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.

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.

As the question implies, two effects often not included in carbon footprints can significantly affect results: 1) carbon stock changes and 2) indirect land-use change.

Carbon stock changes are inherently plausible. They are part of the generally accepted biological and geological carbon cycle. But, only recently have they been recognised as integral to lifecycle GHG emissions accounting (Eric Johnson, 2009). This paper has subsequently been cited over 250 times[1], often by researchers who try to build carbon stock changes into life cycle assessments/carbon footprints. A well-publicised debate of how to include ‘carbon debt’ into life-cycle GHG accounting revolved around a 2010 ‘Biomass Sustainability and Carbon Policy Study’ conducted by Manomet, a non-profit think-tank based in the USA. Although the importance of stock change or ‘carbon debt’ has been widely acknowledged by scientists and independent observers, it has yet to become standard in ‘official’ carbon footprints such as those published by most governments. Moreover, some scientists[2] continue to argue against it.

Direct land-use change is typically included in carbon footprints, but indirect land-use change (iLUC) usually is not. Some analysts dispute the existence of iLUC, which makes it problematic, but more problematic are its variance and allocation. Estimates of iLUC vary by a factor of 2-3, and its allocation among specific feedstocks or biofuels is far from agreed.

Both carbon stock and iLUC are technically difficult. So difficult that some analysts such as John DeCicco[3] argue that life-cycle assessment – as currently defined in ISO standards – is incapable of accommodating them. DeCicco makes a good point, and the best response is for Government to support a re-think of the methods used in carbon footprinting. Instead of slavishly saluting ISO standards, which clearly are dictated by and for industries that profit from them, Government should support efforts to make accounting standards useful to itself and to the best possible evidence.

In this context, life-cycle GHG accounting standards are no different than financial accounting standards. They are important, but they are not science (as is repeatedly claimed). They should be adapted to account for critical phenomena such as carbon stock and iLUC, and if this means rejecting outdated concepts, so be it.

[1] https://scholar.google.com/citations?user=J4rsUqMAAAAJ
[2] https://www.euractiv.com/section/energy/opinion/bioenergy-at-the-centre-of-eu-renewable-energy-policy/
[3] https://link.springer.com/article/10.1007/s10584-017-2026-9

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?~~

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?
    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)
    c) What are the most likely alternative/counterfactual uses of forestry products used for wood pellet production?
    d) How are these wider market impacts (sub-questions a-c) likely to change over time if demand for wood pellets significantly increases?

The problem of wood pellets for electricity is not that of displacement, it is of carbon stock depletion. American pellet producers are harvesting entire trees and processing them to chips or pellets. In some cases the carbon balance would be better if these trees were simply left standing. As a 2011 analysis submitted to OFGEM (Atlantic Consulting, 2011) puts it: "Carbon capture and storage – by sparing trees". The analysis compares the carbon footprint of two options for incremental electricity. One is to harvest trees and burn them to generate power. The other is to leave the trees standing, and to generate power from a plant fired by natural gas. The key finding is that wood-fired electricity carries a far higher carbon footprint, 690 g CO_2e/kWh, than the gas-fired, combined-cycle footprint of 401 g CO_2e/kWh.

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)?

At the small scale, biomass boilers and furnaces tend to emit much more local-air-quality pollutants than do conventional boilers and furnaces. The main offender is particulate matter (soot) and sometimes NOx as well. This is not an issue of imports or supply. It is an issue of emission-control technology, which for small-scale biomass burners compare poorly to other combustion technologies such as gas.

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?

From an environmental standpoint, this preserves UK carbon stock. It also displaces fossil fuels, which does not necessarily improve carbon balances but usually increases energy security.

From an economic standpoint, the case for importing biomass and biofuels is the same as that for imports in general. Larger markets can be more efficient and have better economies of scale and scope.

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?~~

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?~~

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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?~~

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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?

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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?~~

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    ~~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)~~

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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?~~

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.

There is growing evidence that biomass waste could be converted into 10.8 million tonnes/year of bioLPG by 2040 and as much as 5.6 million tonnes/year by 2050 (Table 1). **NB** The current UK market for fossil LPG used in heat and transport is about 1 million tonnes/year.

An independent update of the CCC 2011 Bioenergy report was published in September 2017 by Cadent Gas. Waste-availability estimates in the update[4] [5] are broadly similar to those in the CCC report.

The production of BioLPG via gasification can use the same syngas as used as a precursor for BioSNG. It does not compete for feedstock used in anaerobic digestion to biomethane, and

[4] http://cadentgas.com/getattachment/About-us/The-future-role-of-gas/Renewable-gas-potential/Promo-Downloads/Cadent-Bioenergy-Market-Review-SUMMARY-Report-FINAL.pdf
[5] http://cadentgas.com/getattachment/About-us/The-future-role-of-gas/Renewable-gas-potential/Promo-Downloads/Cadent-Bioenergy-Market-Review-TECHNICAL-Report-FINAL.pdf

this type of biomass (wet manure, macroalgae etc) has been excluded from the biomass availability. Conversion efficiencies have been estimated based upon TRL4-5 experimental findings. It is anticipated that improvements can be made, but this is limited to 60% by 2050 which is a conservative estimate. Note that technology routes do exist for the production of fuels that can be made from captured CO_2, and blended into LPG (e.g. Dimethyl Ether from CO_2 hydrogenation, with hydrogen from surplus renewable hydrogen). Such routes are anticipated in the UK Clean Growth Strategy,[6] but excluded from these projections.

Table 1: Potential UK Biomass Availability (TWh) (Central Estimates)

	2020	**2030**	**2040**	**2050**
Feedstock[7]				
Biogenic Residual Waste	28.8	23.3	24.2	25.2
Wood Waste	24.2	26.2	27.1	28.1
Imported Sustainable Biomass[8]	85	200	180	60
Sub-total Biogenic	135	249.5	231.3	113.3
Other				
Fossil Residual Waste	15.8	12.7	13.3	13.8
Total	**150.5**	**262.2**	**244.6**	**127.1**
Conversion Efficiency to BioLPG	50%	55%	60%	60%
BioLPG Availability (TWh)	75	144	146	76.2
MTonnes LPG (1TWh=74x10^3 tonnes)	**5.6**	**10.7**	**10.8**	**5.6**

The available biomass substantially exceeds the 1 M tonne total UK LPG market requirements. The same core infrastructure (biomass gasification to syngas) can be utilised and scope exists to satisfy increased market requirements as the government phases out the use of heating oil and coal for off-gas grid heating.

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)?~~

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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?~~

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[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/651916/BEIS_The_Clean_Growth_online_12.10.17.pdf

[7] https://cadentgas.com/getattachment/About-us/The-future-role-of-gas/Renewable-gas-potential/Promo-Downloads/Cadent-Bioenergy-Market-Review-TECHNICAL-Report-FINAL.pdf

[8] https://www.theccc.org.uk/wp-content/uploads/2011/12/1463-CCC_Bioenergy-review_interactive.pdf

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.~~
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19. ~~What risks are associated with scaling-up domestic supply and how can these risks be managed?~~
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20. ~~What 'low-regrets' measures should be taken now (e.g. planting strategies) to increase sustainably-produced domestic bioenergy supply?~~
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21. ~~What international examples of best-practice should the UK should look to when considering approaches to scaling-up domestic supply?~~
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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?

As the CCC 2011 Bioenergy report and subsequent updates have shown, the UK's highest-volume feedstocks for biofuels are organic wastes and cellulosic crops. Perhaps 10% of these can be processed via anaerobic digestion (to biogas), but the rest can be converted to biofuels/biogas only through Advanced Conversion Technologies (ACTs): cellulosic ethanol, gasification with Fischer-Tropsch or methanol, and pyrolysis. Gasification is likely to play the biggest role, thanks to its variety of possible products and its commercial maturity.

a) Gasification already is commercial. With Fischer-Tropsch to make liquid fuels, it was commercialised in the mid-1930s. Gasification with subsequent methanol-to-hydrocarbons was run at demonstration-scale in the 1980s, and commercial-scale production is believed to be operating today in western China. All of these process ***fossil*** feedstocks, either coal or natural gas (which of course does not require gasification, but still goes through the subsequent conversion to hydrocarbons). ***Biomass*** feedstocks are equally feasible from a technical standpoint, but they have not yet commercialised, due to lack of funds. Numerous projects planned for biofuels have failed financially – most recently the mid-2017 collapse of Joule Unlimited, which had planned a gasification-FT plant in the USA to process wood wastes. Biomass-based gasification-FT or gasification-methanol-hydrocarbons will go commercial as soon as there is sufficient funding behind it. A major plant to process forest-residues is planned by Chinese-owned Kaidi in Finland for start-up in 2020, but given the many failures of such projects – we'll believe it when we see it.
b) Efficiencies of gasification are about the same for biomass as they are for fossil feedstocks: the output fuels (and sometimes electricity) contain at best 50-60% of the heating value in the feedstock. Unit costs will of course decline if/when biomass plants are built at scale, both due to economies of scale and economies of learning. Still, the key to commercialisation will be pricing of gasification products and their competing products. Just as conventional biofuels needed and still need serious government support, so too will unconventional biofuels – even more so. Feedstocks can be differentiated in two ways: heterogeneous ones will always be costlier, because they will complicate process-optimisation; wastes can provide higher

margins in that they often can generate gate-fee revenue, whereas most non-wastes will incur some purchasing cost. These tendencies are often countervailing (i.e. wastes are often heterogeneous).

c) The main barrier to commercialisation is security of funding. If this can be provided via subsidy or price controls or natural market mechanisms (say, an extraordinary spike in fossil fuel prices), commercialisation is very, very likely. It is not trivial, but it is surely less challenging than was, say, nuclear power.
d) The main risks are financial and economic. The story of conventional biofuels already provides numerous examples. The risks of gasification are higher, because the support required for it will be greater.
e) Subsidies, price supports and mandates are most important. There are many examples, and not just from the energy industry. Take photovoltaics, for example: thanks to these sorts of policies, PVs are now commercially competitive in various regions and market niches. In time, gasification could also become commercially viable.

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

~~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?~~

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?

ACTs should produce biofuels, not electricity

Advanced Conversion Technologies (ACTs) have been defined (UK Dept of Business Energy & Industrial Strategy, 2016) as: cellulosic ethanol production, gasification with Fischer-Tropsch synthesis, gasification and pyrolysis[8].

Our comment is that CfD should not be used to support ACTs, that is, ACTs should support biofuels, not electricity, because:

- Liquid biofuels are the main way to decarbonise off-grid transport and heating over the next 10-30 years.
- ACTs are the only route to high-volumes of liquid biofuels. For LPG, there is already some supply of conventional (non-ACT) bioLPG, but this is unlikely ever to amount to more than 5-10% of demand. The only known way to displace the remaining 90-95% is with ACTs.
- One ACT, gasification, can be used to generate electricity from residual waste. However, it is less efficient, costlier and technically more problematic than conventional incineration of that same waste to generate electricity. Also, there are many other ways other than gasification to decarbonize electricity.
- Therefore, ACT subsidy and support should focus on its best use: not electricity, but biofuels

Other schemes such as the Renewable Heat Incentive (RHI) and the Renewable Transport Fuel Obligation (RTFO) are better suited to promoting ACTs. The highest value of ACTs is in producing fungible fuels for small-scale combustion – not in producing electricity.

Only biofuels can decarbonise off-grid transport and heating in the medium term

Off-gas grid transport and heating are powered mainly by liquid fuels: petrol, diesel, jet fuel, heating oil and LPG. The only way to decarbonise these fossil fuels in the near-medium term is to substitute them with biofuels – including bioLPG for LPG.

[8] The 2016 Call for Evidence adds: ACTs "are a number of technological options available to make use of a wide variety of biomass types, including wastes. Conversion technologies may release the energy directly, in the form of heat or electricity, or may convert it to another form, such as liquid biofuel or combustible gas. Advanced Conversion Technologies are the subject of current research, with some demonstration plants in operation, however are not widely deployed."

ACTs are the only route to high-volume, fungible biofuels

Calor Gas has pioneered the global introduction of bioLPG. Together with its parent company SHV Energy – Calor has worked with Finnish biofuels producer Neste to develop the supply of biopropane into the UK and other European markets. This biopropane is a by-product of a conventional hydrogenation process that mainly produces 'renewable' biodiesel. Supply is limited: in time, this biopropane might be able to cover 5-10% of UK LPG demand, but feedstock limitations make greater penetration unlikely.

This is where Advanced Conversion Technologies (ACTs) come in. ACTs (Table 2) are the only known route to high volumes of liquid biofuels that can push displacement to well above 10%. This is because they are the only way to process high volume feedstocks – namely residual waste, wood waste, dedicated energy crops, crop residues and arboricultural residues.

Table 2: ACTs' suitability to displace liquid fuels

ACT[9]	Displacement of	Scale & Timing	Relevance to CfD
Cellulosic ethanol	Petrol only	First commercial plants are just coming online. Volume is still well under 1% of petrol demand.	Minor, not directed at power generation.
Gasification with Fischer-Tropsch[10]	Full slate of liquid refined products, including LPG.	For biofuels, demonstration plant of APP in Swindon, and demonstration projects in Austria, the Netherlands and Sweden. Commercial-scale *fossil-fuel* plants operate in Indonesia, South Africa and the USA.	Negligible, the product fuels are not economic for power generation.
Pyrolysis	Diesel, jet fuel and petrol. LPG is possible, but less likely.	No known commercial-scale plants for biofuels. Commercial-scale plants do exist, e.g. for converting used tyres into liquid fuel.	Minor, not directed at power generation

How much bioLPG could ACTs produce? The Committee for Climate Change's 2011 Bioenergy Review made an initial estimate of UK biofuel-feedstock availability, and this has been updated several times subsequently. According to the 'medium' scenario in a late-2017 update by (Scholes et al., 2017)[11] of: by 2040, the UK could make available 102 TWh of biomass feedstocks that are suitable for gasification with Fischer-Tropsch into liquid biofuels. According to rule-of-thumb conversion factors, this could be processed into about 2.7 million tonnes/year of bioLPG (Table 1) – about three times current demand for fossil LPG.

Table 1: Potential bioLPG production by gasification, from UK feedstocks, million tonnes/year

	2040	2050
	Scenario	***Scenario***

[9] Defined in BEIS's November 2016 Call for Evidence on fuelled and geothermal technologies in CfD.
[10] An alternative is gasification, followed by conversion of the syngas to methanol and subsequent conversion of methanol to longer hydrocarbons. For the purposes of this consultation, gasification/FT and gasification-methanol-hydrocarbons are essentially the same thing.
[11] https://cadentgas.com/getattachment/About-us/The-future-role-of-gas/Renewable-gas-potential/Promo-Downloads/Cadent-Bioenergy-Market-Review-SUMMARY-Report-FINAL.pdf

Feedstock	*Medium*	*Medium*	*High*
Waste biomass	1.5	1.6	1.6
Non-waste biomass	1.1	1.9	4.4
Total biomass-LPG	2.7	3.5	6.0

However, through Calor's current research and development programme it is anticipated that improvements can be made to conversion efficiencies to propane. As a result it is clear that ACTs could supply the remaining 90-95% of bioLPG to displace fossil LPG completely, plus enough to displace the use of heating oil and coal in the entire off gas grid heating market. ACTs are the only significant way to decarbonise off-grid transport and heating in the medium term.

Supporting ACTs-to-electricity is poor policy

One ACT, gasification, can be used to generate electricity from residual waste. There have been 2-3 such plants in the UK, and some 10 more are planned, several of those with CfD support[12].

These staged gasification plants have a reported electrical efficiency of 12-18% (International Solid Waste Association, 2013). They also are notoriously difficult to operate[13], in that the generator tends to get fouled by tars that are created in gasification. Indeed, two projects in the UK – Avonmouth BioPower and Tees Valley – were shut down due to this problem.

Conventional waste incinerators, by contrast, report electrical efficiencies of 18-27%, and some new plants reach efficiencies as high as 32%. The technology is well proven: over 2,000 plants are in operation worldwide. Typical gate fees are competitive with those of landfilling, and investment capital runs to £350-900 per tonne of annual capacity.

A further obvious, but relevant point is that there are many ways other than ACT to decarbonize electricity (and other ways to dispose of waste).

The conclusion - ACT subsidy should focus on its best use: biofuels

The ACT section of BEIS' latest CfD consultation is evidently directed at gasifier ACTs that generate electricity from waste (discussed in Section 0). The consultation proposes criteria and rules encouraging ACT waste-gasifiers to generate an intermediate fuel – one that is subsequently burned in a generator! Whilst this first part is a step in the direction of biofuels, it is more than negated by the second part. It ends up with a costly, inefficient, unproven and superfluous route to electricity.

ACTs should be focused on biofuels, and their support should be explicitly for this. ACTs should not be focused on power generation, so CfD support for them is unsuitable.

References

International Solid Waste Association, 2013. Alternative Waste Conversion Technologies: White Paper. Copenhagen.

[12] https://www.mrw.co.uk/latest/act-and-biomass-schemes-backed-in-cfd-auction/10023285.article

[13] http://resource.co/article/advanced-conversion-technologies-heated-debate-11503

Scholes, P., Dick, H., Amos, C., Alberts, G., Bauen, A., Kenefick, M., Taylor, R., 2017. Review of Bioenergy Potential: Technical Report.

UK Dept for Transport, 2017. RTFO Volumes of fuels by fuel type.

UK Dept of Business Energy & Industrial Strategy, 2018. Updated energy and emissions projections 2017.

UK Dept of Business Energy & Industrial Strategy, 2016. Call for Evidence – Contracts for Difference. A call for evidence on fuelled and geothermal technologies in the Contracts for Difference.

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?~~

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?~~
    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 biggest weakness is the definition of products and residues. These classifications are sometimes made as a sop to national interests. For instance, crude tall oil is classified as a residue by Nordic government in deference to certain industrial companies and in defiance of its conventional consumers. Palm fatty acid distillate is classified by some governments as residue, by others as a product. Residues could and should be defined rigorously, not by political whimsy that undermines the credibility of decarbonisation policy.

Product/residue confusion also leads to flaws in the carbon footprints of the 'fossil fuel' comparators in the Renewable Energy Directive and related legislation. The comparators' absolute values set the hurdles by which biofuels qualify for government support, and yet these absolute values can vary considerably, depending on product/residue definitions. Currently, refinery outputs such as bitumen, bunker fuels, LPG and petroleum coke are defined as products, despite common knowledge among refiners that they are residues. They are allocated carbon footprint that should instead be allocated to 'on-purpose' products – mainly diesel, petrol and jet fuel.

The main gap in land-use accounting is carbon stock. This should be included in carbon footprints, and a 'counterfactual' case should be part of this, as shown in (E Johnson & Tschudi, 2012).

~~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?

Carbon stock changes should be included in life-cycle accounting of emissions. It already is firmly entrenched in reporting for the Kyoto/Paris Protocols. Doing so would account for real changes in carbon emissions, not those as currently defined that unfairly favour biofuels. Supporting data is sufficiently available to allow definitions and methods of reporting these carbon stock changes.

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?~~

-

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

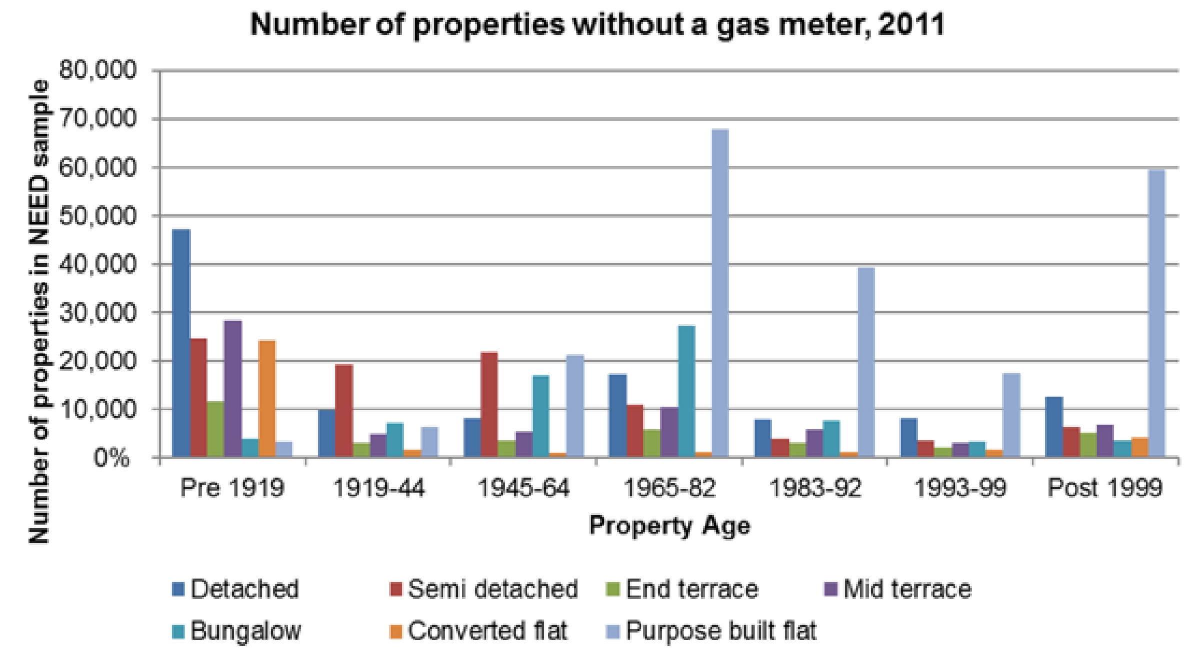
Other

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

Calor has been concerned by the Committee on Climate Change's approach to the decarbonisation of off-gas grid heat in that it has focused completely on the wholesale deployment of electric heat pumps to the exception of any other potential low carbon solutions. This has been further reinforced by the Committee's response to the Clean growth Strategy where it has called for the installation of 1.5 million heat pumps in the countryside.

Calor supports the CCC's motivation to drive the deployment of more efficient heating systems. However, it is clear that electrically driven heat pumps face particular challenges in rural off-gas grid areas:

- **Housing stock –** Properties in off-gas grid rural areas are typically older and this is reflected in the chart below:



Not only that, but a high proportion of these buildings will have solid walls, be listed or in conservation areas. This represents a significant technical and cost challenge for electric heat pumps as they can only deliver their desired efficiencies in extremely well insulated properties.

- **Electricity grid –** There is broad consensus that there is not enough capacity in today's electricity distribution network to accommodate forecast transport, space and water heating requirements. The deployment of heat pumps, along with other technologies like electric vehicles (EVs), is likely to require reinforcement of the electricity distribution network. Rural networks have different construction and density profiles than urban and suburban networks. They typically make more use of overhead cables, longer feeder lengths and have fewer connections per feeder. This means that the cost of grid reinforcement per property is higher than for urban areas. Moreover, given the urgent need to deploy cleaner electric vehicles to improve urban air quality and deliver carbon emission reductions at scale, it is clear that in the coming decade any work to reinforce the grid to facilitate rapid charging of EVs will prioritise urban areas.
- **Spiky heat demand –** Our energy demand varies over the course of the year with heat generating the largest swings e.g. 20% of heat demand occurs over only 31 (non-consecutive) days of an average winter. As such it is clear that we need system flexibility and gas, in the form of LPG/bioLPG, provides just that and can accommodate large seasonal swings in demand. A typical LPG customer uses just under a tonne of gas per year and this number is falling. Given that a high proportion of domestic LPG bulk tanks contain a tonne of gas then this solution provides complete energy security to the householder as they have a year's supply of heat energy stored in their garden.

As such in the near term, we want to see support for the suite of highly efficient LPG-ran heating systems which are available to off-gas grid customers. These technologies will deliver carbon savings against an oil/coal counterfactual.

In the future these systems will substitute LPG fuel for bioLPG, a product that Calor has invested heavily in and will introduce into the UK market in 2018 – delivering 30,000 tonnes in the first year. This is equivalent to 15% of the current UK LPG demand for domestic heating will provide the UK with a long term, low-carbon and sustainable gas option.

1. Development of High Efficiency Low Carbon bioLPG Heating Technologies

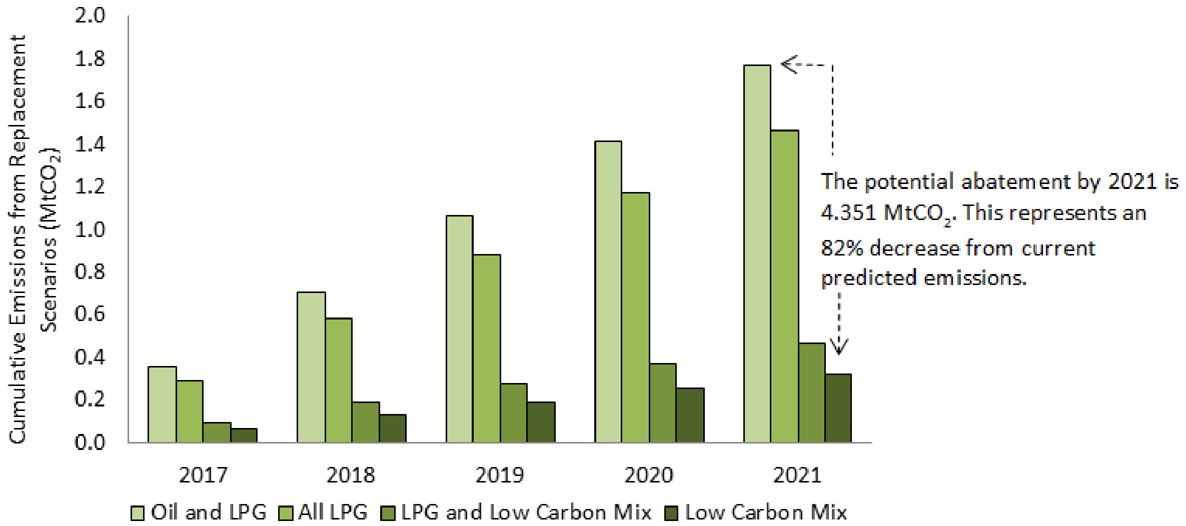
Since the regulation of condensing boilers in 2005 (via Part L of Building Regulations) domestic gas boilers available on the market have become steadily more efficient. Calor supports the Government's intention of taking this to the next level and has been investing in bringing advanced gas technologies to the off gas grid market - such as highly efficient boilers with controls, gas heat pumps, mCHP, hybrid heat pump systems and fuel cells.

After the April 2018 introduction of the advanced system controls and efficient boilers covered in the Government's "Boiler Plus" policy, it should seek to support the penetration of technologies which can offer the next step in system efficiency. This is especially crucial in the off-gas grid sector where the counterfactual heating fuels, such as coal and oil, are carbon intensive.

Each year there are an estimated 99,000 heating systems replaced in the off gas grid sector. Out of these 99,000 systems, 87,000 are oil systems with the remainder being split between LPG and other low carbon systems. The first bar in Figure 5 shows the cumulative carbon emissions that these replacement systems generate over five years, assuming that all non-oil systems are LPG. This is the baseline scenario. The other three bars show the cumulative carbon emissions that would be generated under different distributions of systems. For example, the second green bar shows the emissions from 99,000 LPG systems. This is the most cost effective way to cut emissions significantly. The reduction in emissions from the baseline to the LPG only scenario is 17% after five years and, as demonstrated by Figure 1, this change will not be at the expense of the end consumer.

Next, the third bar shows the emissions from 12,000 LPG systems, which is the number of systems currently being replaced each year, and 87,000 other low carbon systems equally split between Gas Absorption Heat Pumps (GAHP), Micro Combined Heat and Power (mCHP) run off LPG, mCHP run off bioLPG, Fuel Cells and Hybrid systems. The table shows the exact numbers of each technology included under each scenario. Finally, the darkest green bar indicates the emissions from the installation of 99,000 low carbon systems per year only, with no oil systems in the replacement mix. After five years, the emissions saved by removing oil from the replacement mix could be up to 4.351 MtCO2, or 82% of baseline cumulative emissions.

Figure 5: Modelled carbon emissions from potential off gas grid heating scenarios.



Low Carbon Mix includes equal numbers of Gas Absorption Heat Pumps (GAHP), Micro Combined Heat and Power (mCHP) run off LPG, mCHP run off bioLPG, Fuel Cells and Hybrid systems.

Figure 5 [Continued]: The number of heating systems underlying the modelled carbon emissions from potential off gas grid heating scenarios shown above.

Number of Heating Systems (000s)	Existing Technologies		Emerging Low Carbon Technologies					Total
	LPG	Oil	GAHP	Fuel Cell	Hybrid	mCHP LPG	mCHP BioLPG	
Oil and LPG (baseline)	12	87	0	0	0	0	0	99
All LPG	99	0	0	0	0	0	0	99
LPG and Low Carbon Mix	12	0	17.4	17.4	17.4	17.4	17.4	99
Low Carbon Mix	0	0	19.8	19.8	19.8	19.8	19.8	99

However despite the potential shown above, currently off gas grid consumers receive very little government assistance with moving to more energy efficient gas systems as described. Energy Company Obligation (ECO) schemes have not been deployed in rural communities in significant numbers as obligated suppliers actively avoid work in off grid homes; this often involves more costly and complex work than on grid properties. A number of low carbon solutions have been proposed and supported under the domestic RHI, however this support has not translated into the levels of deployment originally envisaged. A key challenge for the off-grid sector is that, due to the older, less energy-efficient nature of many rural properties, low temperature heating systems such as electric heat pumps struggle to operate efficiently.

Micro-combined heat and power (mCHP), gas heat pumps and hybrid heating systems running on LPG are an excellent option for off gas grid properties and can be operated using the same infrastructure and consumer behaviour as a typical gas or oil boiler. Higher temperature heating, such as mCHP, is more suitable for rural, leaky properties and LPG delivers significant carbon savings over oil and electricity (Figure 2). Additionally, LPG mCHP will allow bioLPG to be used in the future, slashing carbon emissions again.

The UK has a comparative advantage as a result of an excellent research base and industrial community that has helped develop gas heating products which are internationally competitive. Indeed this is common amongst much of the residential gas heating industry. The vast majority of gas equipment sold in the UK is manufactured here, and support for this British industry is in keeping with the Government's Industrial Strategy Green Paper.

Furthermore, the Government could provide support for companies who wish to innovate in the off-grid sector. Fuels such as biomethane are still in receipt of government subsidies (via the RHI) despite the fact that they have been effectively proven and are now a commercialised process. This funding, coupled with any residual funding from the RHI scheme, might be more usefully funnelled to emerging technologies and infrastructure. The funding of these technologies would accelerate the transition from demonstration to commercialisation. This would have the effect of making more technologies available faster, ultimately reducing costs to the end user whilst providing the efficiency gains and carbon savings that the government seeks.

2. Development of Sustainable "Green Gas" solutions for Off Grid Rural Britain

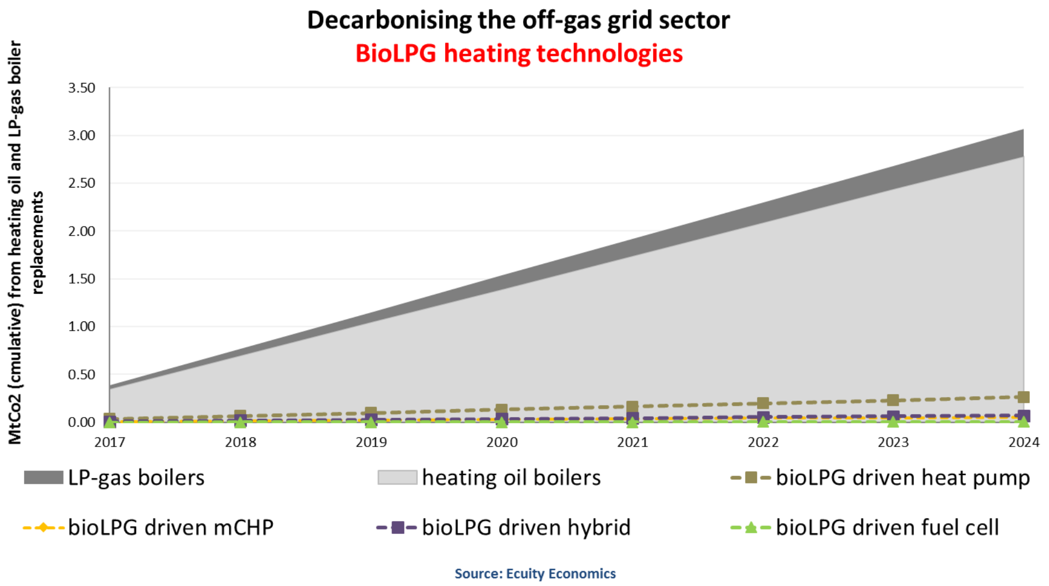
Calor supports the UK's low carbon transition. Whilst the efficient LPG heating technologies described above will lower carbon emissions in the off-gas grid sector, the roll-out of renewable bioLPG will unlock significant decarbonisation potential and turn it into a long term solution consistent with the CCC's carbon budgets. In early 2018, Calor will be bringing the first delivery of bioLPG into the UK. This is the first time that this innovative product will be available to UK customers and will be the first delivery of many. Similar products are already being offered by LPG companies in France and Scandinavia from different supply sources, so bioLPG production is already increasing in Europe.

Calor recognises the importance of finding ways to reduce the carbon footprint of its primary product, LPG, and is therefore committing time and resource to finding additional ways of producing bioLPG at scale and in a sustainable manner.

BioLPG (also known as biopropane) deployment offers real opportunities for carbon reduction. BioLPG is molecularly identical to LPG, but it is derived from organic materials. This means that it is significantly less carbon intensive than LPG; in fact up to 88% less (dependent on feedstock) but can be used with no changes to LPG equipment. It is a true drop-in fuel, which customers can use with no additional capital expenditure or changes to equipment. Overall, the switch to bioLPG offers a significant opportunity to decarbonise the off grid sector. It is estimated that the annual carbon emissions from the domestic LPG heating sector could be reduced by 83% through the introduction of bioLPG by 2025. This number can be increased as equipment and system efficiencies also improve in the countryside.

Figure 6 details a similar scenario as covered in figure 5 above. Here instead of the gas heating technologies running on LPG in off gas grid areas, bioLPG is introduced instead. As explored, this significantly reduces the carbon intensity of energy produced by these systems. Figure 6 shows this graphically, with the bioLPG run mCHP, heat pump, hybrid system and fuel cell producing negligible emissions as compared to heating oil boilers – which continue to be replaced at a rate of 87,000 per year.

Figure 6: Projected emissions from deployment of bioLPG powered heating technologies

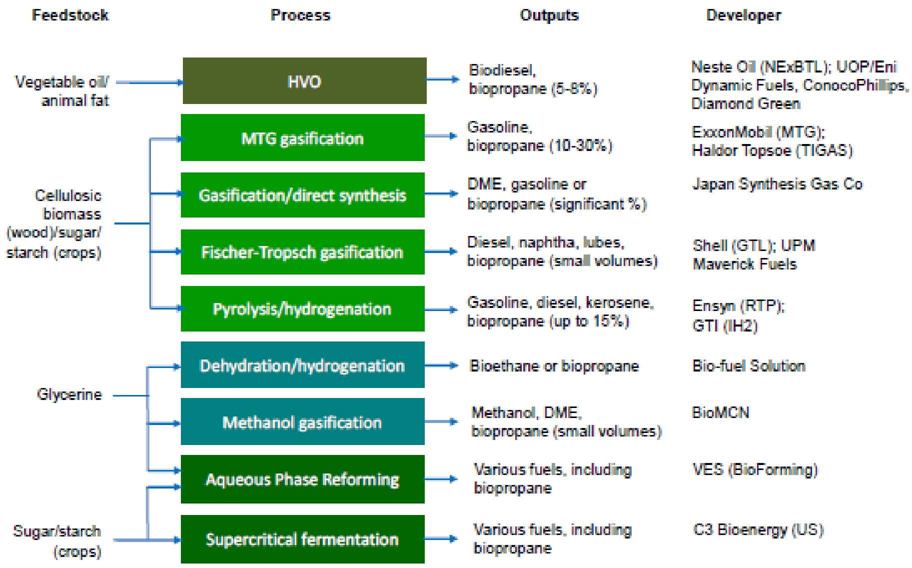


The first delivery of bioLPG will come from Rotterdam, where it is produced by Neste (a Finnish company) as a by-product of their biodiesel production. However, bioLPG can be produced in a number of different ways, as outlined in the DECC report on BioLPG for Grid Injection (2014). This includes gasification where independent research has demonstrated that the feedstocks exist to supply quantities of bioLPG well in excess of current off-gas grid heat demand - as outlined elsewhere in our response.

Figure 7 below shows all of the current possible means for bioLPG production. This shows there is an opportunity for the Government to support the development of indigenous production of bioLPG, which would help its aims of decarbonising heat in harder to address, rural, off gas grid areas. Here, the use of LPG for heating is common but there are fewer alternatives to fossil fuels due to location and house design.

Calor would encourage the Committee on Climate Change to support the development of bioLPG as a lower cost solution to heat decarbonisation in the countryside than electrification.

Figure 7: Different methods of production of bioLPG



Note: *Data from RHI Evidence report: Biopropane for Grid Injection*[14].

Moreover the vast majority of bioLPG production pathways Calor has identified would lend themselves to local production facilities located in the off gas grid market e.g. anaerobic digestion or production based on the processing of household waste. This would facilitate the decentralisation of energy provision and reduce the ancillary environmental impacts associated with fuel distribution. It is easy to imagine bioLPG being produced, stored and then being distributed via local pipelines to businesses and homes in the facility. This would be far cheaper than going down the electrification route which would require substantial investment in transmission system upgrades, building fabric and storage.

[14] DECC (2014), *RHI Evidence Report: Biopropane for Grid Injection*, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/376487/RHI_Evidence_Report_-_Biopropane_for_Grid_Injection__2___2_.pdf