Renewable LPG for New Zealand

LPG in New Zealand

Annual Demand	**185,000 mt (9PJ)**
Annual Production	**165,000 mt**
Customer Installations	**178,000** (excl BBQs camping and mobile)

A wide range of uses including:

- Household cooking, water and space heating
- A range of portable applications including BBQs, heating cooking and lighting
- Commercial and hospitality cooking, water, space heating and forklifts
- Industrial heating applications
- Only choice for gas in the South Island (90,000 mt)
- Christchurch, Dunedin, Queenstown and Wanaka reticulated (35,000 mt total)

What is Renewable LPG?

Renewable LPG or rLPG is the commonly used term to describe any molecules of propane and butane produced from biological sources or renewable electricity and CO_2.

BioLPG is the commonly used term to describe any molecules of propane and butane produced from biological sources only

Why rLPG?
Low/Zero Carbon, clean and uniquely convenient

- Zero net carbon by 2050 can only be achieved if we develop low or zero carbon energy alternatives
- rLPG has a carbon footprint up to 80% lower than conventional LPG and has the potential to become carbon neutral depending on the feedstock and the development of new production processes
- rLPG results in substantially reduced carbon, particulates, and NOx emissions compared to solid and liquid fossil fuels
- Compared to biomethane and hydrogen, rLPG liquefies at a lower pressure at room temperature, which allows for **convenient** cost-effective distribution and storage in off-grid applications
    - A flexible partner for renewable technologies and hybrid systems

Why rLPG?

Seamless transition to 2050
Biofuels enabler

- rLPG is chemically identical to fossil LPG, and is 100% compatible with existing supply networks and end-use infrastructure – we are ***renewable-ready***
- Retaining our existing LPG infrastructure will allow a seamless transition to rLPG as increasing amounts become available – **a pathway to 100% rLPG by 2050**
- Today's investments in LPG supply chain and appliances would be future proof with no upgrade costs
- rLPG is a valuable coproduct to other biofuels with a ready market – an **enabler** of new biofuels plants

DME
Dimethyl ether
CH_3OCH_3

Renewable DME for blending to reduce the carbon intensity of LPG is also worth further investigation

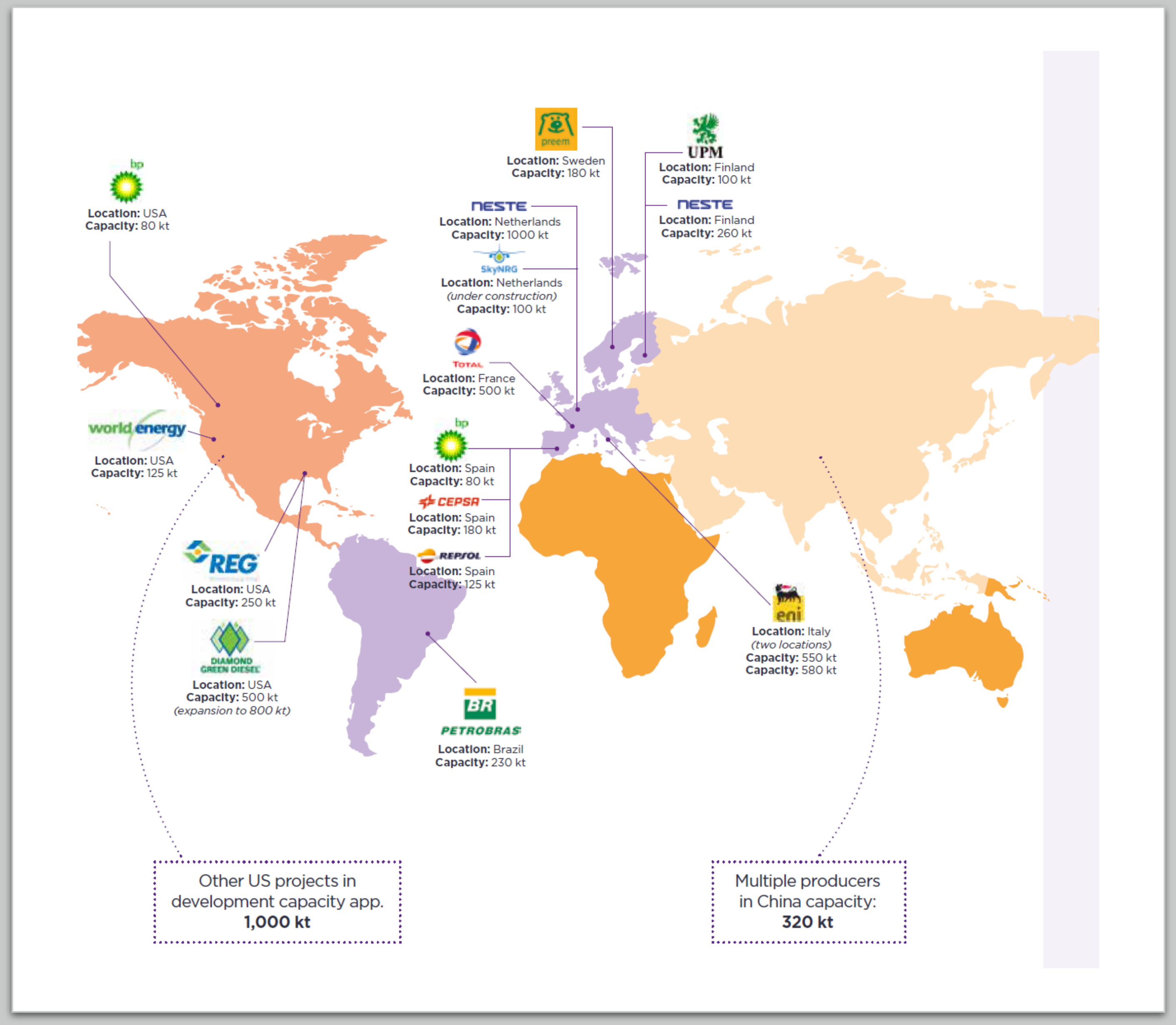
- DME has similar physical properties to propane and can be blended with propane up to at least 20%
- rDME produced from dairy manure has a large negative CI (carbon intensity) of up to -278gCO2e/MJ
- A 20% blend of rDME can reduce propane's CI from 83 to 11gCO2e/MJ a reduction of 87%

rLPG History

- BioLPG was launched in 2018 – produced as a by-product (~5%) of renewable diesel/jet fuel using HVO (hydrotreated vegetable oil) technology
- World-wide interest despite being <1% of the LPG market
- In order to develop and cement LPG's role in the energy transition we need much more rLPG
- The WLPGA is working with industry around the world to develop sources of rLPG
- WLPGA scoping study identified about 20 priority projects and another 100+ possibles that could lead to rLPG

BioLPG Production

- In most cases, bioLPG is a coproduct of several technologies
- Many of these projects are in the early stages of development
- In some the LPG is used on site for process heat.



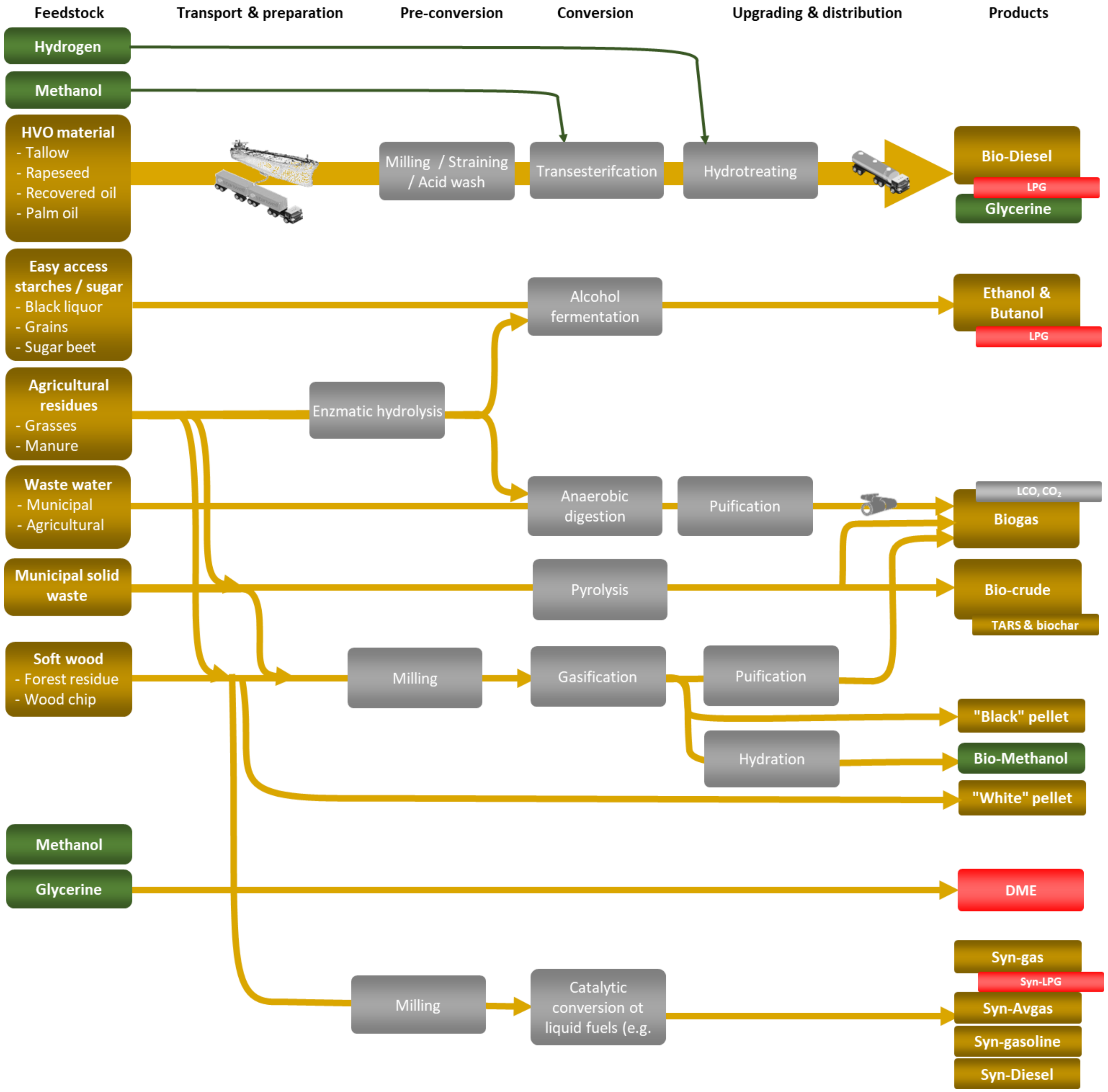
rLPG Feedstocks

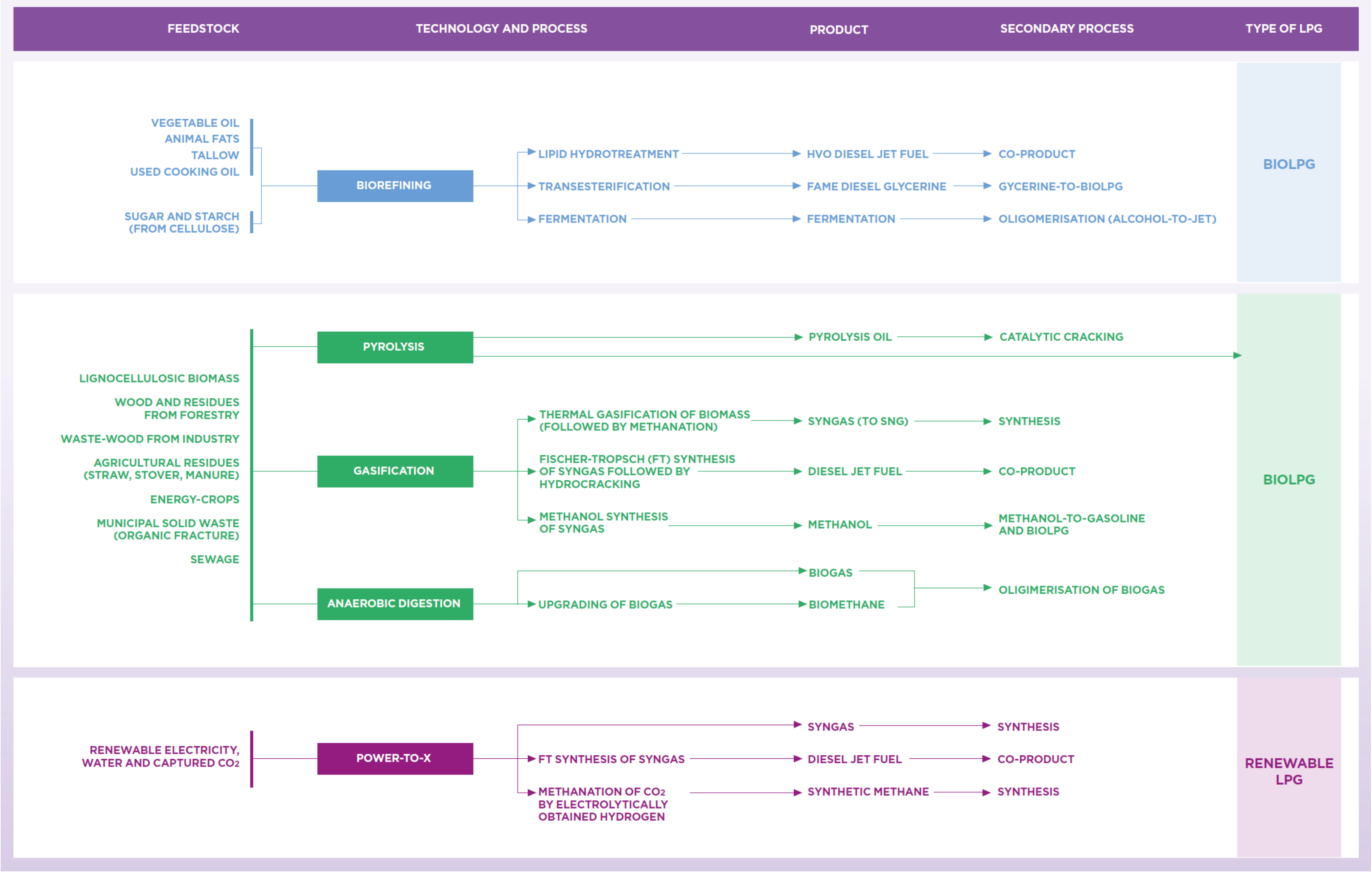
Potential feedstock sources for producing renewable LPG :

- Animal/vegetable oils/fats
- Cellulosics from forest and agricultural residues
- Municipal and agricultural waste
- Recycled hydrocarbons from tyres, plastics and the non-organic fraction of municipal waste
- Recycled CO_2 from industrial sectors such as aluminium, cement, steel and possibly carbon capture and storage,
- Electricity, i.e. using renewable electricity to generate low-carbon hydrogen and then LPG

The same feedstocks used to produce other biofuels

BioLPG
Mostly a Byproduct




FEEDSTOCK
TECHNOLOGY AND PROCESS
PRODUCT
SECONDARY PROCESS
TYPE OF LPG
VEGETABLE OIL
ANIMAL FATS
TALLOW
USED COOKING OIL
SUGAR AND STARCH (FROM CELLULOSE)
BIOREFINING
LIPID HYDROTREATMENT
TRANSESTERIFICATION
FERMENTATION
HVO DIESEL JET FUEL
FAME DIESEL GLYCERINE
FERMENTATION
CO-PRODUCT
GYCERINE-TO-BIOLPG
OLIGOMERISATION (ALCOHOL-TO-JET)
BIOLPG
LIGNOCELLULOSIC BIOMASS
WOOD AND RESIDUES FROM FORESTRY
WASTE-WOOD FROM INDUSTRY
AGRICULTURAL RESIDUES (STRAW, STOVER, MANURE)
ENERGY-CROPS
MUNICIPAL SOLID WASTE (ORGANIC FRACTURE)
SEWAGE
PYROLYSIS
PYROLYSIS OIL
CATALYTIC CRACKING
GASIFICATION
THERMAL GASIFICATION OF BIOMASS (FOLLOWED BY METHANATION)
SYNGAS (TO SNG)
SYNTHESIS
FISCHER-TROPSCH (FT) SYNTHESIS OF SYNGAS FOLLOWED BY HYDROCRACKING
DIESEL JET FUEL
CO-PRODUCT
METHANOL SYNTHESIS OF SYNGAS
METHANOL
METHANOL-TO-GASOLINE AND BIOLPG
ANAEROBIC DIGESTION
BIOGAS
UPGRADING OF BIOGAS
BIOMETHANE
OLIGIMERISATION OF BIOGAS
BIOLPG
RENEWABLE ELECTRICITY, WATER AND CAPTURED CO2
POWER-TO-X
SYNGAS
SYNTHESIS
FT SYNTHESIS OF SYNGAS
DIESEL JET FUEL
CO-PRODUCT
METHANATION OF CO2 BY ELECTROLYTICALLY OBTAINED HYDROGEN
SYNTHETIC METHANE
SYNTHESIS
RENEWABLE LPG

TECHNOLOGIES & PROCESS		POTENTIAL BIOLPG YIELD (OF TOTAL FUEL)	TECHNOLOGY READINESS	EXAMPLES OF EXISTING PRODUCERS OR PROJECTS*
BIOREFINING				
Lipid hydrotreatment	Biorefineries transform biomass into a wide spectrum of products and energy carriers. In biorefineries producing ethanol, sugars are fermented. Such alcohol can be further converted into drop-in jet fuels. BioLPG is a by-product of this process.	**7%**	**Demonstration/pilot phase**	**Eni (Italy), Global Bioenergies (France), Neste (the Netherlands), PREEM (Sweden), Repsol (Spain), Total (France)**
Transesterification	Most bioLPG today is produced as a co-product of the hydrogenated vegetable oil (HVO) process, where vegetable oils are treated with hydrogen to produce renewable diesel or aviation fuel.	**70%**	**Commercial phase**	**Hulteberg (Sweden)**
Fermentation	FAME biodiesel and glycerine can be produced through transesterification of oils. Glycerine can be used as a feedstock and reacted with hydrogen to yield bioLPG and water.	**100%**	**Pilot phase**	**Byogy (USA), Gevo (USA), UOP (USA), Vertimass (USA)**
PYROLYSIS				
	Pyrolysis is a process of thermal decomposition in the absence of oxygen. In fast pyrolysis, biomass rapidly decomposes to generate vapours, aerosols, gases, including bioLPG, and some charcoal. At the next step, after cooling and collection, a dark brown mobile liquid is formed, pyrolysis oil. Through catalysis cracking, it can be transformed into bioLPG.	**5%**	**Demonstration phase**	**BTG (the Netherlands), Gas Technology Institute (India), UPM (Sweden)**
GASIFICATION				
Thermal gasification of biomass (followed by methanation)	Gasification is a complete thermal breakdown of the biomass particles into syngas, volatiles and ash in an enclosed reactor (gasifier) in the presence of any externally supplied oxidizing agent (air, O_2, H_2O, CO_2, etc.). Syngas through methanation is transformed to SNG, which can be futher synthesised to bioLPG.	**20%**	**Commercial /demonstration phase**	**BioTFuel project by Total (France), Cadent (UK), Enerkem (the Netherlands), Fulcrum (USA), Red Rock (USA)**
Fischer-Tropsch (FT) synthesis of syngas followed by hydrocracking	Alternatively, syngas goes through a cleaning stage to remove impurities before the gas can be used in Fischer-Tropsch (FT) synthesis. The FT process means producing liquid fuels from syngas using catalysts. The intermediate product is a solid mixture of hydrocarbons, known as FT wax. It then goes through a process of catalytic cracking to produce drop-in fuels such as petrol, diesel and jet fuel, as well as LPG.	**5%**		
Methanol synthesis from syngas	Syngas can be also synthesised to methanol. In the next step, methanol can be used to produce gasoline. BioLPG would be a co-product in significant quantities of this process.	**8%**		
ANAEROBIC DIGESTION				
Oligimerisation of biogas	Anaerobic digestion is a fermentation process, which takes place in a closed airtight digester where organic raw materials such as manure, food waste, sewage sludge and organic industrial waste are converted into biogas and digestate as products.	**90%**	**Research & development phase**	**Alkcon (USA), PlasMerica (USA)**
POWER-TO-X				
Methanation of CO_2 by electrolytically obtained hydrogen	Power-to-x is a technology that converts captured CO_2 and hydrogen made from water by electrolysis using renewable electricity into gas or, after further synthesis, fuel. Both syngas and synthetic methane can be further synthesised to renewable LPG.	**10%**	**Research & development phase**	**[Nordic Blue Crude (Norway), Sunfire (Germany), Synhelion (Switzerland), Repsol (Spain)]**
FT synthesis of syngas	Renewable LPG would also be a co-product of Fischer-Tropsch synthesis of syngas for synthetic fuels (e-fuels).	**10%**		
Methanol synthesis from syngas	Synthetic methanol can be produced using hydrogen made with renewable electricity and captured CO_2. Further it can be used as a feedstock to produce gasoline and bioLPG as a co-product.	**10%**	**Pilot/demonstration phase**	**Carbon Recycling International (CRI) (Iceland)**

New Zealand Feedstocks (2005)

Cellulosic Residues – 6 million tonnes pa

Forest Harvest	60%
Wood Processing	17%
Agricultural crop	12%
Municipal	9%
Horticultural crop	2%

Effluent and Wastes – energy value of 7 PJ pa

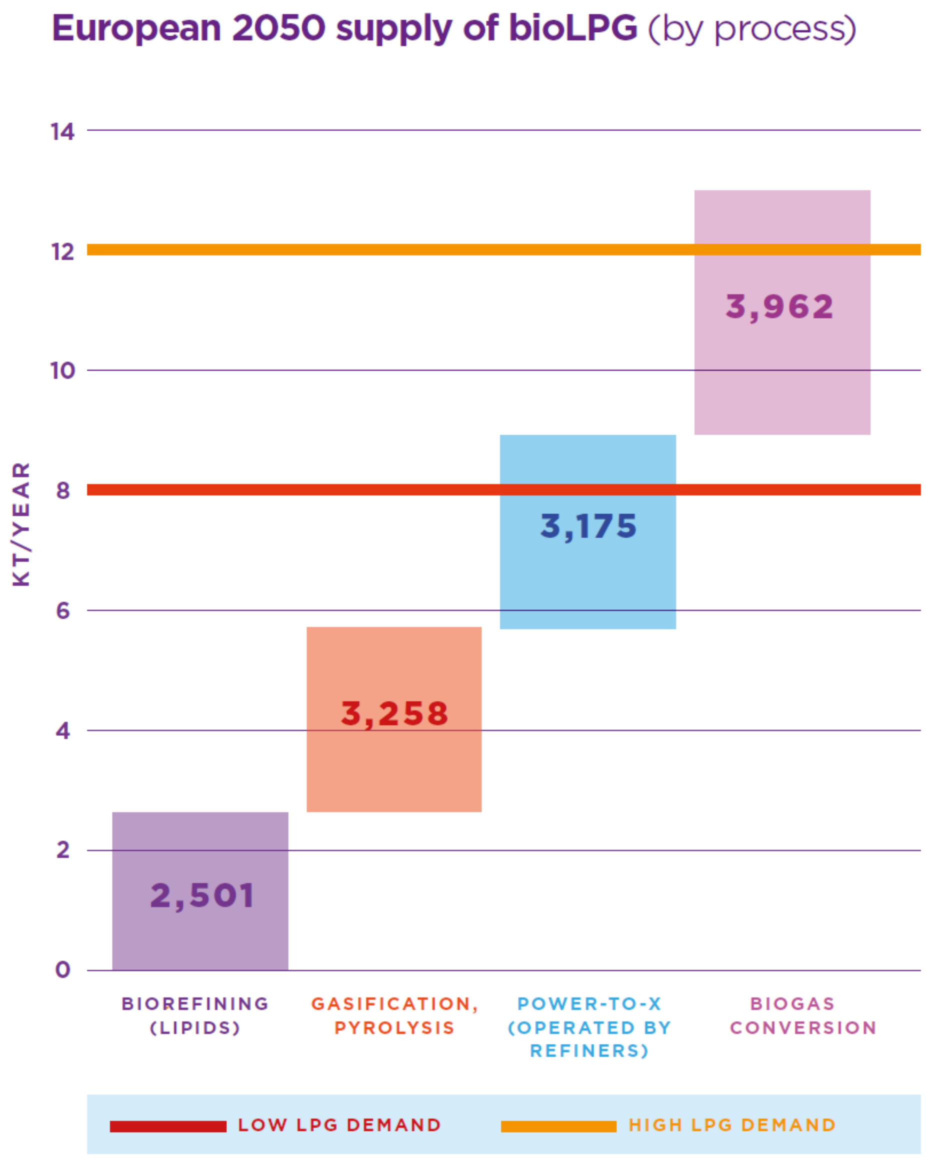
Municipal	57%
Farm	26%
Meat processing	9%
Dairy factory	8%

Europe 2050 BioLPG Supply

European future demand, which should equal to 8-12 million ton of LPG, can be met entirely by bioLPG produced in Europe from the following sources:

- Nearly 9 million tons can come from biorefining, pyrolysis, gasification and power-to-x technologies (operated by refiners)
- Another 3.5 million tons can come from the conversion of biogas
- In case one of the above options fails, there are alternatives such as bioLPG supplied by power-to-x plants operated by the gas industry, from glycerine-to propane and alcohol-to-jet pathways or imports

Our New Zealand pathway will be similar with varying proportions of production expected from each technology



Developments Around the World

WLPGA - Demonstrate the credibility of meeting at least 50% of 2050 non-chemical LPG demand with rLPG

Liquid Gas Europe pledges to transition to 100% renewable LPG by 2050

Liquid Gas UK Aims to transition to bioLPG by 2040

rLPG in New Zealand

Immediate prospects for rLPG production in NZ are limited

- HVO unlikely to produce much rLPG due to the lack of success of biodiesel production.
- Conversion of biogas into rLPG is a possibility if the technology is proven
- rDME for blending to reduce the carbon intensity of LPG is also worth further investigation

Medium to long-term prospects for rLPG production in NZ are much more promising

- Current work indicates that there is a credible pathway to 100% rLPG by 2050
- Cellulosic residues present a potentially massive resource
- Gaseous conversion and synthesis can produce 10 – 50% rLPG as a co-product with other biofuels

Production likely to be North Island based

- Most feedstocks are concentrated in the North Island

Key Issues to be Addressed

- rLPG is mostly a co-product in the production of renewable liquid fuels
  - Producers are focused on the major product and will not consider rLPG unless the LPG industry sells the idea to them
  - Capturing the bioLPG and enhancing its yield will improve the economics of biofuels projects and increase the likelihood of success
  - We need to work together across all biofuels
- The Climate Change Commission must recognise rLPG as a valuable and credible option in the transition to zero carbon
- rLPG must be included in the government’s consideration of biofuels
- We need to work together across all biofuels

A plan for NZ rLPG

Leverage the WLPGA work by:

- Adapting it for New Zealand scale and feedstocks
- Creating a clear New Zealand narrative on why government, producers and investors should support the production of rLPG
- Make a strong submission to the Climate Change Commission
- Work with biofuels organisations, universities, researchers, research funders and project developers to ensure that they are aware of and will support rLPG opportunities

Our work so far indicates that there is a credible pathway to New Zealand to achieve a transition to 100% rLPG by 2050