IMechE response to the BEIS consultation on the role of biomass in achieving net zero

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About the Institution of Mechanical Engineers

The Institution of Mechanical Engineers (IMechE) represents 115,000 engineering professionals and students in the UK and across the world.

The Engineering Policy Unit of the IMechE informs and responds to UK policy developments by drawing on the expertise of our members and partners.

This submission has been produced with input from the following IMechE Industry and Special Interest Groups:

- Process Industries Division
- Powertrain Systems and Fuels Group
- Automobile Division
- Aerospace Division
- Energy, Environment and Sustainability Group
- Construction and Building Services Division
- Safety and Reliability Group

A note about the IMechE response

The Institution's Industry and Special Interest Groups have answered the questions in this consultation that could be authoritatively and succinctly answered given the time and space available. However, it was thought that some of these questions are so large in scope that it was better not to attempt to answer them rather than give a partial picture, which could be misleading. To complement this consultation, we recommend that BEIS commission a number of reports similar in scope the Biomass Feedstock Availability report from 2017.[1]

[1] Ricardo Energy and Environment (2017), *Biomass Feedstock Availability*, commissioned report for BEIS. https://www.gov.uk/government/publications/uk-and-global-bioenergy-resource-model

Consultation questions

Supply of biomass

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?

a) waste

Grass Cuttings

Grassland covers an estimated 26% of the world's total land area[2] and as much as 36.2% of the total in the UK, which being temperate is particularly rich in grass.[3] Much of this UK area is managed in some way through grass cutting, either as recreational, municipal, or marginal land that includes playing fields, sports grounds, golf courses, airports, roadside verges, and railways boundaries, yet despite the relative abundance of this biomass source, as well as the technical capability to process it, grass cuttings have not to-date been significantly utilised for energy production.[4] Where the local logistics allow there are some examples of grass cuttings being used as a feedstock for large-scale anaerobic digesters (AD).[5] But these are very limited in number and the resulting biomethane is either used to generate electrical power that is supplied to the power grid or, more recently, where a mains connection is available upgraded to gas quality for injection into the national gas network.[6]

Since grass cuttings have generally been perceived to date as something to be disposed of, often at a cost to the land manager, rather than a valuable biomass resource for processing, a detailed study of the land area, grass volumes and energy yield potential of the UK's managed grassland has not been carried out. However, in England there are 45,000 football pitches[7], hundreds of rugby clubs, and 1188 golf courses[8], while roadside verges represent 1.2% of Great Britain landmass with 27% frequently mown.[9] The potential energy generated from grass cuttings taken from this managed land, if processed efficiently, could yield significant amounts of methane. This could then be used, for example, to contribute to reducing emissions in the hard-to-electrify heavy-duty transport

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[2] Rodriguez, C. et al. (2017), 'Pretreatment techniques used in biogas production from grass', *Renewable and Sustainable Energy Reviews*, Volume 68, Part 2, February 2017, Pages 1193-1204. https://www.sciencedirect.com/science/article/abs/pii/S1364032116002306

[3] https://www.globalforestwatch.org

[4] Rodriguez, C. et al. (2017), 'Pretreatment techniques used in biogas production from grass', *Renewable and Sustainable Energy Reviews*, Volume 68, Part 2, February 2017, Pages 1193-1204. https://www.sciencedirect.com/science/article/abs/pii/S1364032116002306

[5] Brown, A.E. et al. (2020), 'An assessment of road-verge grass as a feedstock for farm-fed anaerobic digestion plants', *Biomass and Bioenergy*, Volume 138, July 2020, 105570. https://www.sciencedirect.com/science/article/pii/S0961953420301045

[6] https://www.ecotricity.co.uk/our-green-energy/green-gas

[7] FA (2005), Memorandum submitted by the Football Association to the Select Committee on Culture, Media and Sport, UK Parliament. https://publications.parliament.uk/pa/cm200405/cmselect/cmcumeds/507/5040515.htm

[8] https://www.statista.com/topics/3199/golf-in-the-united-kingdom-uk

[9] Phillips, B.B. (2021), 'Road verge extent and habitat composition across Great Britain', *Landscape and Urban Planning*, Volume 214, October 2021, 104159. https://www.sciencedirect.com/science/article/pii/S0169204621001225

sector.[10] Given this potential, the Government should include a detailed and technically robust assessment study of the current as well as future availability of UK managed grassland, its associated grass cuttings volumes, and energy content is supported by Government as part of its Biomass Strategy.

Distillery and Brewery Waste

Waste organic matter (spent malt, hops and botanicals) from the production processes of brewing and distilling represent another underutilised biomass resource for energy supply. The latter can be substituted for the LPG and other bottled/tanked gases typically used at these sites for the provision of heat to the brewing or distilling process, as well as to generate additional income to the businesses through sales of energy surplus to their requirements. For example, one approach would involve an energy extraction process based on a Rapid Leach-bed System (RLS) through which the remaining process nutrient can be extracted as a liquid leachate, this would then be transported to a local farm for co-digesting within manure slurry to enhance the methane yield of the latter. The commercial benefits would be realised through an agreement that sees the export of a portion of the additional energy production back to the brewery/distilling business. This novel approach provides the brewery/distillery with a local low carbon energy source at a reduced price and provides the farmer with a secure customer plus additional income from increased gas yields.

As with the case of grass cuttings, a detailed study of the potential volumes of material available and associated energy yield potential for the UK's brewing/distilling sector has not been carried out. A detailed and technically robust assessment study should be supported by Government as part of its Biomass Strategy.

Wastewater treatment

The annual production of sludge at wastewater treatment sites in England and Wales is around 1.25 million tonnes of dry solids. About two thirds of this undergoes Advanced Anaerobic Digestion (AAD), or conventional Anaerobic Digestion (AD) with the biosolids produced used as fertiliser and soil conditioner in agriculture under strict regulations and quality schemes. About a fifth is lime stabilised for agricultural use, and around 6% used in land restoration; the remainder is used as fuel in waste-to-energy plants or industry (cement). Sludge production is a function of population and wastewater treatment processes, so could be expected to increase by around 10% by 2050 – mostly at existing locations.[11]

b) forestry (Not answered)

c) agriculture

It is estimated that there are around 90 million tonnes of manures and slurries collected, stored and spread back to land untreated in the UK.[12] Processing this material via an AD plant could potentially

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[10] Atkins, P. et al. (2021), 'A Local Ecosystem Assessment of the Potential for Net Negative Heavy-Duty Truck Greenhouse Gas Emissions through Biomethane Upcycling', *Energies*, 14(4), 806. https://www.mdpi.com/1996-1073/14/4/806

[11] https://www.ofwat.gov.uk

[12] http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14500

deliver 17.1 TWh of biomethane, mitigating 3.4 $MtCO_2e$ emissions from the displacement of fossil natural gas.[13]

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?

GHG emissions

Grass Cuttings

Current grass cutting regimes process the cuttings aerobically either through bulk composting or mulching. Both processes need to provide sufficient oxygen circulation otherwise anaerobic activity is initiated resulting in the unwanted or controlled generation of methane, ammonia and NOX, all of which are harmful greenhouse gases. Methane and NO_X are responsible for 42% and 3.6% respectively of near term (20 year) global warming. Irrespective of the potential to realise an energy supply from this as yet untapped biomass resource, the global warming potential of gases emitted due to the poor management of grass cuttings waste from marginal land needs to be addressed and the use of AD offers a potential pathway to tackling the issue. However, given that the use of large-scale centralised plant for processing cut grass results in frequent and intense movements of heavy vehicles and machinery, with significant levels of associated GHG emissions, the increased use of small-scale on-site plant that produce energy for on-site use and local distribution should be incentivised whenever the benefits are not significantly outweighed by economy of scale effects (preferably in liquid fuel form to optimise energy density relative to product volume).

Agriculture

GHG emissions of approximately 6.0 $MtCO_2e$ are estimated to be released to the atmosphere every year as a result of the current practice of spreading untreated manure on UK farmland.[14] Methane and nitrous oxide are the principal emissions and these respectively have a Global Warming Potential (GWP) of 32 and 280 relative to carbon dioxide (CO_2) over a 100-year period. Methane is emitted primarily during the manure's storage phase, as a 'fugitive emission' escaping on farms from the surface of open slurry pits/lagoons where these organic wastes decompose under anaerobic conditions in the body of the stored material. The IPCC guidelines for national GHG inventories suggest that the poor manure management of cows and pigs alone results in 4.8 $MtCO_2e$ being emitted annually in the form of methane.[15] Covering manure slurry lagoons and processing the emissions to extract the methane, CO_2 and nitrous oxide (N_2O) offer a mitigation pathway for these fugitive releases, as well as delivering useful biomass based products for energy supply (Biomethane) and industrial processes (Bio-CO_2). The latter, for example, could include its substitution in the food and drink sector for industrial grade CO_2 which is currently created as a by-product of the production of fossil fuel based artificial fertilisers.

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[13] Calculation by ADBA and based on average biogas yield of 32m^3 per wet tonne digested, and 62% of biogas composed of biomethane. Estimates also assume a parasitic load of 4%, where the AD plant this proportion of the green energy generated to power on-site operations

[14] ADBA (2020), 'ADBA launches Biomethane – the pathway to 2030 report'. https://adbioresources.org/adba-launches-biomethane-the-pathway-to-2030-report/

[15] IPCC (2006), *IPCC Guidelines for National Greenhouse Gas Inventories*, Chapter 10: Emissions from Livestock and Manure Management. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf

Air quality

Grass Cuttings

The current grass processing model based on the use of large, centralised AD plant supplied through the collection of grass cuttings from multiple dispersed sites leads to a high intensity of traffic movements both in terms of frequency and physical scale. The latter is primarily due to the high-water content of grass, typically up to 80%, which requires that large vehicles are needed with high numbers of traffic movements to/from the plant and this impacts negatively on local air quality through pollutant emissions from the vehicles themselves (primarily in the form of particulate matter (PM) and N_2O) and the road congestion they can cause. By processing grass onsite at small-scale with minimal vehicle movements air quality degradation can be minimised.

Agriculture

Methods currently employed in agriculture to reduce ammonia emissions from livestock farming practices are focused on the methods used in the sector for the application and storage of manure slurry digestate. However, the solutions available today to reduce emissions during post-AD digestate storage only delay the release of ammonia to the point of application to the land. Low emission spreading can minimise the ammonia emissions, but removing the risk altogether to be a much better approach.

Low emission/loss application techniques include dribble bar, trailing shoe, shallow and deep injection. Dribble bar and trailing shoe are gaining in popularity and place the digestate close to the ground surface beneath plant foliage, which reduces the surface area of the applied digestate. This has advantages over traditional splash plate spreading (cheapest from a cost of equipment point of view) which produces vast amounts of tiny droplets that fall on all plant and soil surfaces, increasing the surface area and potential for the volatile ammonia to gas-off. The shallow and deep injection techniques work by placing digestate under the soil surface to minimise losses. Emissions of ammonia from the storage of liquid manures (i.e. slurry) and digestate can be reduced to near zero by using sealed storage vessels.

Barriers to the greater use of ammonia emissions reduction techniques centre on cost of equipment, the scale of available AD systems and the perceived value of the digestate amongst farmers and growers, when compared to artificial fertilisers. In the case of cost barriers for example, the cost of ammonia mitigating storage systems is commercially challenging for farm businesses when compared to conventional open clay lined pits (≈£5/m3) - a slurry bag (non-Lagoon AD) system costing ≈£29/m3. To remove these barriers, solutions are required that are commercially attractive to farm businesses, as well as a change in farming practices to those based on methods that promote the efficient utilisation of recycled nutrients and prevent losses, along with awareness raising of the benefits of such an approach.

Solid Biomass

The suitability solid biomass depends on a whole range of factors, including biodiversity impact, proximity of the resource to end use (concerning transport impact) and end use location, in particular given the potential impact of local emissions.

There is a benefit in using local and available biomass for specific suitable projects. For example, UK local authorities must maintain parks and gardens and also ensure that roadside trees are trimmed and kept safe. Trees that are not maintained may have branches that spread and impinge upon traffic flows and can fall over in high winds. Collection of this biomass provides a small but useful source of fuel. In Burnley, Lancashire, the collected wood is used in biomass boilers for heating and hot water of the 9 new schools constructed under the Burnley BSF scheme. The boilers used are all Austrian and have advanced cleaning technologies that ensure exhausted fumes meet environmental health standards and are capable of winding down to low operation effectively and effectively under automatic control.

In Barnsley, the main council offices are heated by wood using similar biomass boilers fed from locally sourced wood.

By adopting a case by case approach in this way, waste biomass can be recovered and used, saving energy costs, reducing carbon emissions and creating local jobs. In relationship to the local economy this follows the Liverpool model – recently renamed as the Preston model – which promoted local investment of this type because it has been shown that for one pound spent there can be up to a nine pound return into the local economy. This is based on economic modelling that shows how the initial investment goes to pay local suppliers and workers who then spend on again in local shops, pay council taxes, children's school costs and so forth so that the original investment flows and generates the economy.[16] [17] [18]

There is also a significant resource of solid biomass from forestry management. As well as providing an energy source, thinning promotes growth of existing trees, and therefore carbon sequestration, through letting more light in through the canopy, without having a negative impact on biodiversity, as can dedicated energy crops. Similarly there is untapped potential from agricultural co-products as an energy source.

Aviation

Sustainable Aviation Fuels (SAF) have been shown to have a lower aromatic content than conventional fossil fuels, this leads to lower quantities of particle matter produced.[19] As well as benefitting the local to airport communities through better air quality, it will also lead to fewer contrails which are estimated to be causing about three times the amount of global warming (measured by current radiative forcing (RF)).[20] This benefit is still subject to ongoing confirmatory research. The benefit of using SAF on reduced contrails was estimated to be 10% to 40%.[21]

Soil Health

Supporting biomethane production from manure slurry based AD plant at the farm-scale, for on-site energy provision and local distribution, has the potential help improve the overall sustainability of farming and facilitate a regenerative approach to soil health. In this regard, through biological post-processing of the resulting digestate, a regenerative replacement for artificial fertiliser can be

[16] Preston City Council (2019), *How we built community wealth in Preston*. https://www.preston.gov.uk/media/1792/How-we-built-community-wealth-in-Preston/pdf/CLES_Preston_Document_WEB_AW.pdf?m=636994067328930000

[17] Sapsford, D. and Southern, A. (2007), *Measuring the economic impacts of Liverpool European Capital of Culture*, University of Liverpool Management School. https://www.liverpool.ac.uk/media/livacuk/impacts08/papers/Impacts08_BusinessImpactsBaselineReport.pdf

[18] https://www.liverpoolcityregion-ca.gov.uk/growing-our-economy/building-back-stronger/

[19] US Department of Energy (2018), *Sustainable Aviation Fuel – Review of Technical pathways*, section 2.2.2. 2018 https://www.energy.gov/sites/prod/files/2020/09/f78/beto-sust-aviation-fuel-sep-2020.pdf

[20] Lee, D.S. et al. (2020), 'The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018' *Atmospheric Environment*. https://www.sciencedirect.com/science/article/pii/S1352231020305689?via%3Dihub#

[21] McKinsey & Company (2020), *Hydrogen-powered aviation*, prepared for the Clean Sky 2 Joint Undertaking. https://www.fch.europa.eu/sites/default/files/FCH%20Docs/20200720_Hydrogen%20Powered%20Aviation%20report_FINAL%20web.pdf

produced that improves nutrient cycling and soil biology. Implementing the latter can not only restore and improve soil structure, health and productivity.[22]

Food Security

Policy makers must be very careful that biomass production is not promoted and supported to the detriment of UK domestic food supply and affordability.

Currently Sustainable Aviation fuel is primarily made by HEFA reliant on the use of oil and fats as feedstock. Due to limited supply of this feedstock without causing environmental issues, this production is likely to be limited to the use of waste oils and fats. Longer term, to achieve the desired quantity of SAF we see substantial use of lignocellulosic waste biomass sources, lignocellulosic or oil crops with a low risk of causing direct and indirect negative social impacts, together with renewable electricity.[23]

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)?

The standard BS EN 16214 deal with the sustainability of biomass. There should be encouragement for widespread adoption of this standard, and development of it to meet current conditions and purposes, as required.

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.

Domestic biomass can support all these, but prioritisation should be based on what is the best use of the scarce land that is available. It may also be best to focus on biomass as a co-product of other activities, and its benefits may be considered in the context of other activities.

For example, domestic biomass plants located close to the source of a rural feedstock can support skilled rural employment and green economic growth, they can link up with other local non-biomass decarbonisation options to create rural clean energy infrastructure tailored to local resources and requirements, and they can be collaboratively developed with the local rural community to ensure feedstock supply is sustainable and the local environment is conserved.

Rural Communities have within them a considerable untapped resource of energy in the form of the biogas that can be derived from farm livestock manures as well as from the grass cuttings from a wide range of existing rural grassland management operations, including for example the maintenance of roadside verges, community and school playing fields, golf courses, country estates,

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[22] Tevi (2020), 'Improving Soil Health in Cornwall for Farmers & Landowners'. Presentation delivered online. Available: https://vimeo.com/458903162

[23] Bauen, A. (2020), 'Sustainable Aviation Fuels: Status, challenges and prospects of drop-in liquid fuels, hydrogen and electrification in aviation', *Johnson-Matthey Technology Review*, 64, (3), 263. https://www.technology.matthey.com/article/64/3/263-278/

etc.[24] In many cases these sources of energy are relatively small, being at a modest farm or village/community scale, but when efficiently sourced, upgraded through processing to produce biomethane for on-site use or for aggregation and distribution to meet local rural energy demand for off-gas-grid heat, vehicle fuel and on-site electricity applications, they represent a considerable placed-based opportunity for the commercially viable deployment of affordable zero emissions energy.[25] By supporting the deployment of this type of local approach, the UK Government can create economic green growth and skilled jobs that help maintain the viability of farms and rural communities whilst simultaneously helping to increase their energy security and resilience, reduce fuel poverty, and contribute to delivering a circular economy along with a range of additional environmental benefits.

Incentivising a scalable roll-out of this innovative approach based on as yet untapped local waste biomass resources would enable communities, rural businesses and farms to become energy independent as well as access revenues that can provide them with profitable income.[26] For example, in rural Cornwall the EU's European Regional Development Fund (ERDF) is part-funding a project to demonstrate the use of livestock manure to establish energy independent dairy farming (including self-sufficiency in power, heat and fuel for farm machinery) that simultaneously generates farm business income through local sales of surplus biomethane; delivers saving on farming input costs, such as reducing fertiliser bills by using the digestate from the manure slurry processing to deliver soil restoring regenerative practices; and substantially reduces the release of ammonia that leads to air quality degradation.[27] [28]

With the forthcoming introduction of the Environmental Land Management Scheme (ELMS) for farming to facilitate a post-Brexit phase-out of the EU's Basic Payment Scheme (BPS) under the Common Agricultural Policy (CAP), farm businesses need to find new sources of revenue based on environmentally beneficial practices to remain operational (typically the BPS provides around 50-80% of UK farms annual income).[29] Through the use AD more broadly, UK farms could process 90 million tonnes of readily available manure to deliver biogas generating, based solely on wholesale gas prices as of Jan 2020, an additional £160-230 million each year to the agricultural sector.[30]

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

The main barriers to the widespread domestic deployment of biomethane producing Anaerobic Digestion (AD) plants include:

1. The high costs of UK AD plants (in the UK most plants are designed, installed, and operated by European companies).

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[24] Rodriguez, C. et al. (2017), 'Pretreatment techniques used in biogas production from grass', *Renewable and Sustainable Energy Reviews*, Vol. 68, Part 2, Pages 1193-1204. https://www.sciencedirect.com/science/article/abs/pii/S1364032116002306

[25] www.energy-now.co.uk

[26] https://www.fginsight.com/news/income-from-slurry-gas-110928

[27] https://www.cornwallislesofscillygrowthprogramme.org.uk/projects/energy-independent-farming/

[28] Tevi (2020), 'Improving Soil Health in Cornwall for Farmers & Landowners'. Presentation delivered online. Available: https://vimeo.com/458903162

[29] HoC Library (2018), *Brexit: Future UK agriculture policy*, Briefing Paper Number 8218. https://www.parliament.uk/documents/commons-library/Brexit-UK-agriculture-policy-CBP-8218.pdf

[30] https://www.ofgem.gov.uk/data-portal/all-charts/policy-area/gas-wholesale-markets

2. Unavailability of competitive, low tech, financially viable AD solutions.
3. The absence of commercially viable solutions for a small-scale AD and biogas upgrading plant system for on-farm or community scale applications.
4. The absence of a commercially attractive AD solution for farms without gas-grid access and/or power grid connection/constraint issues.
5. Perceptions of investment risk and inadequate return on investment.
6. Bio-security concerns about importing high energy waste streams to improve the financial viability of a plant.
7. A lack of research into alternative AD solutions.
8. An incentive scheme that is too coarse and does not provide adequate rewards for smaller plants/operators and those without gas-grid access and/or power grid connection/constraint issues.
9. Lack of security in the form of long term contracts for supply makes farmers reluctant to commit to biomass that can be hard to switch the land away from.
10. Lack of support for end use of biomass (including removal of Renewable Heat Incentive (RHI)).
11. Oil price volatility, with biomass tracking oil price.

As part of the UK's Biomass Strategy, the Government needs to put in place policy interventions, regulatory change, financial incentives, and investment encouraging mechanisms that remove these barriers, along with a timebound roadmap for their implementation. This should include support for the engineering development and commercially viable deployment of affordable, efficient, UK sourced AD plants and biogas processing (upgrading) equipment, including small-scale systems and options for biomethane production where proximity to a gas grid injection point is not available. The Institution of Mechanical Engineers is aware of several private companies that are researching and piloting such plant and systems but does not see UK Government policy or regulatory support for their widespread development and/or deployment.

It is a missed opportunity the fact that the Green Gas Support Scheme is exclusively focussed on supporting biomethane injection into the gas grid and does not offer a support route for off-gas-grid sourcing, processing/upgrading, storage and distribution of biomethane, either in gaseous or liquid fuel form. The Committee on Climate Change (CCC) consider the production of biomethane from waste as a low-regrets option, recommending continued government support (Source: UK Committee on Climate Change (2018), Biomass in a low carbon economy). The lack of this support for the off-grid component of production is not only remiss, but also ignores the full low-regrets potential of biomethane to reduce greenhouse gas and other emissions (including ammonia and N_2O) from waste and agriculture, as well as support jobs in rural areas, reduce fuel poverty and build rural energy security and resilience capacity, through its local sourcing, processing and distribution.

Current regulation blocking the anaerobic digestion of food wastes unnecessarily is also a barrier to the domestic supply of sustainable biomass. In this regard, the Government should reconsider the CAT 1 and ABP classification, for example aviation food waste is very low risk but classed as CAT1 and therefore not easy to use as a feedstock for AD plants.

<u>Grass Cuttings</u>

The use of large, centralised AD plant supplied through the collection of grass cuttings from multiple dispersed sites is inherently inefficient and unsustainable in terms of the associated manpower and plant operational costs, which make a profitable business model difficult to realise thereby creating a barrier to increasing domestic supply of this relatively unexploited biomass resource. The latter is primarily due to the high-water content of grass, typically up to 80%, which requires that large vehicles and machinery are needed with high numbers of frequent and labour intensive (and therefore costly) traffic movements. The use of small-scale on-site plant that produces energy for on-site use and local distribution is recommended (preferably in liquid fuel form to optimise energy density relative to product volume).

Distillery and Brewery Waste

A principal challenge to the commercialisation of this a yet untapped biomass resource is the classification of the leachate as a waste thereby requiring the slurry lagoon AD operator to hold a waste handling licence. To overcome this the re-classification of leachate as a product (supplement) that enhances biomethane production and adjusts the pH of agricultural slurry waste lagoons is advisable. Alternatively, waste handling licences need to be simplified to enable the operators to co-digest feedstocks in lagoons.

Agriculture

In terms of scale, across the UK, there are circa 35-40,000 cattle farms.[31] However, with current farming practices, AD costs, and availability of low-carbon energy production incentives, only 3.5% of UK dairy livestock would be linked to economically viable on-farm plants. This situation acts as a significant barrier to increasing the domestic supply of this as yet underutilised biomass.[32]

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?

Not answered.

End use of biomass

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?**

[31] DEFRA (2021), 'Statistical data set: Structure of the agricultural industry in England and the UK at June'. https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

[32] Jones, P. and Salter, A. (2013), 'Modelling the economics of farm-based anaerobic digestion in a UK whole-farm context', *Energy Policy*, Vol. 62, Pages 215-225. https://www.sciencedirect.com/science/article/abs/pii/S0301421513006162

Heat (Residential and None-Residential Buildings)
The Institution has previously made submissions to the BEIS Future of Low Carbon Heat Consultation and BEIS Committee's Decarbonising Heat in Homes Inquiry in which we have extensively articulated our views on the use of UK biomass sourced biogas as an energy source for heat provision in off-gas-grid residential and none-residential buildings. In these submissions we stated that bioenergy should have a role in displacing fossil fuels for heat provision in off-gas-grid areas, or where electric heating or heat pumps are unsuitable. In this regard, the majority of off-gas-grid buildings (for example the 167,000 such homes in Scotland) are in rural locations, typically use bottled fossil fuel derived gas (i.e. propane, etc.) or oil for heat provision, and have limited or no economically and technically viable low carbon options as alternatives. Solutions often proposed for such properties start with technologies for the electrification of heat provision, including heat pumps and hybrid heat pumps, but these are challenging to deliver in many cases and can exacerbate issues of fuel poverty and social inequity in rural areas.[33] [34]

In such settings the use of electrically powered heat pumps is often not technically possible and/or undesirable/difficult from the perspectives of householders. The technical issues can relate to high heat losses from buildings that cannot be bought down cost-effectively (i.e. there is a greater prevalence in rural areas of older, colder properties which are hard to treat with fabric refurbishment and energy efficiency measures) as well as a lack of physical space making installation difficult; the desirability issues can involve concerns around the historic or listed nature of the building or, in the case of more affluent households, aesthetic considerations associated with mature gardens, landscapes or architecture. Rural off-gas-grid areas can have significantly higher instances of fuel poverty than the national average[35] and heat pump solutions can also potentially exacerbate this issue, particularly in the case of Air-Sourced Heat Pumps (ASHP) which can be relatively expensive to run.

Other 'traditional' alternatives are extremely limited and include district heat networks or biomass boilers. However, the low density typical of rural housing makes the former unavailable in most cases and, as recognised by the UK Government, there are air quality and sustainability concerns associated with the biomass boiler option. This situation is common across rural UK and indeed the UK Government's own modelling work suggests that, for the domestic sector alone, 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, such as biomass or combustion of biogas.[36]

The combustion of upgraded biogas delivered as biomethane in compressed gas or liquid fuel form to produce heat for use in space and/or water heating offers a viable affordable alternative off-gas-grid option in these rural locations which, if produced from locally sourced rural organic waste materials such as farm manure or cut grass, is zero-carbon (or better than zero-carbon in the case of manures). BEIS should explore more fully UK Government incentivisation of building scale technologies that use the combustion of processed biogas (e.g. biomethane) to heat the space and water in rural off gas grid homes, as well as support for small-scale on-site AD plant or slurry lagoon

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[33] Citizens Advice Scotland (2016), *Hot of the Grid: Delivering energy efficiency to rural off-gas Scotland*. https://www.cas.org.uk/publications/hot-grid
[34] Scottish Government (2021), *Heat in buildings strategy - achieving net zero emissions: consultation*. https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings-consultation/
[35] Citizens Advice Scotland.
[36] BEIS (2021), *Consultation outcome: Future support for low carbon heat.* https://www.gov.uk/government/consultations/future-support-for-low-carbon-heat

based AD for the production and local distribution of bioenergy such as biomethane (preferably in liquid fuel form to optimise energy density relative to product volume).

Biomass boilers at a commercial scale running off wood fuel from forestry management, or saw mill co-products, for example, should be encouraged in rural locations, where there will be less impact from particulate emissions than in the urban environment. For urban heat supply, biomass boilers can be suitable in conjunction with district heating networks, as long as abatement technology is fitted to reduce emissions to the required level. Priority in the use of solid biomass should be given to supplying heat loads for which low temperature heat supply is not practical, and therefore less suited to heat pumps.

Heat (Process Heat - Distillery and Brewery Waste)

Biogas (i.e. biomethane) derived from anaerobic digestion of biomass in the form of waste organic matter (spent malt, hops and botanicals) from brewing and distilling processes can be substituted as an energy source for the LPG and other bottled/tanked gases typically used at these sites for the provision of heat to the process itself. This can be achieved at any site irrespective of location, size and heat processes by:

(1) Blended solution – this involves blending biomethane with LPG. This is a low-cost interim step to allow immediate reductions in emissions via blending biomethane with LPG. This would involve a minor modification to an existing LPG fuelling systems and be the lowest cost approach in capex terms.
(2) Compressed Biomethane solution – this involves a complete replacement of the existing LPG system with relatively minor process equipment modifications.
(3) Liquid Biomethane solution – this is for large plant with higher energy requirements using a grid gas supply as an energy source for process heat provision. Cryogenically cooled liquid biomethane is delivered in tankers and stored on-site in methane storage tanks for use in an alternative fuelling system with new process equipment.

The suite of options create a decarbonisation pathway for the micro-breweries and distilleries as well as large industrial scale plants by offering short-term, low-cost, not-regrets wins as well as solutions require more substantial investments.

Electricity

Electricity from biomass should be combined with productive use of waste heat wherever possible in order to make most efficient use of the resource. Otherwise in the order of 75% of energy in the fuel is lost to atmosphere.

It is also important to also recognise the importance of protecting or developing natural ecosystems, such as forests, grasslands and wetlands, to capture carbon dioxide, and electricity generation from biomass must be conducted in conjunction with sustainable forestry.

At local levels, the organic fraction of municipal solid waste has a part to play in the provision of waste to energy (WtE) as the UK moves towards a more circular economy. In particular, the use of WtE is the best option currently for contaminated organic material in the residual waste fraction (recognising that keeping it uncontaminated would be better). However, one challenge is that approximately 50% of the calorific value in residual waste is fossil fuel based and therefore should be processed in a waste-to-energy plant. Another challenge is that the other potentially useful resources in the residual bin are spread beyond the grasp of future generations. We recommend that BEIS explore solutions to these challenges in the developing strategy. This movement will take many years.

Transport

Biomass will play a crucial role as a transitional energy vector for road transport whilst internal combustion engines are still on the road, and also for aviation fuel. Biofuels already make an important contribution today. Currently 5.1% of total road fuel supplied in the UK comprises of biofuels – biodiesel, bio-ethanol, biomethanol, and biomethane. Biogenic waste is the dominant feedstock for biodiesel and biomethane. For bioethanol the feedstock is predominantly wheat and sugar beet, approximately half of which is grown in the UK. The most recent DfT statistics reveal UK biofuel supply achieves an average greenhouse gas savings of 82% compared to fossil fuels.[37] 98% of biofuel feedstocks meet the sustainability criteria via a voluntary sustainability scheme. For the period 2018-19 biofuels in the UK saved approximately two million tonnes of GHG emissions, equivalent to removing more than one million cars from the road.[38] In the longer term, the contribution will be primarily in the heavy-freight, marine and aviation sectors, which are difficult to electrify with batteries being generally too heavy or too large due to their low energy density. Biofuels are projected to supply between 17% and 26% of transport energy in various European Commission 2050 net zero scenarios.[39]

Conventional ethanol (mainly from sugar and starch crops) and biodiesel from FAME are both in widespread use today in blends with petrol and diesel, typically at 5-10% by volume, although there is a lot of discussion around an E20 petrol grade. However, it should be noted 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 biogasolines, an area that is not being researched aggressively enough. Hydrotreated Vegetable Oil (HVO) is a mature technology that produces a paraffinic diesel that can be used as a 'drop-in' fuel. A more severe hydrogenation of the vegetable oil (HEFA) is the main route for producing Sustainable Aviation Fuel (SAF). The amount of conventional biofuel (i.e. from materials that could otherwise be used for food) is limited by the RTFO, although HVO and HEFA are frequently made from waste oil. Many technologies for advanced biofuels are under development around the world, with cellulosic ethanol being among the more advanced, although there are many technologies currently being developed that aim to turn non-food organic waste into transportation fuels (see examples here[40 41]).

Biomethane can be used as a drop in fuel for natural gas vehicles both CNG and LNG and its use for HGVs is growing in the UK freight sector. Fleet operators with biomethane vehicles and commitments include John Lewis Partnership, Kuehne + Nagel, Asda, Howard Tenens, DHL, Ocado, Hermes, DPD, Viola, and the urban Local Authorities of Islington Borough and Camden Borough as well as the rural unitary authority of Cornwall Council. It is estimated that approximately 600 HGVs currently operate on biomethane in the UK and it is also growing in popularity in the bus sector, due

[37] DfT (2021), 'Renewable fuel statistics 2020: Fourth provisional report'. https://www.gov.uk/government/statistics/renewable-fuel-statistics-2020-fourth-provisional-report/renewable-fuel-statistics-2020-fourth-provisional-report

[38] Zemo Partnership and CENEX (2021), *The Renewable Fuels Guide* https://www.zemo.org.uk/assets/lowcvpreports/ZEMO_Renewable Fuels Guide _2021.pdf

[39] European Commission (2021), *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy.* https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

[40] https://www.shell.com/business-customers/catalysts-technologies/licensed-technologies/benefits-of-biofuels/ih2-technology/hydropyrolysis.html

[41] https://enerkem.com/news-release/cad875-million-biofuel-plant-in-varennes/

to specific incentives via BSOG requirements to mandate the use of biomethane in gas buses. There are 350 biomethane buses in operation in cities such as Nottingham, Bristol and Reading.[42]

When used as renewable vehicle fuel in the UK, biomethane is made from a variety of organic waste materials via the process of anaerobic digestion and requires upgrading to a quality suitable for use in gas vehicles (UK suppliers include CNG Fuels, Air Liquide, Gas Alliance, BOC, Gasrec and Bennaman Ltd). Producers can inject the upgraded product into the National Gas Grid for distribution and RTFO scheme allows an equivalent mass of methane to be extracted from the grid at a refuelling station. This process is known as mass- balancing and biomethane can be dispensed as compressed biomethane gas (CBG) or liquid biomethane (LBM), though some producers, notably Bennamann Ltd, are delivering LBM via cryogenic tanker technology.

When Biomethane is sourced from agricultural manure it results in a "better than net-zero" fuel, this is because methane is released to the atmosphere when manure is stored in the open environment. Methane is ~25 times (by mass) more powerful as a greenhouse gas than carbon dioxide, so by using a high proportion of biomethane produced from manure it can achieve a negative GHG emission intensity. Under REDII the biomethane default value for manure is associated with a large methane credit of 206%; this significantly lowers the carbon intensity of biomethane production - 85gCO_2e/MJ.[43] Although the RTFO awards double RTFCs for manure sourced biomethane, it does not currently report negative renewable fuels, but this is likely to materialise in the near future.

Advanced Anaerobic Digestion (AAD), producing high quality biosolids, increased biogas production, solids destruction, and downstream emissions savings, has been widely adopted in the water industry. Several plants already produce biomethane for injection into the grid (over 35,000 m3 since 2016) and companies are looking to use biomethane for the HGV fleets where electric vehicles are unfeasible. The water industry route-map to Net Zero by 2030, and several water company strategies, identifies further movement to AAD through centralisation and upgrade of plant – with biogas to fuel efficient boilers (rather than natural gas fired combined heat and power (CHP)) or to produce biomethane for areas such as heavy goods vehicle (HGV) transport.[44] AAD of sewage sludge can produce biomethane for gas to grid/utilisation as green fuel and has potential for conversion to Hydrogen to further displace fossil fuels.

For aviation, the most optimistic view of the impact of accelerating the introduction of electric, hybrid and zero-emissions (hydrogen) aircraft in the 2035-2040 timeframe[45] 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. For a significant proportion of aviation – long range flights – SAFs appears to be the most likely technical solution.[46]

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[42] Zemo Partnership and CENEX (2021), *The Renewable Fuels Guide* https://www.zemo.org.uk/assets/lowcvpreports/ZEMO_Renewable Fuels Guide__2021.pdf

[43] LowCVP (2020), A review of well-to-tank GHG emission values and pathways for natural gas, biofuels and hydrogen. https://www.zemo.org.uk/assets/reports/LowCVP-WTT_GHG_Emission_Factors-Review_and_recommendations.pdf

[44] Water UK (2020), *Net Zero 2030 Routemap*. https://www.water.org.uk/routemap2030/wp-content/uploads/2020/11/Water-UK-Net-Zero-2030-Routemap.pdf

[45] Waypoint 2050 (2020), *Balancing growth in connectivity with a comprehensive global air transport response to the climate emergency*, Scenario 3 on p. 26. https://aviationbenefits.org/media/167187/w2050_full.pdf

[46] Mckinsey (2020), *Hydrogen-powered aviation: A fact-based study of hydrogen technology, economics, and climate impact by 2050 Hydrogen powered aviation*, prepared for Clean Skies 2 JU and Fuel Cells and Hydrogen 2 JU.

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. These are sometimes known as renewable fuels of non-biological origin (RFNBO) and can act as drop-in fuels. The manufacture of such liquid fuels requires a significant number of energy intensive processes (e.g. electrolysis, Reverse Water Gas Shift, Fischer-Tropsch etc.), to the extent that it has been estimated that five times as much energy is required on a well-to-wheels basis to produce a synthetic liquid fuel as compared to using renewable electricity directly in a battery electric vehicle.[47] This provides an important context for calibrating the ongoing importance of biofuels in transportation sectors that are hard to electrify.

Agriculture

The priorities for decarbonisation in the agricultural sector are firstly the avoidance of fugitive methane emissions from livestock farming and secondly transitioning to regenerative nature-based solutions that reverse compaction damage, improve soil biology to restore soil health (e.g. using digestate as soil conditioner), nutritional value and biodiversity, and increase the carbon sequestration a capability of the UK farming landscape.

Beyond this, agricultural operations need to be decarbonised, including reducing the sectors dependence on fossil fuel-based fertilisers and energy. Biomass in the form of animal livestock manures and other farm wastes / residues have a role to play in meeting this substantial decarbonisation challenge.

Industry

Bioplastics, bamboo and other forms of biomass may be employed in the manufacturing sector to reduce emissions. However, the UKs decarbonisation targets do not currently take account of the GHG impact of imported products, which need to change. In the case of bioplastics, full lifecycle assessment needs to be applied, and compared with polymers synthesised using renewable electricity. There should be incentives for more wood to be used in construction, locking carbon dioxide into a buildings over the long term. Production of any bio-based product for use of wood for construction should be with a view to using the wood for energy generation at the end of it useful life.

Chemicals and materials

Biomass can play a key role as a feedstock from industrial chemicals and often this can be in conjunction with fuels production (see example here[48]).

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.

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https://www.fch.europa.eu/sites/default/files/FCH%20Docs/20200720_Hydrogen%20Powered%20Aviation%20report_FINAL%20web.pdf

[47] John Holladay (2021), presentation to panel discussion on Toward Net-Zero Carbon Fuels for Transportation, SAE WCX Digital Summit.

[48] Enerkem (2019), 'W2C Rotterdam project welcomes Shell as partner'. https://enerkem.com/news-release/w2c-rotterdam-project-welcomes-shell-as-partner/

Sustainable biomass feedstocks should be prioritised for applications where there is no temporal, financially viable, or sustainable alternative. The technology is viable in the very near term. For example, biomass isn't waiting for developments in battery storage, fuel cells, hydrogen storage.

Overall, transportation is likely to be the most important sector for biomass utilisation to contribute to net zero targets in 2050, Biofuels are projected to supply between 17 and 26% of transport energy in various European Commission 2050 net-zero scenarios.[49] By 2050, this will be primarily in the heavy-freight, marine and aviation sectors which are harder to electrify and are also limited by the slower turnover of fleets reducing the ability to introduce new technology at pace.

However, when drilling into the detail, the priority use against the above criteria will depend to a certain extent on the feedstock. For example, forestry thinnings and sawmill co-products, cut grass waste, livestock manure and agricultural residues should be used for off-gas-grid heat. Liquid biofuels (including from waste products such as used cooking oil, cut grass waste and livestock manures) may be used for transport or combined heat and power engines for buildings, with priority given to transport, in the short term for internal combustion engines while in use for road transport, and potentially longer term with aviation, for greatest impact. For liquid organic co-products from agriculture and industry anaerobic digestion may be appropriate, with the potential for onsite heat and power, local production and distribution as compressed biomethane or liquid methane, or biomethane injection into the gas mains.

Chemicals are another important sector, which are closely aligned to transportation fuel manufacture, in the same way that oil refineries currently tend to produce both transportation fuels and chemicals.

Agriculture is important because increasing the carbon stock of the soil is key to net zero targets. Additionally, production of renewable natural gas can go alongside reducing methane emissions from manure.[50]

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?

The priority uses of biomass should be based on lifecycle impact and availability of alternatives for each application. Lifecycle impact will vary in accordance with process energy input, grid electricity mix and land use impact, amongst other factors. Priority should be given to applications for which there are no clear or viable sustainable alternatives.

It must also be recognised that the priority uses will change over time. For example, biomass make a contribution to the decarbonisation of aviation in the long term, but near-term policy incentives should recognise where it can make the biggest impact today, including in road transport.

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[49] European Commission (2021), *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy.* https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

[50] FT (2020), 'Methane from manure offers green fuel revenue for US farmers'. https://www.ft.com/content/773b8934-51a7-11ea-a1ef-da1721a0541e

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?

Not answered.

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?

The Government can incentivise the use of biomass by encouraging a market on the demand side for high-priority applications that drive demand for the development and deployment of the supply side technologies in the prioritised supply-application matches. For example, decarbonising rural off-gas grid heat is potentially a high priority application and in this regard the Government needs to support the use of biomethane for decarbonising heat in rural off the gas grid properties. However, on the demand side, BEIS's current plans for the Clean Heat Grant Scheme will not support biogas combustion by households for heat decarbonisation and on the supply side the Green Gas Support Scheme will only be available to AD operators that have a gas main injection point. To stimulate initial market uptake of off-gas-grid biomethane heating solutions, the combustion of biogas in homes for heat decarbonisation needs to be supported through an appropriate financing mechanism such a householder / property owner grant scheme that provides a partial contribution towards the capital cost of equipment purchase and installation. Supporting the combustion of biogas through the Clean Heat Grant Scheme would help incentivise the growth of off-gas-grid decarbonised heat applications and their supply chains to meet demand for the building-level technologies, as well as the production and distribution of locally sourced biogas in the UK's rural off-gas-grid communities, ahead of the future phase-out of high carbon fossil fuel heating within 15 years (Source: UK Government's 'The Ten Point Plan for a Green Revolution'). From an engineering perspective, BEIS can help not only through financial incentives but also by ensuring that a supportive regulatory environment is put in place for the safe use of biogas for heat in domestic dwellings.

On the priority supply-application match supply side, Government needs to incentivise the development of novel and innovative approaches not only in technology but also in business models. A good example of the latter is Cornwall Council's pilot of a new approach to rural biomethane production on six dairy farms in their Council Farm Estate which, if successful, is intended to lead to a wider roll-out across the county. In this model of public funding being used to leverage and encourage private sector investment, the Council is investing in upgrading the slurry lagoons of the 6 farms engaged in the pilot and commercial arrangements have been put in place with the technology processing solutions provider and the Council's third-party vehicle fleet supplier to use the resulting fuel for HGV and mobile equipment. Similarly innovative investment models to build business cases could be instigated by other local authorities and public bodies for deployment of the supply side technology through public funding leveraging and encouragement of private investment.[51]

[51] Energy Now (2020), 'Trailblazing farms to trial manure slurry as an alternative green fuel'. https://energy-now.co.uk/trailblazing-farms-to-trial-the-production-of-manure-slurry-as-an-alternative-green-fuel/

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

In parallel with the required financial incentivisation, the UK Government can help with market addressing actions including, for example, ensuring a supportive regulatory environment for the safe use of biomethane for space and water heating in off-gas-grid homes. Although from an engineering perspective it is relatively straightforward to technically achieve this, existing gas regulations do not allow the use of biomethane as a substitute for natural gas or botted LPG in homes and commercial buildings. Indeed, the current regulatory environment effectively restricts the deployment of replacement systems to CHP applications where bioheat is provided into a building and does not therefore recognise cases where oversupply of electricity will result and potentially innovative solutions that would enable biomethane to be used directly in converted natural gas (or LPG, etc.) fuelled boilers.

If it can be demonstrated that there are biodiversity advantages, or other benefits, with certain types of biomass compared to current land use, then potentially this could be reflected in support provided to farmers. This would be consistent with the Government's current approach to reforming farm subsidies laid out in the Path to Sustainable Farming report.[52]

There needs to be greater tax on fossil fuels to reflect external costs and bring the relative economics between biomass and fossil fuels into line. Biomass should be subject to the same external costing. Greater taxation on waste would also encourage energy production rather than disposal.

If it can be demonstrated that there are biodiversity advantages, or other benefits, with certain types of biomass compared to current land use, then potentially this could be reflected in support provided to farmers.

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

Local air quality will be an important parameter when deciding on the optimum end use of biomass. Some solid biomass uses will increase particulate matter generation compared to fossil fuels, conversely liquid biofuels with lower aromatic content will have reduced particulate matter generation.

Aviation offers other benefits obtained from the choice of biofuel through reduced global warming over and above the net CO_2 effect as a result of reduced contrail formation as a result of the lower particulate matter (see answer to question 3 for explanation and references).

Supply Chain sustainability

How can we strengthen our sustainability criteria? We welcome evidence and views on:

15. Are our existing sustainability criteria sufficient in ensuring that biomass can deliver the GHG emission savings needed to meet net zero without wider adverse impacts including on land use

[52] DEFRA (2020), *The Path to Sustainable Farming: Agricultural Transition Plan 2021 to 2024*. https://www.gov.uk/government/publications/agricultural-transition-plan-2021-to-2024

and biodiversity? How could they be amended to ensure biomass from all sources supports wider climate, environmental and societal goals?

The existing sustainability standards BS EN 16214 and ISO 13065 cover biofuels sustainability criteria, but there is a case for updating them in line with recent developments in the market and research. In the case of BS EN 16214, the focus was on the Renewable Energy Directive, and with the UK now being outside the European Union, there is a case for reviewing its application. The IMechE was represented on the BSi standards committee overseeing the sustainability criteria (PTI/20), and it is recommended that if the Government wants to act to update the sustainability criteria, then it is done through the BSi. The use of the standards should also be reviewed and encouraged further.

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

Not answered.

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

Not answered.

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

Not answered.

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

Not answered.

Accounting for Emissions – How can we improve the way we account for biomass emissions?

We welcome evidence and views on:

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

Not answered.

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

Not answered.

Innovation – What technological or systems developments do we need to see?

We welcome evidence and views on:

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

For the production of biomethane from sewage sludge the priority end uses should be

- Advanced anaerobic digestion – already quite well proven.
- With conversion to methane – use of membranes results in ~ 99% methane recovery, lower heating, footprint than water scrubbing, and potential for CO2 recovery Needs higher pressure, more carbon to reduce fouling.
- CO_2 recovery – Severn Trent trialling plant to make pelletised fertiliser from CO2 from CHP or biomethane upgrader.
- Methane reformation to hydrogen for fuel – still under development but potentially useful longer term.
- Transport: firstly as a transitional technology to reduce emissions from internal combustion engines for land transport and then for gas turbines in aviation in the longer term.

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?

Advanced technologies of these types have been proposed for use with sewage sludge for many decades but have not proved commercially successful due, typically, to issues of scale, associated costs (particularly if processing to dry state), and the remaining residues, despite this being a relatively consistent feedstock.

There have been development and operational challenges with gasification and pyrolysis. Pilot plants have been made to work but have not been scaled or automated as much as projected, in part due to problems in dealing with tars, requiring difficult and constant cleaning of the plant. Technical and commercial barriers remain.

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?

Not answered.

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

Not answered.

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

Not answered.