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Submitted to **The Role of Biomass in Achieving Net Zero - Call for Evidence**
Submitted on **2021-06-15 21:59:14**

About the Survey

About you

1 What is your name?

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3 Are you happy for your response to be published?

Yes

4 Are you responding:

on behalf of an organisation

About your organisation

5 What type of organisation are you responding on behalf of?

Please choose one of the options from the drop down list:
Small or micro business (less than 50 employees)

6 What sector is your organisation primarily active in?

Please enter your response here :
AgriTech

7 If you wish, please provide your organisation's name.

Please enter your response here :
Bennamann Limited

Analysis of responses

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

Yes

Chapter 1: Supply

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?

Please enter your answer here :

a) waste

Grass Cuttings

An estimated 26% of the world's total land area is grassland and as much as 36.2% of the total in the UK, which being temperate is particularly rich in grass (https://www.globalforestwatch.org/). 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 (https://www.sciencedirect.com/science/article/pii/S1364032116002306). Where the local logistics allows there are some examples of grass cuttings being used as a feedstock for large scale anaerobic digesters (https://www.sciencedirect.com/science/article/pii/S0961953420301045), but these are very limited in number and the resulting biomethane is either used to generated 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 (https://www.ecotricity.co.uk/our-green-energy/our-green-gas/our-green-gasmills ; https://www.fgr.co.uk/our-ethos/greening-up-football) .

Generally, to-date grass cuttings have been perceived as something to be disposed of, often at a cost to the land manager, rather than a valuable biomass resource for processing, and consequently a detailed comprehensive study of the land area, grass volumes and energy yield potential of the UK's managed grassland has not been carried out. However, it is possible to gain a 'rough' sense of the scale of the resource by considering the number of managed facilities across the nation. For example, there are 40,000 football pitches (https://web.archive.org/web/20200607130021/ ; https://footballcollective.org.uk/2020/05/19/there-are-too-many-football-pitches-in-england/) and 2099 registered rugby clubs (https://en.wikipedia.org/wiki/Rugby_union_in_England), 32,000 school playing fields (https://publications.parliament.uk/pa/cm200405/cmselect/cmcumeds/507/5040515.htm) and 1188 golf courses (https://www.statista.com/topics/3199/golf-in-the-united-kingdom-uk/) and roadside verges represent 1.2% of Great Britain landmass with 27% frequently mown (https://www.exeter.ac.uk/research/news/articles/roadvergesprovideopportun.html ; https://www.sciencedirect.com/science/article/pii/S0961953420301045). The potential energy generated from grass cuttings taken from this managed land could be significant. For example, England's golf courses account for 2% (277,000 Hectares) of the country's land and, based on the energy yield figures presented in a recent study by Atkins et al (https://doi.org/10.3390/en14040806), if harvested and processed efficiently could produce 969,000,000 kg of methane annually. This would be sufficient to fill each of the UK's 40 million cars twice over. Given this significant potential energy yield, Bennamann recommends that a detailed and technically robust peer-reviewed 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

Organic biomass matter (spent malt, hops and botanicals) residual to the production processes of brewing and distilling represents another underutilised 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.

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. Bennamann therefore recommend that a detailed and technically robust assessment study is supported by Government as part of its Biomass Strategy.

c) agriculture

About 90 million tonnes of manures and slurries are estimated to be collected, stored and spread back to land untreated in the UK (http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14500). Processing this material via an AD plant could potentially deliver 17.1 TWh of biomethane, mitigating 3.4 $MtCO_2e$ emissions from the displacement of fossil natural gas [footnote: calculation by ADBA and based on average biogas yield of 32m3 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.

Please attach any relevant documents to support your response to this question :
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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 greenhouse gas (GHG) emissions, air quality, water quality, soil health, biodiversity, food security, land availability, etc?

Please enter your response here :

Potential future costs

Brewing and Distillery Waste
Bennamann has undertaken a BEIS funded feasibility study ("The Bennamann-Atlantic Fugitive Methane Green Distillery Solution" funded by BEIS Green Distilleries Competition: Phase 1) in which three distinct energy switching opportunities were explored for replacing the national grid gas (NGG) or liquid petroleum gas (LPG) typically used on these sites with methane derived from the waste (residuals) of the brewing and distilling process (at any site irrespective of location, size, and direct heat processes used). The options were:
1) Blended switching – involves blending biomethane with LPG. This is a low-cost interim step to allow immediate reductions in emissions via blending carbon negative fugitive methane with LPG. This approach is a bolt-on solution to existing fuelling systems and requires minimal capex outlay (~£3,644) and minimal infrastructure upgrades (will operate using existing burners, regulators). The bolt-on solution (biomethane cylinder and gas mixing solution) will be designed and tested as part of a follow-on project proposed to BEIS.
(1) 100% Compressed biomethane switching. This solution is aimed at direct replacement of LPG with biomethane. It involves creating a DSEAR-compliant fuel safe area on site (~£5,450). This solution will be designed and demonstrated with the Atlantic Distillery in Cornwall as part of a follow-on project proposed to BEIS.
(2) 100% Liquid biomethane switching. This solution is aimed at replacing NGG and creating an off-grid solution for small to large distilleries (~£111,150). It is proposed that this option will be conceptually designed as part of a follow-on project proposed to BEIS. It is recognised that the commercialisation of this solution is dependent on large infrastructure investment, so is further to the right on a potential switching roadmap.

The key finding of the feasibility study was that the direct replacement of either NGG or LPG with methane derived from the waste (residuals) of brewing and distilling is the most advantageous method of fuel switching at present, due to the lack of efficient/cost-effective generators/CHPs for indirect switching approaches.

Agriculture
The launch of the New Holland methane powered gas tractor in 2021 presents farmers with the opportunity to replace the red diesel used as a fuel source for agricultural tractors (https://www.fwi.co.uk/machinery/technology/is-biomethane-about-to-become-more-commonplace-on-uk-farms). Before mechanisation, farmers would set aside 20% of their land to grow the fodder required to provide 'fuel' for the draught horses used to work the land. In the same way, farmers could now be justified in setting aside their poorest producing land to generate a sustainable plant-based fuel to provide energy for their farm machinery. For example, the use of nitrogen fixing herbal leys can help facilitate regenerative agriculture and simultaneously provide a sustainable energy source without the need for artificial fertilisers. Through the use of a low cost sealed slurry lagoon, these plants can be provide a supplement to existing farm manure and biomass waste streams to effectively take the farm off-grid from an energy perspective and provide the farm businesses with an additional revenue that can fully fund the investment through reduced energy costs. This approach would provide the opportunity to improve soil health, remediate compaction and deliver improved soil carbon sequestration without the need for artificial fertilisers, resulting in further cost savings.

By using a sealed lagoon that minimises rain ingress, significant fuel and vehicle costs and manpower savings are achieved through the reduced need for slurry movement and spreading.

Data gathered by Bennamann at Chynoweth Farm in Cornwall, which has a sealed slurry lagoon that captures and utilises the fugitive methane generated by the anaerobic digestion of the manure indicates a return on investment period of between 4-6 years for such a system.

Key environmental and land-use impacts (positive or negative)

GHG emissions

Grass Cuttings
Regimes currently used for grass management typically 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 NOX 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, Bennamann recommends the use of small-scale on-site plant that produce energy for on-site use and local distribution (preferably in liquid fuel form to optimise energy density relative to product volume).

Agriculture
Greenhouse gases (GHG) of approximately 6.0 MtCO2e are estimated to be released to the atmosphere every year as a result of the current practice of spreading untreated manure on UK farmland (https://adbioresources.org/adba-launches-biomethane-the-pathway-to-2030-report/). 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 MtCO2e being emitted annually in the form of methane (https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf). Covering manure slurry lagoons and processing the emissions to extract the methane, CO_2 and 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.

Air quality

Grass Cuttings
Grass processing business models 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 nitrous oxide, N_2O) and the road congestion they can cause. and ecological damage etc. By processing grass onsite at small-scale with minimal vehicle movements, as deployed through the Bennamann grass-to-gas system and business model, air quality degradation can be minimised.

Agriculture
Ammonia emissions reduction methods currently employed in livestock agriculture 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.

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 (ie 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 around 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.

Soil Health
Biomethane production from manure slurry-based AD plant at the farm-scale, for on-site energy provision and local distribution, has the potential to help improve the overall sustainability of farming and facilitate a regenerative approach to soil health. In this regard, Bennamann in partnership with Chynoweth Farm in Cornwall is demonstrating that through biological post-processing of the resulting digestate, a regenerative replacement for artificial fertiliser can be produced that improves nutrient cycling and soil biology. Implementing the latter can not only restore and improve soil structure, health and productivity (https://tevi.co.uk/improving-soil-health-in-cornwall-for-landowners-and-farmers/ ; https://vimeo.com/458903162).

Post processing of digestate to reduce the soluble and volatile nutrients that cause the pollution issues has been developed by Bennamann in collaboration with Chynoweth Farm Partners for practical deployment. We are trialling techniques that use the nutrients within digestate to culture a community of soil beneficial microorganisms. This, when combined with a holistic approach to agriculture, demonstrates a range of environmental improvements while reducing the requirement for artificial inputs and improving profit margins. Ammonia and free nitrogen are valuable commodities in their own right across a wide range of sectors and so there are financial as well as environmental incentives for its capture. The use of a sealed slurry lagoon system provides farmers with an economic opportunity to exploit this by-product. This can be achieved firstly through savings made through a reduced need for nitrogen import to the farm (artificial fertilisers) and secondly through its optimal management. We believe the use of sealed slurry and other farm waste handling is an approach that should be adopted across all livestock farms. In doing so it removes the reliance on traditional large scale anaerobic digestion operators that often see the return of digestate to the land as a low-cost way to deal with a waste stream. To a farmer trying to build a sustainable and circular economy business model it is alternatively seen as being a valuable asset.

The work at Chynoweth, which is part funded by the European Regional Development Fund (ERDF) (https://www.cornwallislesofscillygrowthprogramme.org.uk/projects/energy-independent-farming/ ; https://bennamann.com/energy-independent-farming/), seeks to understand how integration of this transformative holistic system into a real-life environment of a working farm business will facilitate a commercially viable sustainable regenerative farming model.

Small scale field trials have been carried out at Chynoweth Farm to assess how subsoiling combined with deep injection of the enhanced digestate and concurrent cover crop establishment can eliminate compaction, restore soils, and prevent the issue reoccurring. This is part of a longer-term trial developing a low disturbance system of growing both perennial and annual forge crops. The trial has shown that this approach can provide a valuable tool to tackle the challenging problem of legacy soil compaction, as well as mitigate rainfall run-off, while simultaneously reducing production costs.

In parallel, Chynoweth Farm and Bennamann will be working with our world-class research institution partners, including University of Exeter, Duchy College, Plymouth University and Roehampton University, to undertake rigorous scientific analysis of microbial soil health based upon biologically enhanced digestate amendments across two proposed test sites – one at Chynoweth Farm and the other at Duchy College's Future Farm.

Please attach any relevant documents to support your response to this question:
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4 How do we account for the other (non-greenhouse gas) benefits, impacts and issues of increasing our access to, or production of domestic biomass (e.g., air quality, water quality, soil health, flooding, biodiversity)?

Please enter your response here :

Please attach any relevant documents to support your response to this question:
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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.

Please enter you response here :

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 (as discussed in our response to question 2) the maintenance of roadside verges, community and school playing fields, golf courses, country estates etc. In many cases these sources of energy are relatively small, being at a modest farm or village/community scale, but when efficiently sourced, processed 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 off-power-grid electricity (e.g for electric vehicle charging or domestic combined heat and power, CHP), they represent a considerable placed-based opportunity for the commercially viable deployment of affordable zero emissions energy.

Bennamann has developed processes to optimise energy production from grass cuttings on a local scale, enabling the exploitation of this previously otherwise inaccessible waste feedstock. Our approach is to undertake anaerobic digestion of the material on the site where the grass cuttings are produced using an innovative yet simple, specifically designed low-cost AD unit. The resulting biogas is processed (upgraded) in-situ to liquid biomethane and stored using our novel miniaturised cryogenic system. Once full storage capacity is reached the liquid product is collected, aggregated with that from other small-scale production sites and sold by us into the segment of the energy market which attracts the highest value. In return the rural community or managed grassland site owner receives a share of the revenue generated by the sale. Co-products of the process include a nutrient rich digestate as well as CO2, the latter can be liquefied, aggregated and sold into the merchant market, for example for use in the food and drinks processing sector or other industrial segment, and the digestate is either applied back to the grassland as a replacement for manufactured fertilizer, or it can be further processed to make a rich soil enhancer.

Similarly, Bennamann has developed an innovative technical and business model approach to enable small-scale livestock farms to become local energy providers based on processing the animal manure slurry as well as energy independent. For example, in rural Cornwall our Energy Independent Farming project, which is part-funded by the European Regional Development Fund (https://www.cornwallislesofscillygrowthprogramme.org.uk/projects/energy-independent-farming ; https://bennamann.com/energy-independent-farming ;), is demonstrating the use of livestock manure to establish energy independent dairy farming (including self-sufficiency in power, heat and fuel for farm machinery) and simultaneously generate farm business income through local sales of surplus fugitive methane, either as compressed gas or liquid fuel (https://bennamann.com/press-cuttings/earning-extra-from-slurry-gas/ ; https://www.fginsight.com/news/news/income-from-slurry-gas-110928). The approach also delivers saving on farming input costs in addition to those associated with energy bills, such as reducing fertiliser bills by using the soil restoring post-processed digestate to underpin regenerative practices (https://vimeo.com/458903162).

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 (https://www.parliament.uk/documents/commons-library/Brexit-UK-agriculture-policy-CBP-8218.pdf). Bennamann estimates that through processing livestock manure to produce biomethane a dairy farm with 75 cows could save over £10,000 on fertiliser bills while potentially earning around £11,500 per annum from the local sale of surplus energy production; 250 cows could save £35,000 on fertiliser and deliver £23,000 respectively (https://www.interregeurope.eu/agrores/events/event/3608/slurry-pit-gas-collection-webinar/). 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 (https://www.ofgem.gov.uk/data-portal/all-charts/policy-area/gas-wholesale-markets).

By supporting the deployment of these types 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.

The roll-out of a local supply of biogas sourced from farm manure slurry and processed to biomethane in small-scale upgrading plants is scalable and viable in the UK. For example, there are circa 600 dairy farmers alone in the rural county of Cornwall (131,000 dairy cattle – 6% of the national herd), many of whom are off-gas-grid and subject to power grid constraints. Of these, there are an estimated 120 farmers in a position to adopt Bennamann's technologies and business models in the short-term, including the 58 dairy farms in Cornwall Council's own Council Farm Estate. Indeed, in the case of the latter, the Council has already begun a pilot installation on 6 of the dairy farms in the Estate which, if successful, is intended to lead to a wider roll-out across the county (https://bennamann.com/dl/6-FarmPilot-Cormac; https://energy-now.co.uk/trailblazing-farms-to-trial-the-production-of-manure-slurry-as-an-alternative-green-fuel/).

In terms of scalability across the UK, there are circa 2,000 dairy farms in the South-West and around circa 35-40,000 cattle farms across the UK, of which 71% (around 29,000 holdings) have herds with less than 150 cattle (GOV.UK, 2015). With current farming practices, current AD costs and current level of low-carbon energy incentives, only 3.5% of UK dairy livestock would be linked to economically viable on-farm plants (https://www.sciencedirect.com/science/article/abs/pii/S0301421513006162). For example, there is a total of only 45 small scale ADs plants in the UK (ABDA, 2015). Alternatively, we estimate that Bennamann's farm-scale biogas sourcing (AD), processing, storage and distribution technology would enable 71% of UK dairy farms to become economically viable local zero-carbon energy producers.

Please attach any relevant documents to support your response to this question:
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6 What are the main challenges and barriers to increasing our domestic supply of sustainable biomass from different sources?

Please enter your response here :

Grass Cuttings

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. Bennamann therefore recommends the use of small-scale on-site plant that produce energy for on-site use and local distribution in liquid fuel form to optimise energy density relative to product volume, such as those we have developed and described in our response to question 5.

The local processing of grass cuttings into the high value outputs, i.e., liquid methane and liquid CO2 is both technically and commercially viable. The main challenges are around the logistics and a management associated with the plant's operation, in particular the removal of the need for skilled operators onsite and the need to place the biogas processing equipment onsite. It may prove difficult, for example to place a grass to gas system on a very large school playing field in a residential setting due to perceived safety concerns, despite the site being capable of providing significant financial return to the community. Other sites such as national parks, golf courses and airports will be more accessible as it is likely that a suitable location can be found for the equipment in a remote corner.

Minimal interaction must take place between the groundsman / landscape operative and Bennamann's technology. This will be achieved by remote monitoring and control carried out using the Internet of Things in combination with space assets. This approach is being adopted in the Bennamann sealed manure slurry lagoon operational model and demonstrated in an ESA funded project. The farmer's interaction with the system ends at the point where the slurry enters the lagoon and all other operations are monitored and controlled remotely, including the scheduling of liquid methane collection and maintenance and servicing visits, and fault detection and diagnostics.

In the grass to gas model, the equipment will often be in a public environment and the high methane potential of grass (six time that of manure slurry) dictates that storage gaseous form is not a viable option. Instead, the gas must be processed into liquefied form in real time. This introduces two challenges. Firstly, the cost of the equipment must be reduced to make the installation and its running commercially attractive and secondly, the equipment needs to be provided a safe and secure operating environment.

Bennamann have tackled the first challenge through a very simple gas processing system design (Patent Pending) that uses liquid nitrogen as the cooling source. The liquid nitrogen can be produced locally at low cost using renewable energy, such as wind or solar, accessed at times of surplus supply, This is provided to the grass to gas processing site as and when it is required. The use of liquid nitrogen also offers an opportunity for the site to participate in energy storage services to the power grid, as a highly density energy store that can be expanded back to high pressure gas and used to drive an electricity generator (as described in our response to question 8).

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 Bennamann recommends the re-classification of leachate as a product (supplement) that enhances biomethane production and adjusts the pH of agricultural slurry waste lagoons. Alternatively, waste handling licences need to be simplified to enable the operators to co-digest feedstocks in lagoons.

Agriculture
As discussed in our response to Question 5, across the UK, there are circa 35-40,000 cattle farms but 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 (https://www.sciencedirect.com/science/article/abs/pii/S0301421513006162). This situation acts as a significant barrier to increasing the domestic supply of an underutilised and potentially energy rich biomass in the form of livestock manure.

The main barriers to the widespread domestic deployment of biomethane producing AD plants include:
1. The high costs of UK AD plants (in the UK most plants are designed, installed, and operated by European companies).
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.

To overcome barriers 1 – 7, Bennamann have developed a suite of technologies covering the entire supply chain from AD to consumer application that facilitate sustainable, commercially viable off-grid small-scale biogas sourcing, processing/upgrading and storage, as well as distribution and consumer use without the requirement of a gas grid. We see using AD as the financial incentive for farmers to seek out sources of nutrients which will not only provide biomethane for gaseous or liquid fuel energy products, but also contribute as a component in a larger system. A system that aids agriculture’s move to a more sustainable regenerative circular economy model by providing a responsible low risk nutrient collection, storage, and processing solution which enables efficient and viable nutrient cycling.

Barrier 8 is for the UK Government to remove through support mechanisms. 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. Bennamann 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.

Bennamann regards as 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 (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 N2O) 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.

Please attach any relevant documents to support your response to this question:
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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?

Please enter your response here :

Please attach any relevant documents to support your response to this question:
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Chapter 2: 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 (chapter 1), to contribute towards the UK's decarbonisation targets, and specifically in the following sectors: a) Heat, b) Electricity, c) Transport, d) Agriculture, e) Industry, f) Chemicals and materials, g) Other?

Please enter your response here, making a clear reference to which sector(s) you response relates to:

I Heat

Residential and None-Residential Buildings

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 circa 167,000 homes in Scotland and 166,000 domestic and non-domestic properties in Cornwall [54% of total stock]) are in rural locations, typically use bottled fossil fuel derived gas (ie 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 (https://www.cas.org.uk/publications/hot-grid ; https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings-consultation/).

The use of electrically powered heat pumps in such settings 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 (ie 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 (https://www.cas.org.uk/publications/hot-grid) 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 (Cornwall Council, BEIS 'Future Support for Low Carbon Heat Consultation' response).

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 (BEIS, Future Support for Low Carbon Heat: Consultation, April 2020), 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 (BEIS, Future Support for Low Carbon Heat: Consultation, April 2020) 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.

Biomethane delivered in compressed gas or liquid fuel form for combustion to produce heat for 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). In particular, solutions should focus on the use of such biomass sources to supply local CHP as this is more efficient than burning gas in a boiler. A CHP combined with a heat pump can provide 200% of the calorific value of the methane and works really well for decarbonising heat in large properties such as schools and government buildings etc. We can also provide an alternative to propane and/or oi through local heat networks, for example on housing estates or industrial parks.

Bennamann therefore recommends that BEIS explores 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 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).

Distillery and Brewery Processs

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. Bennamann proposes that 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.

This 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.

II Electricity

There are two capability gaps in the UK's electricity supply and distribution infrastructure where the the use of liquid biomethane produced from biomass can play a crucial role in achieving net zero.

Firstly, when there is sufficient availability, intermittent renewables such as wind and solar have shown that they are able to supply the bulk of the UK's power needs. However, the nation has insufficient long terms energy storage capacity and instant electrical generation capability to mitigate the impacts of the intermittency inherent in the supply of power from renewable resources.

Liquid biomethane has a higher mass energy density than diesel and can be efficiently used to fuel megawatt scale stand-by generator sets, based on existing methane fuelled internal combustion engine technology, for the mitigation of intermitancy. These ‘gen-set’s can be situated at solar and wind farms utilising national grid connections. Likewise they can be positioned at high capacity access points in the grid. The use of Liquid Air Energy Storage (LEAS) systems working alongside methane fuelled gen-sets can use excess renewable power to produce liquid air (or alternatively compressed air) that can be readily stored at solar and wind farms. The waste heat from the liquid biomethane fuelled electric generators can be used to improve the end-to-end efficiency of the LEAS system by heating the vaporised pressurised gas prior to expanding. Recent advances in split cycle internal combustion heat engines with near zero exhaust emissions (developed Dolphin Ltd as part of a BEIS Advanced Propusion Centre project) are showing mechanical efficiencies of 60%, further improving roundtrip efficiency.

Secondly, range anxiety associated with electric vehicles will persist until there is widespread availability of fast chargers. The current UK grid is power constrained in many areas, particularly in rural locations, and suffers connectivity issues. Upgrade costs are prohibitive nd potentially limit geographically the availability of fast charging capacity. Off-grid mobile chargers based on liquid biomethane fueled electricity generators have the potential to be a disruptive solution. These can be moved as and when required, for example to festivals and events as well as seasonal holiday traffic routes and tourist areas normally sparsely populated out of season. The biomethane use as a fuel can be produced locally from sustainably resourced grass and agriculture waste feedstocks as described in our response to questions 5 and 6. In addition, where convenient, the waste heat produced in the power generation can be recovered in a CHP configuration and used to deliver heat to schools, hotels, leisure centres, community facilities etc. The appetite for such a solution from the retail sector has been tested with national supermarkets through customer engagement by Bennamann and market interest is high.

Bennamann recently secured £668,577 of European Regional Development Funding (ERDF) under Priority Axis 4 to support a truly ground-breaking project in which farm sourced liquid biomethane will be used to fuel mobile off-grid electric vehicle (EV) charging units, with waste heat recovery for use locally in space and water heating. This pioneering integrated energy-transport-heat project will demonstrate the application of the technology in a rural domestic dwelling, a rural car park with adjacent community (Women’s Institute) hall, and in a rural business setting on a working farm. Post-project, the development will deliver a step change to the roll-out of EV charging infrastructure, particularly in off-power-grid or power grid constrained rural locations, as well as help support a transition to more sustainable livestock farming and green recovery led economic growth through the creation of clean energy jobs and business activity.

Bennamann has also recently been awarded an InnovateUK project to supply a fast charging solution to a UK HGV haulage company that wishes to start using LGV EVs but has major grid constraints at it Headquarters.

III Transport

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 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. (https://www.zemo.org.uk/assets/lowcvpreports/ZEMO_Renewable Fuels Guide _2021.pdf).

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. Producers can inject the upgraded product into the National Gas Grid for distribution and the 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, however Bennamann are delivering biomethane fuel direct to customers via cryogenic storage tank technology, thereby providing an off-gas-grid solution and enabling a local clean energy revolution (
https://www.uk100.org/projects/knowledgehub/cornwall-biomethane-pilot ;
https://www.rsta-uk.org/wp-content/uploads/2021/05/RSTA-Renew-Issue-11-210507.pdf ;
https://energy-now.co.uk/trailblazing-farms-to-trial-the-production-of-manure-slurry-as-an-alternative-green-fuel). .

Biomethane sourced from agricultural manure 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 -85gCO2e/MJ (https://www.zemo.org.uk/assets/reports/LowCVP-WTT_GHG_Emission_Factors-Review_and_recommendations.pdf). Although the RTFO awards double RTFCs for manure sourced biomethane, it does not currently report negative renewable fuels, this situation needs to change in the near future.

IV Agriculture

In the agricultural sector the priorities for decarbonisation 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, nutritional value and biodiversity, and increase the carbon sequestration a capability of the UK farming landscape.

Agricultural operations also need to be decarbonised, including reducing the sectors dependence on fossil fuel-based fertilisers and energy. As described in our response to questions 3, 5 and 6, biomass in the form of animal livestock manures and other farm wastes / residues have a potentially significant role to play in meeting this substantial decarbonisation challenge through the on-site supply of ‘better than zero’ emissions energy for off-gas-grid heat, off-power-grid electricity, combined heat and power (CHP), electric charging of non-road mobile machinery and methane fuel to power large heavy agriculture machinery such as tractors.

In agriculture, there are currently no viable or near-term practical electric or hydrogen solutions to the fossil fuel powered tractor and a biomethane fuelled tractor solves this problem, Indeed, this solution becomes particularly attractive when deployed in association with the utilisation of a highly efficient fugitive methane capturing and processing technology such as that developed by Bennamann to deliver energy while simultaneously tackling the issue of emissions from livestock manure and delivering a plethora of environmental and ecological benefits (as described in our response to question 3). Incentivising the adoption and widespread deployment of these combined technologies should therefore be a top priority.

In 2021, agricultural machinery manufacturer New Holland will bring its methane powered tractor to market, enabling livestock farms to meet all their energy and fuel needs from the anaerobic digestion of its livestock manure waste (
https://www.fwi.co.uk/machinery/technology/is-biomethane-about-to-become-more-commonplace-on-uk-farms;
https://bennamann.com/energy-independent-farming/).

Please attach any relevant documents to support your response to this question:
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9 Out of the sectors listed in the previous question, 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.

Please enter your response here :

The UK's limited supply of sustainable biomass should be prioritised for applications where there is no temporal, financially viable, or sustainable alternative. The technology is viable in the very near term. Biomass isn't waiting for developments in battery storage, fuel cells, hydrogen storage. In many case, discussed in our response to questions 5, 6 and 8, biomethane production and use is the best option in this regard but is too readily dismissed by HM Government in favour of a focus on electrical and hydrogen delivery vectors.

Please attach any relevant documents to support your response to this question:
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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?

Please enter you response here :

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11 When thinking of Bioenergy for Carbon Capture and Storage (BECCS) deployment, what specific arrangements are needed to incentivise deployment, compared to what could be needed to support other Greenhouse Gas Removal (GGR) and Carbon Capture, Utilisation and Storage (CCUS) technologies as well as incentivising wider decarbonisation using biomass in the priority sectors identified?

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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?

Please enter your response here :

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 (UK Government, 'The Ten Point Plan for a Green Revolution'). 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 6 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. (
https://www.uk100.org/projects/knowledgehub/cornwall-biomethane-pilot ;
https://www.rsta-uk.org/wp-content/uploads/2021/05/RSTA-Renew-Issue-11-210507.pdf ;
https://energy-now.co.uk/trailblazing-farms-to-trial-the-production-of-manure-slurry-as-an-alternative-green-fuel).

Please attach any relevant documents to support your response to this question:
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13 Are there any policy gaps, risks or barriers hindering the wider deployment of biomass in the sectors identified in question 8?

Please enter your response here :

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 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 Combined Heat and Power (CHP) applications where bioheat is provided into a building and does not therefore recognise cases where oversupply of electricity will result or support potentially innovative solutions that would enable biomethane to be used directly in converted natural gas (or LPG etc) fuelled boilers.

If 'public goods' benefits are associated with certain types of biomass compared to current land use, such as the feedstock set-aside proposal we make in our response to question 3, then this would be consistent with the Government’s approach to farm subsidy reform a(https://www.gov.uk/government/news/government-unveils-path-to-sustainable-farming-from-2021).

Please attach any relevant documents to support your response to this question:
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14 How should potential impacts on air quality of some end-uses of biomass shape how and where biomass is used?

Please enter your response here :

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Chapter 3: Sustainability and Accounting for Emissions

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?

Please enter your response here :

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

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

Please enter your response here :

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

Please enter your response here :

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

Please enter your response here :

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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?

Please enter your response here :

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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 CO2 are being accounted for in different countries?

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Chapter 4: Innovation

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?

Please enter you response here :

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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?

Please enter your response here :

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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?

Please enter your response here :

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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?

Please enter your response here :

Please attach any relevant documents to support your response to this question:
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26 What other innovation needs to take place in order to reduce life cycle green house gas emissions and impacts on air quality in biomass supply chains? Are all of these easily achievable, and if not, what are the barriers?

Please enter your response here :

Please attach any relevant documents to support your response to this question:
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