Engineering the Future

The action forum for engineering

Advanced fuels: call for evidence

Department for Transport

This is an Engineering the Future response to the Department for Transport's call for evidence on Advanced fuels.

The development of this response was led by:

- **The Institution of Chemical Engineers**

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- Energy Institute
- The Institute of Marine Engineering, Science & Technology
- The Institution of Mechanical Engineers
- Nuclear Institute
- Royal Academy of Engineering
- Royal Aeronautical Society
- Society of Environmental Engineers

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We are the action forum for engineering and we provide independent expert advice and promote understanding of the contribution that engineering makes to the economy, society and to the development and delivery of national policy.

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Overview

As part of the transition to a low carbon economy, advanced fuels can contribute significantly to achieving the UK Government's targets. Although this consultation specifically focuses on bioenergy in the transport sector, it should not be treated in isolation from the wider bioenergy strategy since there are overlaps. The question should address how biomaterials (including fuels) can be used to decarbonise the economy. Similarly, the advanced fuels would compete with other uses of bio-derived feedstocks considered in delivering bioenergy and will involve indirect land use change (ILUC) and other sustainability criteria.

Also transport fuels cannot be looked at in isolation from the vehicle and infrastructure. Although a technology may reduce exhaust emissions of CO_2, the energy efficiency and greenhouse gas (GHG) emissions should be considered over the whole fuel cycle. The recent responses to the OLEV ultra-low emission vehicles consultation[1] should also be examined as part of this consultation.

The consultation defines the 'advanced fuels' as being both low-carbon and innovative. This definition has 'drifted' from the definition of advanced biofuels in the UK Bioenergy strategy (2012).

The majority of the conversion technologies depicted in Figure 3 (of the Call) are already well understood; these include gasification, Fischer-Tropsch conversion, pyrolysis, anaerobic digestion (AD) and electrolysis. The definition of advanced fuel should not be based on whether the technology is developed, but to the 'manner in which waste or biomass can be integrated to provide transport fuel'. Similarly, the characteristics of the resultant fuel cannot be used to label it as advanced fuel either as it has to match the characteristics of the fossil fuel being replaced. The definition must therefore relate to the 'integration' whereby feedstock becomes the primary determinant.

It is important to choose advanced biofuels which contribute to meeting both the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD) targets. Recent developments in the proposals for 2030 targets suggest there may be no further FQD targets after 2020. If this is the case, the development of some long-term technologies becomes less certain.

It is recommended that definitions should be tidied up to be workable and systematic.

This response discusses different options that offer solutions on different timescales. For reference, the following is used in this response:

- Short-term: present-2020
- Medium-term: 2021-2035
- Long-term: 2036-2050

[1] http://bit.ly/1asxeAO

1 Should the government focus support for advanced fuels in certain transport sectors? If so, why?

1.1 There are significant variations in what is feasible for different transport sectors. Each sector needs a commercially and technologically viable solution that considers security of supply and the cost to the consumer.

1.2 Electrification of rail is achievable (although more support would be needed for small branch lines and rural areas). Electrification of some personal vehicles is also attainable, although this is only realistic for light duty/short distance scenarios e.g. in urban areas.[2] Furthermore, there are questions over the extent to which electrical vehicles really lead to reductions in greenhouse gas emissions.[3] Electrification is not realistic for long distance road vehicle applications, aviation, and shipping without major breakthroughs.

1.3 In aviation, hydrocarbons are the only viable option in the short- to medium-term and therefore advanced fuels offer a solution in the form of:

- Fischer-Tropsch routes to biokerosene (using fossil-based wastes or biomass) but would require structured policy to support robust development. The current mechanisms are considered too rigid and inflexible.
  Or
- Bioderived fuel from short chain alcohols (through oligomerisation and dewatering). Development costs and risk are the key problems in this option and will need economic assessment.
  Or
- Hydrotreated vegetable oil (HVO), i.e. hydroprocessed esters and fatty acids (HEFA), processed either as
  - Biojet (currently certified as a 50% blend)
  - Or green diesel (certification being sought in 2014)

1.4 As fuel for heavy goods vehicles, advanced fuels offer an achievable target with reductions in GHG emissions. Hydrotreated vegetable oil (HVO) to diesel fuel is an attractive option that is already commercially viable. While this is an effective use for used vegetable oil, the quantities available are too small for it to represent a major solution to the problems of sustainable transport fuels. The challenges with this option are the limited quantity of used (waste) vegetable oil and, if extracted directly from crops, there is the possibility of conflicting with food supply which has led to the recent revision of the EU directive on transport fuels.

1.5 Apart from electrification, advanced fuels in the rail sector, may be subject to requirements similar to those for road HGVs. There is already a well-established fuel distribution network that could achieve a substantially higher fraction of biodiesel incorporation than the 7% discussed for road transport refuelling stations if the biodiesel is ever available in sufficient quantities. The current rail fuel standard allows for up to 7% FAME in the gas oil but currently there is no biofuel added apart from

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[2] European Roadmap Electrification of Road Transport 2nd Edition, ERTRAC, (2012), http://bit.ly/MHwk8n
[3] Comparative Environmental Life Cycle Assessment of Conventional and Electrical Vehicles, Troy R. Hawkins, Bhawna Singh, Guillaume Majeau-Bettez, and Anders Hammer Strømman
Journal of Industrial Ecology, Vol 17, Issue 1, pp. 53-64 (2013).

isolated trials.[4] In 2007, a modified Voyager (class 220) train operated by Virgin trains ran between London and Llandudno using a 20% biodiesel blend.[5] Similarly, Amtrak in the US conducted a successful trial over fifteen months using 20% biodiesel without any modifications to the engine or infrastructure.[6] A trial was also carried out in Canada and showed that a 5% blend of biodiesel could operate effectively, even at temperatures down to -40 ^{o}C.[7] A report published by the International Union of Railways (IUC) in 2007 gave further examples and an international perspective on the topic.[8]

1.6 The distribution network exists with rail networks connecting import terminals, refineries and storage facilities.

1.7 It is simpler to utilise advanced fuels in some sectors than in others, and other things being equal this should be pursued. However, if one sector is therefore seen to be responsible for a larger proportion of GHG emissions, this sector would be vulnerable to changes in government policy and public perception. This could deter companies in these sectors since they would want to minimise risk and avoid being seen as guilty parties in terms of CO_2 emissions.

1.8 Government policy should be designed to promote movement down the most appropriate low carbon route in each sector to reduce GHG emissions rather than assuming all sectors are the same and/or appropriate.

1a What are your views on the government's analysis of the use of advanced biofuels in different transport sectors, as set out in the UK Bioenergy Strategy? Are you aware of alternative estimates of the future uptake of advanced fuels in each transport sector?

1ai It is logical to identify three broad categories for transport sectors (aviation, maritime and heavy goods) that have no alternative to carbon-based energy sources. However, the current focus on biofuels in the automotive sector has not helped to encourage progress in the maritime and aviation sectors.

1aii A recent report by the Royal Academy of Engineering addressed the issue of future ship propulsion technologies, including fuels as well as technologies.[9] There are moves to use LNG fuels and more recently, a proposal to use methanol.[10] Since these usually operate in an international transport network, it is important that internationally agreed solutions are developed. Potential solutions will require integrated solutions and include nuclear propulsion, alternative fuels and improvements to ship designs (including hull shape and coatings). Some of these are already in use and/or being developed (e.g. military nuclear vessels and Russian nuclear ships capable of dealing with ice packs). Analysis of potential biofuels in shipping was reported in 2012.[11]On page 20 of "Advanced fuels: call for evidence" the chart from Redpoint modelling shows aviation biofuels rising to at least 75% of the aviation fuel use, and on page 21 for the 75% figure the EU Flightpath 2050 work

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[4] Assessment of the existing UK infrastructure capacity and vehicle fleet capability for the use of biofuels, AEA (2011), http://bit.ly/1bj6AKW
[5] http://bit.ly/MF7vtz
[6] http://bit.ly/1lVXPuQ
[7] http://bit.ly/MFb4QB
[8] Railways and Biofuel (2007), http://bit.ly/1fZ2NSc
[9] Future Ship Powering Options, Royal Academy of Engineering (2013), http://bit.ly/1iGnIKv
[10] http://bit.ly/1dEXl71
[11] Potential of biofuels for shipping, Ecofys (2012), http://bit.ly/1kxVPqU

is referenced.[12] In the latter EU document (pg 15) the target is worded as: "*In 2050 technologies and procedures available allow a 75% reduction in CO_2 emissions per passenger kilometre to support the ATAG target… relative to the capabilities of typical new aircraft in 2000.*" We believe that this 75% figure has been misinterpreted as being a target that is being delivered purely by alternative fuels alone. Therefore there may be an error in the detailed projections regarding the level of biofuel penetration within aviation. In practice the Air Transport Action Group's (ATAG) 75% goal is anticipated to come from a whole range of technical improvements.

1aiii An alternative projection of aviation biofuel penetration is provided by Sustainable Aviation in their 2012 CO_2 Roadmap,[13] showing a significantly more cautious forecast. This roadmap is due to be updated in 2014.

1aiv The aviation sector is continuing to work on quality assurance and regulation; improving production flexibility and efficiency and developing sustainable certification of capacity and commercialisation.

1b What physical and policy barriers are there to the uptake of advanced fuels in each transport sector?

1bi Traditionally, development of fuels has been undertaken for large scale production. In the transition to bioderived fuels, there is significant merit in targeting smaller, decentralised systems to be able to utilise the available biomass, which is a dispersed resource, more effectively.

1bii The development of new fuels requires structured support mechanisms. In many cases the current mechanisms are considered too rigid and inflexible to offer support for any long-term (over 20 years) developments. It is noteworthy that it takes at least 3-5 years, and usually much longer for a process to be realised at full scale after it has been determined as technically and economically viable. In addition to the technology development, structured support for the development of infrastructure is required to provide a network for supplying the advanced fuels to the point of use. Where the advanced fuels are in the forms, of electricity or biomethane, they can be conveyed via the existing national grid system; for other fuels, new user end infrastructure may still be needed.

1biii The decision to limit the RTFO to the road transport is considered a significant factor in delaying the introduction of advanced biofuels into other sectors. A knock-on effect of this is the delay in the associated learning curve progress. The bias towards road transport acts as a barrier to the take-up in the other sectors, and ways need to be found of overcoming the bias.

1biv Achieving change in aviation and shipping is more challenging unless international agreements are in place. Certification has been addressed and focus to date has been on developing drop-in fuels, resulting in the certification of two biojet routes:

- Up to 50% blend of synthetic paraffinic kerosene (SPK) derived from Fischer-Tropsch biomass to liquid (BtL) fuels
- Up to 50% blend of hydroprocessed esters and fatty acids (HEFA)

[12] Flightpath 2050 Europe's Vision for Aviation, European Commission (2011), http://bit.ly/M4B0F1
[13] Sustainable Aviation CO_2 Road-Map, Sustainable Aviation, (2012), http://bit.ly/1fhHT0v

1bv Regardless of international agreement and certification challenges, it is still essential to support technology developments so the UK can lead in this area. Certification of other feedstock processing routes is currently under discussion. Certification of higher blends can also be anticipated and it is not expected that blend certification will prove a barrier.

2. Is UK government support necessary to commercialise advanced fuel technologies? If so, why?

2.1 Advanced fuels can contribute to achieving energy security, reduced carbon emissions and future economic growth. However, to achieve the required level of innovation for new advanced fuel markets there must be considerable research to develop the required new technology. Such work requires consistent and long-term investment looking towards 2050. Development of energy technologies (including fuels) is a long-term process (generally over 5-10 years) and cost optimisation will only occur when prototype or demonstration plants are developed.

2.2 The issue of bridging the 'valley of death' is still a significant challenge in progressing between TRLs, 6-7 and 7-8.[14] In particular, UK SMEs struggle with this. There has been some work by the Technology Strategy Board (TSB) but this must be better and more widely available.

2.3 Each fuel and process should be considered individually since there are different needs. Assistance may be required in the capital cost of the plants, distribution and refuelling infrastructure and the vehicles themselves. In some cases, modification of fuel duty might be considered.

2a What should 'advanced' mean? What role should process, feedstock and sustainability have in this definition?

2ai The definition of "advanced fuels" in the E4tech report is broadly appropriate with a strong emphasis on the sustainability of a fuel; both in terms of feedstock supply/production and the overall conversion process. Increasing the use of biofuels would lead to increasing demand to import either the biomass or the fuel. Imports would be required due to the large quantity needed, but may also be favoured depending on costs. This may be viable but there would be long-term consequences to energy security. It is recommended that the sustainability criteria are aligned with the Roundtable for Sustainable Biofuels.[15]

2aii Using waste in the production of advanced fuels is challenging due to the variations in origin, composition and handling requirements. Dealing with waste, especially if it is heterogeneous, is challenging. UK engineers are capable of overcoming such high risks, if there were sufficient economic incentives for commercial viability, but it is essential to consider carefully whether producing fuels from waste is more appropriate than producing heat and conventional electrical power..

2aiii In the main analysis report (by E4Tech), the status of the main conversion technologies (figure 5); is misleading in grouping gasification and Fischer-Tropsch

[14] See EtF written submission to Commons Science and Technology Select Committee "Bridging the Valley" enquiry, 2012, http://bit.ly/1dRvTnw
[15] 'RSB Standard for certification of biofuels based on end-of-life-products, by-products and residues', Roundtable on Sustainable Biomaterials, 2013, http://bit.ly/1b0V7Kk

technologies together. The current TRL status of gasification is optimistic (TRL 4-5 more realistic) but FT is already considered to be TRL 8-9.

2b What economic opportunities are there for the UK in developing this industry?

2bi It is considered than an investment of £2bn on FT fuels could cover 60% of HGV fuel requirements. This type of investment would send the right signals to industry to encourage investment but would not compromise the food vs. fuel issue. The large HGV fleet in the UK could come to a general consensus on this, helping the UK achieve its 2020 renewable energy targets.

2bii To promote development and uptake of advanced biofuels, the duration and certainty of technology and support is crucial.

3 What could advanced biofuels deliver, and by when?

3.1 In the short-term (to achieve 2020 targets), the only realistic option is pursuing technologies already at TRL 8-9; namely 1G ethanol, FAME and HVO. Anaerobic digestion (including biogas upgrading) is viable at large scale; the gas needs to be modified before being fed into the grid. This is an area of considerable interest and growth – see Question 6 – but the question must be addressed of whether greater carbon reductions can be achieved by using the biogas for other purposes such as firing CHP plants close to the source of the biogas.

3.2 It is considered that HVO in the HGV network and aviation is achievable by 2020; taking three years from commissioning to get a plant online. The HVO process requires hydrogen which the engineering community feel could be obtained through economical and renewable pathways with the right incentives and infrastructure (see responses to question 4 below).

3a Do you agree with E4Tech's assessment of the technology readiness of different advanced fuel technologies?

3ai We broadly agree with the E4tech report assessment but there are some critical areas (gasification and Fischer-Tropsch) that are not properly represented (see 2a above) and seawater agriculture e.g. halophytes (currently being investigated by NASA) has not been included. The latter can have minimal impact on farmland and a low freshwater footprint. Some airlines have already experimented with the use of alternative biofuel and there has been a recent proposal from Boeing to global regulators for the introduction of a green diesel blend aviation fuel.[16]

3aii Currently there is only financial support for renewable biogenic waste rather than waste that will continue to be produced e.g. through the use of plastics. The definition of waste should be simplified to promote wider utilisation.

3b Do you agree with E4Tech's assessment on the availability of waste and residue feedstocks, and their estimated costs of advanced fuels?

3bi There is broad agreement on the availability of feedstocks. Ensuring sufficient quantity would require imports of biomass but may also be favoured depending on

[16] http://reut.rs/1m0Yefm 14/01/2014

costs. Availability in the UK could also favour smaller, local plants rather than larger ones where transport of biomass to plant is a bigger cost and an environmental impact.

3c Do you agree with E4Tech's proposed criteria for when an advanced biofuel should be supported?

3ci There is broad agreement for support of waste products and the capture and utilisation of waste carbon gases.

3cii Some fuels can be used in existing vehicles without the need for modifications; the challenge is not only in developing and deploying commercial scale production but also in blending. Other fuels such as biomethane, hydrogen and DME require major changes to the existing, commonly used vehicle types.

3ciii Development of new engine technology may also allow vehicles to be more flexible and hence to be more tolerant to different fuels. Currently bioethanol, biobutanol, FAME (limited by fuel injection) and HVO are typically used at less than 10% when blended with petrol and diesel. HVO is currently the most versatile fuel option, with current, unmodified engines able to tolerate it at 100% levels. Similarly, there are no issues with storage of this fuel. Engines can be modified to tolerate 100% levels of biofuels (bioethanol, biobutanol and FAME) but there may be infrastructure/storage issues which may compromise the economics and reduce uptake of these fuels.[17]

3civ Adoption of these new fuels requires incentives for fuel injector manufacturing companies and vehicle OEMs to adopt new technology and support for the technology at the end-user level.

4 What could hydrogen deliver as a transport fuel, and by when?

4.1 Fuel cell cars, buses and vans are under development internationally and expected to be commercially available from 2015.The transition to hydrogen fuel-cell vehicles requires a hydrogen refuelling infrastructure to be implemented. Hydrogen as a transport fuel has attractive qualities provided the high conversion efficiency of a fuel cell is employed as the prime mover rather than a combustion engine. Recent advances by car manufacturers have led to fuel cells with approximately twice the conversion efficiency of combustion engines; resulting in low fuel consumption and virtually no emissions. Unlike electric, battery vehicles, the refuelling time (~three minutes) and range (~350 miles) are in line with current consumer preferences.

4.2 Hydrogen itself is ‘low carbon’ and renewable, however, the current process by which the hydrogen fuel is produced from hydrocarbons and made available as a fuel is energy intensive. There are however, opportunities to achieve an economically viable source of green hydrogen if renewable electrolysis is implemented. If the hydrogen is generated from fossil fuel processes (with their attendant emissions) then the benefit of hydrogen as a clean fuel may be zero or negative. Particularly if used as an aviation fuel, the effects at high altitude of increased water vapour and remaining oxides of nitrogen emissions need to be considered (as GHGs). Pilot projects for green hydrogen production include using glycerine as a raw material (Linde group, Germany), hydropower electrolysis of water (Linde group, Canada) and

[17] A harmonised Auto-Fuel biofuel roadmap for the EU to 2030, (2013), E4tech, http://bit.ly/1hZgAdR

on-site electrolyser refuelling of hydrogen vehicles in the Isle of Wight Eco-Island project.

4.3 In the near term (before 2020), it is viable to use excess electricity on the grid to generate hydrogen by electrolysis. The increasing deployment of wind and solar is leading to increasing amounts of excess electricity on the grid, potentially reaching several TWh by the mid 2020's. Rather than curtailing the input from wind, the excess could be utilised and the energy cost for electrolysis could be zero or negative. Local generation on distributed sites would also reduce inefficiencies from electricity transmission and be advantageously compatible with the need to establish a geographical distribution of hydrogen refuelling stations.

4.4 The hydrogen refuelling stations incur other costs and efficiency penalties for compression and storage (700 bar for cars, 350 bar for buses). This is an intrinsic part of their engineering design and is driven by the decision of the vehicle OEMs to fit high pressure tanks in vehicles. In the longer term developments in hydrogen storage materials may result in cost engineering and efficiency breakthroughs for vehicle manufacturers.

4.5 A UK H_2 Mobility report published in 2013 predicted that 1150 hydrogen refuelling stations by 2030 would provide close-to-home refuelling for the whole of the UK at a cost of £418m.[18] When compared with the £400m already invested in battery electric vehicles this represents a viable investment in a clean fuel infrastructure especially because fuel cell cars offer much longer range and much faster refuelling.

4.6 An alternative to hydrogen fuel for vehicles is methanation of hydrogen using clean CO_2 to produce methane – this synthetic natural gas is produced using renewable electricity (sometimes referred to as e-gas). In 2013, the Audi e-gas plant opened in Germany, utilising wind energy to run electrolysis to generate H_2 which is then methanated.[19] The e-gas is stored in the main gas network, supplying homes, industry and CNG fuelling stations. Although this process uses the CO_2 waste from an anaerobic digestion plant to produce a non-fossil derived fuel, the conversion process incurs a significant energy loss to produce a fuel that is compatible with current engine technology but still releases CO_2 into the atmosphere. This does not present a longer term solution (beyond 2035) since current combustion engines are inefficient in comparison to fuel cell technology.

4.7 In the long term (beyond 2035), cryogenic hydrogen *may* be a possible aviation fuel. Turbine propulsion systems will not require significant change, however, aircraft configuration will need to adapt to higher fuel volumes. This option is only viable if global infrastructure for transportation and storage of cryogenic hydrogen are available. However in the short term (up to 2025), a national hydrogen infrastructure for refuelling fuel cell cars with gaseous hydrogen could be implemented to attract vehicle OEMs to introduce their vehicles here and so encourage consumers to eradicate emissions by switching from petrol/diesel to hydrogen.

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[18] UK H_2 Mobility Phase 1 results (2013), http://bit.ly/1cLPboj
[19] http://bit.ly/1lu7qVV and http://aol.it/1nrzU1N

5 What could synthetic fuels and fuels from fossil waste deliver, and by when?

5.1 In the shift towards decarbonisation it is logical to use wastes, however; the document has an overly simplistic view of this. There are options, but there are also consequences. Critical questions include defining waste, consideration of its fate if not used as a fuel and not only the economic viability but the overall energy efficiency of the system. The consideration must consider cost and impact in terms of climate, transport and landfill; utilising waste for synthetic fuels may be more expensive, however the benefit in reducing landfill may sufficiently counterbalance this. It is essential that transport fuel costs are not considered in isolation.

5a How do we determine the extent to which synthetic fuels from electricity are renewable?

5ai To achieve decarbonisation, the opportunity to utilise these non-renewable wastes should focus on what is technologically feasible. The report case study of CRI in Iceland is less relevant to the UK because much of the electricity in Iceland is generated geothermally which is more consistent. The variation with time of the carbon footprint of electricity is known, (it is a function of what power plant is operating and how government regulates operational practices in the power industry to achieve greener power), so by knowing/controlling the operating periods of electrolysers the carbon footprint of the generated hydrogen can be computed. When the electrolyser is called upon to help raise demand during a period when wind power would otherwise be curtailed, the carbon footprint of the generated hydrogen is zero, By metering the magnitude and timing of these electricity demands, the annual carbon footprint of the generated hydrogen or synthetic fuel can be calculated and regulated to stay within a desired threshold.

5b What information can you provide on waste fossil gas processes and their potential benefits and drawbacks?

5bi The LanzaTech case study involves burning coke. Although this is a waste product, it is not renewable and is a form of captured carbon. Therefore, utilising this as a fuel may not impact on the efforts to reduce GHG emissions.

5bii A recent methanation study carried out by ITM Power has suggested niche applications are achievable in the short-term for using electrolytic hydrogen with waste CO_2. These include utilisation of pure CO_2 from the distillery industry (an existing fossil-based industry located mainly in regions where more wind power can be exploited if it can be used locally), and using anaerobic digestion biogas (reacting the CO_2 component with hydrogen to increase the methane yield and reduce the need for water scrubbing).

5biii Plastics are not normally considered as renewable although it is a consistent fraction of municipal waste. Pyrolysis provides a technique for utilising this waste, but because of the variability and heterogeneity of the feedstock, it would require a high degree of refining and would not be economically viable for producing fuel.

6 What could biomethane deliver as a transport fuel, and by when?

6.1 The call for evidence depicts (Figure 3.2) the use of biomethane in the UK as fairly significant at around 25 TWh. This is incorrect, as one needs to differentiate between 'biogas' and 'biomethane'; the latter being the more refined form that could be used as transport fuel (being essentially the same as natural gas). In contrast, landfill gas and sewage gas are used with little or no cleaning; often as a cost-effective environmental option. Many of these applications have come about since the Government introduced the Non-Fossil Fuel Obligation (NFFO) and later the Renewables Obligation. Prior to this flaring (or in some cases simply allowing the biogas to be emitted to the atmosphere) was quite common. Biogas can be used without being refined for other purposes, notably as a fuel in CHP plants and the potential for using biogas in this way far exceeds supply. Therefore the question must be addressed of whether biogas should be refined and distributed as a commodity, for transport or any other purpose, rather than being used locally in its raw form.

6.2 Methane is a powerful GHG, and emissions through system leaks are a concern. The 5th IPCC report revised its estimate upwards, stating that methane is 28 times more powerful a GHG as CO_2.[20] We manage our natural gas networks effectively, and if biomethane is to be further developed as a fuel, then the same standards will be required throughout biogas generation and capture, storage, upgrading, methane boil-off from LNG and bioLNG fuelled vehicles and methane "slip".

6.3 Biomethane is currently only used in very small applications as a transport fuel in the UK and receives only a small RTFO subsidy. Currently, biomethane that is fed into the grid is considerably more expensive than natural gas but it does receive RHI support. It is attractive as a fuel due to its lower CO_2 and other exhaust emissions (NOx and particulates). Biomethane also appears attractive in terms of its potential contribution towards meeting the FQD as well as RED targets. The technology is developed and demonstrated with over 150 applications of biomethane injection into grid and vehicle use in Sweden, Switzerland, Germany and France. In the UK there are at least three examples of biomethane injection schemes so its TRL could be considered as 9. However, careful assessment is needed to identify the best use of biogas – see above.

6.4 There is no dedicated biomethane infrastructure but there is the Green Gas Certification Scheme[21] being implemented whereby the National Gas Grid is used to transport biomethane. It will enable biomethane ('green gas') to be tracked through the supply chain and works on the basis that each unit of green gas will displace a unit of fossil-derived natural gas. The scheme monitors the contractual, and not the physical flows, of biomethane.

6.5 However, no significant quantities of biogas or biomethane are likely to be used as transport fuel while RO, FIT and RHI incentives remain in place; RHI supports the injection of biomethane into the national gas grid with an attractive incentive of £73/MWh. RTFO would need to exceed this before significant quantities of biogas

[20] IPCC Climate Change report 2013, http://bit.ly/1eQTIah
[21] http://www.greengas.org.uk/ The scheme was founded by National Grid, Eon, Centrica, CNG Services and Bio Group; it is run by a subsidiary of the Renewable Energy Association (REA), the Renewable Energy Assurance Ltd, and DECC has shown interest. Two AD plants, generating biomethane, are currently registered.

will be channelled as transport fuel. In addition, the right kind of infrastructure would need to be in place alongside.

6.6 As a fuel, biomethane can be used in a mixture with CNG or LNG (this kind of fuel is available in Germany and Switzerland). An alternative option is the wider deployment of dual-fuel biomethane-diesel vehicles (already used in some buses and HGVs). Generation of biomethane from waste and through anaerobic digestion could serve a larger fleet of these vehicles although there will be competition for biomethane from the heat and power sector; the current incentives promote non-transport uses of biogas and this is appropriate.

6.7 It should be noted that we have only just begun to implement the new generation AD plants in the UK. A DEFRA study (AC0409) [22] identified and pointed to some 900 AD sites (generating 14 TWh biogas or 550 MWe power), primarily driven by food waste. The study used a multi-criteria analysis to identify optimal type, scale and locations of AD plants in England and Wales by examining geographical distribution of feedstock, technologies and use of the digestate on appropriate land. Figure 1 shows the quantities of different feedstocks that were mapped in the study and the current use of the feedstock in AD plants. It shows that the current use is following a pattern predicted by the Defra study; however, the volume of crops used is above that predicted. While the current level of use should not have significant impact on food security or land use, further increases could raise major concerns.

6.8 We believe that roughly half of this potential could be realised by 2020; i.e. some 400 AD plants generating 7-9 TWh of biogas. The proportion used as transport fuel will be determined by the level of incentives offered and infrastructure as discussed above. It is to be hoped that future incentives will recognise and promote the uses which make the greatest contribution to decarbonisation.

[22] "Implementation of anaerobic digestion in England and Wales balancing optimal outputs with minimal environmental impacts - AC0409", Defra, 2011, http://bit.ly/1jASIU0

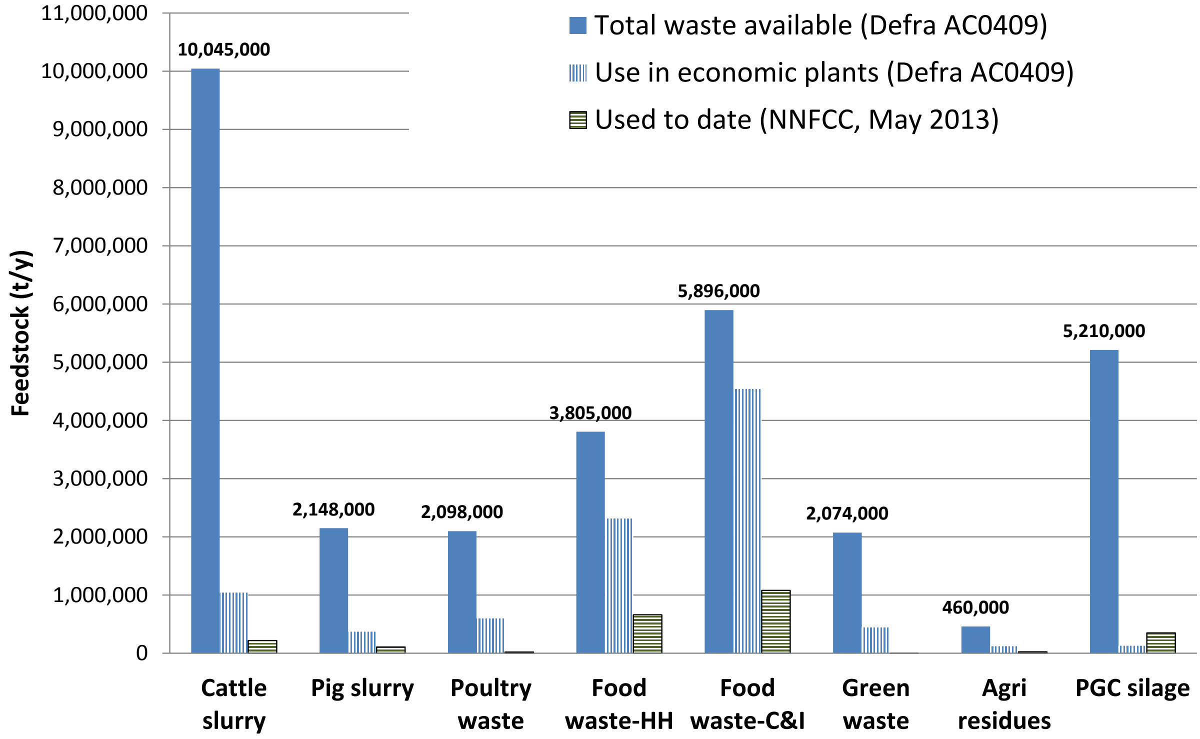

Figure 1: Total feedstock in E&W, its potential utilisation based on current incentives along with current utilisation in AD plants (Mistry, May 2013)[23]

6.9 As an aviation fuel, liquefied biomethane is not viable due to increased volume of fuel, fuel tank design and other challenges of purity, quantity and cost.

7 Which 'nearly' wholly renewable fuels are close to commercialisation? What evidence do you have of the percentage of their inputs that are renewable?

7.1 This response assumes that the consultation document refers to HVO and FAME as "nearly, wholly" renewable fuels. In these cases, the hydrogen or methanol are derived from fossil fuels.

7.2 The terminology of 'nearly' and 'wholly' renewable fuels needs to be changed. For accuracy and clarification, a renewable fuel should be changed to CO_2 cost per kWh.

7.3 The ability to blend a fuel is important if it is to be widely deployed. Fuels that could be considered as close to commercialisation (TRL 7-9) are:

- First generation bioethanol: widely available and can be blended at different strengths. Most vehicles can use 5% or 10%.
- FAME: can be blended into automotive diesel but there are challenges in engine tolerance. The current European standard is 7% although higher concentrations are commercially available but on a more limited basis. Current jet specifications only permit up to 5 mg/kg FAME contaminants. There are FAME plants in the UK but these are mostly mothballed due to a lack of incentives.
- HVO: The UK is behind other countries in the commercialisation of this fuel but a plant could be online in three years.

[23] http://bit.ly/19YwmDh

- Anaerobic digestion: In the UK there are currently at least three examples of biomethane injection schemes (therefore TRL 9) with commercial scale AD and gasification upgrading.
- Renewable electrolysis: the UK is well positioned to exploit wind, marine and solar resources for making hydrogen as the electricity grid becomes progressively greener.
- Biomass to liquids (BTL) is not considered to be close enough to commercialisation, to be considered at this time.

7.4 Other opportunities to progress demonstration plants to commercialisation would require support, incentives and prioritisation. These include:

- Lignocellulosic ethanol: international partnerships are required for this progression. Currently there is significant work in the US.
- First generation butanol: viable in the medium term (2020-2035)
- Mixed alcohols
- Gasification and DME
- Gasification and MeOH: already carried out widely in China using coal
- Pyrolysis: this is considered viable in the medium term. There is currently some commercial activity but this is scattered and not well integrated.
- Aqueous phase reforming: medium term
- Gasification and hydrogen: using hydrogen from gasification

7.5 Although gasification is a well known technology there is little knowledge or experience of scale-up and clean-up. The future of this technology requires this to be developed and deployed.

7.6 Examples of gasification projects include gasification of glycerol (biomass) in the Netherlands and the GoBiGas (Gothenburg Biomass Gasification Project) using gasification and bioSNG in Sweden.

7.7 Fuels from CO_2 and H_2 catalysis and electrolysis are considered optimistic. Similarly, there is a proposed plant in Liverpool; using glycerol to make biopropane but this is not yet at TRL 7.

7.8 It is important to consider which fuels may make the best contribution to decarbonising the transport system. Caution should be urged; it is important to direct focus rather than ‘picking winners’. There may be better technology options but these are not at a TRL that is realistic to develop in the near to medium term. It is wise to couple vehicle solutions with fuel solutions; for example because global car manufacturers are producing battery electric and fuel cell electric cars. It is important that greener electricity and hydrogen are available in the UK to capitalise on these clean end-use vehicle technologies.

7.9 A challenge that has been previously overlooked is feedstock variation. Feedstock flexibility is important since there is natural variation and must be considered in where to direct focus. A challenge is also matching feedstocks to technology, in addition to considering availability of these feedstocks. Some technologies rely on importing feedstocks and importing finished fuels, but this needs considering alongside the energy security challenge.

7.10 The evidence for renewable input percentages can be taken from the Welter LCA analyses. Although these numbers are not current, they are still relevant.

8 What support mechanisms could effectively support the deployment of advanced fuels?

8a If government intervention is necessary, should the focus be on 'market pull' or 'technology push'?

8ai The technology push in research and development is usually limited to TRL 1-3, 4 and 5. To progress beyond TRL 5, both push (R&D support) and pull (from industry) are needed.

8aii Market pull is arguably most likely to increase supply of biofuel over time. This requires effective regulation (including international agreements for some sectors), however; a statement of intent could influence future planning even at this early stage.

8b Which of the listed mechanisms would be most effective? What alternatives have we missed?

8bi There is broad agreement with figure 4.1 in the development and commercialisation of new technologies with the addition of the European Industrial Bioenergy Initiative (EIBI) and ERA-NET Bioenergy programme.

8c What factors would be key in your decision to invest in a UK advanced fuel production capacity? How would the listed mechanisms affect them?

8ci Currently, the RTFO does not provide the appropriate market pull but in fact provides a disincentive for certain fuels (acknowledged in the E4Tech report). It also does not provide the right incentives to do what is necessary for the development of the more expensive production paths. To succeed, something substantial is needed to support progress.

8cii Stable subsidies are needed to give investors assurance that a technology is economically viable and they will receive a return on investment.

8ciii In addition to support for technology development, success will only be achieved if there are support mechanisms and/or incentives to develop infrastructure (e.g. for refuelling) and any investments or modifications required of vehicles by industry or the vehicle user in order to encourage adoption. Such support does not need to be long term but it should be focused on the technologies seen to provide long-term sustainability.

8d Are you aware of any risks, problems or unintended consequences which could arise from introducing these market mechanisms?

8di Regardless of technology development in the UK, unless there is infrastructure to support this, the OEMs will move overseas. It is important that technical and economic feasibility studies are undertaken soon on the key topics.

8e How might each of these mechanisms interact with the current support offered for biofuels under the RTFO? What would be the likely consequences of this interaction? Would it be advantageous to offer both forms of support to advanced fuels, with a new support mechanism acting in addition to the RTFO?

8ei Question unanswered.

9 Conclusion

9.1 Advanced fuels present an opportunity to provide low carbon fuels using some of the key technologies. It is essential that these advanced fuels represent improvements over the current fuels in terms of GHG footprint and carbon footprint (as a quantitative measurement of g per kWh).

9.2 The future of the UKs relationship with the EU is central to the future of this issue, not only in terms of targets but also in enabling technology development. There are significant risks in making decisions now if the UK leaves the EU in the future, but, equally, such decisions cannot be delayed.

9.3 Long term thinking is vital to a sustainable economy with manufacturing excellence in the advanced fuels landscape. Action must be taken now to make progress. Alongside supporting technology development, the supply chain must be understood and UK R&D skills must be recognised in combination with UK active research companies (e.g. Japanese automotives, battery technology and hydrogen refuellers).

9.4 The DfT should be aware of the technologies that are currently at TRL 4-5 and there should be a conscious effort to nurture these.