Renewable Propane Synopsis

1. Introduction to the propane Industry

California is the largest consumer of propane in the United States.[1] Propane provides energy for a variety of markets in the state including residential, commercial, transportation, and agriculture sectors. Propane is important to multiple stakeholders because of its affordability, resiliency during de-energizing events, and portability. In addition to providing primary energy for customers, propane provides backup power for essential services including electric utilities, water treatment facilities, radio and cell phone towers. Propane also serves as a primary source of energy for fire fighters at their basecamps allowing them to have energy for cooking, showering and washing clothes. During the COIVD-19 pandemic, propane provides power for temporary hospitals, testing facilities, and temporary housing for our homeless community.

Propane is a non-methane, low-pressure gas. Through recent innovation the industry has developed pathways for the production of propane from sustainable, non-fossil sources.

2. What is renewable propane

Renewable propane[2] is propane from non-petroleum or renewable sources. Renewable propane may also be blended with smaller percentages of other specific renewable gases including renewable dimethyl ether (rDME). Research is underway for blends with renewable hydrogen.

Renewable propane can be produced a number of different ways. The most commercially viable method used today is renewable propane produced via a hydrotreating process. This hydrotreating method is technically referred to as a HVO/HEFA[3] process. The producer starts with an organic feedstock, i.e. animal fat or vegetable oil. Hydrogen is introduced to the feedstock and via a chemical reaction the feedstock is converted into renewable propane, water, and other renewable products that have commercial value such as renewable jet fuel. In this process, renewable propane is a co-product.

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[1] ICF International & Propane Education & Research Council, Annual Retail Propane Sales Report 2019

[2] Renewable propane which is often referred to as biopropane, bioLPG, renewable LPG, or rLPG is the commercial name for renewable propane and renewable butane or the mixture of the two. Just like propane it also contains small volumes of other compounds such as olefins. Renewable propane is known under different names in different markets. For example, in France it is biopropane and biobutane, in the US it is renewable propane and in the UK it is commonly known as bioLPG.

[3] HVO; Hydrotreated Vegetable Oils, HEFA; Hydrotreated Esters and Fatty Acids. For more details on renewable propane production pathways please refer to the Annex.

Renewable propane can also be produced from numerous other production pathways that are at different stages of technical and commercial maturity. These pathways use a variety of sustainably sourced renewable feedstocks.[4]

Renewable propane production was launched in 2018 and is available in still limited quantities with growing volumes. In 2018, the global renewable propane production was around 250 – 300 k tonnes per year. In 2019, U-Haul in Southern California purchased its first 1 million gallons of renewable propane. The Western Propane Gas Association has identified a pathway to produce up to 280 million gallons of renewable propane as early as 2025.

3. Why and how to produce renewable propane

Why produce renewable propane?

A shift towards net zero carbon economy is needed to avoid increasing air pollution levels and the risks and irreversible impact of climate change. Renewable propane is one solution of many needed to decarbonize multiple market sectors. Renewable propane will provide complementary clean energy alongside solar, when batteries are depleted, or provide a structure's total renewable energy needs. The energy needs for California are great and varied, demanding a diverse renewable energy portfolio.

The California Air Resources Board's Low Carbon Fuel Standard provides a temporary carbon intensity value for vehicles that operate using renewable propane of 45 g CO2e/MJ[5]. As of March 2021, a renewable producer has submitted their pathway that would assign renewable propane a carbon intensity value of 20.5 g CO2e/MJ[6]. For perspective, diesel vehicles have a lifecycle carbon intensity of 102 g CO2e/MJ and electric vehicles have a carbon intensity of 22.05 g CO2e/MJ[7].

For buildings, providing 100% renewable propane for California's propane building sector would reduce CO2 emissions by 2.258 tonnes.[8] This is the equivalent of taking 537,600 cars of the road.

Consumers switching to renewable propane experience a seamless transition to a renewable solution without having to invest in new equipment, appliances, or electrical rewiring. Renewable propane is fungible with its fossil counterpart which means that it can be transported using existing propane infrastructure. This ease of switching to renewable propane is an attractive and affordable energy solution because it is easily deployed. For policymakers, the affordability translates to immediate and

[4] To realize these pathways feedstock supply chains need to be mobilized. The feedstocks, such as sustainably sourced vegetable oils, residue fats, sugars as well as agricultural and forestry residues, are available in abundance, but most of them remain largely untapped.
[5] CA ARB Low Carbon Fuel Standard Proposed New Temporary Fuel Pathway, May, 2019 https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/comments/tier2/rpane_temp.pdf
[6] Published Application CA ARB Low Carbon Fuel Standard Proposed New Tier 2 Fuel Pathway, March, 2021 https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/comments/tier2/b0189_cover.pdf
[7] CA ARB Low Carbon Fuel Standard
[8] Based on 392 million gallons using U.S. Energy Information Administration (EIA) CO2e coefficients. https://www.eia.gov/environment/emissions/co2_vol_mass.php

significant greenhouse gas emission reductions. Equally important, renewable propane allows policymakers to decarbonize communities that were otherwise excluded.

Renewable propane also offers producers of the biogas, especially those that are located in remote areas with no access to the gas grid, an economically attractive option to utilize biomass resources. Conversion of biogas to renewable propane can be a very efficient process from energy stand point. The product itself can then be distributed to consumers using the existing propane infrastructure in rural areas.

How to produce renewable propane?

Renewable propane can be produced from a variety of production pathways. The diversity of production methods shows that renewable propane is linked to the defossilization of many other sectors such as the refining industry, aviation, as well as the power sector. The following pathways can result in significant volumes of renewable propane, which is typically generated as a co-product:

1. HVO/ HEFA
2. Gasification-FT to liquids
3. Gasification-methanation/methanol to gasoline (MTG)
4. Oligomerisation of olefins (alcohol-to-jet)
5. Pyrolysis biomass
6. Oligimerisation of biogas
7. Power-to-X
8. Fermentation to LPG
9. Glycerin-to-propane

4. Why use renewable propane

The urgency around the global challenges of climate change and sustainable development are recognized by WPGA's membership. WPGA has set forth an ambitious commitment to provide 100% renewable propane to California by 2030. The association is also striving to accelerate the deployment of transformative technologies that allow renewable electricity derived from renewable propane to net back to the grid or charge electric vehicles. Renewable propane when combined with innovative efficient technologies such as Micro CHP, generators, fuel cells, or hybrid heat pumps amplify the sustainability footprint. With these ambitions, the propane industry shows its commitment to effectively contribute towards California's goal of reducing GHG to 40 percent below 1990 levels by 2030 and to 80 percent below 1990 levels by 2050.

5. Annex

Feedstock and pathway overview – Renewable Propane

PATHWAY					
Feedstock	**Technology and process**		**Product**	**Secondary process**	**Type of LPG**
Plant oils and animal fats, both new and used	Biorefining	Hydrotreatment	HVO diesel BioJet fuel	LPG as by-product	Renewable propane
		Transesterification	FAME diesel Glycerine	Gycerine-to-bioLPG	
Fermentable crops and wastes		Fermentation	Ethanol	Oligomerisation (alcohol-to-jet/LPG)	
Agricultural residues (straw, stover) Energy-crops Municipal Solid Waste (organic fraction) Lignocellulosic biomass Residues from forestry Waste-wood from industry 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	By-product	
		Methanol synthesis from syngas	Methanol	Methanol-to-gasoline and bioLPG	
Agricultural residues (manure) Municipal Solid Waste (organic fracture) Industrial organic waste Sewage	Anaerobic digestion		Biogas	Oligimerisation of biogas	
Renewable electricity, water and captured CO_2	Power-to-x	Methanation of CO_2 by electrolytically obtained hydrogen	Syngas	Synthesis	e-propane
		FT synthesis of syngas	Diesel Jet fuel	By-product	
		Methanol synthesis from syngas	Synthetic methanol	Methanol-to-gasoline and bioLPG	

Source: World LPG Association (WLPGA)

Renewable Propane Pathway description

#	Renewable Propane Pathway	Description
1	Hydrotreated Vegetable Oil (HVO)/ Hydrotreated Esters and Fatty Acids (HEFA)	Hydrogenated or hydrotreated vegetable oil (HVO), also known as hydrotreating, is a refinery process that uses hydrogen at elevated temperature and pressure in the presence of a catalyst to break down large, vegetable oil molecules into diesel. It also creates a byproduct propane. Plants for this can be purpose-built, or they can be created by retrofitting an existing hydrotreater. The main product is HVO biodiesel, also known as green or renewable diesel. This can be processed further into renewable jet fuel.
2	Gasification-FT to liquids	In the gasification process, biomass and/or waste feedstocks are broken down into a mix of mainly hydrogen (H2) and carbon monoxide (CO) but also carbon dioxide (CO2), methane (CH4) and traces of other compounds. The process takes place at high temperatures and pressures using air or oxygen and often steam. This mixture of gases is called syngas (mainly CO and H2). CO2 is then removed from syngas that is also cleaned of tars and other contaminants. Then it undergoes Fischer Tropsch (FT) synthesis to make waxes which contain shorter and longer chain hydrocarbons (C3 – C12 range). These FT waxes are hydrotreated to make something like a typical slate of refined product that come from a petroleum refinery: renewable diesel, renewable gasoline, renewable jet fuel as well as renewable propane.
3	Gasification-methanation/methanol to gasoline (MTG)	In the gasification process, biomass and/or waste feedstocks are broken down into a mix of mainly hydrogen (H2) and carbon monoxide (CO) but also carbon dioxide (CO2), methane (CH4) and traces of other compounds. The process takes place at high temperatures and pressures using air or oxygen and often steam. This mixture of gases is called syngas (mainly CO and H2). CO2 is then removed from syngas that is also cleaned of tars and other contaminants. Then it undergoes a catalytic reaction to be converted to methanol and DME. This methanol/ DME mix is further reacted to make gasoline, which produces co-products of propane and butane. Another process that can follow syngas production is methanation, which produces Synthetic Natural Gas (SNG), i.e. methane made synthetically. These processes can result in large fractions of renewable propane.

4	Oligomerisation of olefins (alcohol-to-jet)	The conventional process for converting alcohol to jet (AtJ) has been around for years: it consists of three main steps; dehydration, oligomerization and hydrogenation, all of which are well-proven and understood at commercial scale but have never been integrated into existing biorefineries to produce jet fuel. In practice, most attention has been paid to ethanol and isobutanol for jet fuel production. Isobutanol offers: a higher yield of biojet, 75% to ethanol's 60%; capital investment about 40% lower; lower energy costs. However, ethanol is more plentiful and usually cheaper, and it allows more variation in the carbon-chain-length of the biojet product and therefore preferable for propane distributors. Catalytic dehydration of ethanol produces ethylene (olefin) which is oligomerized to alpha-olefins that are hydrogenated to make paraffinic fuels. Renewable propane is also produced as a by-product.
5	Pyrolysis biomass	In pyrolysis, biomass feedstocks are treated under moderate temperatures, with limited oxygen or air, usually at ambient pressure. The process results in a mixture that contains oils, gases and solids (char). Pyrolysis mostly generates hydrocarbons in C5-C20 range. For the propane industry the product that is of interest is pyrolysis oil which is also referred to as bio-oil. Bio-oil is broadly similar in composition to vacuum gasoil (VGO) or crude oil, except that it has a significant content of oxygen. The pyrolysis oil can be processed similarly to VGO in a conventional refinery, even directly blended with fossil VGO at 10-20%. It can be cat cracked, or hydro-deoxygenated (because when made from biomass it has more oxygen that needs to be adjusted) and then hydrocracked to make renewable propane.
6	Oligimerisation of biogas	Organic wastes such as manure and sewage sludge can be treated by anaerobic digestion. The process results in biogas which produces methane (CH_4) and carbon dioxide (CO_2) in approximately-equal molar quantities. Biogas also contains small amounts of organic acids, nitrogenous and sometimes sulphurous compounds. Biogas is produced 'naturally' at waste landfills, from the digestion of waste organic materials that can be either bio or fossil in origin. Biogas can be burned to produce electricity (and heat). It can also be upgraded to make biomethane, which can be injected into the gas grid.

		Another possibility is the thermo-chemical conversion of biogas/biomethane into higher hydrocarbons including renewable propane.

7	Power-to-X	Water electrolysis produces hydrogen and oxygen. Hydrogen can be combined with CO2, sequestered from the flue gas stream of an industrial unit or a power plant, to make syngas.
		
		The syngas synthesis from H2 and CO2 is currently being explored by multiple routes. Syngas can then be used to make the following:
		• Synthetic fuels via Fischer Tropsch synthesis:
		  o Diesel
		  o Gasoline
		  o Jet fuel
		  o Propane
		• Synthetic Natural Gas via methanation or Gasoline via Methanol (MTG)
		
		All these pathways can result in fractions of renewable LPG or in this case e-propane.

8	Fermentation to LPG	Fermentation is the conversion of sugars by bacteria, yeasts or other microorganisms, in the presence of air (aerobic), into other chemicals, usually alcohols. The best-known example is the fermentation of alcoholic beverages: yeast convert sugars into ethanol. Alcohol is fermentation's best-known product, but fermentation can generate other products, including renewable propane. Biobutylene is the only renewable propane produced by fermentation: this has so far been done only at a demonstration scale. Fermentation of biopropane has been proven at laboratory scale.
9	Glycerin-to-propane	Converting glycerol to propane involves several chemical steps, including dehydration and hydrogenation. Glycerol is first dehydrated using a catalyst to make acrolein. Acrolein is then hydrogenated to propanol which is dehydrated to propene (propylene) which is further hydrogenated to make propane or renewable propane. The same process can also result in ethene (ethylene) via decarbonylation of acrolein.

Source: World LPG Association (WLPGA)