Committee on Climate Change – Bioenergy Review (2018) Call for Evidence

Joint Response by the Energy Systems Catapult (ESC) and Energy Technologies Institute (ETI)

Questions answered: 14-16, 18-24

Information on organisation submitting a response

Energy Systems Catapult (ESC): The ESC supports innovators in unleashing opportunities from the transition to a clean, intelligent energy system. It is part of a network of world-leading centres set up by the government to transform the UK's capability for innovation in specific sectors and help drive future economic growth.

By taking an independent, whole energy systems view, we work with stakeholders across the energy sector (consumers, industry, academia and government) to identify innovation priorities, gaps in the market and overcome barriers to accelerating the decarbonisation of the energy system at least cost. In doing so, we seek to open up routes to market for innovators, as well as supporting them to understand how their products, services and value propositions fit into the transforming energy system.

Energy Technologies Institute (ETI): The ETI is a public-private partnership between global energy and engineering firms (BP, Caterpillar, EDF Energy, Rolls-Royce, and Shell) and the UK Government. Our mission is to accelerate the development, demonstration and eventual commercial deployment of a focused portfolio of energy technologies which will increase energy efficiency, reduce greenhouse gas emissions and help achieve energy and climate change goals.

We carry out three key activities:

- modelling and strategic analysis of the UK energy system to identify the key challenges and potential solutions to meeting the UK's 2020 and 2050 targets at the lowest cost to the UK
- investing in major engineering and technology demonstration projects to de-risk and build capability in both technology and supply-chain solutions for subsequent commercial investors
- enabling effective third party commercialisation of project outcomes.

The ETI developed an internationally peer-reviewed national energy system design tool (known as 'ESME' - Energy System Modelling Environment), to underpin our strategic techno-economic analysis of the UK energy system. ESME models choices across power, heat, transport and infrastructure sectors and is informed by evidence drawn from our private sector members, our technical projects and a range of expert advisers. As such it has enabled the ETI to deliver evidence-based insights on how to deliver affordable, secure and low carbon energy for Britain in the decades ahead, including identifying credible, lowest-cost pathways to secure low-carbon energy in future.

The ETI was established as a fixed-term partnership operation which will come to an end in December 2019. To continue the legacy beyond the ETI, in September 2017 the ETI's whole system analysis team including its ESME modelling team was transferred to the ESC.

Written evidence submitted by Geraint Evans (Bioenergy Programme Manager) on behalf of the ETI and Hannah Evans (Bioenergy Practice Manager) on behalf of the ESC, February 2018.

Supply of bioenergy feedstocks

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.

A 2017 report commissioned by Cadent (written by E4tech and Anthesis)[1] updates the assumptions used in the 2011 CCC Bioenergy Review using latest data from public and private sector sources. This modelling exercise resulted in a central estimate of 73 TWh residual waste available in 2050 (range 64 -77 TWh), similar to current levels across the categories considered (wood, food and residual waste, plus sewage sludge). However, their analysis shows a decline in waste availability out to 2030 as increases in recycling outweigh waste growth, followed by a net increase in waste available as recycling growth slows but waste production rises as a result of population growth.

This is a more up to date assessment of waste availability than the ETI's 2009 Energy from Waste project. However, this project's assessment of the role for different energy from waste technologies (anaerobic digestion, gasification, pyrolysis and incineration) is still valuable and has informed the ETI's investment in an energy from waste gasification demonstration project. The Energy from Waste project concluded that anaerobic digestion is best placed to handle wet wastes, such as unavoidable food waste, manures and slurries. However, we would caution against mixing these feedstocks with purpose-grown crops (often maize) as this can significantly reduce the emissions savings potential of anaerobic digestion, due to the inputs used in maize production and methane slip from the AD process, and is unlikely to be the best use of land[2]. For dry waste, our whole energy system analysis identifies gasification with syngas clean up as a scenario resilient technology due to its ability to generate a range of end products (electricity, heat, liquid and gaseous fuels and chemicals) from a range of biomass and waste feedstocks (see response to Q23).

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

The ETI and others have carried out analysis on the quantity of UK land which is suitable for growing second generation energy crops (such as Miscanthus, Short Rotation Coppice Willow, and Short Rotation Forestry). This analysis (summarised in the Perspective, *Increasing UK Biomass production through more productive use of land*[3]) identified between **1.0 and 1.8**

[1] Renewable gas potential to 2050
[2] ETI (2016), Delivering greenhouse gas emission savings through UK bioenergy value chains
[3] ETI (2017), Increasing UK biomass production through more productive use of land

Mha of land that could potentially be made available for other agricultural uses, including bioenergy planting, by the 2050s without impacting on the level of UK-grown food consumed. Key to delivering this potential is improving the productivity of land throughout the agricultural sector (particularly grassland management for livestock) and reducing food waste. International data on total factor productivity in agriculture shows that the UK has fallen well behind the gains achieved in other comparable countries, suggesting that there is significant unrealised scope for productivity catch up[4].

Planting around 1.4 Mha of second generation energy crops could deliver between 70-105 TWh of feedstock annually[5]. However, the UK is starting from a low baseline, with around 10kha of Miscanthus and SRC Willow currently planted[6]. While research has shown that planting second generation energy crops can deliver several wider environmental benefits, we advise gradually increasing the planted area (~30-35 kha/yr) to monitor and manage the impact of these crops on the wider environment and other agricultural outputs. One of those impacts highlighted by the ETI's ELUM project[2] can be an increase in soil carbon, which is likely if planting on existing arable or temporary grassland. This increase in soil carbon could be valued within agricultural support mechanisms as a form of Greenhouse Gas Removal (GGR) – not only for energy crops, but any land use transition which increases soil carbon stocks. Given the current emphasis on paying farmers for ecosystems services (which could include carbon removal), we would encourage the CCC to consider the potential for agricultural support policy reforms to incentivise increased domestic bioenergy resource production, and how incentives can be shaped to incentivise the most GHG-favourable land use choices by farmers.

A gradual increase is also needed to develop the skills and supply chains needed to service this industry. An ETI-commissioned report by ADAS[7] found that, to deliver an annual increase of 30-35kha/yr, investment is needed in the production of plant breeding materials, including research into new establishment techniques (such as developing Miscanthus seeds to replace more costly and labour intensive rhizomes) to reduce costs. Investment is also needed in training and specialised equipment for planting and harvesting.

Finally, consideration needs to be given to the difference in supply chain logistics between imported and domestically grown biomass. Delivering 10% of final energy demand from biomass (ESME analysis indicates that this could contribute to a cost-effective route to delivering the UK's 2050 targets) will require a mix of domestically grown and imported biomass. Import supply chains are large scale and designed to handle huge quantities of wood pellets. Currently Drax are the largest importer of wood pellets and have made significant investments in port infrastructure and rail transport to underpin their supply chain. Importantly, the location of most biomass imports (north-east England and Liverpool)

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4 http://webarchive.nationalarchives.gov.uk/tna/20111108234748/http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/documents/ProdRep.pdf
&
https://ahdb.org.uk/documents/Horizon_Driving%20Productivity_Jan2018.pdf

5 ETI (2016), The evidence for deploying BECCS in the UK (Table, p12)
6 Defra (2017) Non-food crops
7 Summarised in: ETI (2017) Opportunities for rural job creation in the UK energy crops sector

coincides with potential sites for coastal hubs for offshore CO_2 storage. The policy support for this end use of biomass will end in 2027, but the infrastructure assets financed by UK electricity consumers could underpin logistics for other future uses of sustainable biomass feedstock imports (including the potential future development of BECCS supply chains). Specific consideration should be given to the strategy for incentivising best use of this biomass logistics capacity in supporting future optimal development of the bioenergy sector.

While the domestic sector can learn from import supply chains in terms of feedstock handling, there are limited opportunities to integrate the two and further investment will be needed to scale up the logistics road and rail requirements for UK grown biomass.

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)?

We consider that this is a question of economics, and one which should take into account not only the price the UK is willing to pay for the biomass as a fuel, but also the value placed on the carbon credit associated with that fuel. The price users are willing to pay will also depend on how high the marginal cost of carbon abatement is in the UK relative to other importing countries and how well we can process the biomass to produce valuable products while avoiding greenhouse gas emissions (for example, the UK may be willing to pay more if the biomass is used in BECCS technologies, if polices appropriately reward CCS).

The global resource model published by BEIS provides a range of scenarios for international resource availability. Using this range of estimates in the ESME model revealed that the quantity of imported biomass does not impact the way in which that biomass is used (BECCS is the preferred technology) but a reduction in biomass availability does have an important knock-on impact on decarbonisation activities in other sectors, particularly transport, which will need to decarbonise more rapidly in order to still meet 2050 emissions targets. This is because the reduction in biomass reduces the potential amount of negative emissions.

Scaling up UK sustainable supply

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.

The ETI's analysis indicates that there is a significant opportunity to increase the supply of sustainably produced domestic biomass through planting second generation energy crops. These crops can be grown on land which is poorly suited to first generation arable crops and can deliver additional environmental benefits. To significantly scale up the domestic biomass sector without impacting on food production, more productive use needs to be made of agricultural land as a whole. In the short term, planting could focus on economically marginal or long-term fallow land, while longer term opportunities will require a reduction in food waste and more productive management of livestock on grassland. Please see response to Q15 for further details and links to research.

This feedstock would be in addition to wastes and the bioenergy feedstocks produced from existing forests where the management regime would need to balance the demand for different wood products with the delivery of ecosystem services, including carbon storage.

19. What risks are associated with scaling-up domestic supply and how can these risks be managed?

Impact on other agricultural outputs

In relation to second generation energy crops, while opportunities exist to use economically marginal or underutilised land (such as those highlighted in the ETI's case studies[8]), delivering a substantial area of planting (1.4 Mha) is only possible without impacting on UK food production, if land use productivity is increased elsewhere in the agricultural sector and if there is a reduction in food waste.

Inappropriate land use transitions

The ETI's ELUM Project[2] (which investigated the impact on soil carbon of planting second generation energy crops) found that planting second generation energy crops on arable or temporary grassland (which typically has a lower starting soil carbon level than permanent grassland) could actually increase soil carbon levels. Planting on permanent grassland gave a more mixed picture with most transitions resulting in a fall in soil carbon levels (although when emissions associated with a fall in soil carbon levels from grassland are viewed in the context of the whole bioenergy value chain emissions, these crops can still deliver carbon savings when used in the right application). To mitigate the risk of poor grassland transitions, we recommend focusing on marginal arable and temporary grassland whilst continuing research into establishment methods which can minimise any soil carbon loss from a permanent grassland transition. As expected, and as already forbidden under sustainability rules, the ELUM project found that transitioning from forestry to a non-forestry energy crop is very detrimental to soil carbon levels.

Skills gap

The UK is starting from a small planted area of Miscanthus and SRC Willow. Scaling up too quickly will put stress on supply chains (particularly production of plant breeding materials) and may result in a labour gap filled by workers not familiar with establishing and harvesting these crops. This could impact on the yield produced throughout the crops' ~20-year life cycle.

Additional market opportunities

Planting energy crops is a long-term commitment (~20-year life cycle) and there are currently a limited number of buyers within the UK market. Three case studies of farmers growing biomass (carried out by ADAS and E4tech for the ETI) found that for all three farmers the ability to enter into a relatively long-term contract for their crop (5-yr+) was a key factor in their decision to plant the crop. The risk of farmers being stranded with no buyer could be reduced by developing multiple markets for these products (for example CAT

[8] ETI (2015) Bioenergy crops in the UK: Case studies of successful whole farm integration

(Centre for Alternative Technology) are researching whether Miscanthus can be used as an insulating material in buildings[9]) and through revenue from agricultural support payments reflecting the value of the additional benefits energy crops can bring to the wider environment (such as soil carbon sequestration and increased biodiversity). This would encourage farmers to maximise the emissions savings and other ecosystems services associated with growing bioenergy. If a range of markets did develop for Miscanthus and Willow, the relative price paid by those different markets should reflect the level of emissions saving delivered by the Miscanthus/SRC Willow relative to a likely alternative.

20. What 'low-regrets' measures should be taken now (e.g. planting strategies) to increase sustainably-produced domestic bioenergy supply?

As covered in the responses above, steadily increasing the area of second generation energy crops will allow the industry to learn by doing and monitor impacts on the wider agricultural sector. Scaling up production to the point where the UK can increase the area of planting by 30-35 kha/year would put the UK on a trajectory towards delivering between 70-105 TWh of feedstock (from 1.4Mha, based on analysis using the ETI's Bioenergy Value Chain Model). This planting should initially focus on economically marginal arable and temporary grassland (to maximise soil carbon sequestration benefits) while further research is carried out into minimising emissions from permanent grassland transitions.

An annual increase of 30-35kha (of Miscanthus, SRC Willow or Short Rotation Forestry) is large compared to the current 10kha planted with Miscanthus and SRC Willow but is within the annual fluctuations in planted area seen for several cereal crops (e.g. between 2010 and 2017 the average absolute annual change in wheat area was 128 kha (ranging from a loss of 337kha between 2012 and 2013, followed by a recovery (+321 kha) in 2014[10]).

Investing in low-cost pre-processing technologies to improve biomass quality could make UK-grown energy crops (and potentially waste wood) a more attractive fuel for buyers and open up new end uses for this feedstock. The ETI is investing in a commercial scale water washing demonstrator which will be commissioned during 2018[11]. This follows promising research at a lab scale into the impact of water washing on feedstock properties[12].

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[9] http://blog.cat.org.uk/2017/09/01/worlds-first-miscanthus-bale-house/

[10] Defra (2017) Structure of the agricultural industry in England and the UK in June, Cereal and oilseed yield, area and production

[11] BioFIP: http://www.eti.co.uk/programmes/bioenergy/biomass-feedstock-improvement-process-project

[12] Gudka B; Jones JM; Lea-Langton AR; Williams A; Saddawi A (2016) A review of the mitigation of deposition and emission problems during biomass combustion through washing pre-treatment. Journal of the Energy Institute, 89 (2), pp. 159-171. https://doi.org/10.1016/j.joei.2015.02.007
Gudka, B. Pre-treatment of waste wood via washing and the use of an additive to optimise fuel properties. Presentation available at: https://irp-cdn.multiscreensite.com/57706d10/files/uploaded/B%20Gudka%2C%20Leeds%2C%20Leeds%2C%2027-06-17.pdf

21. What international examples of best-practice should the UK should look to when considering approaches to scaling-up domestic supply?

The ETI's research has focused predominantly on understanding the impacts of developing a UK biomass market. However, we are aware that the IEA Bioenergy Task 43 (Biomass Feedstocks) are collating information on perennial biomass crop research and production locations worldwide[13].

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

Farmers and foresters need the right market conditions in order to make energy crops a viable business decision. In the ETI's case studies of three farms growing Miscanthus and SRC Willow[10], all three farmers highlighted the importance of being able to enter long-term, fixed-price contracts with buyers in their decision-making process. Buyers could offer a long-term revenue stream at a price which delivered a return on investment to the farmers, in part because the crops were being used on sites that were receiving subsidies through the Renewables Obligation (RO). However, with the closure of the RO to new entrants and a desire from government to see low carbon technologies reduce their reliance on subsidy, these prices may not be sustainable for the end users in the long term which is likely to weaken the economic case for growing Miscanthus and Willow purely as an energy crop. By quantifying the value of the additional ecosystem service these crops can deliver, and rewarding farmers and foresters for these services, as well as paying for the fuel, it should be possible to deliver a more robust, long-term business case for growing energy crops in the UK.

In considering the future of agricultural support payments and policy to reward farmers for delivering public good after leaving the EU, the government should consider the options for incentivising farmers to deliver carbon services. There is a need to consider in more depth how incentive payments could be practically structured and targeted to reward farmers for land use decisions which have significant GHG benefits. In doing this there will be a need to align incentives with scientific evidence and to ensure that policy can be adapted as the evidence base improves.

The ELUM project conducted a synthesis of the ecosystem services impact of land use transitions *to* second generation crops (such as Miscanthus, willow and short rotation forestry) and found that for transitions *from* first generation feedstocks (food crops), studies suggest significant benefits may arise for a number of ecosystem services, including hazard regulation, disease and pest control, water and soil quality. Although less evidence is available, the conversion of marginal land to second generation energy crops production will likely deliver benefits for some services while remaining broadly neutral for others. However, they highlight the importance of further research to broaden, and deepen, our understanding of the implications of transitions to 2G feedstocks on ecosystem services,

[13] http://task43.ieabioenergy.com/projects/perennial-biomass/

providing empirical evidence for policy development, particularly for commercial deployment where landscape scale effects may emerge[14].

In addition, the SUPERGEN bioenergy hub based at Manchester University are currently investigating the role energy crops could play in remediating contaminated land and whether crops grown on these land types are suitable for use in energy production[15], AFBi in Northern Ireland are carrying out field trials to assess the potential for SRC Willow to reduce nutrient run-off from agricultural land into water courses[16], and Iggesund, a paperboard manufacturer in West Cumbria who power their CHP boiler with waste wood and willow, are working with Rothamsted research to understand the role willow can play in mitigating the effects of flooding[17].

As well as valuing the wider benefits of bioenergy crop planting, policy measures are needed to reduce food waste and increase productivity of food production if the UK is to have sufficient land available to scale-up domestic biomass production.

As well as fuel supply, research and development is needed into the best ways of pre-processing these feedstocks and optimising the conversion processes which use them. The ETI is investing in a commercial scale water washing pre-processing demonstration project (led by Forest Fuels and Uniper Technologies Ltd) after research, in particular by the University of Leeds, has found that water washing can remove surface contaminants and encourage leaching of problematic species from the biomass itself[12,18.]

Best-use 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?

The answer to this question very much depends on what is meant by gasification. Gasification is an old technology (19th Century) and is commercially available for coal and hence for coal with CCS as a low carbon solution. For biomass and wastes, the technology choices are different and are not yet robustly commercially available.

The answer to this question when applied to biomass and wastes also depends on what end outcome is needed. If the end outcome is power then:

[14] Holland, R.A., Eigenbrod, F., Muggeridge, A., Brown, G., Clarke, D. and Taylor, G. (2015) A synthesis of the ecosystem services impact of second generation bioenergy crop production, Renewable and Sustainable Energy Reviews, 46, 30-40. http://dx.doi.org/10.1016/j.rser.2015.02.003
[15] http://www.supergen-bioenergy.net/
[16] https://www.afbini.gov.uk/articles/renewable-energy-crops#toc-2
[17] http://biofuel.iggesund.co.uk/balance-is-everything-for-jan-wilkinson/
[18] http://www.eti.co.uk/programmes/bioenergy/biomass-feedstock-improvement-process-project

- at low efficiency, "close coupled" gasification systems are available
- at high efficiencies and large scales (e.g. >15MWe power output), gasification systems where the hot syngas is treated to remove undesirable components but leaves tars as vapours are commercially available from the likes of Valmet[19]. However, the application in the UK setting of this kind of gasification type (Type 2 as defined in ETI's report, *Targeting new and cleaner uses for wastes and biomass using gasification*[20]) is not easily made economically viable, in particular because District Heating is not widely practised.
- also at high efficiencies, but at smaller scales (suited to town scale applications and private wire arrangements), are gasification systems where the syngas is cooled, tar is removed and contaminants such as sulphur removed down to the parts per billion (ppb) level. This additional treatment of syngas enables its wider use, not only to produce power, but to also enable the production of fuels such as aviation fuel, and chemicals. This kind of technology is challenging to develop and is only now (2018) emerging. Key development projects are those by Advanced Plasma Power supported by DfT, and KEW technologies supported by the ETI. Should these projects successfully demonstrate their objectives, then 2nd and 3rd projects should be starting production in the early 2020's. This commercial deployment would represent a key stepping stone on the path to further upscaling and deployment with other feedstocks in the medium and long term.

The latter option (gasification with syngas tar removal and clean-up) is where the ETI's whole systems analysis suggests that gasification can add real value in the short to long term as a scenario resilient technology due to its ability to make a range of different end products from a variety of feedstocks. While waste feedstocks provide the best commercial proposition at the moment (due to the gate fee they attract), gasification can also use virgin biomass feedstocks. Gasification could also be coupled with CCS in future to deliver 'negative emissions'. Waste gasification at town scale could be commercially deployed within the next 5 years. Further work is needed to develop commercial deployment strategies for larger scale biomass gasification applications, which can underpin longer term hydrogen and BECCS value chains.

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.

Efficiencies are difficult (if not impossible) to compare between different gasification types/projects. System boundaries are rarely the same and efficiencies will change according to type and scale of gasifier and type of feedstock. Costs also are difficult to define, again because of undefined boundaries, but also because of the early nature of development for the type of project ETI is supporting.

[19] see https://www.lahtigasification.com/

[20] http://www.eti.co.uk/insights/targeting-new-and-cleaner-uses-for-wastes-and-biomass-using-gasification

In seeking to costs "likely to be achieved", careful definition of the question being asked and analysis is needed to avoid yield incomparable (and potentially unrepresentative) figures. There are some key projects which could provide the CCC with indicative costs (e.g. Advanced Plasma Power c£28M biomethane project in Swindon and ETI's Kew-Tech c£11.5M power project in the West Midlands). However, these are FOAK plants and so the costs will not be representative of future plant costs. These plants also have different uses for their clean syngases so their costs are not directly comparable (without detailed analysis).

On a feedstock day hopper to net power output basis, we should anticipate whole plant efficiencies for gasification plants with tar removal and syngas clean-up in the range 27-30% initially with scope to rise to 35%, perhaps 40% for the largest and most sophisticated future projects.

Costs can most effectively be reduced by speeding up the construction phase of a project (when the plant is not taking waste/producing saleable power). There are a number of ways in which the construction process can be streamlined and innovation through learning from the building industry (e.g. prefab homes) is one example.

c) What are the main barriers and uncertainties associated with the development, deployment and use of gasification technologies?

- Funding (especially debt) is almost impossible to get for early stage technologies moving from TRL 5-8. Funding is also difficult for companies seeking to build a "second" project (i.e. the move from TRL 8 to 9. Typically, such projects must be funded by supportive grants and/or equity investments. Where grant funding is used, significant engineering and project management skills are needed within the grant body to monitor and evaluate project outputs and outcomes. Good examples of this are the ABDC and F4C projects led by DfT.
- Where equity investments are used, sufficient contingency to manage 'teething problems' is often not included. Investors invariably anticipate that a new plant will work 'out of the box'. This is rarely the case and recent high-profile failures in gasification demonstrate where investors/backers have lost interest or faith and have chosen to close projects down rather than allow engineers to resolve teething issues. A key need therefore is to provide early stage OPEX funding to these projects as reliability might not be expected to exceed 40-50% in the first year post commissioning.
- Clearly, given the high-profile failures, there is a lack of robust experience and data available upon which to design gasification plant. While UK experience is already being gained in gasification design, this is still a weakness. For example, designers continue to underestimate the challenges in feedstock handling.
- There is a lack of trained personnel able to reliably operate a gasification plant in the UK. This can be mitigated by using technologies which have been used in other applications (e.g. fluidised bed reactors). There is a lack of grant funding to initially support high training costs to reskill the UK work force

- Gasification technology providers are usually small SME's and are unused to developing large scale projects. For example, they struggle to understand when to relinquish complete control and bring in external expertise, in particular project management expertise. SME's need advice and ongoing guidance on how to structure projects and how to implement good quality governance to increase the possibility of project success. This is an area in which Universities could input by bringing these aspects into their engineering courses. Again, the process being used by DfT for managing the ABDC and F4C projects may provide an example of good practice.

d) What risks are associated with gasification technologies and how can these be managed?

- There are still issues around whether the group of individual units that make up a single gasification plant (with syngas cleaning) can be made to work together. We do not yet know (for sure) that we can sufficiently clean up a syngas made from waste or biomass to make power reliably from an engine or fuels via a chemical synthesis step.
- There is a lack of reliability data for gasification plants upon which investors can base their decisions.
- Synthesis processes to make, for example, hydrogen and biomethane are expensive conversion processes and not yet fully proven on biomass/waste derived syngases – new lower cost syngas conversion processes are needed, perhaps using biological routes (e.g. syngas fermentation). None are yet robustly demonstrated / available.
- Gasification is a challenging subject to understand – there is a risk that policy / regulation is not well written and so discourages the development of gasification in the right direction.
- There is a risk that poor quality / failed gasification projects discourage future investors and skew public perceptions in the wrong direction.

e) What policies and incentives are required to facilitate commercial deployment?

Policies should seek to encourage the development of gasification technologies that yield a cold, tar-free, clean syngas which can be used to produce power via gas turbines/engines/fuel cells or otherwise used to synthesise fuels and chemicals, either via a chemical or biological synthesis stage. However, the versatility of gasification (which gives it its system-level value) means that it cuts across a number of different support mechanisms and government departments. A more concerted, strategic and co-ordinated approach to technology development and support for early commercial scale deployment would be beneficial in developing the technology at scale and driving efficiencies and cost reductions.

At present most government subsidies are targeted towards technologies with a TRL 8-9. Gasification with syngas clean-up is only now being demonstrated at a commercial scale

(TRL 5-7) and dedicated support is needed during this commercialisation phase (such as the funding and support provided by the ETI or the DfT's ABDC project) and then subsequently from TRL8-9.

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?

Fossil CCS has been commercially deployed in countries including Canada, Norway and the USA and BECCS has been deployed in the USA (ethanol plant)[21]. There are also several plants which capture CO_2 for use in other applications. In the UK, the first CCS plant is likely to be fossil fuel based (gas) as this is a better understood and demonstrated value chain, with potential projects in the pipeline[22]. The UK has done a lot of work to de-risk CCS deployment, including investing in detailed storage site appraisals and monitoring equipment, and is also well placed to exploit the benefits of CCS given its expertise in oil and gas, project management and health and safety. The ETI's paper, *The evidence for deploying BECCS in the UK*,[23] sets out the progress at various stages of the supply chain that has been made towards deploying BECCS in the UK and concludes that barriers to deploying BECCS are financial and political, rather than technical.

Research carried out as part of the ETI's CCS programme has concluded that the UK is in a position to deploy CCS at a commercial scale and that greater cost savings now could come from deploying a few large projects sequentially, rather delaying deployment to invest in low TRL research and development [24]. The earliest a CCS project could realistically come on-line in the UK is the mid-2020s. If a BECCS plant were to follow that, the earliest commercial scale deployment is likely to be late 2020s/early 2030s.

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

BECCS delivers the greatest amount of carbon savings when used to produce electricity or hydrogen. The optimal vector will depend on decisions made elsewhere in the energy system (such as deployment of other low carbon electricity sources, the role for hydrogen in decarbonising homes and industry and how this is integrated into existing networks). Biomass to hydrogen (via gasification) has not been demonstrated at a commercial scale. Investing in demonstrating the syngas to hydrogen clean-up and conversion process at a commercial scale will help to keep

[21] https://www.globalccsinstitute.com/projects/large-scale-ccs-projects
[22] OGCI Clean Gas Project, http://www.oilandgasclimateinitiative.com/investments/
[23] http://www.eti.co.uk/insights/the-evidence-for-deploying-bioenergy-with-ccs-beccs-in-the-uk
[24] ETI (2017) An argument for CCS in the UK

this option open. Projects, such as Hydeploy are progressing understanding of how hydrogen could be used in different applications and blended with natural gas.

Biomass to hydrogen + CCS may also require the deployment of different capture technologies compared to those fitted to biomass, coal or gas post combustion power plants.

c) What efficiencies and costs are possible?

As stated earlier, the UK has developed a substantial biomass imports logistics network. Beyond 2027 it is not certain whether these assets will be used or the supply chains continued. If BECCS plants were located strategically to make use of these assets it could reduce the overall CAPEX costs.

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)?

BECCS technologies are likely to be deployed at scale and be situated near a coastal hub for carbon dioxide storage. Logistically this makes an import supply chain (such as the one used at Drax) simpler to implement. For an individual site it may be too costly to integrate domestic and import supply chains but smaller users (who may be connected to a CCS cluster) may be able to make use of locally sourced biomass.

Whichever biomass feedstock is used, it will be important to ensure that it contains low levels of contaminants which could make carbon capture more difficult. For example, sulfur and chlorine can form acid gases which degrade the amine used in post combustion capture processes. Pre-processing steps, such as water washing may be needed to remove these species.

e) What are the main barriers and uncertainties associated with the development, deployment and use of BECCS?

As stated above, the main barriers to BECCS are financial and political, rather than technical.

In terms of technical development, amine based capture processes are likely to be the first capture plant technology to be commercialised in the UK. There is ongoing research at PACT in Sheffield to investigate the compatibility of biomass combustion flue gases with these capture technologies. This will identify whether additional flue gas cleaning steps are required for BECCS compared to fossil CCS, and whether certain capture technologies are better suited to BECCS.

There is still a need to develop other capture technologies, as the technique used will vary depending on the end vector produced. For example, hydrogen production is likely to require pre-combustion capture using adsorption.

In terms of political and financial barriers, there is no mechanism in place to reward ‘negative emissions’. The industry is also wary of making large, long term commitments in CCS since the sudden cancellation of the CCS commercialisation competition. A clear steer from government is needed that any policy and market frameworks put in place are long-term measures that companies can invest against.

More broadly, CCS is a new technology for the UK and social acceptability will be an important factor in whether these plants are able to obtain the necessary permissions to proceed.

f) **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?**

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