

Use of gaseous fuels in transport



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1 Introduction

This discussion paper sets out the case for the UK to have a clear strategy and policy support for the use of gaseous fuels in transport. The paper summarises discussions within the REA's Working Group on Gaseous Fuels in Transport, which was formed following members' participation in the Department for Transport's 'Transport Energy Taskforce', in particular WG 5 on Advanced Fuels¹. A list of the members of the RTFG Working Group can be found at Appendix IV.

This paper primarily focuses on methane as a vehicle fuel, and especially methane from renewable sources. It should be noted that throughout this paper and the Working Group discussions, 'biomethane from renewable sources' is interpreted to mean biomethane derived from 'waste' feedstocks (those in Annex IX Part A of the "ILUC" Directive (EU) 2015/1513 of 9 September 2015²). A much larger amount of biomethane could be produced if crops are used for anaerobic digestion, as has happened in Germany, but this brings with it sustainability issues such as 'food vs fuel', indirect land use change and soil impacts.

There are two other gaseous fuels that can be used in transport - liquid petroleum gas (abbreviated to LPG, this is mostly propane) and hydrogen. Like methane, both propane and hydrogen can be obtained from fossil or renewable sources.

Renewable LPG, or 'biopropane' is now coming into the UK market in relatively small but significant quantities. As there is an existing fleet of LPG vehicles in the UK, and a fuelling infrastructure, this biopropane is an easily deployed drop-in fuel that achieves excellent greenhouse gas (GHG) savings. Provided the feedstock meets the sustainability criteria of EU and UK legislation, including the uses of crop-based vegetable oil, there are no significant policy barriers to its deployment. It is not considered further in this document, but extra detail supplied by Neste and Calor is provided in Appendix V.

Hydrogen is also, of course, a gaseous fuel that can be produced by renewable means and used in transport. However, methane vehicles are widely deployed around the world, and the UK has an extremely well-developed methane distribution infrastructure, meaning that methane, and renewable methane, are very much current technology. Hydrogen, by contrast, has yet to solve a number of technical problems and/or bring its costs down to a level approaching current alternatives, so its widespread deployment is still some way off and difficult to predict. The Working Group has not therefore entered into speculation into hydrogen's place, and it is not considered in this paper.

1.1 Methane as a vehicle fuel - fundamentals

The main benefit of methane (whether of fossil or renewable origin) as a transportation fuel is that it is inherently 'lower carbon'. Burning methane to release a given amount of energy will release roughly 25% less CO₂ than burning diesel to release the same amount of energy³. However, some of this benefit is lost due to the fact that gas engines are generally less efficient than diesel engines. The benefit is further eroded if any methane escapes unburned, whether

¹ Transport Energy Task Force: Options for transport energy policy to 2030 - <http://www.lowcvp.org.uk/projects/transport-energy-task-force.htm>

² "ILUC" Directive - <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&from=EN>

³ Defra emission factor (tank-to-wheel) for diesel 0.268 kgCO₂e/kWh and for natural gas 0.205 kgCO₂e/kWh

from the vehicle itself, or upstream during the extraction/generation or distribution of the gas. Both of these points are considered in more detail below.

Gas (methane) has several other inherent benefits over diesel, most notably:

- Zero particulates (from burning of the fuel itself)
- Gas vehicles are significantly quieter than diesel vehicles
- Low cost and secure supply - natural gas is available from an increasing range of locations around the world, not just the main oil producing regions
- Multiple options for further decarbonisation - renewable methane can be generated from multiple feedstocks, and gas production/handling offers multiple opportunities to extract 'pure' streams of CO₂ for Carbon Capture and Storage (CCS)
- Historically gas vehicles have had considerably lower NO_x emissions than equivalent diesel vehicles. With the advent of the 'Euro VI' emissions standard for heavy duty vehicles (HDVs) this is no longer the case - although test results vary, at the Euro VI standard both gas and diesel vehicles have very low NO_x emissions indeed. However, in order to achieve this, diesel vehicles have much more complex exhaust treatment technology than gas vehicles require. At this time, Euro VI vehicles have only been in service for a few months, but some fleet operators have reported much lower maintenance requirements for their Euro VI gas vehicles than for their Euro VI diesel vehicles, so this may prove to be a benefit in time.



1.2 Summary of the case for supporting gas vehicles made in this paper

While the Department for Transport (DfT) is responsible for UK policy on transport fuels, the Committee on Climate Change (CCC) strongly influences longer term strategy. The positions of both have been influenced by a number of sources, including the HGV taskforce, the Low Carbon Truck Trial (LCTT) run by Innovate UK, and reports prepared for the Department by Ricardo-AEA, LowCVP, E4Tech and others, many of which are referenced in this report.

To paraphrase the consensus view of these bodies, their position is very broadly:

1. Running gas vehicles on natural (fossil) gas offers only marginal benefits in terms of emissions (GHG, NO_x and PM) compared to the latest diesel vehicles.

2. Running gas vehicles on biomethane offers excellent GHG savings (60-95%), but the potential supply of biomethane from wastes alone is quite limited, so vehicles running specifically on biomethane will always be niche.
3. If biomethane supply is limited, it makes more sense to use that limited amount of biomethane to replace fossil gas in its existing uses, and find other ways to cut vehicle emissions. Using the biomethane in transport means replacing diesel vehicles with more expensive gas vehicles and infrastructure.

This broad set of arguments characterises the longer term view taken especially by the CCC⁴. Their GHG reduction scenarios currently suggest a very small role for methane or biofuels in the medium to long term. The Low CVP has produced vehicle, fuel and infrastructure roadmaps that project rather higher penetration of gas vehicles, although still with modest uptake to 2030⁵. The DfT has been represented on the REA Working Group, and has expressed strong support for biomethane as a means of achieving its targets for renewable energy in transport under the Renewable Energy Directive (to 2020), but there are policy challenges to achieving this which are discussed later in this paper. The DfT will be consulting on these issues in 2016.

The Working Group believes that there is potentially a larger role for methane, and particularly biomethane, in heavy duty vehicles (HDVs) in the medium to long term. This view is based on our responses to the points above which can be summarised as follows:

1. Developments are currently underway in gas vehicle technology that will improve their efficiency, such that even running them on fossil methane will have significant GHG emissions benefits vs diesel.
2. The amount of biomethane potentially available is greater than the estimates currently considered by the DfT or the CCC. This is primarily because the existing estimates have not considered the potential to produce biomethane through gasification in the medium-long term, and this allows a far greater range of feedstocks to be economically exploited.
3. Gas vehicles are not inherently more expensive than diesel vehicles. The basic internal combustion engine technology is the same, and the vehicles can be produced with mostly the same parts by the same engineers. The current price premium on gas vehicles is mostly down to their lower production volumes, and if the market can be expanded (to, say, 10% of sales of trucks, or buses) then there should be little price difference.
4. Given the above, in an energy economy with an effective carbon price across all energy uses, the financial incentives will favour the use of biomethane in transport, specifically heavy duty vehicles. This is primarily because there are very few ways of achieving large cuts to GHGs for these vehicles, whereas there are far more ways of producing low GHG energy for heat and power, and of reducing demand in these sectors. In addition, analysis for the DfT suggests that switching a vehicle from diesel to biomethane achieves a higher GHG saving than using that unit of biomethane to produce heat or power.

⁴ See for example 'Sectoral scenarios for the fifth carbon budget - Technical report' at www.theccc.org.uk (pg. 142)

⁵ <http://www.lowcvp.org.uk/initiatives/transportroadmap/RoadmapsHome.htm>

5. The economic scenario in (4) is also likely to favour the use of the available waste feedstocks to produce biomethane, rather than direct heat or power, or liquid biofuels. In the first instance this is due to the relative inefficiency of directly burning the feedstocks for heat or power. Assuming the feedstock is processed instead, then producing biomethane is also both cheaper and more efficient than producing liquid biofuels.

All of the above points are expanded on in more detail in section 2 below.

This paper does not advocate that all heavy duty vehicles should switch to gas, or that all waste feedstocks should be used to produce biomethane for transport. It does seek to present a case for government to support the following:

- Development of the market for heavy duty gas vehicles in the UK to a point at which they have large enough production runs to be independently competitive with diesel counterparts.
- Continued development of anaerobic digestion and gasification, including not just the technology but also the ability to collect and process waste - Annex IX Part A feedstocks.
- An effective market and level playing field for biomethane to be bought by companies in heat, power or transport and reported against their carbon targets (and potentially taxation in the future).

A very low carbon economy will require markets that are effective at allocating renewable resources to achieve the greatest carbon benefit at the most economic price. This economy will employ a much wider range of energy sources, waste management, fuels and vehicle types than we do currently. The Working Group believes that there is good evidence that the use of renewable gases in transport has an important, and cost effective, part to play in the mix, but if the gas vehicle market is not supported through its initial stages, the UK will not reap the rewards it has to offer.

The development and use of gas as a transport fuel should be broadly analogous to the deployment of electric cars and vans. In the case of electrification, development of electric vehicles began while their well-to-wheel (WTW) GHG savings were minimal or negative. However, it was recognised that development of the vehicle technology and decarbonising of the grid would proceed in parallel to lead to genuinely low GHG vehicles in the future.

The Working Group also concluded that the focus for gas as a fuel should be on HDVs, for two reasons. First, if the renewable gas resource is limited then it is best used where there are fewest other options for decarbonisation, and lighter vehicles can be electrified. Second, the economic cost will be lower, as HDVs can be serviced by a targeted fuelling infrastructure, and their higher mileage per vehicle means that fuel cost savings provide a greater economic benefit over the lifetime of the vehicle⁶.

⁶ The group did not rule out the idea that cars and vans could run on methane, indeed some already do in the UK. It seems likely that once refuelling infrastructure is in place, local van fleets might switch to gas to take advantage of it, especially if the relative fuel prices favour it. However, it was agreed that this need not be explicitly supported or discouraged by government policy.

2 Expansion of key points

2.1 The 'efficiency gap' between diesel and gas

The 'efficiency gap' between gas and diesel vehicles will decrease, most likely through direct injection for dedicated gas vehicles, and high pressure direct injection for dual fuel vehicles. Diesel vehicle technology has had over 100 years and billions of dollars of investment, whereas gas vehicle technology is only recently getting serious attention.

There are two approaches to fuelling engines with gas – using 100% gas ignited by a spark plug, and using a mixture of gas and diesel, in which the diesel ignites the gas. The Innovate-funded Low Carbon Truck Trial (LCTT) has examples of both technologies (though mostly dual fuel), and both show a limited benefit in their current state. However, there is good reason to believe there will be significant improvements to both in the near future, relative to diesel.

2.1.1 Dual-fuel

Most of the dual-fuel trucks in the LCTT are aftermarket conversions of diesel engines, with one OEM product produced by Volvo. Two of the conversion companies, Hardstaff and Clean Air Power (CAP), pursued a strategy of trying to engineer high levels of gas substitution by adjusting engine timing and other means. While substitution levels of 60+% were achieved, a significant proportion of the methane injected into the engine went unburned as a result - so called 'methane slip'. Both Hardstaff and CAP have gone bankrupt in the past year, and the IP and assets of both have been bought by Vayon Group.

With the exit of Hardstaff and CAP, the dual-fuel market is heading in two distinct directions. Volvo, which had used CAP technology in its Euro V truck, has declined to produce a Euro VI version on the same lines and is instead focusing on HPDI (High Pressure Direct Injection) technology for its Euro VI offering. Vayon Group is likewise pursuing HPDI with a view to licensing its IP to OEMs. At the cheaper end of the market, conversion companies Diesel-Gas and G-volution are continuing their strategy of producing aftermarket conversions that substitute around 40-50% of diesel for gas, while making only minor modifications to the engine. The benefit of lower substitution is that there is less risk of gas going unburned, and as the conversion is relatively inexpensive the payback is still attractive.

HPDI technology was developed around 10 years ago by Westport in the US, and is the dominant dual-fuel approach in North America. Dual-fuel trucks deployed in the UK are essentially tweaked diesel engines, and will still run on diesel only if required. HPDI engines are designed from scratch, use over 90% methane and will not run on diesel alone. They use a small amount of diesel to ignite the gas, but still achieve diesel engine efficiency overall.

HPDI technology has not been deployed in the UK as yet for two reasons. Firstly, the first generation Westport HPDI engines were very expensive - in the US with very cheap gas and long mileages they could achieve payback more readily than in the UK. Secondly, most European truck manufacturers make their own engines (unlike in the US where they buy engines in from a few specialists such as Westport and Cummins) and they did not have the resources to develop their own version.

It seems that HPDI is now likely to come to Europe. As mentioned above, Volvo is switching to this technology, Westport last year (2015) released its second generation of HPDI engines which it

claims are the same price as diesel⁷, and Vayon Group will be taking this route and seeking to support European OEMs.

2.1.2 Dedicated gas

Dual-fuel engines only perform well when put under fairly constant heavy load, rather than in stop-start operation. For this reason, dedicated gas engines have been, and will likely continue to be, the main choice for running buses, refuse collection vehicles (RCVs) and rigid trucks on gas.

Since gas on its own will not ignite under compression, a dedicated gas engine needs a spark plug, and is essentially very similar to a petrol engine in emissions and efficiency. Current dedicated gas engines use a stoichiometric air/fuel ratio, which allows for the use of a 3-way catalyst for exhaust treatment - meaning they can achieve Euro VI emissions standards much more cheaply and simply than a Euro VI diesel engine. However, the stoichiometric approach limits efficiency.

In common with petrol engines, manufacturers are currently developing 'direct injection' gas engines which will be able to achieve higher efficiency⁸ while maintaining low emissions. Key to this, and other gas approaches, is the development of more effective methane catalysts, an area of research that has had little or no investment for over 20 years.

2.1.3 Fuel cells

The Committee on Climate Change gives little attention to the subject of HDVs and gas as a fuel in the long term, predicting that by 2050 all HDVs will run on hydrogen fuel cells. It is worth noting that fuel cells can also run on methane and other fuels. At present the fuel cells that run on fuels other than hydrogen operate at high temperature and are not suitable for mobile applications, but serious research is underway into developing some that are. It may well be that in the 2050 timeframe, it is more likely that these fuel cells will become a reality than that we will develop an infrastructure for producing and distributing renewable hydrogen.



⁷ More information available at: <http://www.westport.com/is/core-technologies/hpdi-2>

⁸ See also the Horizon 2020 project 'HDGAS' run by Ricardo and 19 other partners to develop direct injection, dual-fuel and HPDI technology, at: <http://www.greencarcongress.com/2015/09/20150923-hdgas.html>

The supply potential for ‘low carbon gas’

This was the first question tackled by the RTFG Working Group. The group felt that the DfT had considered landfill gas and biomethane from anaerobic digestion in reasonable detail. However, its estimates of the GHG reducing potential of gaseous fuels did little to quantify the potential from gasification, and nothing to address ‘renewable methane’ (methane from excess renewable electricity) or the potential that gas offers for capturing or ‘recycling’ carbon.

The group first sought to compare estimates for landfill gas and biomethane from AD. Michael Chesshire (Lutra Ltd) produced the table included at Appendix I.

Broadly speaking it was felt that the different sources agreed on the overall biomethane potential. The key difference is that the E4Tech figure includes all the waste going to landfill as a single figure. While not all of this waste could go to AD, once gasification is included, all the feedstocks in the table can be utilised.

Andy Cornell (Advanced Plasma Power) also took a closer look at the E4Tech figures with this in mind, and produced the very useful table and figures at Appendix II, and drew attention to the E4Tech report on the sustainability Annex IX Part A feedstocks at Appendix III.

Overall, the conclusion of the group was that if AD and gasification are combined, then all of the Annex IX Part A feedstocks identified by E4Tech could be used to create biomethane. Together these would equate to around 83 TWh/yr (300 PJ/yr) of gas - although this is an upper limit⁹. In reality, only some of this is realistically accessible, the key limiting factor being gathering enough of each feedstock together in one place to be used for biomethane production. (Biomethane requires a minimum scale to be economic - smaller amounts of feedstock would be more likely used to generate electricity. One unknown in this is how much AD and biogas upgrading technologies will develop towards allowing economic deployment at smaller scales.)

How much of this total potential can be realised is an ongoing question, with new estimates regularly calculated as technology and policy develop. Certainly full development of this potential resource is unlikely to happen until the period 2025-2030, even with a supportive policy/financial environment.

However, the key point for the purposes of this paper is that current official estimates are significant underestimates, because they are based only on extrapolations of existing biomethane sources.

No firm estimate of renewable methane from renewable electricity was agreed by the group. While this does have potential, the group agrees that (a) it is impossible to predict how much ‘excess’ renewable electricity there might be, given development of ‘smart grids’ etc., and (b) renewable methane will compete with a range of other electricity ‘storage’ solutions as yet unquantified.

Two other sources of ‘low carbon gas’ are not covered in these estimates. Carbon Capture and Storage (CCS) is a technology that many stakeholders consider vital in the overall GHG saving mix. While CCS efforts have focused on combining the technology with coal fired plants, this has stalled recently, e.g. with the abandoning of plans to build a demonstration CCS plant next to

⁹ As well as these 300 PJ/yr, there is currently an additional 61 PJ/yr of landfill gas. As waste to landfill is being steadily reduced, it is estimated that this will fall to around 6 PJ/yr by 2030.

Drax. However, several gas industry experts have pointed out that there are a variety of ways to incorporate CCS into the gas infrastructure much more easily than can be done with coal.

The other unknown source of low carbon gas is through the use of marine algae (i.e. seaweed) as a feedstock for AD. In the table of feedstocks at Appendix III this is listed but no estimate of the size of the resource is given. A great deal of effort has been put into producing biodiesel from oils in micro-algae, with no success, and this is very complex. However, the use of seaweed as a feedstock for AD is simple proven technology - the challenge is one of producing and harvesting large amounts of seaweed. However, seaweed is cultivated extensively in some parts of the world already, and the EU is funding a large scale programme of research into this currently, with three facilities looking at sustainable macro-algae cultivation (one in the UK)¹⁰. Given the very high productivity of aquaculture compared to agriculture (per unit area) this could be a major source of sustainable feedstock.

The overall conclusion of the group was that while current production of biomethane through AD is relatively small, the potential exists for it to supply a significant amount of vehicle fuel. To compare to transport energy demand, total fuel use by HGVs in the UK is around 100 TWh/yr. However two things are needed to realise this potential: (1) an overall strategy for decarbonising the gas grid (as is the case with electricity), and (2) a strategic decision to direct more low carbon gas towards transport over other uses. This second point is addressed further in the latter part of this paper.



2.2 The cost of gas vehicles

The price gap between diesel and gas vehicles is only due to low production numbers, and should mostly disappear once gas vehicles are produced in volume.

Gas engines are not inherently any more expensive than engines running on petrol or diesel. There may be some differences between different technologies, depending on the pressure of

¹⁰ <http://www.enalgae.eu/>

the fuel and other factors, but these are relatively minor. The vast majority of components and processes are the same whether the fuel is liquid or gaseous.

The fuel tanks for gas vehicles, whether running on CNG or LNG, will always be more expensive than those for liquid fuels. However, this is largely balanced out by the fact that exhaust after-treatment for gas engines is much simpler, and therefore cheaper, than for diesel.

The present higher cost of gas vehicles is therefore mostly due to the fact that they are produced in lower volumes than diesel vehicles. It is reasonable to assume that once gas vehicles achieve significant market penetration, they will be at or near cost parity with diesel counterparts.

In their report for the DfT on gaseous fuels¹¹, AEA-Ricardo estimated the costs of GHG abatement through running HDVs on gas as generally higher than using biogas for other energy applications. They noted however that this was entirely due to the additional cost of gas vehicles and infrastructure. By implication, once gas vehicles achieve cost parity, and once a basic refuelling infrastructure is in place, the marginal abatement cost of GHG reductions through using gas as a fuel will be competitive with other options.

2.3 Using renewable methane to replace diesel often achieves a higher GHG saving than using it for heat or power production

If the intention is to achieve the highest GHG savings from a limited feedstock resource, then producing renewable methane to fuel vehicles is the most effective pathway. This is mainly because diesel has higher levels of carbon emissions per unit of energy than gas does.

AEA-Ricardo¹² quantified these emissions savings as per the following table:

End use	Savings if displacing natural gas (kgCO ₂ /GJ of biogas)	Savings if displacing petrol or diesel (kgCO ₂ /GJ of biogas)
Electricity, gas engine	32	
CCGT, boilers and large CHP	52	
Road vehicles using CNG	53	46 to 72
Road vehicles using LNG	55	69

Producing electricity through a gas engine produces the lowest saving, as the counterfactual is marginal electricity production through a more efficient CCGT plant. The figure of 52 is essentially the difference between natural gas and the biomethane¹³, as the plant (or engine) efficiency and other factors are all equal. In the case of road vehicles, the appropriate counterfactual overall is diesel, and the range of savings shown reflects the range of vehicle efficiencies - however, as

¹¹ <https://www.gov.uk/government/publications/waste-and-gaseous-fuels-in-transport-final-report>

¹² *ibid*

¹³ It may be possible to argue that a particular source of biomethane offers a greater or lesser saving per GJ than this figure. However, the key point here is not the absolute saving achieved, but the relative merits of different uses of the biomethane once produced.

discussed in point (1) with development in technology, this is likely to tend towards the upper end of this range.

2.4 Producing methane is often more efficient than producing liquid biofuels

Although the calculations are complex and will depend on feedstock, producing biomethane from AD can have an efficiency of around 60%. Producing renewable methane via gasification involves producing syngas first, then using a catalyst to reform this to methane. This also has an efficiency of around 60%. The same feedstocks and initial gasification to syngas can be used to produce liquid fuels.

The difference between the liquid fuel route and the methane route is what is done with the syngas. A methane catalyst is very specific - i.e. the reaction produces methane and very little else. Different catalysts are used to produce longer hydrocarbons for liquid fuels, and the longer the molecules produced the less specific the reaction, meaning that the resulting product is a soup of many different molecules.

The product of catalysis to longer hydrocarbons must therefore be refined, in much the same way as crude oil is refined, into a variety of different products. This requires an additional 'biorefinery' to be added after the catalysis step - adding hugely to the capital and operating cost of the overall process. It also means that less transport fuel is produced (since a variety of products are refined) and an additional drop in overall efficiency.



3 Policy support

3.1 Support for certification of biomethane supplied via the gas grid

Biomethane is physically supplied to the transport market in three ways - by liquefaction and tanker transport, by compression and tanker transport or by injection into the grid followed by extraction and compression.

Liquefaction of natural (fossil) gas is usually done at large scale facilities near major gas fields. Sources of biomethane are generally too small for a liquefaction plant to be economic. There are

currently two plants in Europe that liquefy biomethane, one in Sweden and one operated by GasRec in the UK - both were set up as demonstration plants with significant financial support.

All of the biomethane currently supplied to the UK transport market under the RTFO is liquefied biomethane from the GasRec plant. There is considerable interest from fleets and governments across the EU in finding more sources of liquefied biomethane, yet due to the cost of plant there are currently only plans for one further biomethane liquefaction plant in Europe, in Norway.

The other potential means of supplying biomethane to the transport sector is to inject the gas into the gas grid, and withdraw and compress it at another location on the grid. This requires use of a mass balance system in which each unit of gas is issued with a certificate at the point of injection, and these certificates are transferred (possibly on an open market) to the end user for them to certify that the gas they withdraw from the grid is the 'same' biomethane.

There are currently two certification schemes in the UK for grid injected biomethane. Both were set up voluntarily by industry bodies and allow trading of gas certificates on an open market. The DfT allows bus companies to use these certificates to show that they are running their gas buses on biomethane, and thus claim a subsidy for running a 'Low Carbon Emission Bus'. As a result of this bus companies are currently the largest purchasers of certificates.

Although bus companies are nominally the largest users of biomethane in the UK, the DfT is unable to count this use towards its RED transport subtarget. This is because biomethane injected into the grid is not eligible as a transport fuel under the current interpretation of the mass balance chain of custody rules of the RED. This interpretation may be revised in the future but this issue may not be resolved before the 2020 deadline for renewable energy targets to be met.

The Working Group concluded the following points in relation to biomethane certification:

- Given the high cost of biomethane liquefaction, some approach to supplying biomethane via the gas grid will be required if significant amounts of biomethane are to be used in transport¹⁴.
- The current use of certified biomethane in buses in the UK shows that such a system is practical.
- In order to generate the desired outcome (i.e. more gas vehicles in operation) certificates must only be used against gas extracted from the same grid. There was some discussion as to whether certificates should be traded separately from the gas (e.g. allowing fossil gas to be purchased from one supplier, and certificates from an open market, and then surrendered together as 'green' gas) - the main concern would be to prevent double counting. However, it was agreed that certificates should not be redeemable against gas (or other energy) that was not taken from the same physical grid into which the original biomethane had been injected.
- If certification is to be used to support national accounting towards binding targets, subsidy schemes etc., beyond the current use in buses, then it is recognised that government will need to set more stringent criteria for the operation of certification schemes.

¹⁴ The group did note that in some cases it is theoretically possible to refuel gas vehicles directly on the site where the gas is produced, thus eliminating the need for liquefaction or grid transport. However, it was agreed that the number of sites and/or vehicles for which this would be practical is likely to be very small.



3.2 Support for biomethane in the context of the RED, 2016-2020

As noted in 3.1, the only supply of biomethane to the transport sector currently officially recognised under the RED is the liquefied biomethane supplied by GasRec. Under the current interpretation of the mass balance rules, the RED does not allow grid-injected biomethane to be counted as a transport fuel. If this position were to change and if biomethane supplied via the gas grid were to be recognised as an eligible transport fuel under the RED, this would be a valuable step forward but would still require further policy co-ordination to be implemented in the UK.

Currently new sources of biomethane that inject into the gas grid can claim the Renewable Heat Incentive (RHI)¹⁵. This incentive provides a consistent, index-linked payment for every unit of gas produced for a 20 year period, providing a stable case for long term investment. Any unit of gas in receipt of an RHI subsidy is counted against the UK's renewable heat target under the RED.

If grid-injected biomethane were to become eligible under the RED, investors in new sources of gas would currently need to choose whether to claim RHI or Renewable Transport Fuel Certificates (RTFCs). The Renewable Transport Fuel Obligation (RTFO) is a mandate on fuel suppliers rather than a subsidy, and RTFCs are a market traded mechanism for fulfilling that mandate. Their value varies considerably, they might cease to exist if policy is changed, and they are traded at the duty point rather than at the point of production of the gas. For all of these reasons, biomethane producers and their investors would be very unlikely to choose RTFCs over the RHI, and thus there would still be very little biomethane officially¹⁶ supplied as transport fuel.

¹⁵ Landfill gas is excluded from the RHI, and landfills are some of the largest sources of raw biogas - the GasRec plant is sited on a landfill for example. However, landfill gas is declining as more and more waste is diverted away from landfill, so further investment in upgrading and using landfill gas for anything other than electricity generation is not expected.

¹⁶ As noted in 3.1, a large proportion of biomethane is sold to bus operators, but not officially counted under the RED. The producers of this gas have all claimed RHI, while the bus operators claim their low emission bus subsidy.

There are no easy solutions to this clash of subsidies. The Working Group debated the problem, and proposes the following solutions, though they are not ideal and the group would be very willing to consider and debate other proposals that may be put forward.

- Allow gas producers to claim the RHI, but switch to claiming RTFCs at such times as the RTFC market value is higher than the RHI value. This solution has the benefit of providing investor confidence, while allowing the transport market to ‘pull in’ biomethane if renewable fuel is scarce enough. The disadvantages are (i) that DECC would find it hard to forecast its RHI commitments, and (ii) RHI is claimed at the point where gas is injected into the grid, whereas RTFCs are claimed at the fuel duty point, meaning the two subsidies would probably benefit different actors in the chain of custody and thus making a switch from one to the other unlikely even if the value of RTFCs exceeded the RHI value.
- Allow gas producers to claim RHI and fuel producers to claim RTFCs for the same unit of gas. While this sort of ‘double counting’ is normally disallowed, an argument could be made that the RHI has already been degressed considerably from its original value (and is likely to be degressed further). Thus, the total value of RHI + RTFC would still be below the original RHI value cleared under EU state aid rules, and the RTFC could be seen simply as a way for the gas supply chain to replace some of the ‘lost’ RHI value.
- The Working Group agreed that if RTFCs are to play a significant role in incentivising biomethane for transport they will need to have a considerably higher value than they have been traded at to date. This could be achieved by multiple counting, although this would probably require more than double counting, possibly quadruple counting, and multiple counting has its own problems. The group fully supported the DfT proposal that within a revised RTFO there should be a ring-fenced sub-obligation for advanced fuels (of which biomethane would be one), with its own separate certificates and buy-out price trading in a tighter market. There could also be the possibility of introducing banded buy-put prices for individual technologies within the sub-obligation.

3.3 Support for development of vehicles and vehicle market

Regardless of the support for biomethane supply, a key point of this paper is that the market for gas vehicles needs support in order for the technology to develop and achieve economies of scale. The group did not debate in detail what this support would look like, as it was felt that the LowCVP would be a more appropriate forum for such questions. However, the following broad suggestions and points were made:

- The various rounds of the ‘Green Bus Fund’ have been successful in expanding the number of Low Emission Buses and something similar could be rolled out for trucks. It is noted that the LowCVP (which developed the standard used for low emission buses) is developing a testing process for low carbon truck technologies, and this could be linked to market support in some way. Other support mechanisms should also be explored and consulted on with vehicle manufacturers and fleet operators.
- It would be of value to establish in more detail what level of market penetration of gas vehicles would be required for them to achieve similar economies of scale to diesel vehicles. This could be a focus of future industry working groups or a commissioned study.
- Similarly it would be useful to attempt to quantify the likely timeline for the closing of the efficiency gap between gas and diesel vehicles.



3.4 Learning from other countries

The ICCT has produced an excellent white paper and set of policy recommendations for the US context, which would serve extremely well for the UK as well. The paper is available at:

http://www.theicct.org/sites/default/files/publications/ICCT_NG-HDV-emissions-assessmnt_20150730.pdf

4 Conclusions and recommendations

4.1 The need for a clear strategy for gaseous fuels in transport

The views of the REA Working Group are based on:

- i) The direction of policy towards reducing GHG emissions and the GHG emission benefits of using renewable gaseous fuels, in particular renewable methane.
- ii) The greater supply of renewable methane, including from the gasification of waste feedstocks, than has been previously estimated.
- iii) Actual and potential technological advances in gas vehicles.
- iv) The identification of the HDV sector as having few alternative and cost-effective means for decarbonisation.

4.2 Policy challenges (supply and demand)

- i) Ensuring a sector-neutral method of encouraging the supply of all types of renewable methane. If a hybrid of the current RHI and RTFO is deemed to be legally inadmissible, policy must face the reality that a significant proportion of biomethane currently injected into the grid is used for transport, particularly in the bus sector. A long-term policy mechanism that overcomes this legal technicality to allow the efficient decarbonisation of the whole HDV sector is essential.

- ii) Including biomethane and other renewable gases in the proposed sub-obligation for advanced fuels within an amended RTFO, with a possible banded buy-out price.
- iii) Supporting the development of gas vehicle technology and the production of sufficient vehicles to ensure the benefits of scale.
- iv) Developing the current independent certification schemes such that these promote the use of genuinely sustainable feedstocks for low carbon gaseous fuels. In this context the REA Renewable Transport Fuels Group is also drawing up recommendations on sustainability which should be taken into account.



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Lutra Ltd, Community food waste AD plant

CNG Fuels Limited, Leyland bio-CNG filling station in Lancashire

CNG Services Limited, X-Store - composite tank CNG Trailer

Renewable Energy Association - April 2016

Appendix I - Comparison of estimates of potential biomethane resource

Biomethane for Transport Potential Production (PJ/yr)

	MJC	AEA	E4T
Domestic Food Waste	23	48	155
Commercial Food Waste	16		
Other OFMSW	22		
Manure	27	18	43
Sewage Sludge	10	13	10
Agricultural Residues	6	6	6
Farm Crops	30	30	30
Total from AD	134	137	244
Landfill Gas	61	61	61
Total Biogas	195	198	305

Sources

MJC - Michael Chesshire (July 2015)

AEA - Ricardo AEA "Waste & Gaseous Fuels in Transport" (July 2014)

E4T - E4Tech "Advanced Biofuel Feedstocks" (January 2014)

Notes

1. Other "OFMSW" is the organic fraction of municipal solid waste, excluding food waste, e.g. paper & card, which is also potentially a source of syngas.
2. The numbers in blue are taken from the other studies where no figures are published.
3. The AEA figures are the "2025 the accessible resource".
4. The E4Tech figures are the "2020 potential resource".
5. The MJC figures are based on the total resource in 2015, and allow for the parasitic energy demand of the AD plant and upgrading equipment.
6. The MJC figures for agricultural residues are based on a production of 5 million tonnes per year, which has not yet been verified.
7. The figures for crops are from "The case for Energy Crops in AD" (November 2011), a joint report by NFU, CLA, REA & ADBA. The potential is based on a land area of 220,000 ha, which is 1.2% of farmed land.

Appendix II - Pathways for Gas Production

	Landfill Gas	Anaerobic Digestion	Thermal Treatment	Gas from Electricity
Current Feedstock	Mixed waste	Non-cellulosic biogenic waste and biomass	None	None
Future Feedstocks	None	Cellulosic waste Micro algae etc.	Mixed waste All types of biomass	Waste CO ₂ streams CO ₂ from air Electricity
Feedstock Cost	Gate fees around £7/MWh	Suitable wastes attract gate fee 14/MWh. Biomass input has cost of £17/MWh.	RDF has gate fees of £15/MWh. Biomass input costs £17/MWh.	UK average £45/MWh cost but off peak costs may be much lower, even negative.
Energy Efficiency	???	Assumed at around 60% - reality complex driven by biomethane potential.	60%	50%
Capital Cost	£0.9m/MW	£2.0m/MW	£2.5m/MW	£5.3m/MW
Other Operating Cost	£0.1m/MW p.a.	£0.5m/MW p.a.	£0.3m/MW p.a.	£0.1m/MW p.a.
Load Factor	85%	85%	85%	Linked to power price and grid management
Data Source	Ricardo report on biomethane production ¹⁷	Government consultation on large scale RHI tariff ¹⁸	APP Data	P2G-LEAP submission to NIC ¹⁹ Audi egas project ²⁰
Potential Production	Currently 61 PJ/annum 6PJ/annum in 2030	295PJ/annum across AD and thermal	Very complex – limited by availability of low cost power.	
Issues	Encouraging significant investment will be difficult with volumes declining.	Natural gas has low value compared to electricity and other products.	Forecasting quantities of low cost electricity very difficult. Competes with other storage technologies.	

¹⁷ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/416002/biomethane-for-transport.pdf

¹⁸

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/315608/Biomethane_Review_Final_-_FOR_PUBLICATION.pdf

¹⁹ https://www.ofgem.gov.uk/sites/default/files/docs/2015/05/gas_esp_power_to_gas_project_0.pdf

²⁰ http://www.audi.com/com/brand/en/vorsprung_durch_technik/content/2013/10/energy-turnaround-in-the-tank.html

Appendix III - ILUC Directive Annex IX Part A - Assessment of Sustainability, E4Tech

Table 4: Summary of feedstock supplies (in wet "as received" tonnes) and biofuel production potentials (i.e. without conversion plant capacity constraints) – both before any competing uses for the feedstock are considered

Feedstock	Current feedstock supply (wet Mt/yr)			2020 feedstock supply (wet Mt/yr)			Expansion post 2020?			Data quality	Current biofuel production potential (PJ/yr)			2020 biofuel production potential (PJ/yr)		
	UK	EU	Global	UK	EU	Global	UK	EU	Global		UK	EU	Global	UK	EU	Global
Bio-fraction of MSW	22	189	861	22	147	1,039	↓	↓	↑↑	Medium	68	591	2,694	68	460	3,253
Bio-fraction of C&I waste	25	133	560	25	104	690	↔	↔	↑↑	Medium	85	460	1,941	87	359	2,390
Straw	7.4 - 11	72	885	7.4 - 11	155	934	↔	↓	↑↑	High	52	405	4,963	52	870	5,240
Animal manure	68	1,521	16,202	68	1,340	18,866	↔	↑	↑↑	Medium	43	969	10,320	43	853	12,016
Sewage sludge	35	632	1,069	37	648	1,183	↑↑	↑	↑↑↑	High	9	161	272	9.5	165	301
Palm oil mill effluent	0	0	159	0	0	338	-	-	↑↑↑	High	0	0	60	0	0	127
Empty palm fruit bunches	0	0	51	0	0	109	-	-	↑↑↑	High	0	0	81	0	0	172
Tail oil pitch	0.001	0.16	0.4	0.001	0.19	0.5	-	↑↑	↑↑	High	0.02	5.3	14	0.02	6.6	17
Crude glycerine	0.03	1.0	2.9	0.04	1.4	4.9	↔	↔	↑↑	High	0.25	8.3	25	0.36	12	42
Bagasse	0	0	413	0	0	599	-	-	↑↑↑	High	0	0	1,205	0	0	1,748
Grape marcs	0.02	4.1	7.7	0.02	4.1	8.5	↔	↔	↑	High	0.05	9.5	18	0.05	9.5	20
Wine lees	0.004	0.8	1.5	0.004	0.8	1.6	↔	↔	↑	High	0.01	2.6	4.9	0.01	2.6	5.4
Nut shells	0	0.8	10	0	0.8	11	-	↔	↑↑	Medium	0	4.5	55	0	4.5	61
Husks	0	0.5	120	0	0.5	133	-	↔	↑↑	Medium	0	2.3	583	0	2.3	645
Cobs	0.01	3.6	36	0.01	3.6	40	↔	↔	↑↑	High	0.04	17	167	0.04	17	185
Bark, branches, leaves	3.4	127	317	3.4	122	316	↔	↔	↑	Medium	15	554	1,377	15	532	1,376
Saw dust & cutter shavings	1.6	37	104	1.6	42	115	↔	↑↑	↑↑	High	8.5	199	552	8.5	221	614
Black and brown liquor	0.28	66	200	0.28	72	246	-	↑	↑	High	1.9	459	1,392	1.9	498	1,714
UCO	0.13	1.1	2.8	0.19	3.0	7.8	↔	↔	↑↑	High	4.3	37	94	6.6	102	266
Animal fats Cat I & II	0.12	1.2	3.5	0.12	1.3	3.8	↔	↔	↑↑	High	3.7	38	107	3.7	39	119
Miscanthus	0.12	0.9	1.2	0.36	4.1	4.7	↑↑↑	↑↑↑	↑↑↑	Medium	0.6	4.6	6.2	1.8	21	24
Short rotation coppice	0.04	0.3	9	0.11	1.3	11	↑↑↑	↑↑↑	↑↑↑	Medium	0.15	1.2	39	0.46	5.6	47
Short rotation forestry	0	0	0	0	0	0	↑↑↑	↑↑↑	↑↑↑	High	0	0	0	0	0	0
Small round-wood	3.3	333	829	3.3	310	772	↔	↑	↑	High	14	1,417	3,523	14	1,320	3,282
Micro-algae	0	0	0	0	0.0001	0.015	-	↑↑	↑↑↑	High	0	0	0	0	0.002	0.51
Macro-algae	0	0	0.01	0.01	0.24	2.2	↑↑↑	↑↑↑	↑↑↑	High	0	0	0	0.01	0.24	2.2
Renewable electricity (Mtoe)	2.2	51	403	7.8	82	575	↑↑↑	↑↑↑	↑↑↑	High	67	1,536	12,142	235	2,455	17,316
Waste carbon gases	0.9	10	101	0.9	10	138	↔	↔	↑↑	Medium	3.3	36	375	3.3	37	511

Advanced Biofuel Feedstocks - An Assessment of Sustainability

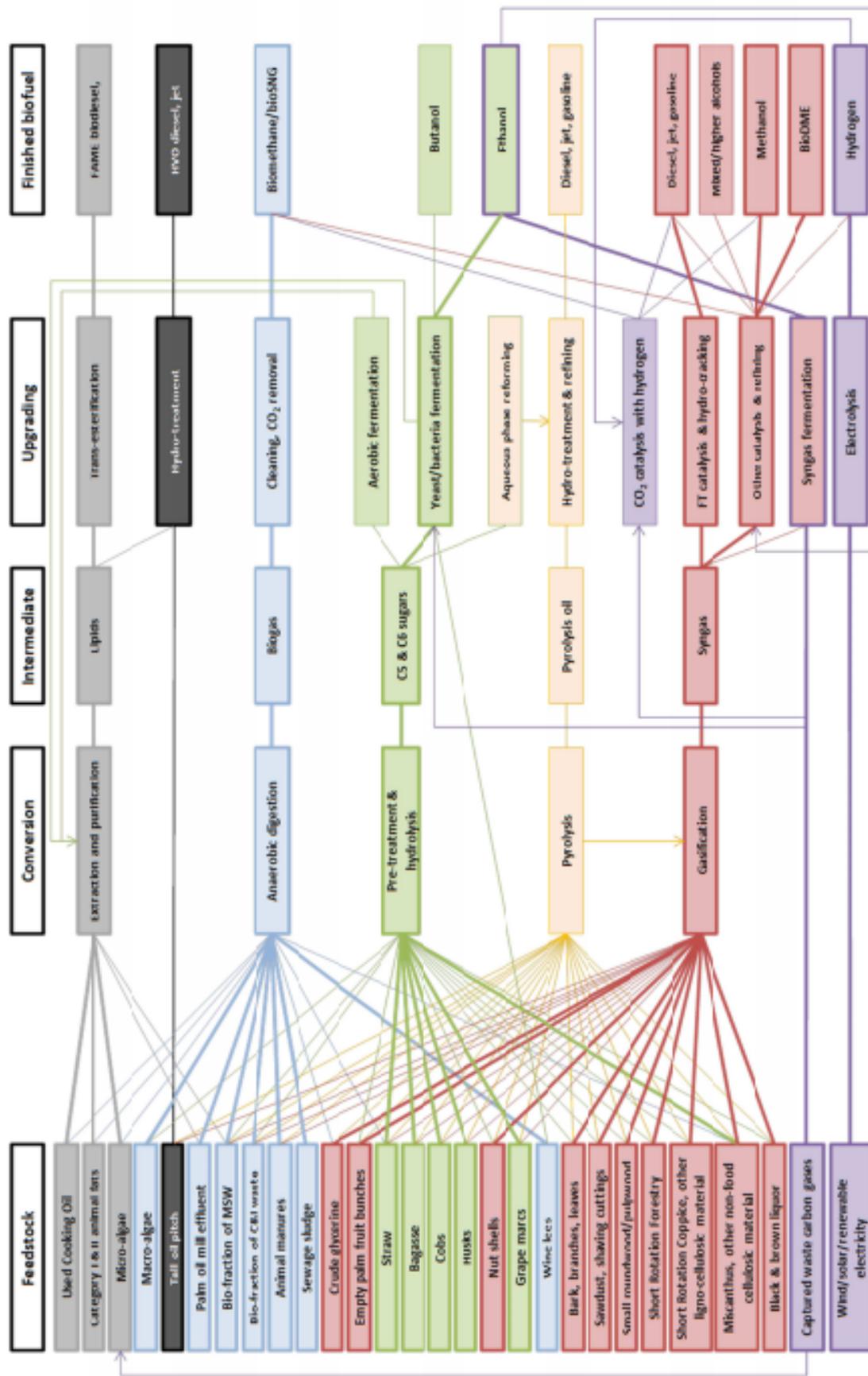


Figure 4: Potential conversion pathways from each Annex IX feedstock to biofuel. Most likely options (selected for analysis) shown by bold highlights

Appendix IV - Members of the REA Working Group on Renewable Gases for Transport

Dominic Scholfield - Mint Green Sustainability - Chair

Syed Ahmed - Advisor to Green Gas Certificate Scheme

Adam Baisley - Olleco

Alan Bell - ET Biogas Ventures Ltd

Ciaran Burns - REAL Green Gas Certificate Scheme

Mike Cairns-Terry - Progressive Energy Ltd

Michael Chesshire - Lutra Ltd

Mark Cleaver - Calor

Richard Cook - National Grid

Andy Cornell - Advanced Plasma Power

Gloria Esposito - Low Carbon Vehicle Partnership

Philip Fjeld - CNG Services

Jonathan Hood - DfT, Low Carbon Fuels Team

Ruby Jones - Qila Energy

Jenny Keating - DfT, Freight Policy, Freight, Operator Licensing and Roadworthiness

Chris Manson-Whitton - Progressive Energy Ltd

William Mezzullo - Future Biogas

Nick McAllister - Farm Renewables

Lucy Natrass - E4Tech

Bill Prescott - OSPRE

Tom Reid - DfT, RTFO Unit, Low Carbon Fuels

Paul Thompson - Qila Energy

David Veale - Purac-Puregas

Ian Waller - Five Bar Gate

Clare Wenner - Head of Renewable Transport, REA

Kiara Zennaro - Head of Biogas, REA

Appendix V - Biopropane

Available in 2016

Biopropane or Bio LPG as it is also known will be made available to the UK market in 2016, with 40,000 mT of product available from Neste's HVO Bio-diesel refinery in Rotterdam. Unlike many biofuels, this HVO²¹ biopropane is completely fungible with its fossil counterpart. It can substitute conventional LPG up to 100% or in a blend, without any change in performance, and without requiring any change to the infrastructure of distribution and usage. As such, HVO biopropane is an excellent renewable option for road fuels and off-gas-grid heating as it would require no capital investment from existing LPG users and delivers identical performance to existing LPG systems.

Like 'green' electricity or biomethane, HVO biopropane need not be distributed physically to its customers; instead it can be credited to them on a 'mass balance' basis, which can be verified by government with minimal effort and uncertainty.

HVO biopropane is produced as a residue of HVO biodiesel processing, at a biopropane:feedstock weight ratio of about 5-6%. Primary feedstocks are those for HVO biodiesel: fats and oils, largely non-edible, some of them wastes, from plants and animals. At commercial scale, HVO biodiesel currently is produced by Neste Oil in Rotterdam with further possible production in Porvoo (Finland) and Singapore. Further sources of supply are anticipated to come on-stream in the next 5 years, with global production expected to exceed 200,000 tonnes / year by 2020. The current UK market for LPG, as a vehicle fuel is about 155,000 tonnes/year - road vehicles 80,000; Fork lift trucks 75,000.

Although currently there is no known HVO biopropane production in the UK, capacity could very feasibly be located here. Moreover, there are a number of research projects looking at developing bio propane from a range of alternative sources, specifically from the modification and fermentation of e-coli by the Manchester Institute of Biotechnology.

HVO biopropane: the basics

HVO (hydrotreated vegetable oil) biopropane is an unavoidable residue of HVO biodiesel processing, made from the same feedstocks. Its chemistry and nomenclature are identical to that of propane, which makes it completely fungible with LPG and allows a 'mass balance' system of biofuel accounting.

Residue of HVO biodiesel

HVO biopropane is similar to bioglycerine: both are unavoidable residues from the production of biodiesel; both residues stem from the triglyceride backbone of the fat or oil feedstock. When oils/fats are reacted with methanol, the product is FAME²² biodiesel plus a bioglycerine residue (Figure 1). When oils/fats are reacted with hydrogen, the product is HVO biodiesel plus a HVO biopropane residue (Figure 2).

²¹ Hydrotreated vegetable oil

²² FAME means fatty acid methyl ester

The HVO process is able to handle a much greater proportion of waste or low-grade fats and oils than are most FAME processes. Indeed, HVO could handle 100% waste feedstock, if it were available. Most FAME processes, by contrast, must use highly-refined vegetable oils, often food grade, that contain no more than 2-3% free fatty acids (Atlantic Consulting 2010). Although a few, small plants produce FAME entirely from waste fats and oils, most of the more robust FAME processes can accept only a limited proportion (typically one-third to one-half) of waste or low-grade feedstocks.

Chemistry

HVO biopropane is a hydrocarbon molecule, C_3H_8 , with identical chemical and physical properties to fossil propane, also C_3H_8 , the primary constituent of LPG²³. Except perhaps by carbon-dating, the two types of propane are indistinguishable.

Complete fungibility with LPG

Because of its chemical and physical sameness to fossil propane, HVO biopropane is completely fungible within the existing LPG supply-chain. Unlike, say, biomethane, no upgrading is needed. Unlike FAME biodiesel or ethanol, no blend limits are needed.

'Mass balance' rather than physical distribution

Thanks to this fungibility, HVO biodiesel - like 'green' electricity - need not be delivered physically to its customers. It can be supplied to the LPG pool, and credited notionally to customers or suppliers. This minimises costs and carbon emissions in distribution, and it greatly simplifies monitoring or verification of use.

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²³ LPG, or liquefied petroleum gas, consists mainly of propane, plus some butane and at times some propylene.

About the REA

The REA was established in 2001, as a not-for-profit trade body, representing British renewable energy producers and promoting the use of renewable energy in the UK.

The REA endeavours to achieve the right regulatory framework for renewables to deliver an increasing contribution to the UK's electricity, heat and transport needs. It is influential in helping shape UK energy policy and has a track record in delivering high quality events on a wide range of energy related topics. REA aims to help its members build commercially and environmentally sustainable businesses.

REA Expertise

The Renewable Transport Group is the REA's forum for renewable transport fuels and the de-carbonisation of the transport sector.

The REA has been closely involved since 2005 with the development of the Renewable Transport Fuels Obligation (RTFO) and the transposition into UK law of the EU Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD). This detailed work is carried out by Renewable Transport Fuels Group (RTFG).

The RTFG represents 75 member companies including UK biofuel producers, importers, feedstock suppliers, technology providers and life cycle analysts. The RTFG is involved in the development of policy for gaseous and advanced fuels and electricity for transport. The REA is a key stakeholder in this emerging and increasingly important market for the UK economy.



Renewable Energy Association
25 Ecclestone Place
London SW1W 9NF
Tel: 020 7925 3570
Twitter: @REAssociation
Email: info@r-e-a.net
www.r-e-a.net



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