Is there a role for BioLPG in Decarbonising the UK's Economy?

To achieve the goal of limiting global warming to 1.5°C above pre-industrial levels, fossil fuels will need to be replaced with alternatives fuels and technologies. In the interim, whilst power-to-liquid fuels are developed, biomass will provide alternatives to fossil fuels as a solution to reduce greenhouse gas emissions (GHGs). This has created many opportunities to develop new processes using biomass to produce renewable fuels such as gasoline, diesel, and kerosene. Liquefied petroleum gas (LPG) is a fuel that can be found on many UK forecourts for transport, or being used as a heating fuel, however its future has not been given the clarity that other fuels have received. Liquid Gas UK, the trade association for the renewable gas industry, have been lobbying the government to make a commitment to support the development and use of BioLPG in the UK.

What is BioLPG?

LPG is a liquefied mixture of light hydrocarbons mostly made up of propane, propylene, butane, butene, or isobutanol. Since the boiling point of both propane and butane is below 0°C, it is stored under pressure to keep it in a liquefied form. This means it is an energy dense fuel, 46-49 MJ kg^{-1}, that is used for a variety of heat, power, and transport applications. BioLPG is a blended fuel containing biopropane, biobutane or renewable dimethyl ether (rDME). Biopropane and biobutane are chemically identical species to their fossil counterparts that can be used as a direct replaced in LPG, whereas rDME can be blended up to 20% in LPG. There is the potential to use 100% rDME as a replacement for LPG but modifications to the burners/engine will be required in energy systems.

How is BioLPG Produced?

Currently the main sources of BioLPG are as by-products of other renewable fuel processes. The most common source is from hydrogenated vegetable oil (HVO) biodiesel production. During the HVO process glycerine is broken down by hydrogen to form biopropane, a small amount is also produced during isomerisation of paraffin diesel molecules to optimise their combustion and storage properties[1]. Processing 1 tonne of vegetable oil to HVO will produce up to 100 kg of biopropane.

Development of dedicated processes that produce biopropane as their primary product are at demonstration scale. In Europe, Ekobenz use alcohol to hydrocarbon technology to produce bioLPG that has been sold into the UK market. Other projects by Vertimass and Gevo are expected to come to Europe soon. The process starts with ethanol produced from the fermentation of sugar beet and wheat. The ethanol is dehydrated, releasing water, then oligomerised and cracked to produce biopropane. This process was designed for producing gasoline and kerosene, without the cacking, but has been used to produce biopropane. Ethanol from second generation feedstocks could also be used in this process such as from the waste of the sugar processing industry or even from carbon monoxide or carbon dioxide rich waste gases. The conversion of e-methanol to biopropane is also in development, this process could be advantageous as power-to-liquid technology is commercialised.

Other processes designed to produce biopropane as a primary product include hydroprocessing of glycerine or from converting biomethane to biopropane. Alternatively, isobutene can be blended as a

[1] Isomerisation is a process used to rearrange the atomic structure of a molecule. This is because the molecular shape can influence chemical and physical properties of the fuel/chemical.

replacement for butane. Isobutene is produced from the fermentation of sugar feedstocks. These routes are summarised in Table 1.

Since the routes to biopropane and biobutane as a main product are currently limited, rDME could offer a decarbonisation alternative. The routes to rDME use methanol as an intermediate, this can be through either gasification or from power-to-liquids. Dimeta is in a joint venture with SHV Energy and UGI International to produce the UK's first volumes of rDME by 2024. This uses a technology being developed by Circular Fuels and Kew Technology.

Table 1: Renewable LPG Technologies

Technology	Main Product	Example Projects
HVO/HEFA	Diesel/Kerosene	Neste PREEM Shell
Alcohol to Hydrocarbon	Gasoline, Diesel and Kerosene	EkoBenz SHV & LanzaTech Vertimass Gevo
Gasification to Methanol and Methanol to Gasoline	Gasoline	Enerkem TIGAS
Fermentation of Sugars	Isobutene	Global Bioenergies C3 Biotechnologies
Conversion of Biogas	Propane/Butene	PlasMerica
Hydroprocessing of glycerine	Propane	Hulteberg Chemistry & Engineering

What are the Applications for BioLPG?

Road vehicles running on Autogas (LPG) in the UK hit a peak in 2011 with approximately 170,000 vehicles. This has been on a decline since (1). The Autogas market for road vehicles in Germany is substantially bigger, just under 400,000 vehicles, and in France approximately 200,000 Autogas vehicles are in operation (2) (3). Since the UK government's announcement to end the sale of new combustion engine vehicles by 2030, the Autogas market for road vehicles is on a steep decline and could cease to exist within the next decade. However, uptake of rDME is increasing because of its use in heavy goods vehicles (HGVs), which have been identified as a hard to decarbonise area.

Non-Road Mobile Machinery (NRMM) such as forklifts, tractors, and diggers are another sector that has historically used LPG as a fuel. The ease of changing gas cylinders to refuel these vehicles has been advantageous compared to using traditional fuels. Additionally, for traditional fuels, costly fuel pumps would need to be installed and maintained which is also hazardous. However, with the push to be seen as "greener", company ESG targets often include plans for transitioning from using LPG vehicles to using electric vehicles or even hydrogen-powered ones. However, the transition to electric vehicles is not always possible as batteries cannot always fulfil power or duration requirements.

A large application of LPG is for heat, and this includes a variety of different functions. Cooking and heating in UK homes is a big part of this sector. There are 193,000 homes in the UK that currently use LPG and since LPG is a cleaner burning fuel than kerosene or heavy fuel oil there is an environmental incentive to change from kerosene or heavy fuel oil to LPG (4). LPG is also used as a heating gas in many commercial settings including in the hospitality industry and for many off-gas grid premises. Blending biopropane into LPG produces a chemically identical product so it can be used as a drop-in fuel in existing LPG systems. These heating systems could also run on an LPG blend with rDME (up to 20%) or switch to 100% rDME with changes to the burners.

Biopropane is also a popular heating gas in manufacturing processes such as soldering and thermal treatments.

LPG also has important non-energy applications, the biggest being for polypropylene (PP) production. PP is widely used for rigid plastic packaging such as bottles, containers, car parts and cladding. In 2021 approximately $922 million USD of PP were imported to the UK, making the UK one of the top 20 importers of PP in the world (5). Other chemical applications include aerosol propellants, paints and resins. rDME can also be used in propellants.

How can BioLPG Decarbonise the UK?

There are many options for using bioLPG and rDME, but understanding how feasible that is, is a different question. There are three market opportunities, transport, heating, and chemicals, which together create a sizeable market for the use of bioLPG. However, with the UK government plans to electrify transport and heating, this significantly diminishes the size of those market opportunities. Since these electric technologies are already in the marketplace, this threat to the bioLPG market is imminent.

Regarding the use of biopropane in the chemicals sector, as an input for polypropylene production or as propellant, any increase in uptake is limited by production economics. Except for propane produced as a by-product of HVO production, all other routes currently in development proceed through intermediates (methanol, glycerine, iso-propanol, and n-propanol etc) which have high volume markets and can command a similar or higher price than propane. Given the additional processing costs to convert these intermediates to biopropane, it makes greater economic sense to sell these intermediates directly into the transport fuel or chemical market. This includes when rDME is produced as an intermediate of converting methanol to propane.

So how can BioLPG help to decarbonise the UK? Currently because of the small supply volumes, its impact in the main markets is limited, and since there are other technologies available, it could make more sense to make a greater capital investment and move away from using LPG. However, using the biopropane by-product from HVO production makes sense even if this only has a small impact on decarbonisation.

However, there are more opportunities with rDME both technically and commercially. There are dedicated processing pathways that can be scaled to produce rDME as the main process output and it can be used in similar applications as LPG such as in transport, heating and for aerosol propellants. Critically it can be blended into bioLPG which could have a substantial impact on decarbonising niche sectors such as off-grid heating. Additionally, small modifications to diesel engines mean they could run on 100% rDME which increases the potential for rDME to decarbonise the transport sector. Therefore, rDME could be an important part of the UK's strategy for decarbonisation.

If you wish to understand more about decarbonisation options with rDME or bioLPG and how they fit your business, then please feel free to contact the team.

Bibliography

1. **World LPG Association.** Auto-gas.net. *United Kingdom: Autogas market trends.* [Online] 2021. https://auto-gas.net/government-policies/autogas-incentive-policies/united-kingdom/.

2. —. Auto-gas.net. *Germany: Market Trends.* [Online] 2021. https://auto-gas.net/government-policies/autogas-incentive-policies/germany/.

3. —. auto-gas.net. *France: Market trends.* [Online] 2021. https://auto-gas.net/government-policies/autogas-incentive-policies/france/.

4. **Liquid Gas UK.** Liquid Gas UK. *LPG in the home.* [Online] 2023. https://www.liquidgasuk.org/about/lpg-in-the-home.

5. **OEC.** Propylene polymers. [Online] 2022. https://oec.world/en/profile/hs/propylene-polymers.

6. **Sloane, S, Velson, J.C, and Fox, T.** Nexant ECA. *Blogs: The problem with on-purpose bio-propane.* [Online] 23 05 2022. https://www.nexanteca.com/blog/202205/problem-purpose-bio-propane.

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