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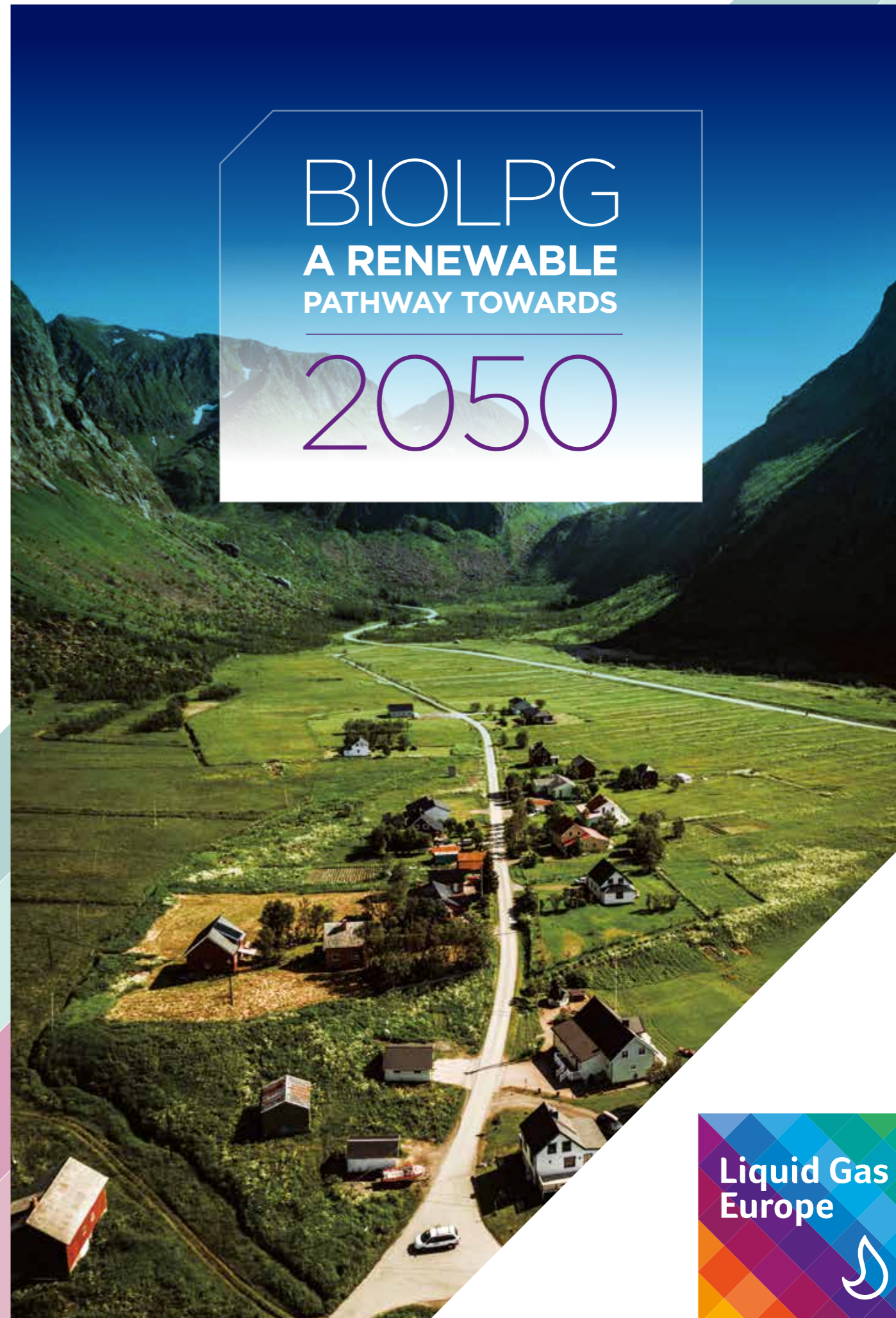


**Liquid Gas
Europe**

LPG – The Smart
Alternative,
Everywhere
You Need It



BIOLPG A RENEWABLE PATHWAY TOWARDS 2050



**Liquid Gas
Europe**



The Challenge

BioLPG is a drop-in gaseous fuel produced from biological sources, and potentially from renewable electricity and CO₂.

It is identical in use and performance to conventional LPG and gives today up to 80% lower carbon footprint. In the long run, bioLPG has the potential to become carbon neutral depending on the development of new production processes.

BioLPG is a cost-effective solution to the decarbonisations in segments such as, but not limited to, transport as well as industry, heat generation and cooking in rural areas. Launched in 2018, it is available on the European market in small, but growing, quantities.

Today only one production process is commercialised in Europe:

bioLPG as a co-product of hydrotreated vegetable oils (HVO) diesel or its variation - hydroprocessed esters and fatty acids (HEFA) resulting in Sustainable Aviation Fuel.

The European HVO/HEFA capacity alone would not be enough to supply bioLPG volumes to meet the industry's commitment by 2050.

Additional production pathways are needed to deliver bioLPG volumes required by the industry.

There are several other promising technologies available to produce bioLPG. But These pathways are not fully mature and commercially available today. They still require time and resources to grow from the research and development or demonstration scale. To further develop the technologies to produce bioLPG, a predictable and attractive investment climate is needed.

The LPG industry's concern is exacerbated by a general lack of awareness amongst producers as well as policymakers about the role bioLPG can play in the energy sector transition.

Our Vision

The ambition of the European Union is to be climate neutral by 2050. The European LPG industry is committed to support this ambitious goal.

Our industry truly believes that LPG and bioLPG, as clean-burning, versatile, and resource-efficient gaseous fuels are perfectly placed to immediately help to reach these goals especially in rural areas and in road transport.

Nowadays bioLPG is already available in small, but growing, quantities.

We are ready to continue dialogue with European and national policymakers, sustainable liquid fuel and biogas producers as well as other stakeholders across Europe to develop the necessary and stable policy framework for new investments in production facilities to increase bioLPG volumes.

This report offers a potential pathway for the European LPG market to become 100% renewable by 2050.

To get there, several critical policy interventions and industry actions will be necessary:

- BioLPG must be recognised within European policy frameworks and regulations
- European and national policies should offer incentives for consumers to switch to LPG in the short-term and bioLPG in the future
- European and national policies should provide incentives for low-carbon liquid fuel and renewable gas producers to produce and valorise bioLPG

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TODAY LPG AND BIOLPG ARE ONE OF THE FEW COST-EFFECTIVE SOLUTIONS IMMEDIATELY AVAILABLE TO DECARBONISE AND LOWER POLLUTANT EMISSIONS FROM OFF-GRID HEATING IN HOMES, LOCAL BUSINESSES AND INDUSTRIES, TRANSPORT AS WELL AS FROM STOVES AND BBQS.

It is a gaseous fuel that contributes to cleaning the air in Europe's countryside and cities. With the right policy environment in place for the producers to secure the necessary feedstock and sustain a stable business model, the entire European LPG market can become 100% renewable by 2050. Our industry will be thriving to deliver on this ambitious objective.



Road transport



Residential heating, industrial power and heat generation

Improving air quality with LPG

LPG cars have almost no pollutant emissions. They emit **98% less NO_x than diesel cars and 90% less PM than gasoline cars** in real driving conditions**

Boilers using LPG emit **80-99% less PM and 50-75% less NO_x** than solid and liquid fuels boilers (such as coal, heating oil, peat)

Reducing carbon emissions with LPG

LPG well-to-wheel carbon intensity as in the Fuel Quality Directive is also significantly lower than **diesel (-23%) and petrol (-21%)**

LPG is a lower carbon alternative to liquid and solid fuels for combustion purposes. Switching from an oil or coal boiler to an LPG one can reduce emissions respectively by **25% and 50%**

LPG Today In Europe

LPG is a co-product of...



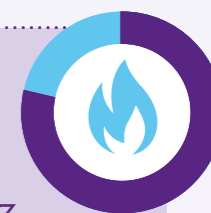
Natural Gas

OR



Oil Production

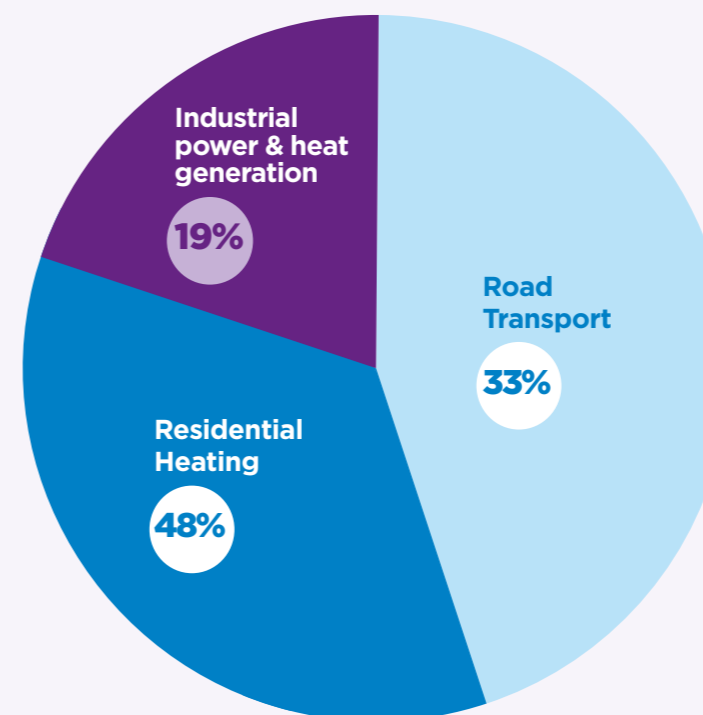
and thus resource efficient by its very nature



60%

of all LPG produced globally derives from natural gas extraction

Energy-users of LPG*



IT IS A HIGHLY VERSATILE ENERGY SOURCE IMPORTANT APPLICATIONS IN THE HOME, IN INDUSTRY, IN ROAD TRANSPORT AND AGRICULTURE.

Currently, LPG covers the heating needs of more than 20 million EU citizens and 700,000 businesses, predominantly in areas where the natural gas network is not available. Autogas (LPG as transport fuel) fuels a current fleet of over 8 million vehicles and a network of 32,000 stations across Europe.**

*40% of European LPG demand is used as feedstock by chemical industry

**Measuring emission performance of Autogas cars in Real Driving Conditions (2016) Liquid Gas Europe

TRANSITION TO BIOLPG

ONE OF THE PATHWAYS FOR THE INDUSTRY TO OFFER FURTHER EMISSION REDUCTION IS TO GROW THE SUPPLY OF BIOLPG.

In 2018, it was estimated that consumption of branded bioLPG, a product available on the market explicitly labelled as such, was at about 100 kilotonnes a year.*

The rest of the produced bioLPG, another 100 kilotonnes a year, is used today internally as a process fuel. Sometimes bioLPG is also put on the market without being labelled as such.

Nevertheless, the available volumes are still growing. The following operators are currently producing bioLPG in Europe:

- ENI (ITALY)
- GLOBAL BIOENERGIES (FRANCE)
- NESTE (THE NETHERLANDS)
- PREEM (SWEDEN)
- REPSOL (SPAIN)
- TOTAL (FRANCE)

BIOGAS CONVERSION TO BIOLPG IS POTENTIALLY ATTRACTIVE TO 'STRANDED' BIOGAS PRODUCERS

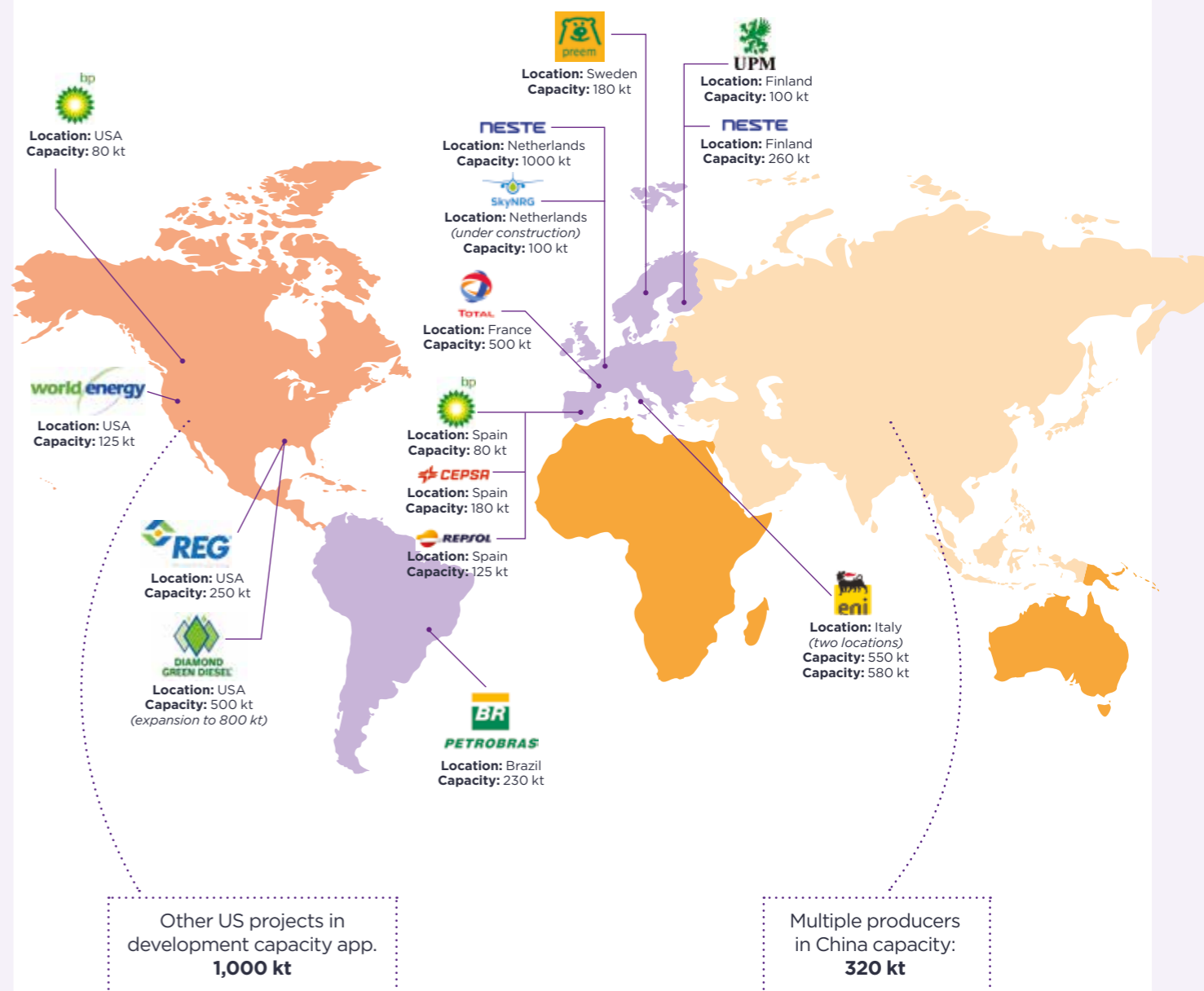
Less than 1% of biogas produced in Europe is injected to the gas grid. Majority of biogas is currently produced in remote locations which are unlikely to make biomethane injections in the future. It is reasonable to presume that significant amounts of biogas will still be stranded from the grid.

Conversion to bioLPG and distribution using the existing LPG infrastructure would in many cases be most attractive economically, if a biogas-to-bioLPG process were commercialised. This process is being pursued by several technology suppliers.

BIOLPG PRODUCTION

IN MOST CASES, BIOLPG IS A CO-PRODUCT OF SEVERAL TECHNOLOGIES.

Some of them are still at an early stage of development in Europe. Therefore, Liquid Gas Europe looks into a potential pathway for the European LPG market to become 100% renewable by 2050.



Source: Atlantic Consulting; * Process Technologies and Projects for BioLPG (2018) E. Johnson

NB. The above refinery capacity figures represent capacities for HVO biodiesel. Most of these plants produce bioLPG as a co-product at approx. 5-7% by weight of the biodiesel output. These capacities reflect the rated amount that a given plant can manufacture per year, actual production can be lower.

LPG AND BIOLPG FOR THE EU GREEN DEAL

Liquid Gas Europe sees a significant role for the European LPG industry in meeting the EU Green Deal ambition and achieving climate neutrality by 2050.

Our renewable pathway will help European and national policymakers understand the potential of bioLPG for decarbonisation of off-grid residential heating, local businesses and industries as well as for road and maritime transport.

The gradual, seamless transition to bioLPG can be done in existing appliances without any additional costs of modifications

POLICY	BENEFITS	ADDED VALUE OF BIOLPG
Smart Sector Integration Strategy and the Renewable Energy Directive	BioLPG helps reducing carbon footprint of off-grid residential heating, local industrial and rural business. In rural areas, there is a greater role for LPG and bioLPG in gas-powered heating combined with renewable thermal systems and hybrid systems	Synergies with the decarbonisation of aviation, maritime and road transport fuels
Renovation Wave Initiative	BioLPG can turn the existing rural building stock into 'future-proofed' homes using readily available, well-established and affordable heating solutions. LPG heating solutions also offer rural communities an opportunity to invest in common small LPG networks	Scaling up the uptake of solar thermal and hybrid solutions
Strategy for Sustainable and Smart Mobility	Autogas (LPG as transport fuel) is Europe's leading alternative road transport fuel with a good network of filling stations already in place. Converting existing vehicles to Autogas or purchasing a new LPG vehicle is affordable for the consumer, and a cost-effective solution to accelerate road transport emissions reduction efforts	Improving air quality in cities by tackling emissions from today's car park



BIOLPG AND ITS BENEFITS



BioLPG¹ is the commonly used term to describe any molecules of propane and butane² produced from biological sources or renewable electricity and CO₂.

To reap the benefits, LPG and bioLPG must be recognised within policy frameworks and regulations. The producers need to be able to secure the necessary feedstock and sustain a stable business model backed by a supportive, clear and predictable EU legal framework.

¹ In some European markets bioLPG is better known as biopropane

² BioLPG might also contain molecules of isobutane, propene, and butenes

WITH THE RIGHT VOLUMES, SWITCH TO BIOLPG COULD HAPPEN OVERNIGHT
BioLPG is a direct renewable replacement of conventional LPG, making it a drop-in gaseous, liquified fuel. Therefore, it can be used pure or blended in the very same applications ranging from vehicles to boilers. This means that when available in sufficient volumes all users of LPG appliances can seamlessly switch to bioLPG.

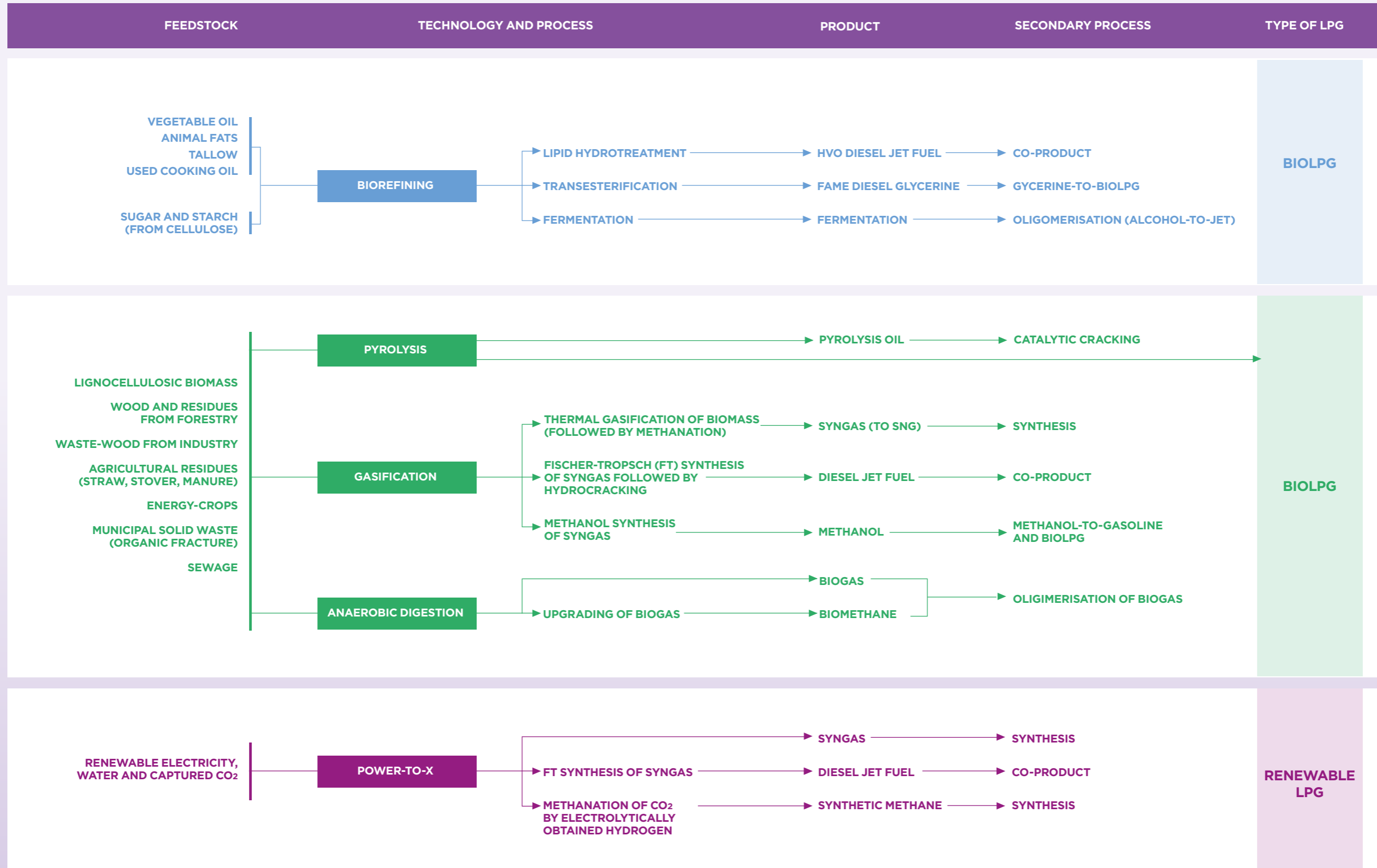
COST-EFFICIENT SOLUTION TO RENEWABLE ENERGY UPTAKE
The growing availability of bioLPG means that today's investments in LPG supply chain and appliances are future-proof as they can operate on bioLPG without any additional upgrading costs. Switching to bioLPG saves households and businesses the budget and hassle from changing to appliances or vehicles now running on conventional LPG.

FLEXIBLE PARTNER WITH RENEWABLE TECHNOLOGIES AND HYBRID SYSTEMS
In rural areas, there is a greater role for bioLPG as a gaseous fuel for gas-powered heating combined with renewable thermal systems, for cogeneration, fuel cells and hybrid systems (an electric heat pump with an LPG boiler, for cold days). Hybrid heating systems are the enabler for affordable renewable residential heating and an improvement in the overall energy efficiency in Europe. Further, Autogas-electric hybrids offer bigger environmental benefits than petrol hybrid systems.

DECARBONISATION AND BETTER AIR QUALITY WITH BIOLPG
BioLPG is a renewable solution that can provide up to 80% emissions reduction compared to conventional LPG. However, these GHG savings are expected to increase when production processes will move towards further use of waste or cellulosic materials as feedstocks. With the same molecular structure, bioLPG is a clean-burning fuel that produces very low concentrations of particulate matter and NO_x.

PATHWAYS TO BIOLPG

In most cases, bioLPG is produced as a co-product, a minor output of a multi-product process. All possible synthesis routes to bioLPG (and their development status): conventional and advanced chemical processes, biological processes, and other, are described below. Only one process is already commercial: the HVO diesel production.



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 ₂ O, CO ₂ , etc.). Syngas through methanation is transformed to SNG, which can be further 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%	Pilot/demonstration phase	Carbon Recycling International (CRI) (Iceland)
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%		

THE EUROPEAN BIOLPG MARKET IN 2050

Based on existing, authoritative scenarios and forecasts, Atlantic Consulting for Liquid Gas Europe concludes that the European LPG market can become 100% renewable by 2050.

Potential future demand for LPG

In the next 30 years, the non-chemical European LPG demand* will decline by 25-50% from today's some 16 million tonnes. This drop can be explained by overall trends in European energy demand leading to 2050:

- Final energy consumption will decline by around one-third
- Electrification will rise almost as sharply, mainly displacing liquid fuels in transport and space heating and cooling
- Gaseous fuels' consumption will decline, but not as sharply as liquids
- Solid fuels will mostly disappear

This forecast does not consider the possibility of LPG displacing competing fuels, thereby gaining market share. However, the European Commission projects heating oil and coal demand in building heating to decline by about 70% from 2020 to 2030. Further decarbonisation of rural commercial and industrial heating needs could be achieved with LPG.

One can imagine that in the short to medium term, LPG could displace heating oil and coal in off-grid homes, businesses, and industries, due to its lower carbon footprint and lower air pollutant emissions. But for consumers to be able to accept and participate in the further energy transition, they need to have access to renewable energy sources at an affordable price.

A 2050 pathway to bioLPG

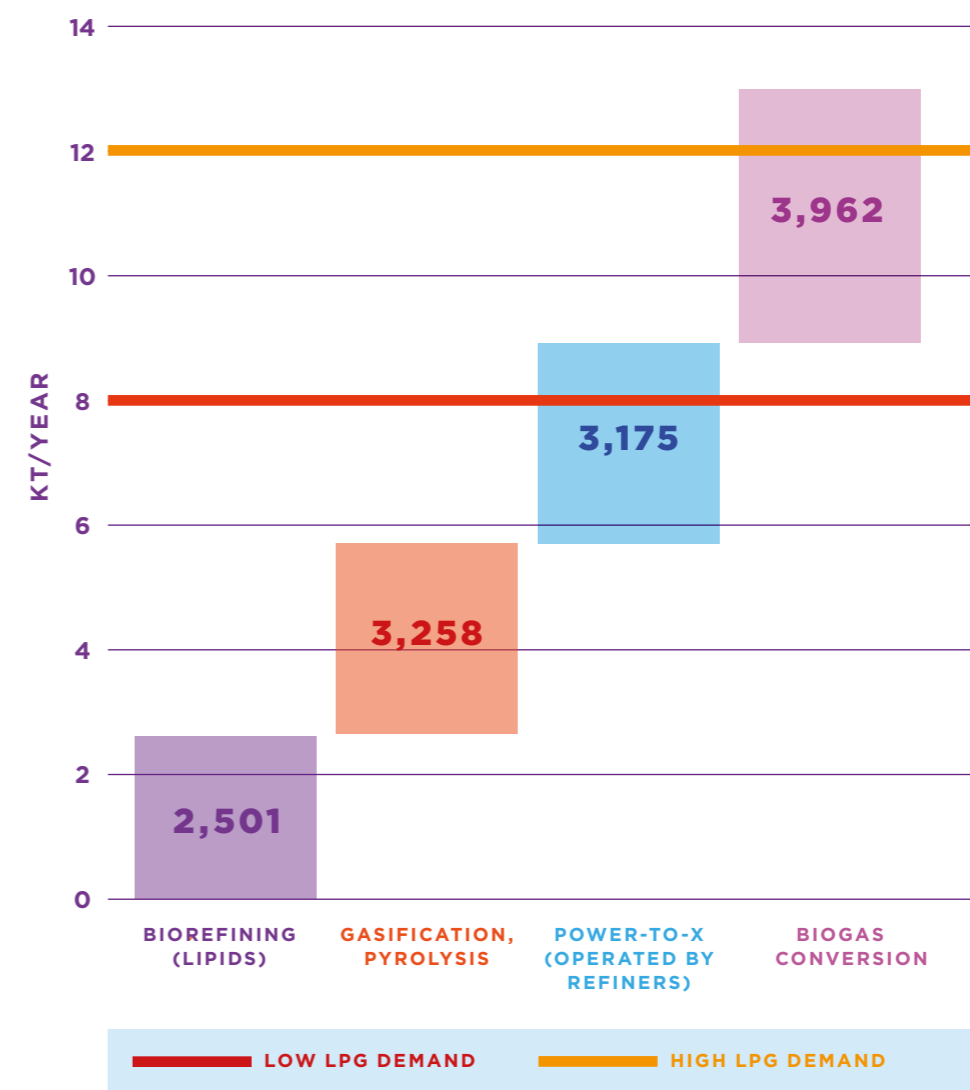
The future demand, which should equal to 8-12 million tonnes of LPG, can be met entirely by bioLPG produced in Europe from the following sources*:

- Nearly 9 million tonnes can come from biorefining, pyrolysis, gasification and power-to-x technologies (operated by refiners)
- Another 3.5 million tonnes 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 (not mentioned in the analysed reports) or imports

In the short to medium term, bioLPG volumes are expected to come mainly from the biorefining of lipids, biogas conversion and gasification of biomass. Power-to-x technology is expected by the European Commission to start penetrating the European market only after 2030. This means that to ensure the right level of bioLPG supply by 2050, the LPG industry needs all available technologies producing sustainable renewable gaseous and liquid fuels to succeed.

European 2050 supply of bioLPG (by process)



Biorefining (lipids)

Already commercialised today, processing of natural lipids will be a source of around 2.5 million tonnes of bioLPG in 2050

Gasification, pyrolysis

Gasification with Fischer-Tropsch and pyrolysis of biomass routes can bring some 3 million tonnes of bioLPG to the market

Power-to-x (operated by refiners)

Conversion of captured CO₂ and green hydrogen can be integrated into European refineries to produce more than 3 million tonnes of bioLPG

Anaerobic digestion (biogas conversion)

Even 3.5 million tonnes of bioLPG can come from biogas conversion at a 90% yield. These volumes will depend on the actual biogas production levels

*Still including the UK

*The analysis shows that there should be sufficient feedstocks (biomass and renewable electricity) available for the pathway to be realised. Feedstocks are not double counted

POLICY RECOMMENDATIONS



BioLPG must be recognised within European policy frameworks and regulations

A holistic view is particularly important.

The European policymakers are missing an opportunity to support the alternative low-carbon renewable gas solution in transport and for homes, buildings and processes, especially in off the gas grid areas. To encourage decarbonisation of the energy mix used by cars and in rural homes, businesses and industries, the legislation needs to explicitly recognise bioLPG. To fully benefit from the lower carbon footprint of bioLPG, a Well-To-Wheel (WTW) should be the basis to assess car emissions and energy efficiency.

- The revised Renewable Energy Directive should include a clear definition of bioLPG, the list of default energy content should be extended to various types of bioLPG (Annex III) and default GHG emission savings coming from bioLPG production pathways should be recognised in Annex V

- If bioLPG is injected together with biomethane to meet the calorific value required for the gas network, it should be eligible for any incentives offered to biomethane in such cases



European and national policies should offer incentives for consumers to switch to LPG in the short-term and bioLPG in the future

Decarbonising off-grid homes, businesses and industries, as well as the passenger car park with LPG and through the gradual introduction of bioLPG is the best chance of reaching climate-neutrality cost-effectively. Without having to resort to expensive upgrading or future retrofitting of the heating systems the European rural areas can lock-into lower CO2 emissions. BioLPG fully complements existing alternative fuel infrastructure, not only for new car sales, but also serve to decarbonise and improve the air quality from the existing fleet.

- The Renovation Wave initiative should encourage providing European and national incentives for consumers to switch from high carbon fuels (such as coal or heating oil) to LPG and bioLPG in the future

- The upcoming review of the Energy Taxation Directive should continue allowing Member States to exempt from energy and CO2 taxation LPG and bioLPG

- The Commission should carefully consider the impact of any new proposals have on low-income households in rural areas, which might be disproportionately affected by policies encouraging expensive retrofits

- The revision of the Alternative Fuels Infrastructure Directive should maintain the current definition of “alternative fuels”, some of which can easily penetrate the market and are compatible with the internal combustion engine (ICE) technologies



European and national policies should provide incentives for low-carbon liquid fuel and renewable gas producers to produce and valorise bioLPG

BioLPG production is an exciting opportunity for the EU and regions which specialise in developing circular economy solutions. Any new production facilities, utilising sustainable local feedstock's, will create new jobs for the local area, contributing to economic growth and ultimately creating the renewable energy needed to reach the climate-neutrality ambition.

- European and national R&D funding should be made available for low TRL processes to obtain bioLPG through Horizon Europe or the LIFE programme

- The bioLPG production should be subsidised to allow various technologies to mature

- Renewable and low-carbon fuel producers should be incentivised to capture or directly produce bioLPG

- Generate more research, development and deployment funding for transport modes and alternative fuels if their climate targets become more ambitious



LPG industry's Pledge

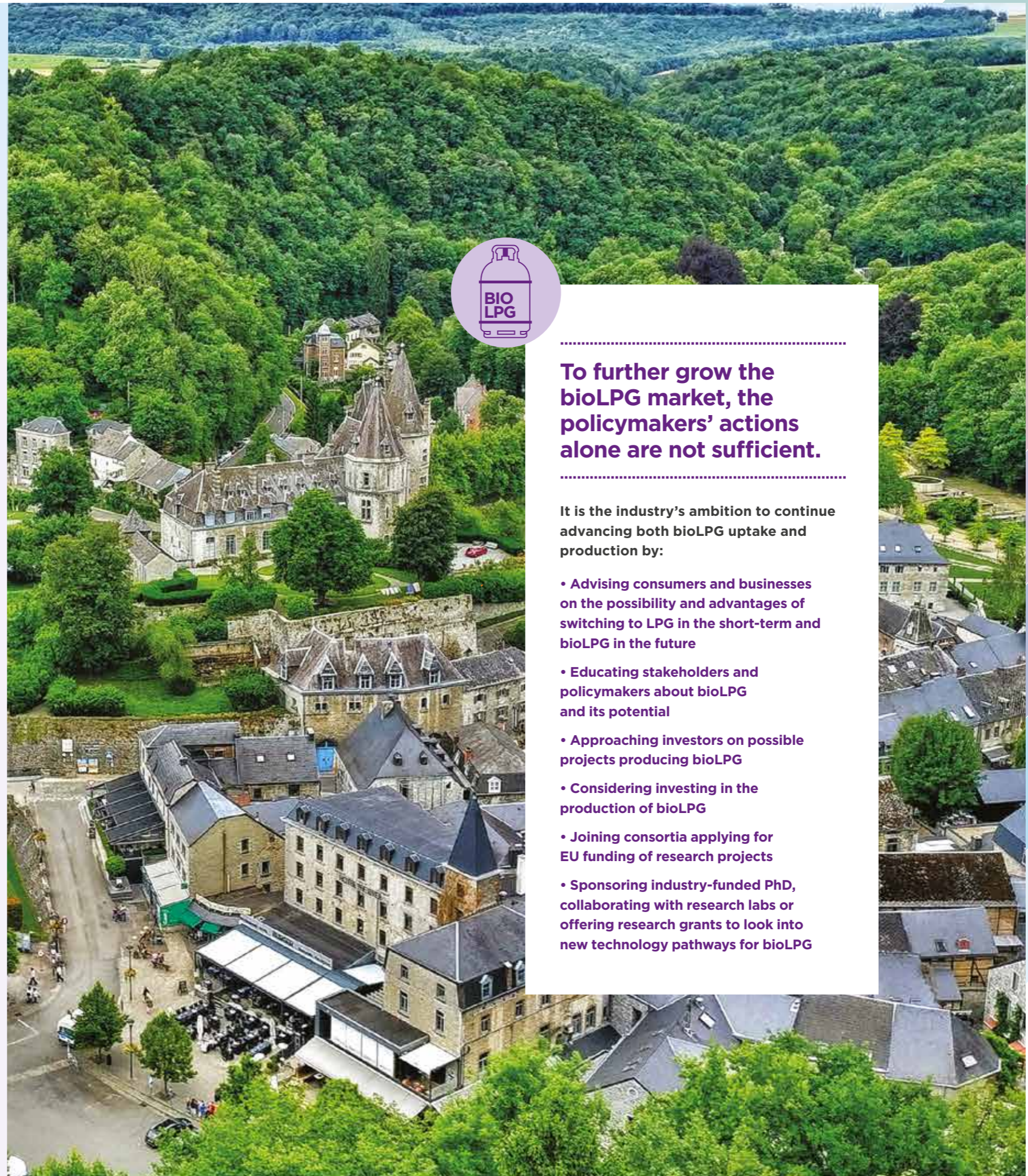
Liquid Gas Europe pledges to transition to 100% renewable bioLPG by 2050.

In recent years, the LPG industry has succeeded in commercialising and scaling bioLPG distribution. The industry delivers a new renewable energy source through a readily available, well-established and affordable supply chain to energy-users who are not connected to the gas grid.

Nevertheless, rural consumers' choice of flexible and affordable energy sources is still limited. The reality of rural private and non-domestic properties is that they are often old or historic buildings that are difficult to treat and hard-to-decarbonise. There is no one size fits all solution to provide sufficient warmth at an affordable price, avoid expensive retrofitting and keep the visual integrity of a property.

Liquid Gas Europe advocates a mixed technology approach to the transport sector and heating technologies in off-grid homes, businesses and industries. It is the most effective approach to reduce their carbon and air pollutant emissions today and in the future with bioLPG.

Today Autogas is the number one alternative fuel in the EU, counting 8 million vehicles and 35,000 fueling stations. Further, converting existing vehicles to Autogas is affordable for the consumer, and a cost-effective solution to accelerate road transport emissions reduction efforts from today's car park. All these efforts are a perfect basis for the segment to increase the uptake of bioLPG.



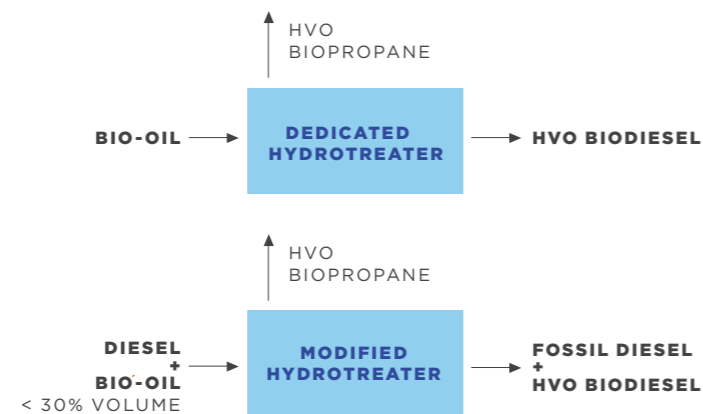
To further grow the bioLPG market, the policymakers' actions alone are not sufficient.

It is the industry's ambition to continue advancing both bioLPG uptake and production by:

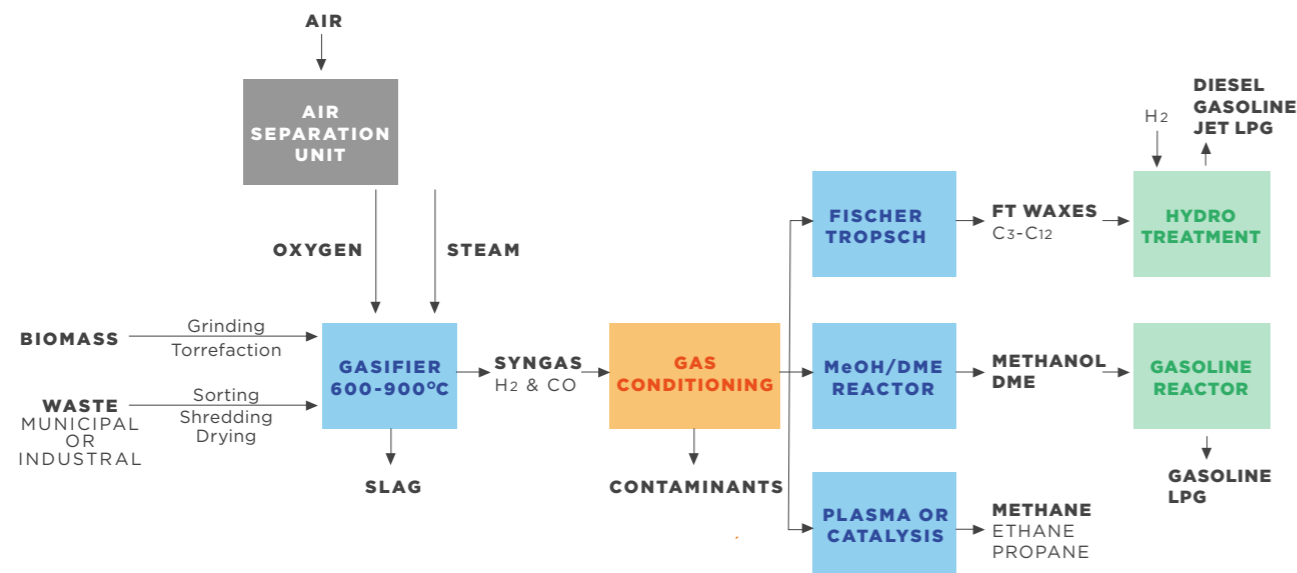
- Advising consumers and businesses on the possibility and advantages of switching to LPG in the short-term and bioLPG in the future
- Educating stakeholders and policymakers about bioLPG and its potential
- Approaching investors on possible projects producing bioLPG
- Considering investing in the production of bioLPG
- Joining consortia applying for EU funding of research projects
- Sponsoring industry-funded PhD, collaborating with research labs or offering research grants to look into new technology pathways for bioLPG

ANNEX: TECHNOLOGIES AND PROCESSES FOR THE BIOLPG PRODUCTION

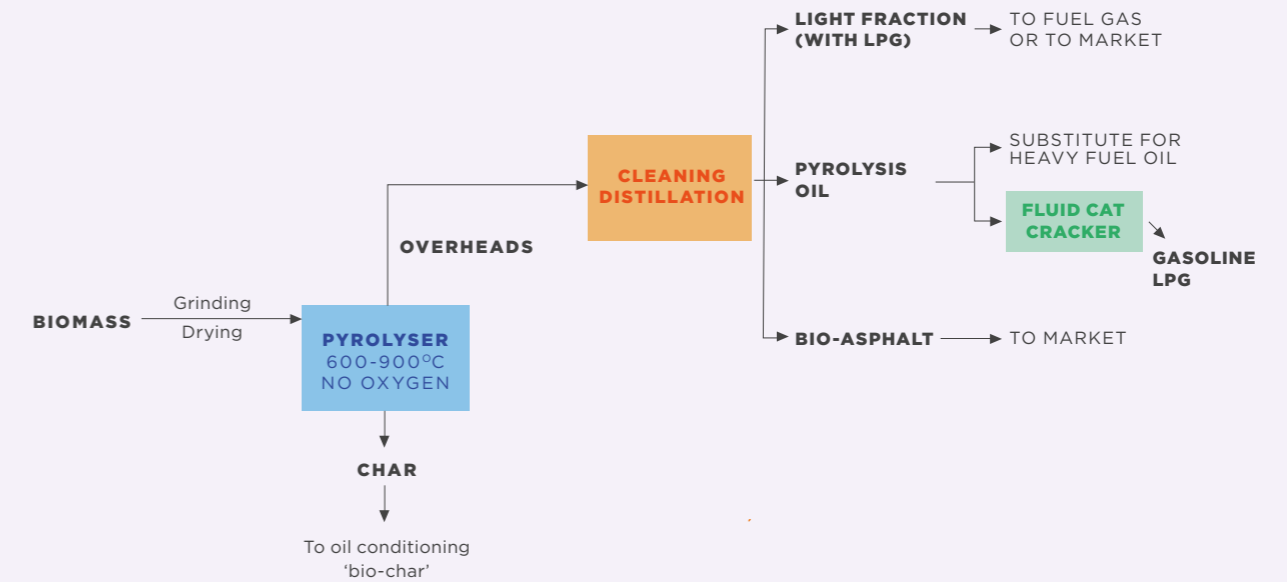
HVO - Hydrogenated Vegetable Oil



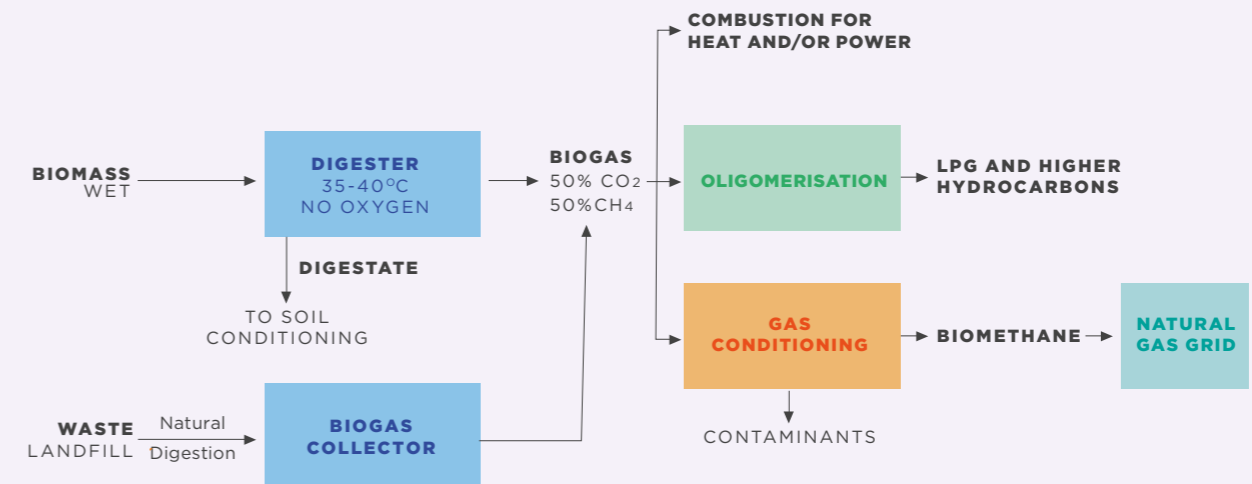
Gasification to biofuels/biogases



Pyrolysis to biofuels/biogases



Biogas to LPG



Power-to-X

