SHV ENERGY

SHV Energy Sustainable and Renewable Fuels
Open Innovation Challenge

sustainablefuelschallenge.innoget.com

Webinar – Advancing biobased and renewable fuels with SHV Energy

Supported by innoget

Agenda

- Webinar Introduction
- Introduction to SHV Energy
- Presentation of the Open Innovation Challenge
- Mechanics of submission
- Q&A Session
- End of Session

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Sustainable Fuels
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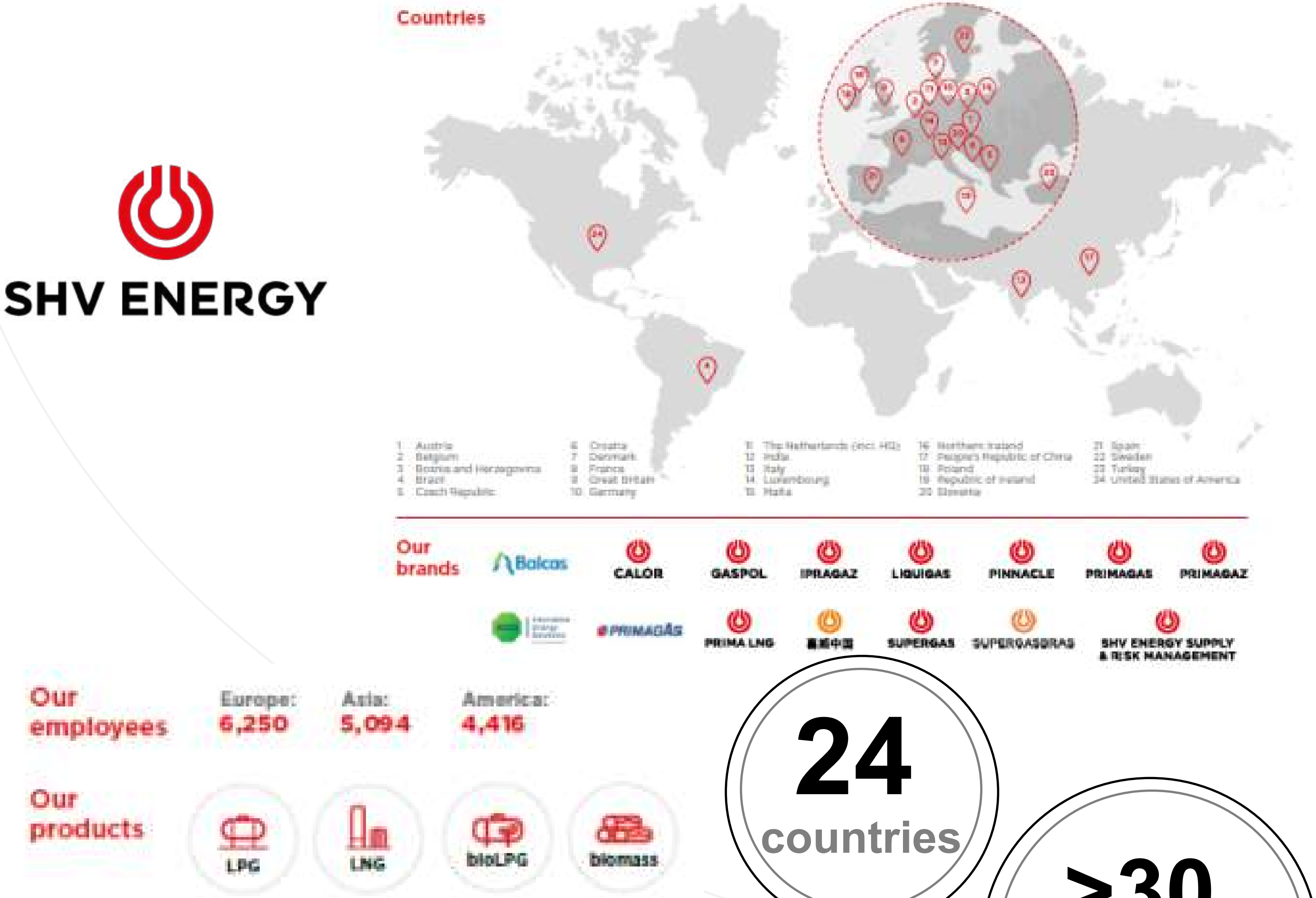


24 countries

>30 million customers

Source: SHV Energy 2020 report

9.3 *million* tonnes fossil propane/butane (wholesale and retail)
59 *thousand* tonnes renewable propane

Our bold ambition :

100% of our energy products to be from renewable sources in 2040

~114 million EU citizens live in rural areas not connected to a gas grid

114 MILLION

EU citizens live in rural areas

OFF-GRID

Off-gas grid homes are typically older and less energy-efficient

45%

of rural heat comes from heating oil and coal (off-the-gas-grid & non-electrical)

DIVERSE

The off-grid building stock is diverse in characteristics

24%

of people in rural areas are at risk of poverty or social exclusion

72%

of heating & cooling demand of single-family homes is consumed in rural areas

Free
Future of Rural Energy in Europe

The Future of Rural Energy in Europe (FREE) initiative was created by SHV Energy in 2010 to promote the use of sustainable energy within rural communities. FREE is supported by a variety of stakeholder groups, together giving a voice to all those who believe that rural energy needs are important, and aiming to add new perspectives to the EU's energy and climate debate. Identifying untapped potential in Europe's rural areas to decarbonise and improve air quality in a cost-effective manner. Filling in rural energy data gaps. Engaging and supporting rural communities is essential if government energy, climate and environment policies are to be realised.

LPG is an important clean burning fuel

- According to the World Health Organization (WHO), 40 percent of the world population (2.9 billion people) use solid fuels for cooking.
- Indoor air pollution results in the premature deaths of an estimated 4 million people annually from lung cancer, cardiovascular disease, pneumonia and chronic obstructive pulmonary disease
- Women and children have a higher risk of health complications due to indoor air pollutants, as they spend the most time in and around the home, burning solid biomass

Open Innovation @ SHV Energy

Smart Cylinders

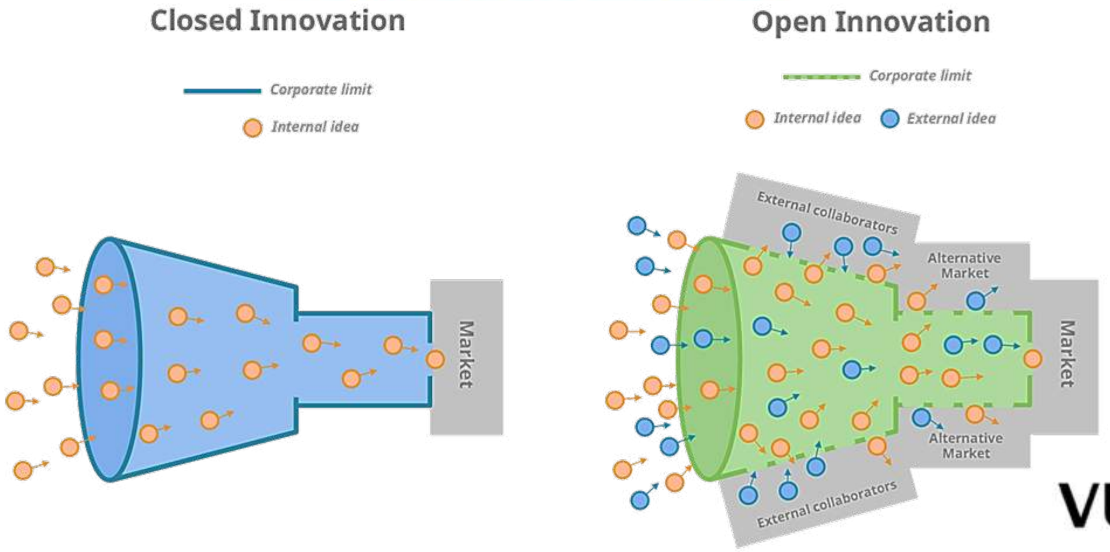
Solutions to improve cylinder management through the value chain

Sustainable Fuels

Pathways to produce LPG from sustainable feedstock with high yields

Health and Safety

Seeking Customizable Solutions for Transferring LPG Cylinders between Cages



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UGI INTERNATIONAL

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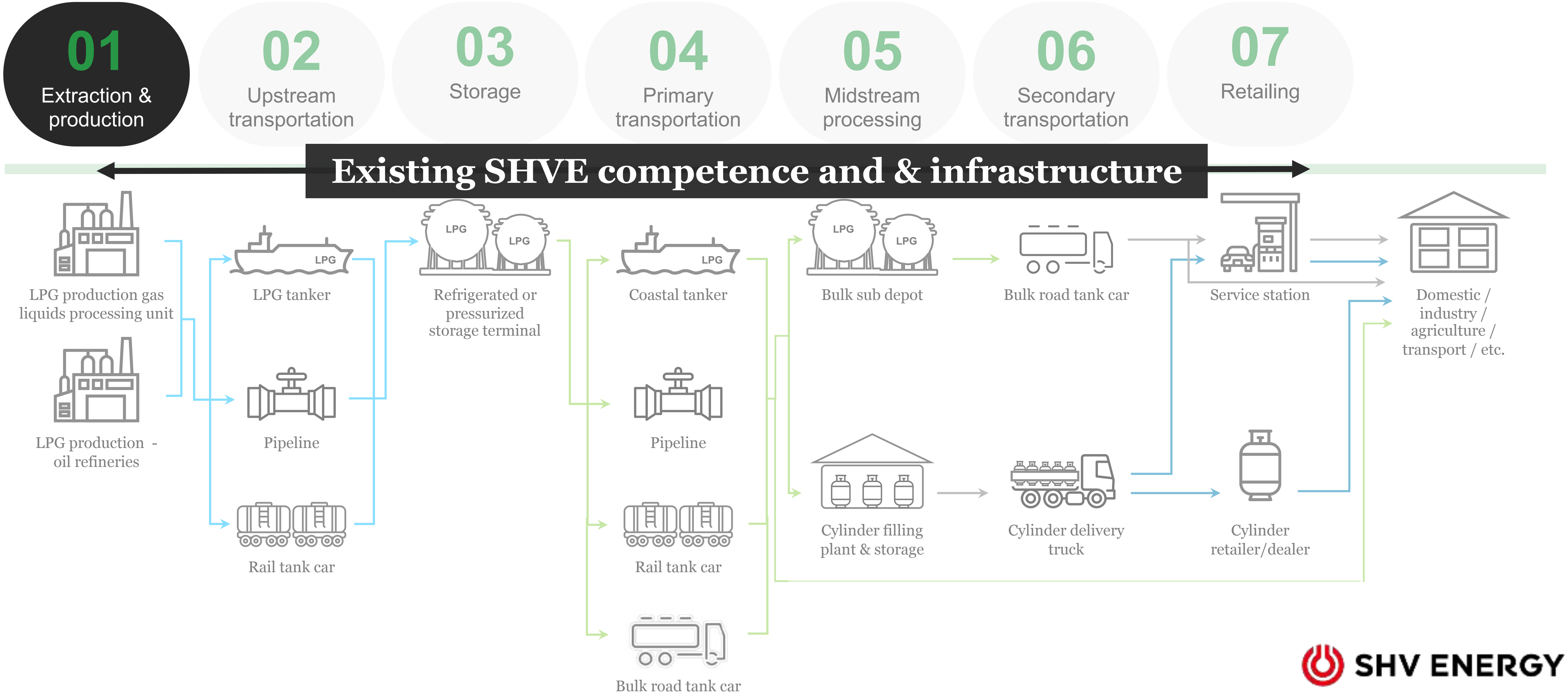
SHV Energy and UGI to Launch Joint Venture to Accelerate the Transition of the LPG Industry to a Sustainable Future

SHV Energy and UGI International, a subsidiary of UGI Corporation (NYSE: UGI), leading distributors of off-grid energy, announce the intention to launch a joint venture to advance the production and use of Renewable Dimethyl Ether ("rDME"), a low-carbon sustainable liquid gas, to accelerate renewable solutions for the LPG industry. By leveraging the expertise, innovation capabilities and distribution power of both companies, the joint venture will aim to develop the full potential of rDME as a sustainable solution.

The parties anticipate the development of up to 6 production plants within the next 5 years, targeting a total production capacity of 300 kilotons of rDME per year by 2027. The aggregate investment is estimated to be up to $1 billion which is expected to involve third party investment.

SHV Energy traditional focus is steps 2 to 7

Our Open Innovation Challenge is to partner and collaborate with the skills and competencies to transform step 1



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Renewable LPG pathways – Outputs & list of example projects

WLPGA

TRL levels								
TRL 1 Basic research	TRL 2 Concept definition	TRL 3 Proof of Concept	TRL 4 Lab validation	TRL 5 Pilot validation	TRL 6 Technical demo	TRL 7 Operational demo	TRL 8 Operational deployment	TRL Commercial operation

	Renewable LPG Pathway	TRL	Main product	Renewable LPG % of fuel output	Example projects
1	HVO/HEFA	9	Diesel, Kerosene	5-8%	• Neste • PREEM • REG
2	Gasification – Fischer Tropsch (FT) to liquids	8	Diesel, Kerosene	3-4%[1]	• Fulcrum • BioTFuel • RedRock
3	Alcohol to hydrocarbons (Jet fuel)	8	Gasoline, Diesel, Kerosene	3-4%[1]	• Gevo • Ekobenz • Vertimass
4	Pyrolysis biomass	7	Biocrude	2-3%	• BTG • GTI/CRI • Setra/ Preem
5	Gasification to Methanol & Methanol to Gasoline (MTG)	6	Gasoline	10-30%	• Enerkem • TIGAS
6	Gasification to methanation	6	Methane	Significant fractions	• Cadent • Fiberight Advanced Plasma Power
7	Fermentation to LPG	5	Isobutylene	100%	• C 3 Biotechnologies • Global Bioenergies
8	Oligomerization of biogas/biomethane	4	Biopropane	100%	• Alkcon • Plasmerica
9	Glycerin to propane	3	Biopropane	60%	• Hulteberg
10	Power to X	2	Gasoline, Diesel, Kerosene, Methane	10%[1]	• Nordic blue • Sunfire • Repsol

1- Significantly higher quantities are possible depending upon the configuration

High TRL – Low % Propane Yield

Low TRL – High% Propane Yield!

Johnson, E. Process Technologies and Projects for BioLPG. Energies 2019, 12, 250
BioLPG: A Renewable Pathway Towards 2050, www.liquidgaseurope.eu

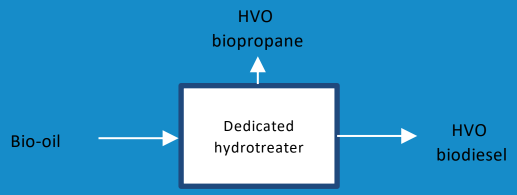
LPG EXCEPTIONAL ENERGY

Hydrogenated Vegetable Oil (HVO) pathway

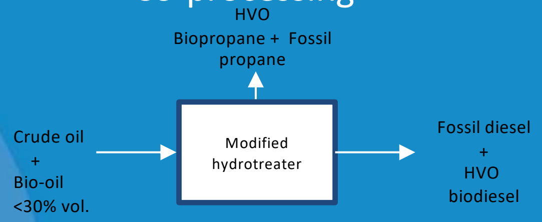
1A

TRL: 9

Dedicated HVO



Co-processing



Process description

- Hydrogenated or **hydrotreated vegetable oil (HVO),** also known as hydrocracking, is a refinery process that uses hydrogen at elevated temperature and pressure in the presence of a catalyst to break down large vegetable oils' molecules into diesel.
- The main product is usually HVO biodiesel, also known as green or renewable diesel. The process can also be modified to produce renewable diesel and jet fuel and is termed as **hydrotreated esters and fatty acids (HEFA)**.
- The process also produces by-products such as **propane (5-8%)** and naphtha (<1%).
- Hydrotreatment of (bio) oils is also possible through **co-processing** of bio and fossil feedstocks. In this process one uses existing refinery hydrotreaters that have been modified to handle bio-oils. It produces a mixed stream of diesel/biodiesel and propane/biopropane.

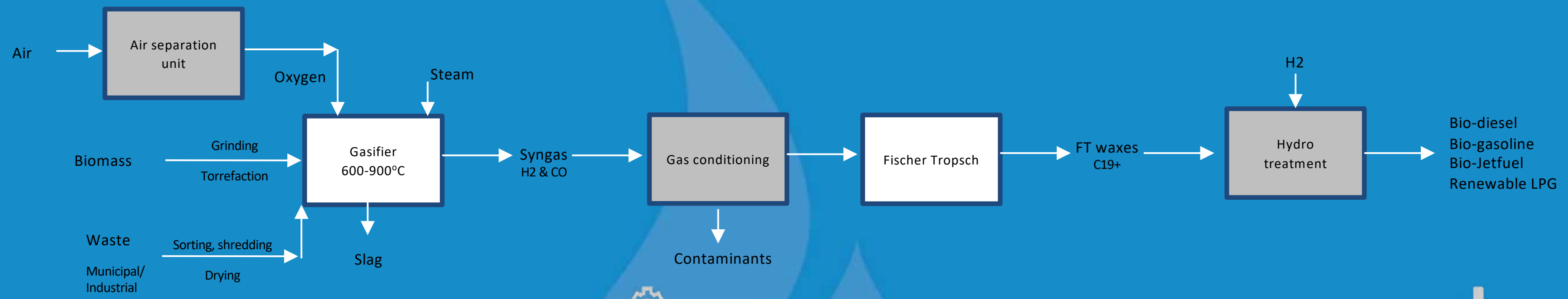
Case Study - Neste

- The production capacity of Neste's Rotterdam HVO biodiesel production facility is over 1 million ton/yr. The company plans to expand its global renewable production capacity from 3.2 million tonnes now to 4.5 million tonnes by Q1 2023.
- Biopropane, which is part of hydrotreater off-gases, was being used as a fuel for electricity generation. Neste invested in the construction of a biopropane extraction unit which included the basic installation itself plus storage. The total investment was approximately 60 million euros. The Rotterdam facility started extracting biopropane in 2018 and has a production capacity of 40 kt/yr.
- SHV Energy were the exclusive off-taker of biopropane, receiving 160 k tonnes over 4 years. The company now supplies biopropane as bioLPG or renewable LPG to its European customers.
- About 80% of Neste's feedstock supply is based on wastes and residues. The company is committed to increasing it to 100% by 2025.

Gasification - Fischer Tropsch to liquid fuels

2

TRL: 8



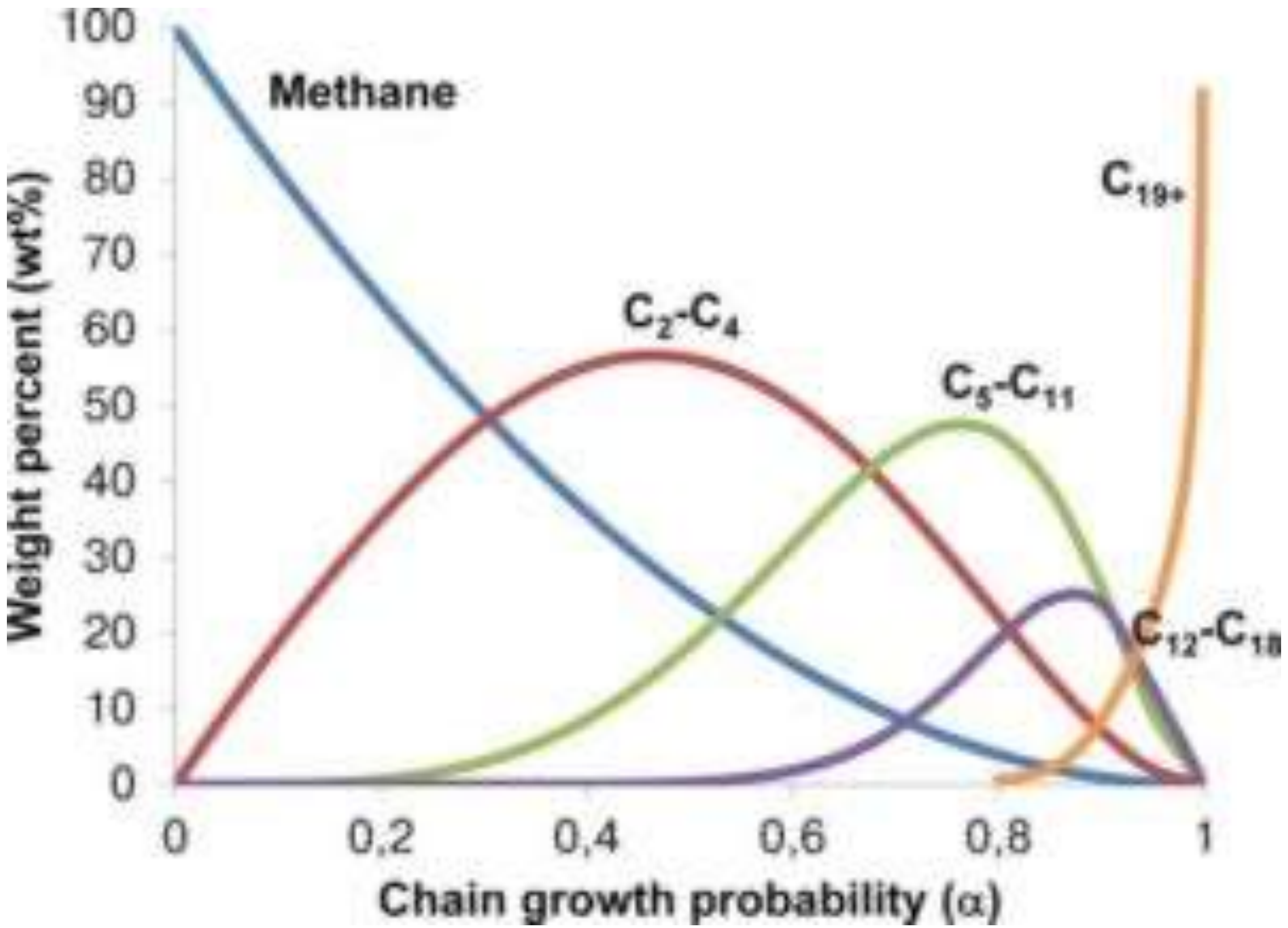
Process description

- In the **gasification process**, biomass and/or waste feedstocks are broken down into a mix of gases: mainly hydrogen (H2) and carbon monoxide (CO) but also carbon dioxide (CO2), methane (CH4) and trace amounts of other compounds. The process takes place at high temperatures and pressures, usually using oxygen and often steam. The end mixture of gases is called **syngas** (mainly CO and H2).
- CO2 is removed from syngas which is also cleaned of tars and other contaminants. After syngas cleaning, it is catalytically reacted in a process called **Fischer Tropsch (FT) synthesis** to make waxy hydrocarbons, typically in the C19+ range.
- These FT waxes are hydrotreated to make a slate of refined products, including bio-diesel, bio-gasoline, bio jet fuel as well as **renewable LPG**.

Case Study – RedRock Biofuels

- RedRock Biofuels will be using gasification plus Fischer Tropsch refining to make renewable jet and diesel fuels in Lakeview, Oregon. The plant is nearing completion and anticipates start-up in spring 2021.
- The plant converts approximately 166,000 dry tons of waste woody biomass into 16 million gallons/yr or 0.56 million tonnes of low-carbon, renewable jet and diesel fuels.
- Recently RedRock and Shell have entered into a fuel purchase and sale agreement. Shell will purchase sustainable aviation fuel (SAF) and renewable diesel from RedRock. It will market Red Rock's cellulosic renewable diesel fuel whereas SAF will be distributed to Red Rock's existing airline customers.

Fischer-Tropsch – Can we beat Anderson-Schultz-Flory?



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Alcohol to hydrocarbons (Jet Fuel)

3

TRL: 8

Process description

- The conventional processes for converting **alcohol to jet (AtJ)** have been around for years: they consist 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. For production of bio-jet, most attention has been paid to ethanol and isobutanol feedstocks.

- Isobutanol offers: a higher yield of biojet, 75% to ethanol's 60%; capital investment about 40% lower; and 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, which makes it preferable for LPG distributors.

- Catalytic dehydration of ethanol produces ethylene (olefin) which is oligomerized to alpha-olefins that are hydrogenated to make paraffins.

Case Study – Vertimass

- A company called **Vertimass** has recently piloted a process that takes only one step (instead of three) and requires no external source of hydrogen. Other companies are reportedly working on the same. It is not clear if Vertimass has done this at more than laboratory scale.

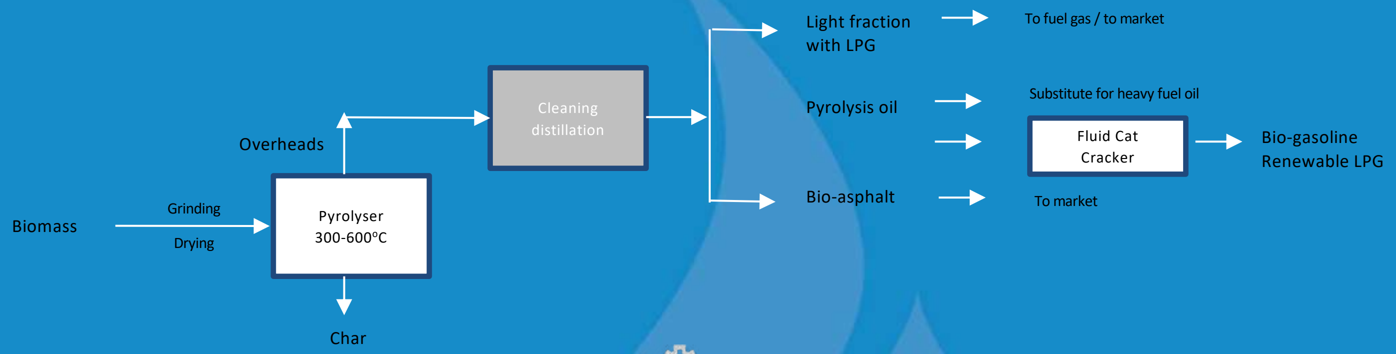
- Vertimass is a company founded around 2014 that grew out of two research centers run by the US Department of Energy, (i) Oak Ridge National Laboratory and (ii) the National Renewable Energy Laboratory. Vertimass claims its process has three advantages over conventional AtJ:
    - One step process
    - Uses no external hydrogen
    - Does not require a pure alcohol feedback (lower feedstock price)

- The process is reported to produce 3-4% biobutane/renewable LPG as currently designed. This percentage could also be increased.

Pyrolysis biomass

4

TRL: 7



Process description

- In **pyrolysis**, biomass feedstocks are treated under moderate temperatures, with limited oxygen or air, usually at ambient pressure. The process produces oils, gases and solids (char). Pyrolysis generates hydrocarbons mostly in C5-C20 range.
- For the LPG industry the product of interest is **pyrolysis oil** which is also referred to as **bio-crude**. Bio-crude is broadly similar in composition to vacuum gasoil (VGO) or crude oil.
- 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 LPG**. There have been tests with pyrolysis oil in fluid cat crackers that yield up to 10% biopropane.

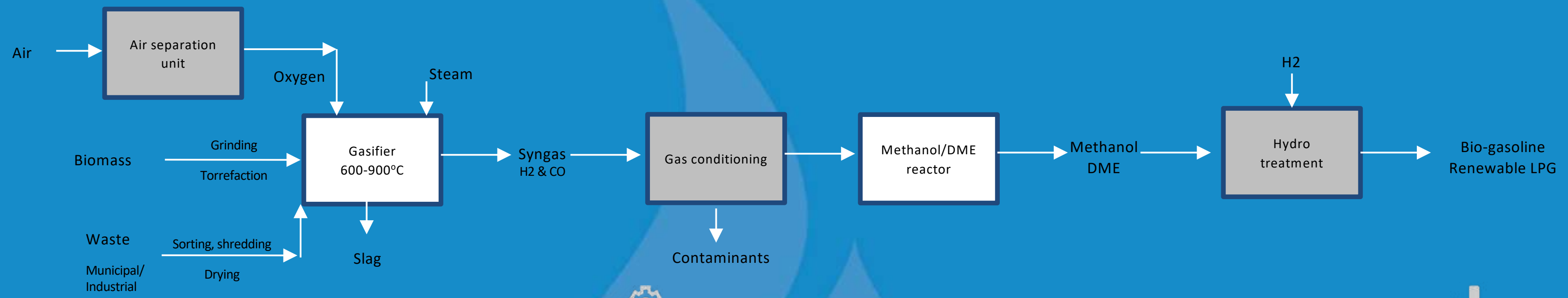
Case Study – Setra/ Preem

- The wood industry company Setra and the fuel company Preem are collaborating to produce fossil-free pyrolysis oil from sawdust through the jointly owned company Pyrocell.
- Pyrocell's new plant at the Setra Kastet sawmill in Gävle, Sweden is under construction. Pyrocell will produce pyrolysis oil as a raw material for the production of renewable fuels.
- The pyrolysis oil will be refined into renewable diesel and gasoline at Preem's refinery in Lysekil, Sweden.

Gasification to Methanol & Methanol to Gasoline (MTG)

5

TRL: 6



Process description

- In the **gasification process**, biomass and/or waste feedstocks are broken down into a mix of gases: mainly hydrogen (H_2) and carbon monoxide (CO) but also carbon dioxide (CO_2), methane (CH_4) and trace amounts of other compounds. The process takes place at high temperatures and pressures, usually using oxygen and often steam. The end mixture of gases is called **syngas** (mainly CO and H_2).
- CO_2 is removed from syngas which is also cleaned of tars and other contaminants. After cleaning, syngas is passed through a series of reactors where it gets converted to methanol and DME. This methanol/ DME mix is hydrotreated to make gasoline.
- The process can result in large fractions of **renewable LPG** that can go above 20% of the total fuel output.

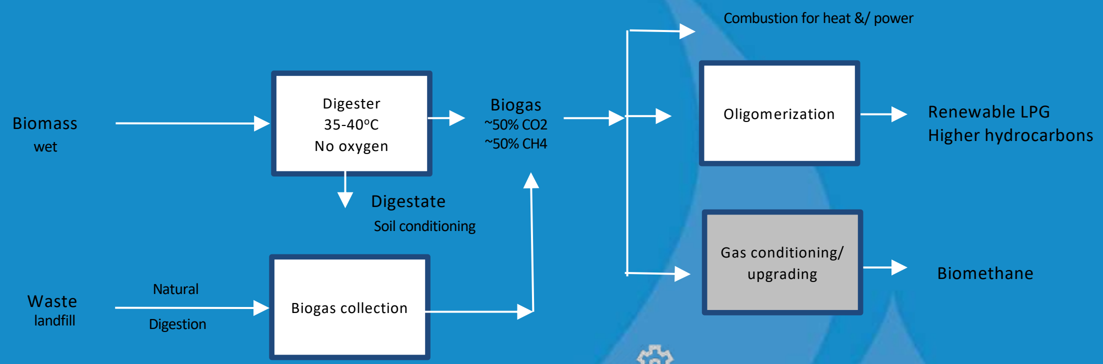
Case Study - TIGAS

- The technology that produces gasoline from methanol (MtG) has existed for decades. Exxon Mobil operated a facility in New Zealand that used natural gas. Haldor Topsoe has also developed a technology called 'TIGAS' that can convert biomass derived methanol to gasoline. Wood to green gasoline pilot plant ran from 2010-2014 at GTI in Des Plaines, Illinois . It used Carbona gasification and Topsoe TIGAS processes.
- Renewable Carbon Initiative (Iceland), BioMCN (Netherlands) and Enerkem (Canada) are making renewable methanol but there are no plans for down stream conversion to gasoline.
- The process can also be applied to 'stranded' natural gas or to natural gas that is currently flared. Possibly the former and certainly the latter can be viewed as low- or lower-carbon fuels.

Oligomerization of biogas/biomethane

8

TRL: 4



Process description

- Organic wastes such as **manure and sewage sludge** can be treated by anaerobic digestion. The process results in **biogas** which contains methane (CH4) and carbon dioxide (CO2) in an approximate 50/50 split. Biogas also contains small amounts of organic acids, nitrogenous and sometimes sulphurous compounds. Biogas is also produced 'naturally' at **waste landfills**, from the digestion of waste organic materials that can be either bio or fossil in origin.

- Biogas can be used to produce electricity (and heat). It can also be upgraded to make biomethane which can be injected into the gas grid.

- Another possibility is to convert biogas/biomethane into higher hydrocarbons including **renewable LPG**. This is a thermochemical route that involves oligomerization of biogas/biomethane.

Case Study – Plasmerica

- Plasmerica – an Oklahoma based technology company – has developed a process that converts methane gas into propane.

- The company's technology earned the 2019 Innovation Award at the World LPG Association's (WLPGA) Global Technology Conference and is starting to gain international attention. The starting point is methane (CH4) that has one carbon atom, but the company's technology strings together three of those methane molecules to create propane (C3H8).

- The technology offers the opportunity to utilize methane emitted through flared or vented gas to make propane. The stranded biogas potential in areas with no access to the gas grid can also be converted to renewable propane, which can then be distributed using existing LPG infrastructure.

Fermentation to LPG

TRL: 5

Process description

- Aerobic fermentation is the conversion of sugars by bacteria, yeasts or other microorganisms, in the presence of air, into other products. The best-known example is the fermentation of alcoholic beverages: yeast converts sugars into ethanol. Alcohol is fermentation's best-known product, but fermentation can generate other products, including renewable LPG.
- Fermentation of sugars to isobutylene has been demonstrated at pilot scale while the fermentation of sugars to biopropane has been proven at laboratory scale.
- Sugars can also be fermented to alcohols that in turn can be converted to renewable LPG. Another possible route involves conversion of sugars to propanol, with subsequent catalytic dehydration to propylene followed by catalytic hydrogenation to propane or renewable LPG.

Case Study – Global Bioenergies

- Global Bioenergies converts sucrose (sugar) from sugar beets and sugarcane to isobutylene at a demonstration plant in Leuna, Germany. Capacity is reported at around 150 tonnes/year.
- Global Bioenergies and Cristal Union partnered in a Joint Venture (IBN-One) to build and operate the first full-scale bio-isobutene commercial plant somewhere in France. The plant targets the conversion of sugar beet-derived sucrose into 50,000 tonnes of bio-isobutene annually.

Naturally-occurring Microbial Biosynthetic Pathways for Renewable Propane

Felicity Currie[1*], Keith E. Simons[2], Roger Marchant[1] and Ibrahim M. Banat[1]

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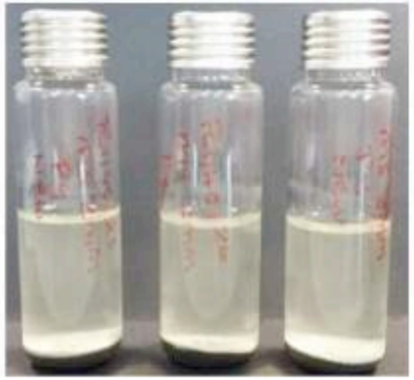
Detection of propane production by marine microorganisms

Marine sediment samples

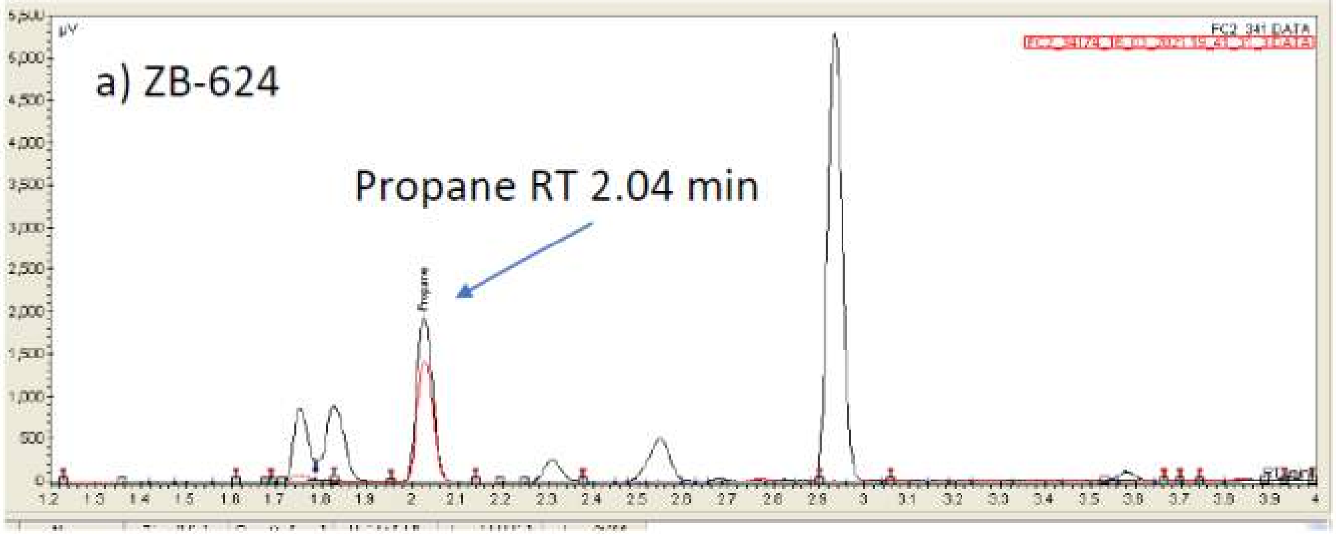
Microbial seed cultures

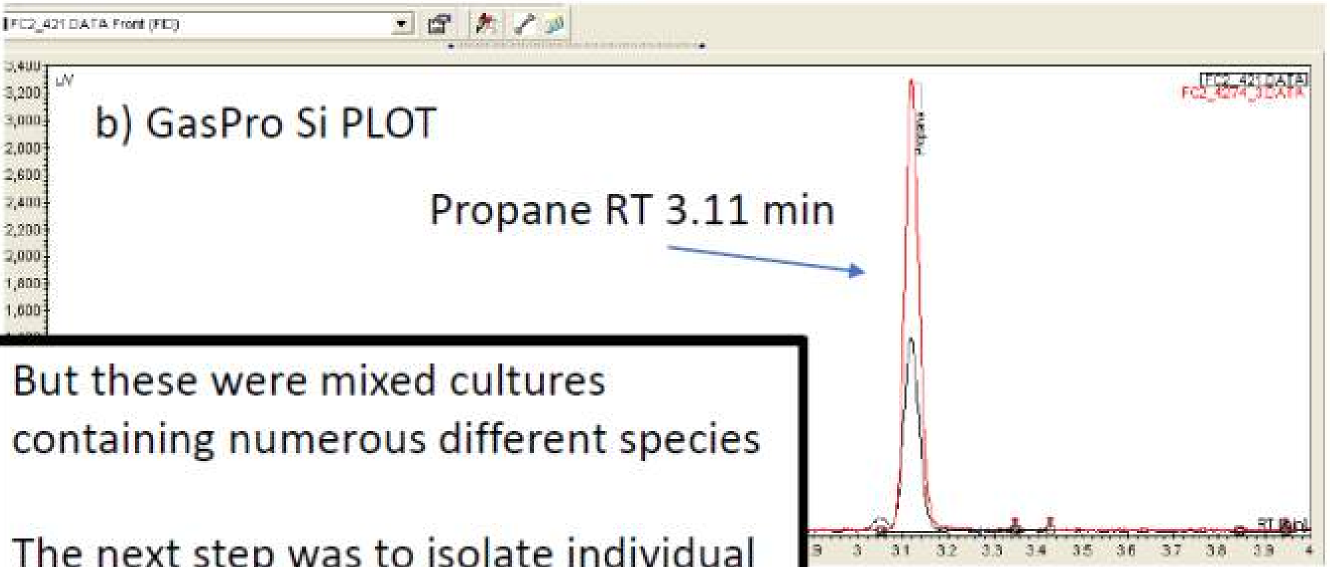


- GC analysis for propane
- Compounds are separated based on their volatility and chemistry

We detected propane in our samples

- Compounds are identified by comparison of their retention time (RT) with a Propane Standard
- The ID of our compound peak was confirmed using a second gc column with a different column chemistry



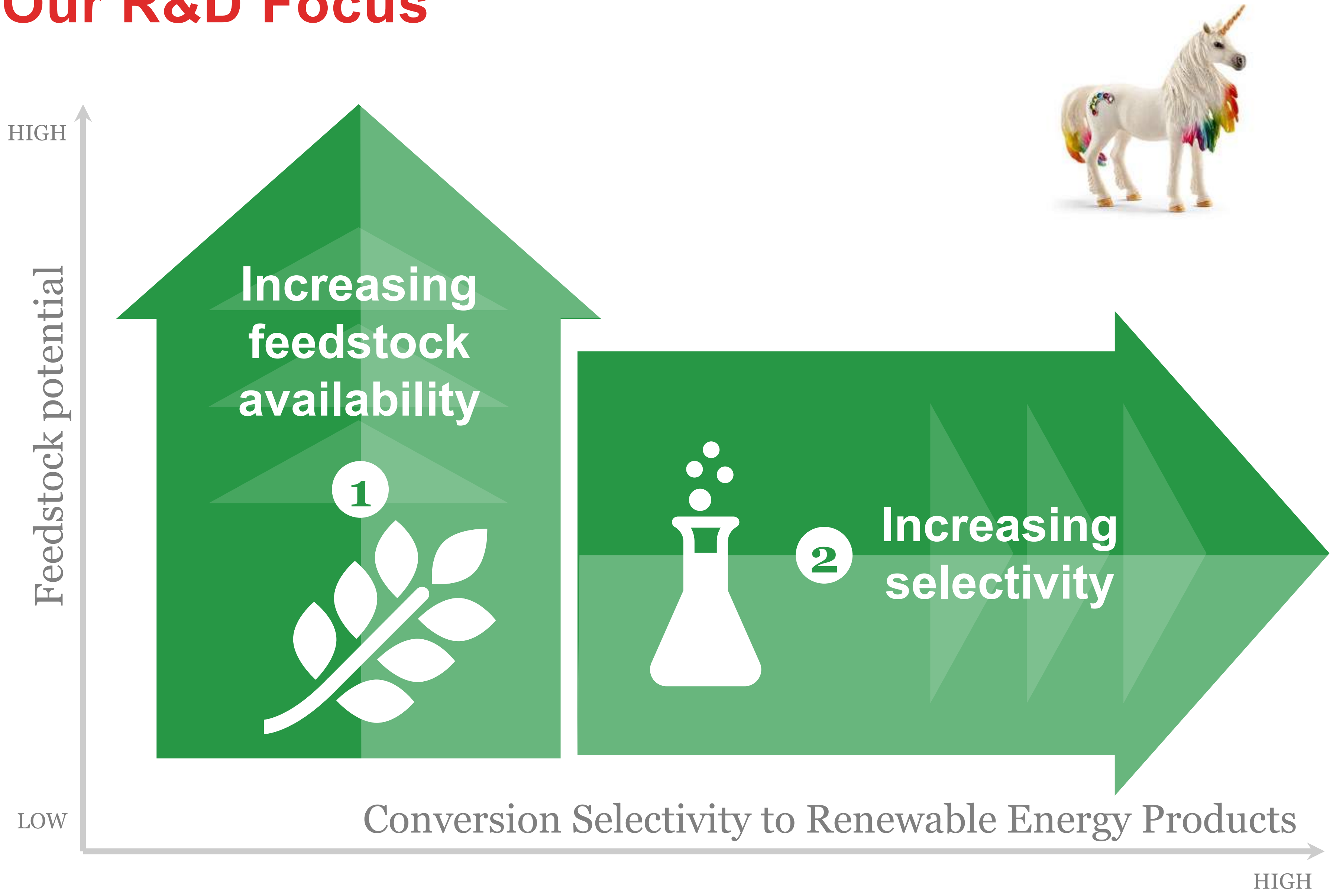


But these were mixed cultures containing numerous different species

The next step was to isolate individual species

Ulster University

Our R&D Focus



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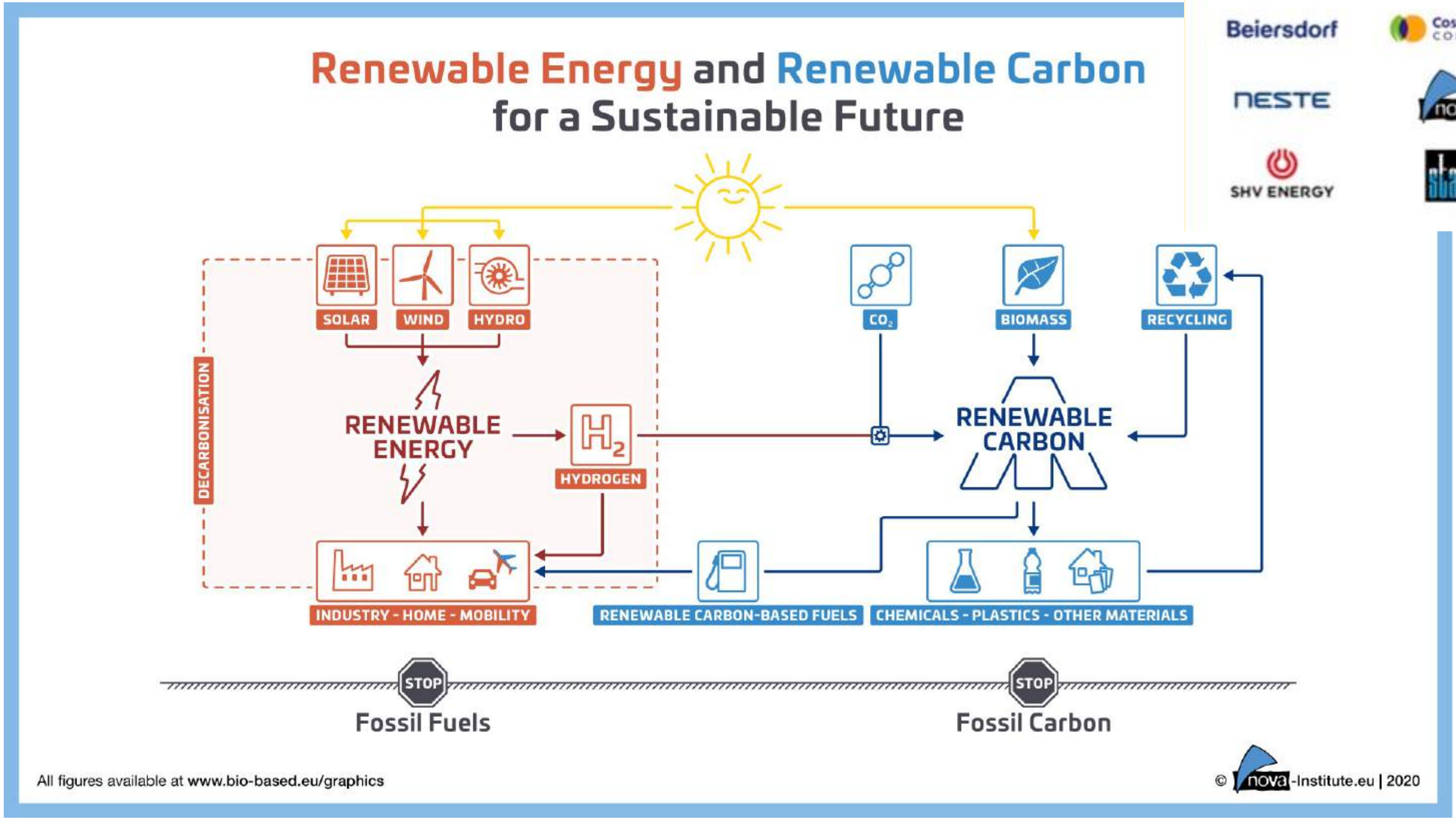
We are a founder member of the Renewable Carbon Initiative



BOARD MEMBERS OF THE INITIATIVE

Beiersdorf, Cosun Beet Company, covestro, Henkel, Neste, nova, Lenzing, LanzaTech, SHV Energy, stahl, Unilever, UPM Biofore

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The Sustainable Fuels Open Innovation Challenge

Seeking pathways to produce C3/C4 saturated hydrocarbons (propane/butane) from sustainable feedstocks with high yields

A novel or significantly enhanced known process that could ultimately be scaled to make production commercially viable.

(Focus should be the final stage reaction step to make propane/butane)

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Abundant and Sustainable Feedstocks

- Indigenous Biomass
- Wastes/Residues
- Dedicated Energy Crops
- Sludges
- Manure slurries
- Industrial waste gases
- Algae
- Etc.

Available as a substantial point-source

......but preferably not (used) vegetable oil

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Cooperation Models

Partnership

You have a viable technology, SHVE could

- SHVE could become an off-taker and give a fair market price
- Joint-development to enhance C3/C4 yield and recovery
- Fund a feasibility study (upto €50K) to explore scale-up
- Support/fund patent filing
- Support financing effort to commercialise technology

Provide sufficient detail in your proposal to allow us to evaluate your proposition

Research Collaboration

You are an academic institute, SHVE could

- Co-fund a feasibility study, an MSc, a PhD/post-doc (upto €50K)
- Partner on a research grant application
- Offer non-financial support

Describe your research concept, technical capabilities and also indicate the type of co-funding programs

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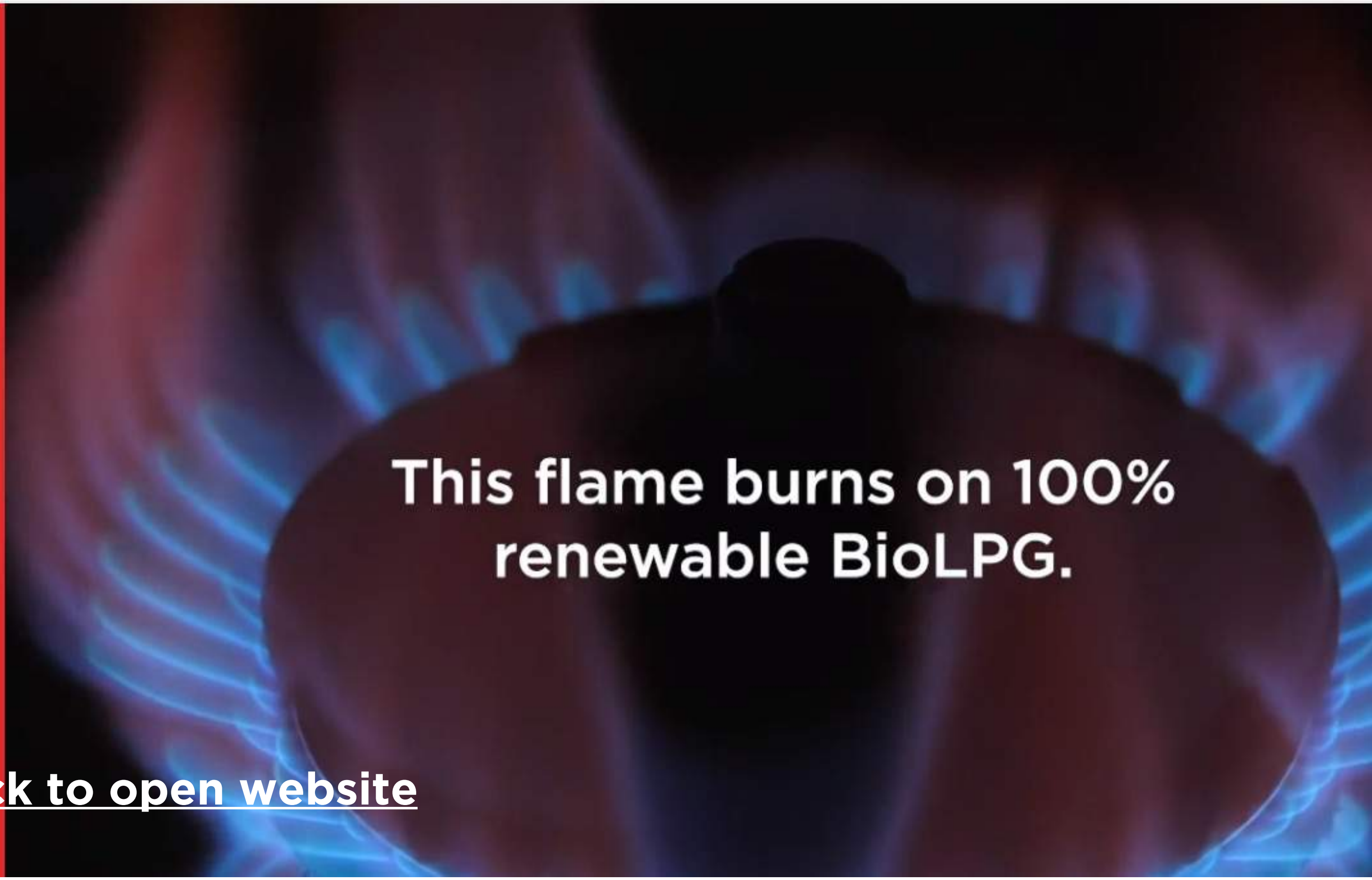
Learn more about the Challenge



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Any questions?

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Open Innovation Challenge

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The road to better is a long one.

We build, we innovate, we future-proof.

We no longer dream of renewable energy.

Welcome to the Sustainable Fuels Open Innovation Challenge!

For more information please contact
SuFuChallenge@shvenergy.com

shvesustainablefuelschallenge.innoget.com/

Dr. Keith Simons