Bioenergy Review (2018) - Call for Evidence

Please answer only those questions where you have particular expertise and are able to provide links to supporting evidence.

In 2011 the Committee on Climate Change (CCC) published a Bioenergy Review to provide an assessment of the potential role of bioenergy in meeting the UK's carbon budgets. The Bioenergy Review drew on the best available evidence to address questions relating to the sustainability of bioenergy, lifecycle emissions, resource availability and best-use across the economy. It highlighted the importance of bioenergy for meeting the UK's climate change targets and made recommendations for tightening the sustainability standards for bioenergy resources - recommendations that were subsequently adopted by the UK Government.

The CCC is now planning to update its work on bioenergy, culminating in a new Bioenergy Review to be published in Autumn 2018. This will consider the latest evidence to provide an updated view on the role of bioenergy in decarbonising the UK economy through to 2050. Key themes to be explored include sustainability and certification, GHG emissions accounting, developing sustainable supply, non-energy uses of bioenergy resources, and transitions to future best-uses of bioenergy resources. We will identify recommendations for further action and aim to develop indicators to allow the CCC to monitor progress over time.

Stakeholder engagement will underpin the 2018 Bioenergy Review. This Call for Evidence is the first formal step in the engagement process. It is intended to provide all stakeholders with the opportunity to input to the CCC's work and to enable the CCC to draw on the full range of up-to-date evidence relating to bioenergy production, sustainability and use.

The Call for Evidence will be followed by stakeholder workshops on specific key topics in 2018. In addition, we will be establishing an Expert Advisory Group to provide advice and support to the CCC throughout the review.

Responding to the Call for Evidence

We encourage responses that are brief and to the point (i.e. a maximum of 400 words per question, plus links to supporting evidence), answering only those questions where you have particular expertise. We may follow up for more detail where appropriate.

Please use the website form when responding, or if you prefer you can use this word form and e-mail your responses to: communications@theccc.gsi.gov.uk. Alternatively, if you would prefer to post your response to us, please send it to:

The Committee on Climate Change – 2018 Bioenergy Review Call for Evidence
7 Holbein Place
London SW1W 8NR

The deadline for responses is 9am on 5th February 2018.

Confidentiality and data protection

Responses will be published on the CCC website after the response deadline, along with a list of names or organisations that responded to the Call for Evidence.

If you want information that you provide to be treated as confidential (and not automatically published) please say so clearly in writing when you send your response to the consultation. It would be helpful if you could explain to us why you regard the information you have provided as confidential. If we receive a request for disclosure of the information we will take full account of your explanation, but we cannot give an assurance that confidentiality can be maintained in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not, of itself, be regarded by us as a confidentiality request.

All information provided in response to this consultation, including personal information, may be subject to publication or disclosure in accordance with the access to information legislation (primarily the Freedom of Information Act 2000, the Data Protection Act 1998 and the Environmental Information Regulations 2004).

Information on organisation / individual submitting response

If you are responding on behalf of an organisation please provide a brief description of your organisation and your role within this organisation.

This is submitted on behalf of the bioenergy researchers at the Tyndall Centre for Climate Change Research, University of Manchester, who lead the Supergen Bioenergy Hub. Those making direct contributions to the submission are: Patricia Thornley, Mirjam Roeder and Andrew Welfle, but the work discuused includes that of our colleagues and research partners. Patricia Thornley is professor of sustainable energy systems and director of the Supergen Bioenergy hub, Mirjam Roder is research fellow and Supergen Bioenergy Hub investigator, Andrew Welfle is research assistant and Supergen Bioenergy Hub researcher.

If you are responding as an individual we would be grateful if you could provide a brief description of your background and interest in bioenergy.

GHG emissions and sustainability of bioenergy imports

Our 2011 Bioenergy Review concluded that UK and EU regulatory approaches should be strengthened to better reflect estimates of the full lifecycle emissions of bioenergy feedstocks, taking into account both direct and indirect land-use change impacts. Whilst changes have been made to these regulatory frameworks, both life-cycle emissions and the wider sustainability impacts of bioenergy remain highly contested issues, particularly in relation to bioenergy imports. Given the potential role for bioenergy in the UK's low-carbon transition, and the potential increase in bioenergy feedstock production in the future, it will be essential that policy is based on the latest available evidence and that bioenergy is genuinely sustainable.

The term 'sustainable' here is used to cover a wide-range of issues relating to GHG emissions, biodiversity, water use, land-use, land-rights, air-quality and other social and environmental issues.

1. What is the latest evidence on lifecycle GHG emissions of biomass and other biofuels imported into the UK? How could this change over time as a function of scaling up supply? We are particularly interested in evidence that considers the full range of relevant issues including changes to forest and land carbon stocks, direct and indirect land-use change and wider market effects.

Emissions from bioenergy systems over full life cycle vary significantly depending on feedstock, conversion pathway and counterfactual assumed. Our work has generally shown very significant reductions in greenhouse gas emissions compared to fossil fuel equivalent systems for the (industry relevant) cases we have studied *(e.g. see Thornley, P., Gilbert, P., Shackley, S., Hammond, J., "Maximizing the greenhouse gas reductions from biomass: the role of life-cycle assessment", Biomass and Bioenergy 2015 for examples in electricity and heat)*.

Compared to coal fired electricity, we have round emissions from imported biomass and best case scenarios are within the 80% reduction target remit. However, supply chains need to be sustainable and carefully managed (*see Röder M, Whittaker C, Thornley P. How certain are greenhouse gas reductions from bioenergy? Life cycle assessment and uncertainty analysis of wood pellet-to-electricity supply chains from forest residues. Biomass Bioenergy 2015; 79; Laganière J, Paré D, Thiffault E, Bernier PY Range and uncertainties in estimating delays in greenhouse gas mitigation potential of forest bioenergy sourced from Canadian forests. GCB Bioenergy 2015)*

Where relevant, land-use change can offset emission savings, particularly for biofuel systems (*e.g. Upham, P., Thornley, P., Tomei, J., Boucher, P., in press, "Substitutable biodiesel feedstocks for the UK: a review of sustainability issues with reference to the UK RTFO", Journal of Cleaner Production, 2009, Thornley, P., "Biofuels Review" for Government Office for Science, 2012, commissioned*) and it is also very important to consider counterfactuals which may have a very significant effect on reported savings *(e..g see Welfle A, Gilbert P, Thornley P, Stephenson A. Generating low-carbon heat from biomass: Life cycle assessment of bioenergy scenarios. Journal of Cleaner Production 2017; 149:448-60).*

It is difficult to generalize as the carbon emissions are very sensitiivto how the biomass is produced and sourced and how this interfaces with other products and systems. This is in most cases very context specific and can easily vary between supply chains

2. Under what circumstances can imported biomass and other biofuels deliver real GHG emissions savings (considering full life-cycle emissions and indirect/wider market effects)? Conversely, what evidence is there for ruling out certain sources on the grounds of lifecycle GHG emissions or sustainability risks?

Waste and residue feedstocks often achieve higher emission savings *(Welfle A, Gilbert P, Thornley P. Securing a bioenergy future without imports. Energy Policy 2014; 68:1-14; Welfle A, Gilbert P, Thornley P. Increasing biomass resource availability through supply chain analysis. Biomass and Bioenergy 2014; 70:249-66; Röder M, Whittaker C, Thornley P. How certain are greenhouse gas reductions from bioenergy? Life cycle assessment and uncertainty analysis of wood pellet-to-electricity supply chains from forest residues. Biomass and Bioenergy 2015; 79:50-63; Röder M, Thornley P. Waste wood as bioenergy feedstock Climate change impacts and related emission uncertainties from waste wood based energy systems in the UK. Waste Management 2017; Welfle A, Gilbert P, Thornley P, Stephenson A. Generating low-carbon heat from biomass: Life cycle assessment of bioenergy scenarios. Journal of Cleaner Production 2017; 149:448-60; Horschig T, Adams PWR, Röder M, Thornley P, Thrän D. Reasonable potential for GHG savings by anaerobic biomethane in Germany and UK derived from economic and ecological analyses. Applied Energy 2016;)*

Converting significant fractions of high yielding systems also often achieve high savings e.g. GHG emission savings from dedicated lingo-cellulosic energy crops (wood or grass) can be high if grown sustainably in a way that does not reduce carbon stocks.

LCA can provide a good inside into what can/cannot be achieved with bioenergy but there are always uncertainties and significant variability even within apparently similar systems. For this reason it is difficult to justify ruling in or out certain sources: a full assessment is needed to be confident of savings.

3. Currently the UK imports a significant proportion of wood pellets for biomass electricity production from North America, particularly the south-east USA.

   a) What are the wider market impacts of demand for wood pellets on forestry management practices and carbon stocks at the landscape level in North America?

Pellets are produced from primary (forest) and secondary (sawmill) residues. This does not necessarily have an impact on forest carbon stocks as it does not require new management activities but is integrated with conventional wood products. Hence, forests are not grown for wood pellet production but wood pellet production becomes an additional product soured from mainly unused residues not requiring and different forest management practices.

This can be different if for example poorly managed or disturbed forests are harvested to use low quality wood for bioenergy. This could mean that a forest with low or even decreasing carbon sequestration rates is re-established and gets back into management, growth with higher sequestration rates. Work on this is currently conducted by the Supergen Bioenergy hub, but some region specific evidence is provided here: Barrette J, Thiffault E, Achim A, Junginger M, Pothier D, De Grandpré L. A financial analysis of the potential of dead trees from the boreal forest of eastern Canada to serve as feedstock for wood pellet export. Applied Energy 2017; 198:410-25

Recent (to be published) work we have carried out has shown very little market impact on U.S. forestry systems despite significant increases in European pellet demand, since the actual European demand represents only a very small proportion of the overall market and the price paid is low compared to the saw log price driving forestry decisions.

b) What evidence is there that wood pellet production displaces other uses of forestry products in North America? (e.g. panel board or lumber production)

Pellets are produced from primary (forest) and secondary (sawmill) residues. The feedstocks currently used are not in competition with panel or lumber production. Most of the feedstocks are currently not used or to some but a very small extend used for pulp and paper and to a larger extend sawmill residues are used for kiln drying. We are not aware of any substantial, convincing evidence that the currently used feedstocks for wood pellets compete with other products, as they are mainly waste products either left in the forest or even burnt at landing or processing sites to dispose of. Instead, the downturn of the pulp industry has resulted in some additional feedstock becoming available for wood pellets (in particular wood chips form sawmills previously used for pulp).

c) What are the most likely alternative/counterfactual uses of forestry products used for wood pellet production?

Counterfactuals would be leaving residues in forest for decay, burning some of the residues in forest landing sites, burning sawmill residues on production site or leaving it to rot, replacing some of the sawmill residues used for kiln drying with other fuels (but unlikely with decreasing pulp industry and unused feedstocks).

d) How are these wider market impacts (sub-questions a-c) likely to change over time if demand for wood pellets significantly increases?

The increasing demand for wood pellets might create some competition with other conventional wood products but currently there is lots of unused feedstock available and it is unlikely that there will be any major competitions with other wood products (Thiffault, E. Tattersall Smith, C., Junginger, M., Berndes, G., Mobilisation of forest bioenergy in the boreal and temperate biomes: Challenges, opportunities and case studies", Academic Press, http://www.ieabioenergy.com/publications/mobilizing-sustainable-bioenergy-supply-chains/)

Other future scenarios could be an increasing demand for wood pellets in the producer countries in North America and an even higher/faster increasing demand wood pellets, which would require economic market analysis to assess projections. of how wood products are affected or feedstocks displaced.

4. Aside from GHG emissions, what evidence is there of other sustainability impacts associated with imported biomass or other biofuels? What evidence is there for how these might change as a function of scaling up supply (from the US, and internationally)?

5. Are there any benefits resulting from importing biomass or other biofuels into the UK (e.g. development benefits)? How might these vary internationally? What are the conditions required for any benefits to be realised?

Sustainable bioenergy systems should provide other services and benefits beyond energy and climate change benefits. If done right, bioenergy can provide various economic, social and environmental benefits to the biomass production regions (jobs, income, empowerment, soil management, ecosystem services, ...). However, in terms of development benefits it is important to consider the livelihood and energy supply situation of the region biomass is sourced from and the question has to be ask if it is ethical to possibly source biomass for UK imports from regions with significant energy insecurity and limited energy access. (Tomei J, Helliwell R. Food versus fuel? Going beyond biofuels. Land Use Policy; Tomei J. The sustainability of sugarcane-ethanol systems in Guatemala: Land, labour and law. Biomass and Bioenergy 2015; 82:94-100; Röder M. More than food or fuel. Stakeholder perceptions of anaerobic digestion and land use; a case study from the United Kingdom. Energy Policy 2016; 97:73-81; Röder M, Stolz N, Thornley P. Sweet energy – Bioenergy integration pathways for sugarcane residues. A case study of Nkomazi, District of Mpumalanga, South Africa. Renewable Energy 2017; 113:1302-10)
Integrating energy crops into agricultural systems or feedstock sourcing along other conventional agri and forest products can also provide environmental and emissions benefits *(Röder M. More than food or fuel. Stakeholder perceptions of anaerobic digestion and land use; a case study from the United Kingdom. Energy Policy 2016; 97:73-81; Röder M, Stolz N, Thornley P. Sweet energy – Bioenergy integration pathways for sugarcane residues. A case study of Nkomazi, District of Mpumalanga, South Africa. Renewable Energy 2017; 113:1302-10)*

Sustainability policy and certification

The sustainability framework for bioenergy in the UK has evolved significantly since 2011. Changes have included the tightening over time of lifecycle GHG emissions limits for bioenergy supported under Government incentive schemes, changes to EU rules on liquid biofuels and the development of certification schemes. Nonetheless questions remain regarding the current framework's capacity to guarantee high sustainability standards.

The term 'sustainability framework' refers here to the policies, regulations and incentives in place to promote bioenergy sustainability in the UK.

6. What are the strengths, weaknesses and gaps of the current sustainability framework for bioenergy in the UK? How could the current sustainability framework for bioenergy in the UK be improved to address these issues?

The current framework is a crude instrument that prevents worst excesses, but does not incentivize best performance or recognize the potential for trade-offs between different impacts *(Thornley, P., Gilbert, P., "Biofuels: Balancing risks and rewards", Interface focus, 2013).*

Important work on certification schemes and sustainability frameworks has been done by Tomei: (*Tomei J. The sustainability of sugarcane-ethanol systems in Guatemala: Land, labour and law. Biomass and Bioenergy 2015; 82:94-100; Afionis S, Stringer LC, Favretto N, Tomei J, Buckeridge MS. Unpacking Brazil's Leadership in the Global Biofuels Arena: Brazilian Ethanol Diplomacy in Africa. Global Environmental Politics 2016; 16:127-50*)

7. Ofgem has identified a number of certification schemes that it considers appropriate for demonstrating compliance with the 'Land Criteria' under the Renewable Obligation sustainability standards. Are these certification schemes adequate? Why/why not? How could they be improved?

8. What certification schemes currently represent 'best practice'? Why?

9. Ofgem has set out approaches to calculating bioenergy GHG emissions for demonstrating compliance with the 'GHG Criteria' under the Renewable Obligation sustainability standards. Are these approaches adequate? Why/why not? How could they be improved?

10. Please highlight any further measures you feel are required to ensure bioenergy feedstocks used in the UK are sustainable and deliver significant life-cycle GHG emissions savings. Why are these measures needed?

Emissions related to the shipping of bioenergy would require the inclusion in national budgets (as the shipping is still not properly accounted for in NIFs). Consideration of changes in carbon stock resulting from biomass removal should be included in calculations even if these are separately treated under relevant accounting frameworks.

11. Some large UK users of imported biomass use a risk-based approach to assess the sustainability risks associated with importing biomass from specific jurisdictions. What is the role for these approaches?

Supply of bioenergy feedstocks

In our 2011 Bioenergy Review we considered scenarios for the amount of sustainable bioenergy resource available to the UK over the coming decades. Our central 'Extended Land Use' scenario suggested that around 10% of the UK's primary energy demand could be met from bioenergy in 2050, with over half coming from domestic feedstocks. We are now looking to develop new supply scenarios through to 2050 to reflect the latest evidence on sustainability and different assumptions about the potential future availability of imported and domestically produced bioenergy resources.

To support the development of these scenarios and our wider work, the CCC is currently undertaking new analysis on how the use and management of land in the UK can deliver deeper emissions reduction and increased sequestration. This analysis will provide updated data on the potential supply of non-waste and non-food bioenergy resources from UK sources. For projections of international bioenergy resources and waste-based UK bioenergy resources we will review the latest evidence and publicly available literature. We are particularly interested in quantitative estimates of resource potential, broken down by feedstock type, that are underpinned by explicit assumptions relating to sustainability.

12. What are the most credible and up-to-date estimates for global bioenergy resource potential through to 2050, broken down by feedstock type? What key assumptions underpin these estimates?

    Please provide details of any assessments of global bioenergy resource explicitly tied to sustainability standards (covering GHG emissions, biodiversity, water use, land-use, land-rights, air-quality and other social and environmental issues)

Estimates of global bioenergy resource potential are hugely variable and sensitive to key assumptions around land availability, yield and competing market demands for some material. The U.S. 1 billion tonne report, Danish equivalents and the GloBiom work all make valuable contributions to knowledge in this, but all are fraught with uncertaintly and variability, most often in relation to related systems e.g. how land bioenergy production is affected by population, dietary trends (affecting both agri-resiude availability and land availability).

13. What is the latest evidence relating to the availability of 'marginal' and abandoned agricultural land for growing bioenergy crops (where possible, reflecting broader sustainability requirements e.g. water stress, biodiversity, social issues)? Is this evidence adequately reflected in global resource estimates?

    Great care needs to be taken in assessment of marginal land as GIS, satellite and other data sets may identify land as "unused" which is actually used on a rotational or partial basis.

14. What are the most credible and up-to-date estimates for the amount of bioenergy resource that could be produced from UK waste sources through to 2050? Where possible please state any assumptions relating the reduction, reuse and recycling of different future waste streams.

Our own work shows that across a wide variety of different projected UK future resource levels waste feedstocks become more dominant. Therefore one of the biggest impacting factors for the UK is assumptions about our future waste production and management. The work we have done involves detailed analysis of a wide range of input streams and hundreds of different drivers/parameters. (*Welfle, A., Gilbert, P., Thornley, P., "Securing a bioenergy future without imports", Energy Policy, 2014, Welfe, A., Gilbert, P., Thornley, P., "Increasing biomass resource availability through supply chain analysis", Biomass and Bioenergy, 2014).*

There is also a Supergen Bioenergy Hub flexible funding project currently underway, which will specifically answer the question of availability and suitability of UK wastes and residues for bioenergy. This brings together researchers from University of Manchester, Aston University and Cranfield University, the projects outputs will be available by the end of June 2018.

Our own analysis on waste wood (*Röder M, Thornley P. Waste wood as bioenergy feedstock Climate change impacts and related emission uncertainties from waste wood based energy systems in the UK. Waste Management 2017)* has shown that when energy is recovered there are significant uncertainties associated with the potential release of N2O which could undermine climate benefits.

15. What factors (opportunities, constraints, assumptions) should the CCC reflect in its bioenergy resource scenarios through to 2050?

16. What should be the assumptions on the share of international resource which can be accessed by the UK (e.g. per capita, current or future energy demand)?

It is extremely difficult to forecast the share of international resource without careful consideration of the extent to which producer countries will increase their internal domestic use in future. There are many developing economies with growing energy demands and significant bioenergy potential. The trajectories for development of these will vary and that will impact on the extent to which they may avail of export opportunities. There are very significant potential development benefits that can be accessed in country and these should be prioritized before export. However, in some cases, development may be accelerated by production for an export market.

It is important that the UK works with such countries to support development on a low carbon trajectory but also to better understand the future resource base. DFID have recently reviewed the situation in sub Saharan Africa and LTS International produced some reports on this for them in 2018. That work is now being taken forward by the Carbon Trust and should be considered when evaluating access to international resource.

Our own work has evaluated the situation in Brazil *(Welfle A. Balancing growing global bioenergy resource demands - Brazil's biomass potential and the availability of resource for trade. Biomass and Bioenergy 2017; 105: 83-95. 2017),* south east Asia (*Nguyen, V.H., Topno, S., Balingbing, C., Nguyen, V.C.N., Roeder, M., Quilty, M., Jamieson, C., Thornley, P., Gummert, M., "Generating a posititve energy balance from using rice straw for anaerobic digestion", Energy Reports 2016*), Colombia (forthcoming – information can be provided), Ghana (forthcoming – information can be provided) and Supergen partners have studied Argentinia and Mozambique (again more detail can be provided).

- Brazil has vast biomass resources which are forecast to steadily increase over the analysis timeframe to 2030.
- Brazil's dominant category of biomass resources are plantation crops and feedstocks required to produce biofuels, whilst also having the potential to produce/mobilise large wood based biomass resources.
- Brazil is well placed to continue to be a dominant player in exporting resources for global trade in the future.
- Brazil's current energy strategies and targets are relatively conservative and modest when placed in perspective of Brazil's renewable energy potential.
- Brazil could export up to 25.8% less biomass if it were to adopt and realise more ambitious energy strategies, which cautions against countries developing bioenergy strategies that will require large biomass resource imports to balance their future demands.

A key issue is balancing the potential for biomass to service sustainable development goals by providing indigenous feedstocks with potential for economic growth by accessing export opportunities. Our work in south Africa shows that medium scale enterprises offer business models that could maximize local benefits, but are not being encouraged by national governance arrangements. Established exports from the U.S. form a mainstay of current UK imports. At present these represent only a small fraction of the available material and our own work work does not indicate any significant anticipated reduction in the accessibility of this feedstock in the near future.

17. What are the prospects for the development and commercial production of 3rd generation bioenergy feedstocks (e.g. algae)? What are the timescales, costs, risks, opportunities and abatement potential of using algae to make biofuels?

    Work on algae to date has not indicated a prospect of financial viability without focusing on higher value speciality chemicals. While these might be useful from a resource/circular economy perspective, they will not deliver bulk decarbonisation as they are not replacing commodity scale carbon intense products.

Scaling up UK sustainable supply

An objective of our current work on bioenergy is to better understand and reflect the potential for scaling-up of the supply of sustainably produced domestic (UK) bioenergy resources through to 2050. We aim to identify and develop policy recommendations for 'low-regrets' measures/strategies that can be implemented in the near term.

18. What are the main opportunities to scale-up the supply of sustainably-produced domestic bioenergy supply in the UK? Where possible please provide details on the scale of opportunity.

University of Manchester has undertaken research that evaluated the dynamics within supply chains that determine the availability for bioenergy and the actions and policy interventions that may increase this availability (Welfle A, Gilbert P, Thornley P. Increasing biomass resource availability through supply chain analysis. Biomass and Bioenergy 2014; 70: 249-266. 2014):-.

- UK biomass and energy crops, agricultural residues and household wastes are identified as the biomass resources that demonstrate the greatest promise for the UK bioenergy sector, in terms of their availability quantity and bioenergy potential.
- UK grown biomass resources are identified as potentially providing >31 Mt for the bioenergy sector by 2050. The standout driver influencing the availability of these resources was identified as the uptake of available land dedicated for its growth. However the analysis also highlighted that this resource currently has a relatively low starting base, with >1.9 Mt forecast by 2015. Therefore concerted efforts will be required in managing the drivers that influence availability, if anywhere near the upper levels of resource forecasts are to be realised. These should include the implementation of policies that encourage/incentivise the utilisation of available land for the growth of resource dedicated for the bioenergy sector.
- UK residue resources are identified as potentially providing upto >29.8 Mt of resource for the bioenergy sector by 2050. Agricultural residues (straws & slurries) make up the majority of this quantity. The availability of residues was forecast to steadily increase and be comparatively robust to supply chain influences. Biomass residues therefore representing a potentially continuous and reliable near and long-term indigenous resource option for the bioenergy sector.
- UK biomass waste resources are identified as potentially providing up to >89 Mt of resource for the bioenergy sector by 2050. Household wastes being the largest waste contributor. Wastes were found to be highly influenced by one key driver, the waste management system adopted. The availability of waste resources was found to be much diminished when the adopted waste management strategy was uncomplimentary to the bioenergy sector.
- The paper highlights the importance of applying a targeted approach for increasing the potential of indigenous resources. This is contrary to the broad policy focus approach currently being implemented in the UK. The analysis has identified that there are multiple biomass resource opportunities in the UK, but realisation of the upper levels of resource availability forecasts is highly dependent on the implementation of effective policies that target and manage the specific supply chain drivers most influential for each respective biomass resources.

There are opportunities around bringing woodlands into management (recent work by Rothamsted research has looked at this) and planting of energy crops to deliver ecosystem benefits to land owners around flood resilience and prevention. It is difficult to predict the scale of this opportunity as it increases with the degree of climate change experienced and adaptation necessary, but it is actively being considered by a range of landowners.

19. What risks are associated with scaling-up domestic supply and how can these risks be managed?
Landowners need confidence in the market in order to invest in perennial crops, while technology providers need security of supply to invest in capital plant. Previous incentive mechanisms to try to bridge this gap have failed and careful consideration of options is necessary.

20. What 'low-regrets' measures should be taken now (e.g. planting strategies) to increase sustainably-produced domestic bioenergy supply?
A key area of increasing interest to many land owners is planting of perennial crops that confer ecosystem benefits e.g. particularly in relation to soil carbon accumulation and fertility, phyto remediation, flood protection and extreme weather event resilience.

21. What international examples of best-practice should the UK should look to when considering approaches to scaling-up domestic supply?
Brazil adopts a very strategically planned approach led by the national agricultural agency Embrapa. Biomass cultivation is part of an integrated strategy designed and planned to adapt to future climate conditions, with designated zones suitable for sugar cane and eucalyptus cultivation. Such a didactic approach may not be appropriate in the UK, but there are certainly regional differences in the form of biomass and bioenergy that could be implemented and a strategy that approrpriately considered and implemented a strategic plan via appropriate incentives along the supply chain is needed.

22. What policy measures should be considered by Government to help scale-up domestic supply?

Best-use of bioenergy resources

Our 2011 review developed a hierarchy of appropriate uses for bioenergy feedstocks based on minimising costs and maximising abatement. We concluded that if CCS technology is available it is appropriate to use bioenergy in applications with CCS, making it possible to achieve negative emissions under the right circumstances. This could include power and/or heat generation, hydrogen production, and biofuels production for use in aviation and shipping. If CCS is not available, bioenergy use could be skewed towards heat generation in energy-intensive industry, and to biofuels in aviation and shipping, with no appropriate role in power generation or surface transport. In either case, we concluded the use of woody biomass in construction should be a high priority given that this can potentially secure negative emissions through a very efficient form of carbon capture.

We are now looking to update this analysis to reflect the latest technological and market developments. We are particularly interested in technologies such as biomass gasification, CCS and advanced second and third generation biofuels as well as the potential role of hydrogen to support decarbonisation across the economy. To support our consideration of these areas, the CCC is currently undertaking analysis into the potential of the hydrogen economy and we are planning to undertake further investigation into non-energy uses of bioenergy resources.

23. Gasification has been identified as a potentially important technology for unlocking the full potential of bioenergy to support economy-wide decarbonisation.
    a) What are the likely timescales for commercial deployment of gasification technologies?
    b) What efficiencies and costs are likely to be achieved? What scope is there for improvement and/or cost reductions over time? Please differentiate between feedstocks where possible/necessary.
    c) What are the main barriers and uncertainties associated with the development, deployment and use of gasification technologies?
    d) What risks are associated with gasification technologies and how can these be managed?
    e) What policies and incentives are required to facilitate commercial deployment?

24. Bioenergy with Carbon Capture and Storage (BECCS) has been identified as a key potential mechanism for achieving the UK's 2050 carbon target due to the 'negative emissions' it could offer.
    a) What are the potential timescales for commercial deployment of BECCS technologies?

Small scale BECCS is happening now, but is constrained by the carbon sink accessibility. Current applications are removing CO_2 for reuse rather than storage and markets for this are limited. Development of fossil-focused carbon sinks e.g. offshore is key to unlocking this. Additionally it must be acknowledged that locking up the CO_2 is expensive and will only happen when a high enough carbon price prevails. At present there is no incentive to deploy or develop BECCS and the carbon price projections are such that the price will not be high enough to facilitate investment for the foreseeable future.

    b) What are likely to be the optimal uses of BECCS (e.g. electricity generation, hydrogen production)?

So much depends on how the rest of the energy system evolves. Bioenergy could provide a base load electrical capacity (particularly useful if new nuclear has not materialized as fast or cheaply as envisaged). This would be more useful if it were BECCS, but that requires capital investment that is not viable at current or foreseeable carbon prices. If in the form of BECCS the flexibility of the base load provision would be more limited, so less useful unless we were more actively managing demand.
Biomass could provide hydrogen via a number of different conversion routes with different associated products and pathways, but whether this makes more sense than electrolysis routes depends on grid decarbonisation and the markets for the byprodcuts and fate of the carbon elements of the biomass.
We could take the approach of prioritizing "hard to decarbonize sectors" in which case hydrogen distributed via the natural gas infrastructure could have a huge impact on heat decarbonisation. Equally biofuels could be used to service aviation demands. However, care is needed to ensure we do not over-commit our sustainable resource. If

the aviation sector were to switch completely to biofuels this could use an amount of biomass commensurate with the total UK indigenous supply. So, BECCS would then have to be serviced from imports.
Off gas grid decarbonisation of heating could be provided with community heating schemes as a key way to decarbonize this sector and address rural fuel poverty.
Implementing higher blend rates for liquid transport fuels from products that deliver significant carbon savings will be needed for the considerable future as vehicle technology and consumer interfaces evolve.

c) What efficiencies and costs are possible?
d) How will performance and cost differ according to feedstock type? What are likely to be the optimal feedstock types for BECCS? What are the implications for domestic supply vs imports (e.g. feasibility, considerations in scaling up over time)?
a. What are the main barriers and uncertainties associated with the development, deployment and use of BECCS?
b. What are the risks associated with the pursuit of BECCS that go beyond the risks that relate to supplying sustainable feedstocks and CCS more generally? How can these be managed?

The fundamental issue with BECCS is the lack of a governance framework that incentivizes or even facilitates maximisation of negativity per unit of biomass resource. The second issue is the lack of a liquid market that adequately values carbon sequestration.

25. Once developed BECCS is a technology that could be deployed in many different countries around the world. What principles and mechanisms should be used to determine where BECCS is deployed and how any associated negative emissions are accounted for? Should any UK participation in any international BECCS scheme be counted as additional to efforts to meet domestic carbon budgets?

If our objective is global planetary net negative emissions in future collaboration is essential. The current territorial based accounting system does not support imports, exports or large scale transfer of resource and/or associated credits/liabilities. If we are to achieve a cost effective and efficient global paradigm a more flexible framework is needed.

26. There is currently substantial interest in the development of 'advanced' biofuels for use in sectors such as aviation, shipping and/or heavy duty transport.
    a) What are the most promising technologies/processes for advanced biofuel production up to 2050? Please provide details on each technology/process including advantages/disadvantages, timescales for commercial deployment, feedstock type, fuel type and end-user.
    b) What efficiencies and costs are likely to be achieved? What scope is there for improvement and/or cost reductions over time? Please differentiate between technologies/processes.
    c) What are likely to be the optimal feedstock types for advanced biofuel technologies?

d) What are likely to be the optimal end-uses of advanced biofuel technologies?
e) What are the main barriers and uncertainties associated with the development, deployment and use of advanced biofuel technologies?
f) What risks are associated with the pursuit of advanced biofuel technologies and how can these be managed?
g) What policies and incentives are required to facilitate commercial deployment of advanced biofuels?

27. In 2015 the Government published the Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050. These Roadmaps explored decarbonisation options across multiple industrial sectors and the estimated deployment potential, timescales, cost data and abatement for each option (including bioenergy). Are there any substantial changes from these estimates that the CCC should consider when assessing abatement options in industry? If so please provide your reasoning and details of any recent evidence that relates to these changes.

28. In our 2011 review we identified wood in construction as a potentially effective method of CCS and a high priority 'non-energy' use in our best-use hierarchy.
    a. What lifecycle GHG emissions savings can be achieved by using WIC? Under what circumstances does WIC fail to deliver GHG emissions savings? Please consider the full range of impacts associated with using WIC including substituted product emissions (e.g. cement), product equivalence (impacts on co-products), end-of-life options and biogenic carbon storage.
    b. What is the potential for increasing the amount of wood used in construction in the UK? What are the barriers and how can they be overcome?
    c. What is the potential for using UK-produced timber in construction rather than imports? What are the barriers and how can they be overcome?
    d. What is the expected lifetime of different wood products in construction (e.g. cross-laminated timber)?
    e. What currently happens to wood in construction at the end of its useful life? What other viable options should be developed?

The benefits of the use of wood in construction are critically dependent on the lifetime of the building which is difficult to realistically project given changing development climates.

Secondly consideration of wood in construction also requires consideration of the forestry and wood production industry. Construction grade timber is not produced in isolation, but in conjunction with a number of other products of varying utility and value. There is potential for synergy between production of wood for construction and for bioenergy with one economically supporting the other i.e. saw log costs can be more competitive if value can also be ascribed to co-products.

Great care needs to be taken about the end-of-life for construction timber. If the timber has been treated or processed it may then be classed as waste wood or contaminated and have potential to actually release much greater greenhouse gas emissions at end of life than would have been the case if it had been grown and used for other purposes not requiring preservatives of processing into fibre-board or similar products. Our work shows that N_2O emissions may increase in this scenario.

29. There are also a number of other potential non-energy uses of bio-feedstocks including bio-based plastics and bio-based chemicals.
    a. What other non-energy uses of bio-feedstocks have the most potential through to 2050 in terms of GHG abatement, cost, timescales and market size?

There is a potential market for biomass derived platform chemicals and speciality products including bio-plastics. The LBNet group recently produced a report indicating the top 10 chemicals the UK should produce, discussed with key chemical industry players, but not yet publicly released.
Two key issues are that maximum impact will be achieved by utilizing the largest proportion of the feedstock possible (Thornley, P., "Biofuels Review" for Government Office for Science, 2012, commissioned) and by managing land-use change to increase not decrease terrestrial stocks.

    b. What are the barriers to increasing these non-energy uses and how can these barriers be overcome?
    c. What risks are associated with the pursuit of other non-energy uses of bio-feedstocks and how can these be managed?

GHG emissions reporting and accounting

GHG emissions reporting rules for bioenergy are different to those for other forms of energy. Emissions relating to the use (combustion) of bioenergy resources are not reported in the country of use but rather in the country where bioenergy resources are produced. Only Annex 1 countries under the Kyoto Protocol currently account for land-use emissions as part of binding emission reduction targets. In addition under Paris Agreement rules emissions (as under the Kyoto Protocol) will be reported against land-use baselines that may already assume a degree of land-use change. For these reasons and others, bioenergy GHG accounting has been criticised for not properly reflecting the impacts of bioenergy.

30. What are the strengths and weaknesses of the current approach to GHG emissions accounting for bioenergy in the UK and internationally? Specifically, what are the main gaps in the current land use emissions accounting rules?

The Intergovernmental Panel on Climate Change (IPCC) oversaw the development of the universally adopted methodologies and guidelines for accounting GHG emissions. Within this framework nations are required to individually account all their emissions within a series of GHG inventories, including emissions from: Energy Generation; Industrial Processes & Product Use; Agriculture; Land-Use & Land-Use Change (LULUCF); and Wastes.

The IPPC's accounting framework of allocating emissions to different national inventories, or not to any inventory can make bioenergy a highly attractive option for nations decarbonising their different GHG inventories - but the accounting framework doesn't provide the true overall GHG performance of bioenergy. The reality is that in order to evaluate the GHG performance of a given bioenergy pathway, all emissions from the biomass supply chain, from the transportation steps, and from each bioenergy process need to be accounted collectively regardless to where they are geographically emitted (Welfle A, 2017).

See:

Welfle A. Bioenergy – A Low Carbon Renewable Energy Pathway. University of Manchester, 2017. Online at: http://www.supergen-bioenergy.net/news/is-bioenergy-really-sustainable.htm

31. What are the risks, in terms of GHG emissions, associated with importing biomass or other biofuels from countries that have not committed to limiting or reducing emissions under the Kyoto Protocol or Paris Agreement? How can these risks be managed?

32. What alternative method(s) for bioenergy emissions accounting should be considered? What would the implications of these alternative method(s) be?

Life Cycle Assessment (LCA) is a well developed and widely implemented technique for analysing the whole life cycle emissions of bioenergy pathways, where the respective balance of emissions from all the processes and activities within a given bioenergy pathways are calculated and summed up to provide an indication overall GHG performance.

Examples of specific LCA research where this is demonstrated include the UK Government's analysis of UK power bioenergy pathways using North American pellets (MacKay and Stephenson, 2014) and related work by University of Manchester that focused on evaluating the GHG performance of heat bioenergy pathways (Welfle et al, 2017):

- Such LCA analyses have been much publicised and widely used to discredit the choice of bioenergy as a low carbon renewable energy option. What this research actually shows is that where pellets are produced for bioenergy using bad practice techniques such as the intensification of forestry harvests or where land-use change occurs resulting in the large releases GHG emissions from carbon sinks, the resulting bioenergy was found to reflect poor GHG performance – the results of these bad practice bioenergy pathways being much publicised.
- The research also highlights that where pellets are produced for bioenergy using good practice techniques the resulting bioenergy was found to reflect highly attractive GHG performances compared to fossil fuel generation.
- The true message from such research is not to stop bioenergy, but to develop policies, regulations and supply chain reporting that stamps out bad practice.

SEE:

MacKay D, Stephenson A. Life cycle impacts of biomass electricity in 2020. London: Department of Energy & Climate Change, 2014.

Welfle A, Gilbert P, Thornley P, Stephenson A. Generating low-carbon heat from biomass: life cycle assessment of bioenergy scenarios. Journal of Cleaner Production 2017; 149: 448-460. 2017.

Indicators

As part of the 2018 Bioenergy Review the CCC is planning to develop a set of indicators to track progress towards key bioenergy outcomes. We envisage these will cover key areas such as sustainability, policy development, supply and best-use.

33. What key areas should be reflected in these indicators?

Wider impacts of sectoral integration. Bioenergy is usually imbedded in the agricultural, forestry or waste sector and trade-off and synergies with these sectors are very important in the assessment of sustainability and impact of bioenergy
Bioenergy as port of the wider energy systems. Bioenergy is be part of the energy mix and it would be important to discuss the role bioenergy should/could take and what this means for the wider sustainability implications of the energy system.

34. Please provide details of any examples of international best-practice in the area of bioenergy indicators.

Other

35. Please submit any further evidence that you would like us to consider.