents
Academia	10
Biomass Supplier (Agriculture)	3
Biofuel / Biogas Producer & Technology Provider	9
Biomass Boiler Manufacturer	1
Certification Body	1
Chemicals	1
Consultancy	1
Biomass Supplier / Technology Provider (Forestry)	4
Government Organisation	3
Non-profit organisation / Special Interest Group / ThinkTank	3
Other	6
Trade Association / Representative Group – Agriculture	1
Trade Association / Representative Group – Biofuels / Biogas	4
Trade Association / Representative Group – Biotech / Chemicals / Products	2
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	1
Trade Association / Representative Group – Forestry Supply / Products	1
Trade Association / Representative Group – General	2
Trade Association / Representative Group – Heating Appliances	1

Respondent type	Total number of respondents
Trade Association / Representative Group – Professional Engineering Services	1
Utilities / Energy Asset Owners / Distributors	5
Waste Management	0
Total	**60**

Question 24 had fewer respondents than the previous two Questions with 60 responses from participants. As with the previous Questions, respondents identified more than one answer for the Question. Therefore, multiple regions were often mentioned by one respondent, and it is the specific mentions for a region that have been counted for the statistical analysis.

Some respondents gave a specific region of the UK, e.g. the Northeast of England or Central Scotland, whilst other respondents gave a more general region of the UK, e.g. rural or urban areas. Therefore, the analysis has taken this into consideration, grouping responses by both specific country and also general region as to get the key points and justifications for these choices by respondents.

No specific region

Some respondents to the Question did not mention a specific region/location of the UK and rather opted to suggest a more general area. Of those respondents, 38% of mentions were location agnostic and rather explained the characteristics that these selected regions should have in order to be considered best placed to focus on technological innovation and the scale up of feedstock supply chains. **Rural locations** accounted for 31% of non-region-specific mentions whereas 14% mentioned **urban or industrialised areas** and 17% the whole UK.

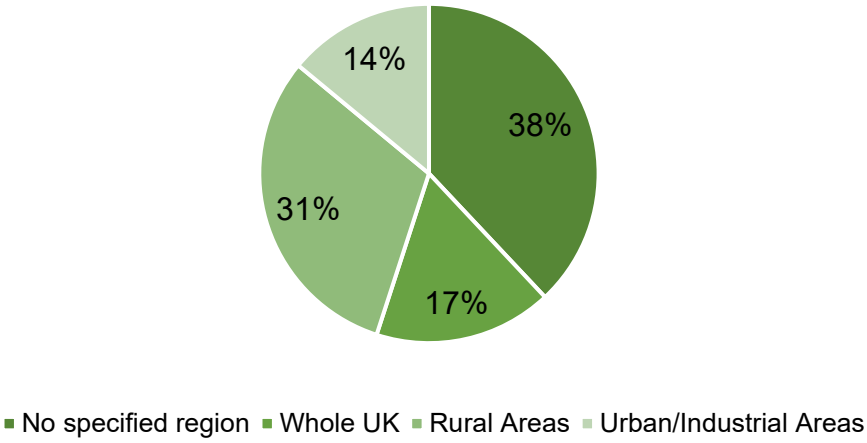

Figure 26 - Areas identified by respondents who were not location specific

The respondents who did not specify a specific region of the UK generally proposed that there were more nuanced reasons as to why specific areas should be chosen to either focus on technical innovation or feedstock supply chain scale up. Some respondents said that the **region would depend on the local demand and availability of biomass and that these differing quantities would depend on the local landscape.** Respondents suggested that the locations should be **prioritised to scale up biomass feedstock supply close to locations that utilise biomass** (end-users and existing low-carbon infrastructure) as to reduce the impacts of transportation.

Rural areas

Some respondents who did not specify a location or region of the UK instead generalised and provided an overview of key characteristics that should be targeted. Rural areas were one such example as nine respondents stated it is **logical to focus the scale up of feedstock supply chains which use biomass resources.** It is anticipated that these areas will fall outside the existing industrial clusters which already tend to benefit from government and private investment. One of these respondents said **that focusing technological innovation and feedstock scale up here would 'support biomass deployment and hence decarbonisation in rural areas of the country'.**

Another respondent stated that the **domestic biomass feedstock development and further growth of the 'green gas sector' should mean 'growth of rural jobs, with specific potential for developments near biomass demand centres'.** The nine respondents who identified rural areas agreed that more rural production facilities will mean that energy production is in the locality of where it will be consumed and where the feedstocks are available. One respondent added that 'this not only reduces the distribution carbon footprint but also provides local jobs, employment and economic growth' in rural areas of the UK.

Three of the nine Biofuel/Biogas respondents identified rural areas as best placed to focus on technological innovation and scale up of feedstock supply chains. The Boiler Manufacturer who responded to this Question reiterated this.

Whole UK

Some respondents did not identify a particular region and instead stressed that biomass can be deployed across the whole of the UK. Three Biofuel/Biogas respondents, and two from the Representative Group sector identified the whole UK as suitable for the scale up of feedstock supply chains and technological innovation. **Similar to the respondents who were location agnostic, they said that the scale up of feedstock supply chains should be UK-wide wherever organic wastes arise and that in order to achieve net-zero, innovation in all areas of the UK are required with respect to biomass supply chains.**

Urban/Industrialised

Respondents also identified urban and industrialised areas as potential regions of the UK for technological innovation and feedstock supply chain improvements. **Air quality improvements in urban areas were cited as a benefit of new waste disposal options**. Additionally, respondents identified urban and industrial centres as potentially having **access to large scale streams of waste biomass that would only need to travel a short distance to be utilised as fuel**. They added that this **addresses one of the key problems with biomass; emissions associated with transportation**. Another three of the Biofuel/Biogas responded to the Question by suggesting the urban and industrialised areas of the UK should be prioritised.

Region specific

The majority of respondents mentioned a specific region of the UK (these have been grouped together by country in the below map). Regions within England or England as a whole were most commonly highlighted as being best placed to focus on technological innovation and the scale up of feedstock supply chains. Scotland and Scottish locations had the next most mentions, followed by Wales and finally Northern Ireland and Jersey. Northern Ireland and Jersey have been categorised as ‘other’ for the purpose of this analysis.

Of the respondents who were region specific when identifying the best places to focus on technological innovation and scale up of feedstock supply; 50% said an English region, 26% specified a Scottish region, 17% a Welsh region and 7% specified other locations (see Figure below).

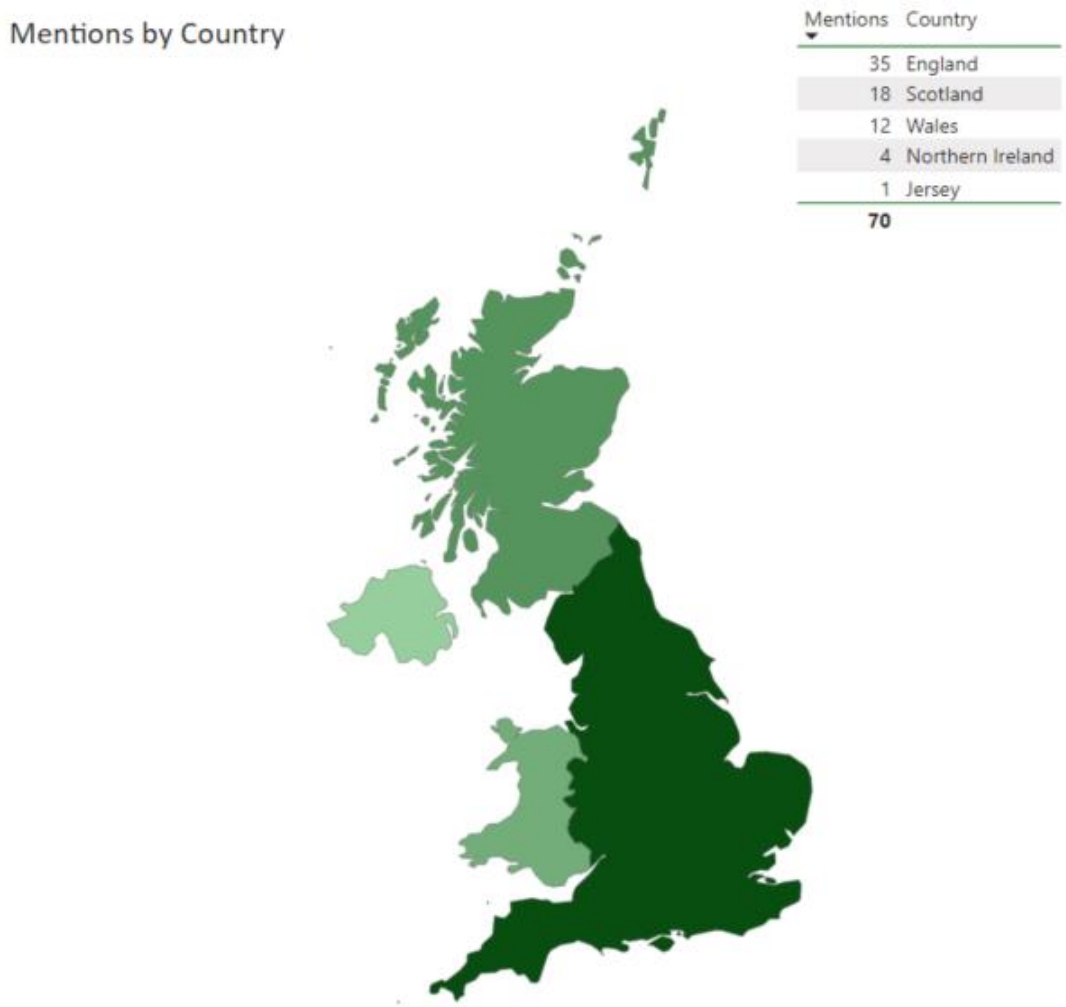

Figure 27 - Choropleth map showing mentions by country deemed best placed to focus on technological innovation and scale up of feedstock supply chains

England

Of the 60 respondents to Question 24, ten from the Representative Group sector mentioned England or regions of England as being best placed for technological innovation of biomass and the scale up of feedstock supply chain. A further five respondents from the Utility/Distributor sector and seven from the Academia sector agreed.

The midlands and the southwest were identified by respondents as regions that are well placed for innovation due to the Energy Research Accelerator institutes in the midlands and the Bio-renewables centre in Bristol. The southeast's feedstock potential was also highlighted due to the established sugar production.

However, it was the **North of England** that was predominantly mentioned as best placed to scale up feedstock supply chains and also technological innovation of biomass. Respondents focused on Tyneside, Teesside and Humberside port areas explaining that it makes sense for innovation and scaling up of feedstock to be tied to 'low carbon industrial clusters' and areas that are 'earmarked to become low carbon industrial clusters'.

These **northern areas benefit from proximity to existing industry, including within proposed industrial clusters and ports with significant growth ambitions that already have an understanding of their 'potential role in decarbonisation'**. This has been displayed already in the recent 'Freeport bids and the Port of Tyne's 'award-winning decarbonisation and clean energy strategy, Tyne 2050'[66]. Furthermore, it was noted **that investment in the technological innovation and scale up of biomass feedstock will support the government's goals of delivering successful 'low carbon urban clusters' and their much-publicised goal of 'levelling up the North of England'.**

Scotland

Scotland was the most referenced country after England with two of the three NGOs as well as a further five from the Academia sector suggesting Scotland as the hub for biomass feedstock supply scale up and technological innovation. **Respondents cited the 'exceptional diversity of academic research, technical expertise, and world-class facilities that industry can tap into to design, build and test bio-based processes'.**

Scotland is placed well in relation to biomass development as over **80% of the production of sustainable wood pellets in the UK takes place in Scotland**. Moreover, **Scotland has the highest number of pellet burner installations in the UK.** Respondents explained that Scotland produces a multitude of biomass, has a great breadth of businesses working in, or relying on, the bioeconomy and hosts academic leadership in biotechnology research. Extensive UK and Scottish Government investment has grown the bioeconomy in Scotland, this is supported by government programmes based around sustainability (to be embedded in the Scottish Circular Economy bill in 2020), and reports detailing circular economy opportunities.

Wales

Six of the Representative Groups and four respondents from the Biofuel/Biogas sector mentioned Wales as being best placed for feedstock scale up and technological innovation. One reason one of the respondents gave for identifying Wales was because of the work that has been carried out at

[66] https://www.portoftyne.co.uk/news-and-media/news/port-of-tyne-clean-energy-programme-cuts-carbon-emissions-by-700-tonnes-in-12-months

Aberystwyth University which involved planting biomass feedstock sources in North Wales by **breeding new varieties of feedstock which are adapted to specific areas where soil is not typically suitable for arable crops.**

Furthermore, **like Scotland, Wales has existing major forestry areas which could be expanded for biomass supply.** There is also poor-quality farmland that could be transitioned to biomass production. The expansion of agroforestry was supported as it can drive regenerative agricultural techniques.

Other

The other regions of the UK that were mentioned were Northern Ireland and one mention for Jersey. The respondents who identified these regions were all from different sectors so there is no clear correlation. The reason **Jersey is unique is because of its Industrial Hemp that has been grown openly in fields for three seasons.** However, it is small scale and would only currently be viable for use in the Channel Islands.

Northern Ireland however has a large amount of agricultural waste including farm waste and solid waste which could be used in AD facilities. Current energy policy in Northern Ireland implies that future biomass use may be more concentrated in the devolved administrations or that devolved administrations could be net exporters to the rest of the UK.

BIOENERGY WITH CARBON CAPTURE AND STORAGE (BECCS)

Question 25 - Post-combustion capture on biomass electricity generation is one method in which Bioenergy with Carbon Capture and Storage (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?

51 respondents answered Question 25 equating to 36.7% of all respondents. The Table below summarises the respondent types for this Question.

Table 30 - Breakdown of Respondents by Organisation Type for Question 25

Respondent type	Total number of respondents
Academia	8
Biomass Supplier (Agriculture)	2
Biofuel / Biogas Producer & Technology Provider	9

Respondent type	Total number of respondents
Biomass Boiler Manufacturer	0
Certification Body	0
Chemicals	0
Consultancy	1
Biomass Supplier / Technology Provider (Forestry)	1
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	4
Other	5
Trade Association / Representative Group – Agriculture	2
Trade Association / Representative Group – Biofuels / Biogas	2
Trade Association / Representative Group – Biotech / Chemicals / Products	2
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	2
Trade Association / Representative Group – Forestry Supply / Products	2
Trade Association / Representative Group – General	2
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	2
Utilities / Energy Asset Owners / Distributors	4
Waste Management	0
Total	**51**

Respondents most highlighted the need for government investment to drive innovation (39 separate mentions). It is important to note that reference to government investment covered a range of different interventions, as such this has been categorised into the following sub-groups: infrastructure development, demonstrator programmes/commercialisation, improved market mechanisms, industry

stakeholder collaboration, and funding support. All these categories pertain to the overarching category of government investment which equated to 58.2% of the total mentions in this Question from those who responded.

There were two parts to this Question 'how could innovation support be targeted' and 'how can this support develop the maturity of other BECCS applications.' In general, respondents answered this Question by suggesting what other BECCS applications needed. **It should be noted that the first part of the Question was given more focus**. There were some responses to which focused on other technologies.

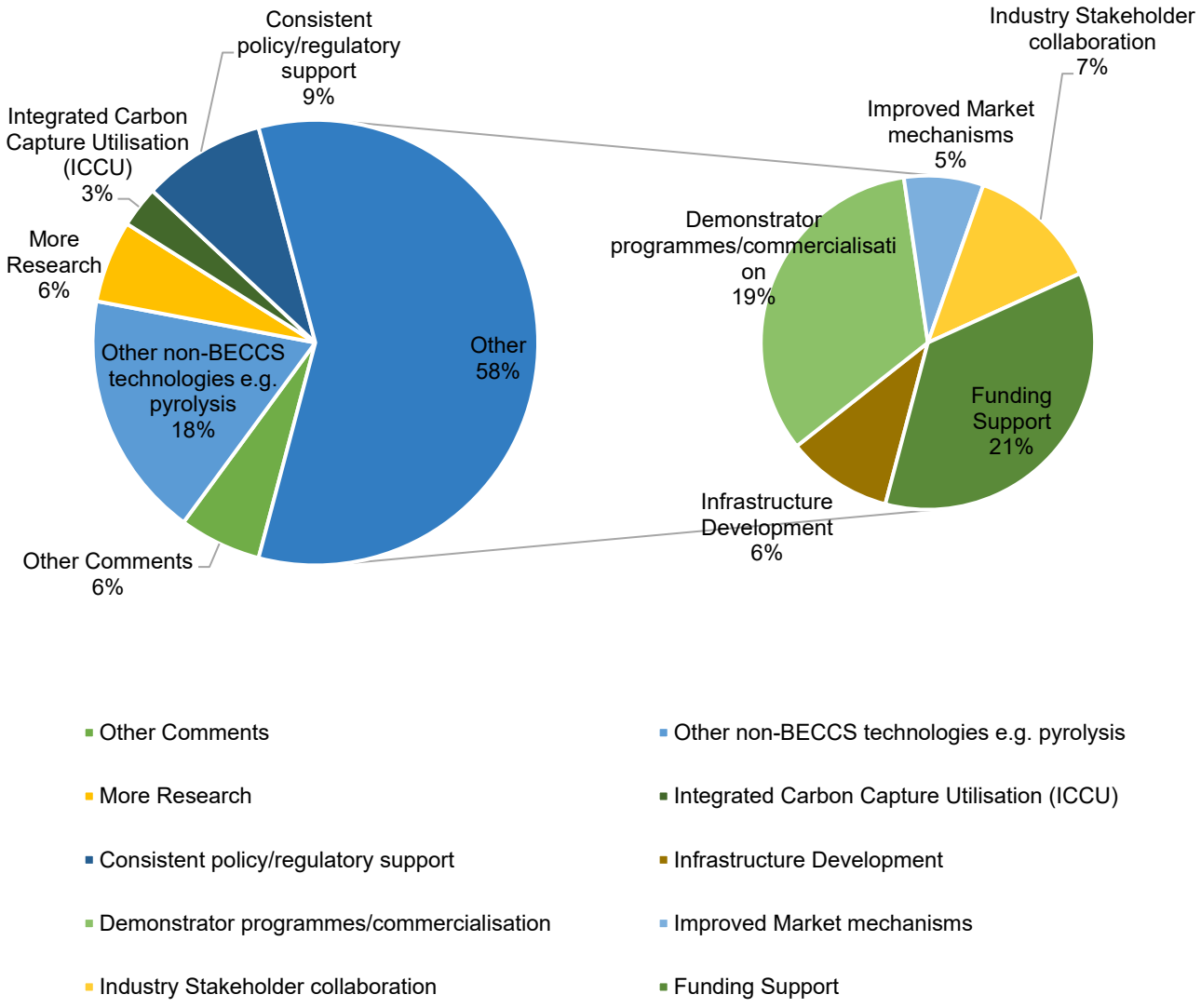

Figure 28 – Identified innovation areas to be targeted to develop the maturity of other BECCS applications

Government Investment and support

The need for greater government investment and support in relation to BECCS and other technologies was highlighted by numerous respondents. One respondent from the Utility/Distributor sector noted that **BECCS is not utilised on a commercial scale because there is need to develop large scale transportation and storage networks for captured emissions**. Another respondent, also from the Utility/Distributor sector cited the success of the Net Zero Teesside and Northern Endurance Partnership **and suggested that more funding and investment support should be given for low carbon innovation clusters to develop high-quality skilled labour and economic growth**.

Respondents also noted that **innovative solutions will be constrained until either funding is directed to research and development or the level of policy certainty incentivises operator investments at risk.** Investment in innovation can be reduced through providing medium-term policy certainty via market mechanisms that support ongoing biomass developments and existing biomass generation facilities without BECCS.

One respondent from the Forestry sector suggested there should be increased stakeholder engagement on what is defined as 'CCS Ready', as well as the readiness of the transport and storage network. A respondent from a Representative Group commented **that a focused task force should be set up within BEIS to link the end users to potential producers with support for a £/tonne subsidy in the first year/s to develop the market. The task force could initially bring together larger producers then look at the commercial implementation of medium to small sites**.

It was noted that using academia partnerships such as Decarbonisation Research and Innovation Centre (IDRIC) can accelerate certain applications of BECCS. It is important that government provide a clear a pathway of mechanisms and support to bring the technologies with low TRL through to commercial deployment.

Gasification

Respondents advocated for the use of gasification technology; however, it was noted that more needs to be done to promote this solution. Supergen Bioenergy Hub report on Bioenergy and waste gasification in the UK Barriers[67] and research needs was cited by an NGO. **The report emphasises a need to address technical challenges at all stages of the gasification process to make meaningful progress for Net Zero 2050 targets.**

[67] https://www.supergen-bioenergy.net/wp-content/uploads/2019/06/Bioenergy-and-waste-gasification-report-2019.pdf

A respondent from a Representative Group advocated for a CfD Based Business Model for large scale BECCS that would allow biomass power projects to receive a reliable revenue for the power generated, and a similar approach could be adopted for other BECCS non-power plants, e.g. thermal gasification plants. **BECCS would allow biomass power projects to receive a reliable revenue for the power generated, along with any additional benefit for services provided to the grid**. A separate carbon payment could then be provided to reward negative emissions. **It was recommended that this carbon payment was set at a £/tonne and would need to cover both the operational costs of capturing carbon, along with transporting and storing it.**

Although some gasification technologies are 'mature' at lab-scale, it was emphasised that it is difficult to secure finance to test it at larger scale**. A reassessment of public funds made available, or technologies would be highly beneficial.**

On the other hand, respondents belonging to the Utility/Distributor sector mentioned the industry does not need to support gasification given current technologies with carbon negative ATT. Furthermore, respondents belonging to the Academia sector noted that **biomass gasification or pyrolysis do not have large scale potential in the UK.**

Pyrolysis

A respondent belonging to the Academia sector noted that **Py-BECCS concept is applicable across a wide range of scales** and does not depend on development of CO_2 transport and storage infrastructure. They cited evidence from 'Prospective contributions of biomass pyrolysis to China's 2050 carbon reduction and renewable energy goals'[68] from Nature Communications.

Other Technologies

A respondent belonging to the Academia sector noted that **bioethanol production gives rise to a pure source of CO_2** providing a cheaper approach to CCS compared to traditional approaches. This innovative method removes the costly clean-up of post-combustion flue gases associated with BECCS. It was suggested that using a bioethanol CCS approach opens the opportunity for carbon negative chemicals including SAF. However, there was no supporting evidence that specifically detailed the cost comparisons.

Another respondent in the Academia sector noted that the post-combustion **capture of CO_2 by microalgae is known to be possible** but requires support for innovation to produce processes and value additions that maximise the innovative capacity of the resource.

[68] https://doi.org/10.1038/s41467-021-21868-z

Other Challenges or Concerns raised

A Representative Group respondent cited research from the Society of Operations Engineers 'Review of the UK Government's 2020 Energy White Paper Powering our Net Zero Future [69] from the perspective of ending CO_2 originated by equipment operation entering the atmosphere June 2021' that **explains why CCS results in high CO_2 levels in the atmosphere**.

One respondent stated that **BECCS is an unproven technology at large scale**, it cannot address the harms done to forests through clearing for biomass and it has no proven carbon emission reductions. One respondent cited the 2021 Ember report on BECCS (Gambling with Biomass: Reliance on BECCS Undermines National Grid's Net-Zero Scenarios[70]), which concluded that **a large scale BECCS plant does not ensure meaningful guarantee of emission reductions**. It was noted that the expense, estimated at almost £500 per person in the UK, would be more expensive than the Hinkley Point C nuclear power station.

OTHER INNOVATION

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

48 respondents answered Question 26 equating to 34.5% of all respondents. The Table below summarises the respondent types for this Question.

Table 31 - Breakdown of Respondents by Organisation Type for Question 26

Respondent type	Total number of respondents
Academia	5
Biomass Supplier (Agriculture)	2
Biofuel / Biogas Producer & Technology Provider	4
Biomass Boiler Manufacturer	0
Certification Body	2
Chemicals	0

69 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf

70 https://ember-climate.org/commentary/2020/10/28/gambling-with-biomass/

Consultancy	2
Biomass Supplier / Technology Provider (Forestry)	2
Government Organisation	2
Non-profit organisation / Special Interest Group / ThinkTank	6
Other	5
Trade Association / Representative Group – Agriculture	1
Trade Association / Representative Group – Biofuels / Biogas	2
Trade Association / Representative Group – Biotech / Chemicals / Products	4
Trade Association / Representative Group – Carbon Capture Utilisation and Storage	0
Trade Association / Representative Group – Forestry Supply / Products	2
Trade Association / Representative Group – General	2
Trade Association / Representative Group – Heating Appliances	1
Trade Association / Representative Group – Professional Engineering Services	1
Utilities / Energy Asset Owners / Distributors	4
Waste Management	0
Total	**48**

This Question had the fewest responses of any Question in the call for evidence. **Technological innovation was most commonly highlighted as a means to reduce life cycle GHG emissions in biomass supply chains**. Supply chain innovations and agricultural practices and Reforestation were the next most mentioned responses. As shown in the graph, there was a fairly even split across the innovation areas identified by respondents.

There were two parts to this Question and as with previous Questions, **the second part wasn't answered by respondents as in detail** so the data on barriers to reduction of GHG emissions in biomass supply chains is not as detailed suggesting a potential evidence gap.

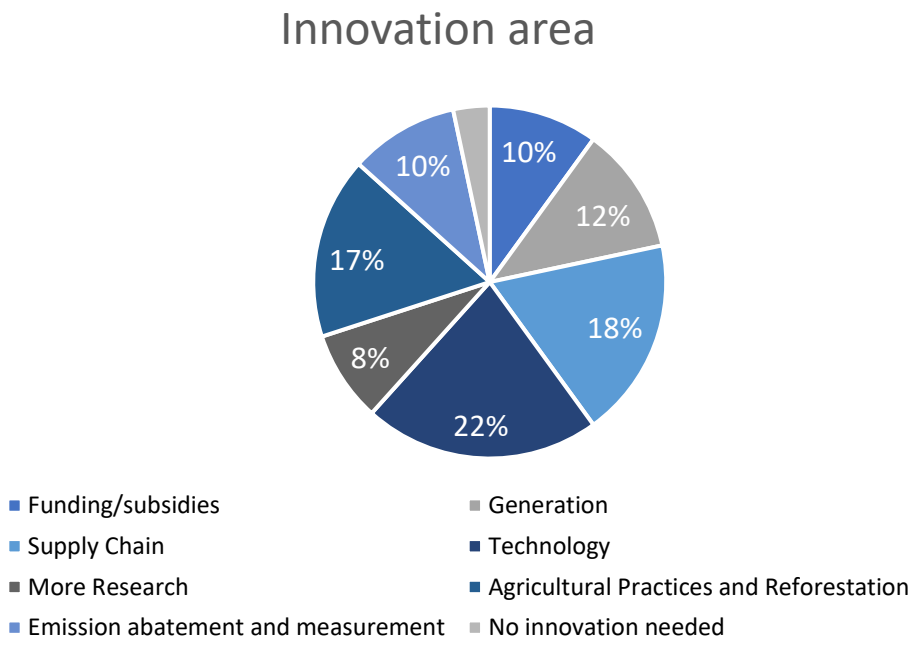

Figure 29– Innovation areas identified to reduce life cycle GHG emissions and impacts on air quality in biomass supply chains

Technology

Innovation in biomass technology was identified the most times by respondents. Representative Groups, Utility/Distributors and NGOs mentioned technological innovation five, three, and two times respectively.

Respondents noted that **GHG reductions will be possible following the further decarbonisation of the transportation of biomass by technological innovation of either biofuels or electrification**. One respondent added that this will need to happen at all scales, from international transportation of large supplies of biomass feedstock, requiring decarbonisation of shipping, along with transportation of relatively small volumes of biomass or waste, over small distances.

Further innovation in computing technologies was identified to potentially have significant contributions in 'ensuring sustainability and tracking emissions from the bioeconomy both nationally and globally'. Additionally, the technological innovations of AI and Machine Learning were raised as potentially having 'significant roles to play in biomass supply chain monitoring and optimisation'.

Supply Chain

Feedstock supply chain innovations were identified by a high proportion of respondents. Supply chains were mentioned by five of the Representative Groups and two of the NGOs.

Respondents explained that **tackling supply chain emissions is an important part of ensuring biomass sustainability.** The NGO respondents both conceded that importing a proportion of biomass feedstock to ensure demand can be met will still be needed but it **will require changes in how biomass is 'pelletised and transported'**. One respondent said that supply chain and logistics modelling may be one way to reduce GHG emissions, especially if verified and supplemented by field-based research. Respondents agreed that the **complexity of biomass supply chains is likely to grow** as the bioeconomy expands across different industrial and commercial sectors.

Agricultural practices and reforestation

Agricultural practices and reforestation initiatives were also earmarked by respondents as being key areas for innovation to reduce emissions in biomass supply chains. In particular, both Consultancy respondents mentioned these techniques.

Both Consultancy respondents suggested that **endorsing restoration activities that improve forest health would improve biomass supply chain quality whilst mitigating the long-term impacts of increased demand.** One claimed that increasing forest cover from cover from 13% to 17%, requiring 30,000 hectares of woodland planting each year combined with carbon capture technologies would drastically help reduce the emissions associated with the biomass supply chain. **Developments in bio-crops to create new, more resilient crops** that can be planted in a variety of different landscapes and soils was also identified as an area of agricultural innovation that could scale up the supply chain to reduce emissions.

Barriers

The second part of Question 26 asked for views on the barriers to reducing emissions in biomass supply chains. Most respondents identified research and innovation challenges. These research and innovation barriers affect most of the biomass supply chain, with respondents mentioning logistics, biomass selection and conversion technologies as needing further innovation to effectively reduce emissions in the supply chain.

Additionally, the **cost of new technological innovations was identified as a barrier.** Respondents highlighted the need to reduce lifecycle GHG emissions in biomass supply chains but noted that this is hindered by a lack of investment in bioenergy technologies and feedstocks which deliver the lowest possible GHG emissions. One respondent explained that 'promoting low carbon generation, increased energy efficiency and use of low carbon equipment (e.g. cars)' will better mitigate the impacts of these emissions in the supply chain.

Annex 1 - Plastic Demand and the Carbon Footprint Associated with Traditional Plastics and Bio- Attributed Plastics (Data Provided by Respondent)

Polymer	% of European plastic demand	Applications	Carbon footprint	In use lifetime (years)	Bio-based Status
Polypropylene	19.4	Food packaging, sweet and snack wrappers, hinged caps, microwave containers, pipes, automotive parts, bank notes, etc.	1.86kgCO_2eq per kg (2) (-2.2kgCO_2eq per kg of bio-attributed PP) (2)	Mainly short life non-durable packaging and household, leisure & sports but also durable applications in automotive and construction	Commercially available (mass balanced)
Polyethylene (Low-Density and Linear Low-Density)	17.4	Reusable bags, trays and containers, agricultural film, food packaging film, etc.	1.79-1.92kgCO_2eq per kg of LLDPE (1,2) 2.25kgCO_2eq per kg LDPE (2) (-1.91kgCO_2eq per kg of bio-attributed LDPE) (2) (-2.2kgCO_2eq per kg of bio-attributed LLDPE) (2)	Predominantly short life non-durable packaging	Commercially available via steam cracking or via ethanol.

Polyethylene (High-Density and Mid-Density)	12.4	Toys, milk bottles, shampoo bottles, pipes, houseware, etc.	2.079kgCO_2eq per kg of HDPE(2) (-2.1kgCO_2eq per kg of bio-attributed HDPE) (2) (-3.09kgCO_2eq per kg of bio-based HDPE (3)	Mainly short life non-durable packaging but also durable construction	Commercially available via steam cracking or via ethanol.
Polyvinyl chloride (PVC)	10	Window frames, profiles, floor and wall covering, pipes, cable insulation, garden hoses, inflatable pools, etc.	1.6-1.8kgCO_2eq per kg(1,6) Bio- attributed PVC GHG saving of over 90% compared to conventionally produced PVC (4)	Predominantly long-life durable applications in construction (5)	Commercially available via steam cracking
Polyurethane	7.9	Building insulation, pillows and mattresses, insulating foams for fridges, etc	-	Long-life durable applications in construction and automotive	Various commercial polyurethane equivalents
Polyethylene Terephthalate (PET)	7.9	Bottles for water, soft drinks, juices, cleaners, etc	2.19kgCO_2eq per kg (bottle grade) (1)	Predominantly short-life non-durable packaging	Commercially available as partially bio-based. 100% bio-based production demonstrated at pilot scale
Polystyrene and Expanded polystyrene	6.2	Food packaging (dairy, fishery), building insulation, electrical & electronic equipment, inner liner for fridges, eyeglasses frames, etc	2.37kgCO_2eq per kg (EPS) (1) Bio-attributed PS produces 74% less GHG when compared to conventional grades	PS mainly short life non-durable packaging and EPS predominantly long-life durable applications in construction	Commercially available via steam cracking

Other thermoplastics	11.3	Hub caps (ABS); optical fibers (PBT); eyeglasses lenses, roofing sheets (PC); touch screens (PMMA); cable coating in telecommunications (PTFE); and many others in aerospace, medical implants, surgical devices, membranes, valves & seals, protective coatings, etc	-	Varied	Several polymers commercially available as partially or 100% bio-based including PTT PBS, PLA, PA PBAT and thermoplastic starch.
Other thermoset plastics	7.5	Includes other thermosets such as phenolic resins, epoxide resins, melamine resins, urea resins and others	-	Varied	Epoxide resins commercially available based on glycerol derived epichlorohydrin.

1. European Ecoprofile
2. SABIC. Certified Renewable Polymers from TRUCIRCLE Portfolio. Available At:

3. Braskem. Green PE – LCA Summary 2017. Available At: http://plasticoverde.braskem.com.br/Portal/Principal/Arquivos/Download/Upload/GreenPE-LCASummary2017-CarbonTrust_v.2_230.pdf
4. Inovyn. INOVYN Launches World's First Commercially Available Grade of Bio – Attributed PVC. Available At: https://www.inovyn.com/news/inovyn-launches-worlds-first-commercially-available-grade-of-bio-attributed-pvc/
5. European Commission. Lifecycle Assessment of PVC and of Principal Competing Materials. Available At: https://ec.europa.eu/docsroom/documents/13049/attachments/1/translations/en/renditions/pdf
6. PVC Forum. Eco – Profiles and LCA. Available At: http://www.seepvcforum.com/en/content/65-eco-profiles-and-lca
7. European Bioplastics. Bioplastics Market Data. Available At: https://www.european-bioplastics.org/market/
8. Plastics Europe. Plastics: The Facts. Available At: https://www.plasticseurope.org/application/files/3416/2270/7211/Plastics_the_facts-WEB-2020_versionJun21_final.pdf

To find out more please contact:
Samantha Shea
T: 020 7090 1001
E: Samantha.shea@gemserv.com
W: www.gemserv.com

London Office:
8 Fenchurch Place
London
EC3M 4AJ

Company Reg. No: 4419878

Gemserv