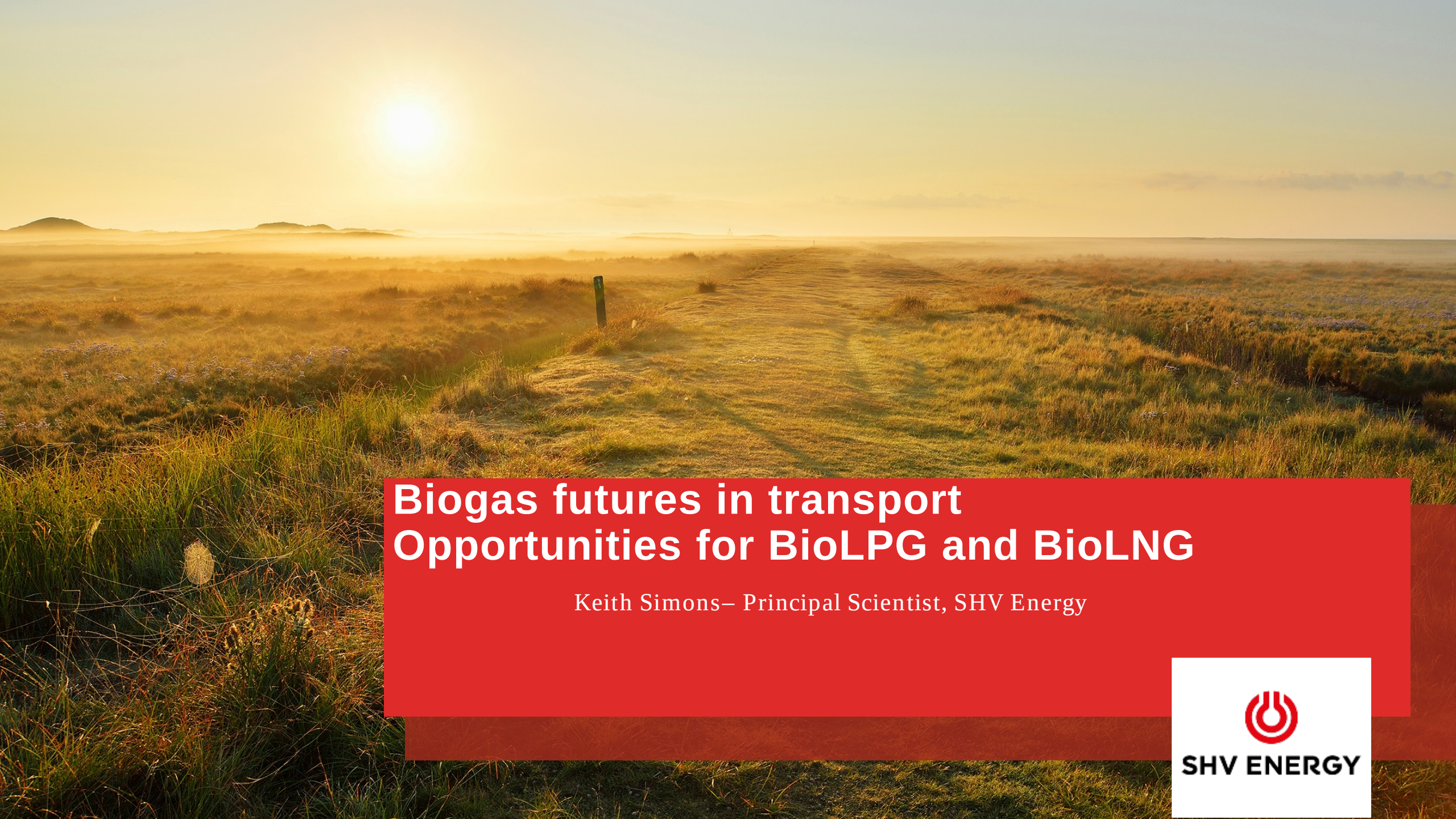


Biogas futures in transport
Opportunities for BioLPG and BioLNG

Keith Simons– Principal Scientist, SHV Energy

SHV ENERGY

SHV Holdings trading group
Privately owned, *international* in reach and *local* in focus

SHV Energy is part of SHV Holdings, a family owned Dutch trading company, regarded as one of the world's largest private trading groups.

SHV Holdings is a highly diversified company

makro ERIKS MAMMOET nutreco NPM CAPITAL SHV ENERGY

SHV Holdings employs around 60,000 people in 60 countries.

Est. 1896

60 Countries

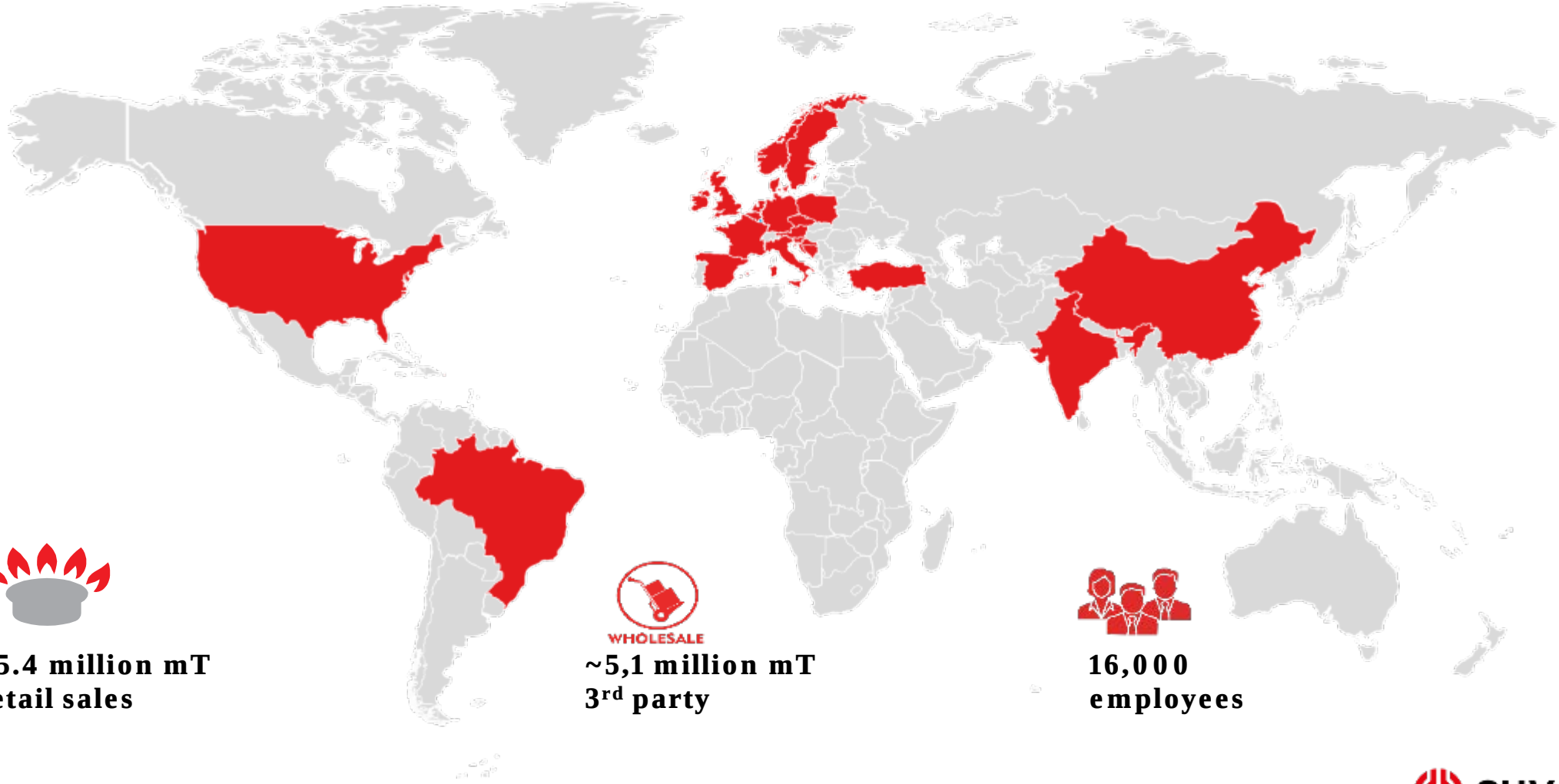
60,000 Employees

€20B Turnover 2017

SHV ENERGY

SHV Energy : Our global brands

PRIMAGAS · SUPERGASBRAS · PRIMAGAZ · iPRAGAZ · CALOR · LIQUIGAS · GASPOL · 喜威 · SUPERGAS · LIQUIVEX · PRIMAGAS · PRIMA LNG · BUTAN PLIN · PINNACLE · BALCAS



~5.4 million mT
retail sales

WHOLESALE

~5,1 million mT
3rd party

16,000
employees

Source: SHV Energy 2017 report

SHV ENERGY

...But innovation is part of our DNA

The past | *The present ...* | *& the future ...*

Coal

1896

LPG
Propane
Butane

1950

Biomass

2008

LNG

2013

BioLPG
Renewable
Propane

2018

.....

.....

SHV ENERGY

Biofuels Ambition

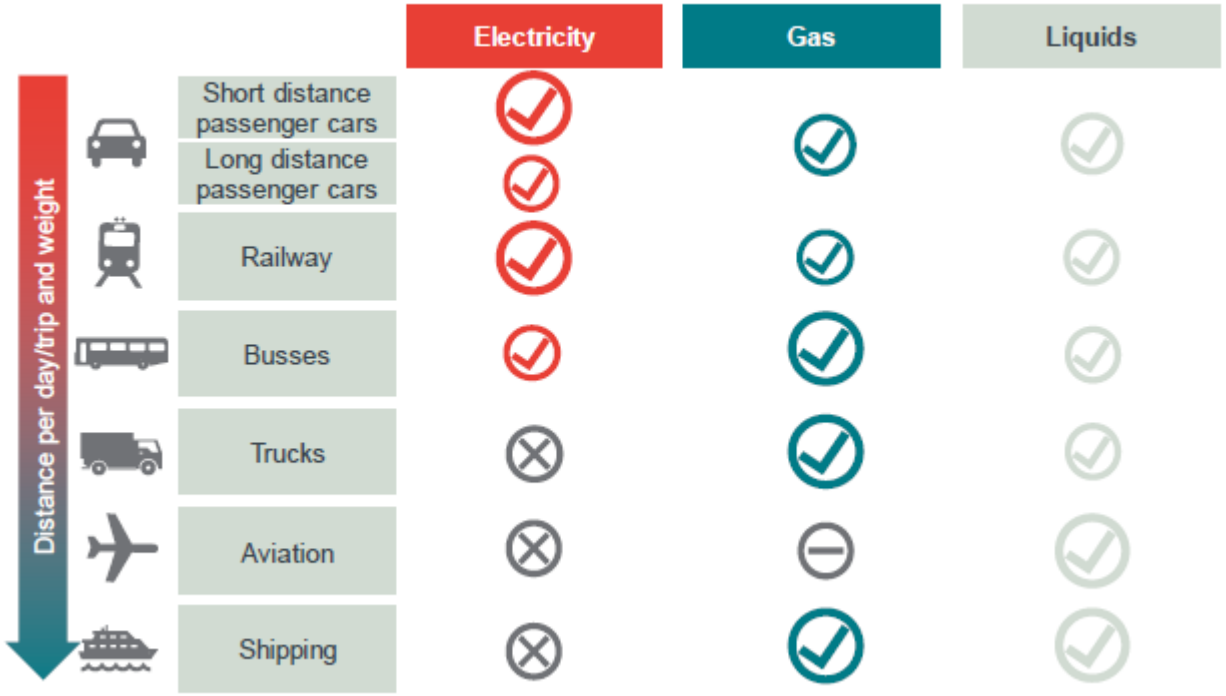
As a leading player in the energy market, we want to actively speed up the sustainable energy transition. BioLPG and BioLNG have an important role in this transition. They are versatile, viable and feasible drop-in solution significantly reducing CO2 emissions, today and into the future. By investing in Bio-based renewably sourced gas we can stay relevant and accompany our customers into the new green era. Investments will result in a stronger market position and growth.

Our bold ambition is that 100% of our energy products will be from renewable sources by 2040.

Is there a future for bioLNG and bioLPG in transport?

Even in a scenario of advanced electrification, there will be applications for which (bio) LPG / LNG and natural gas will still be required

Figure 64 Gas in transport as a promising decarbonisation option, particularly in heavy-duty road transport and shipping



Source: *Frontier Economics*

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BioLNG and BioCNG

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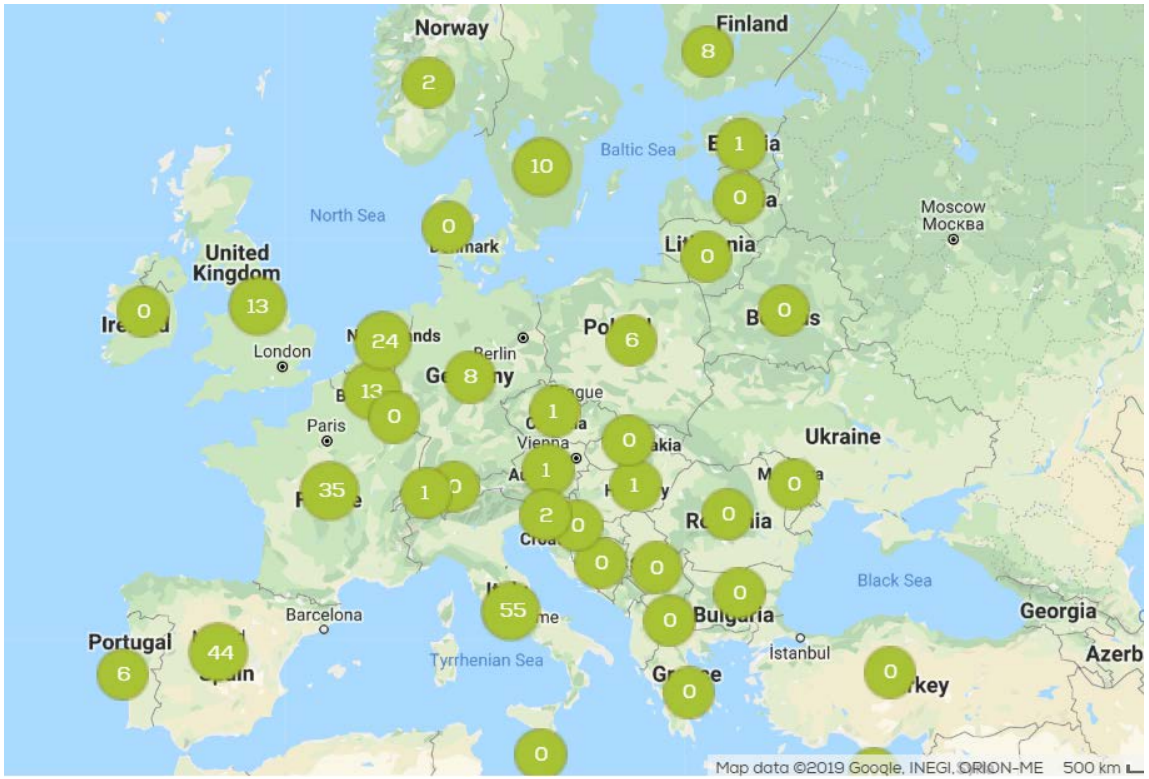
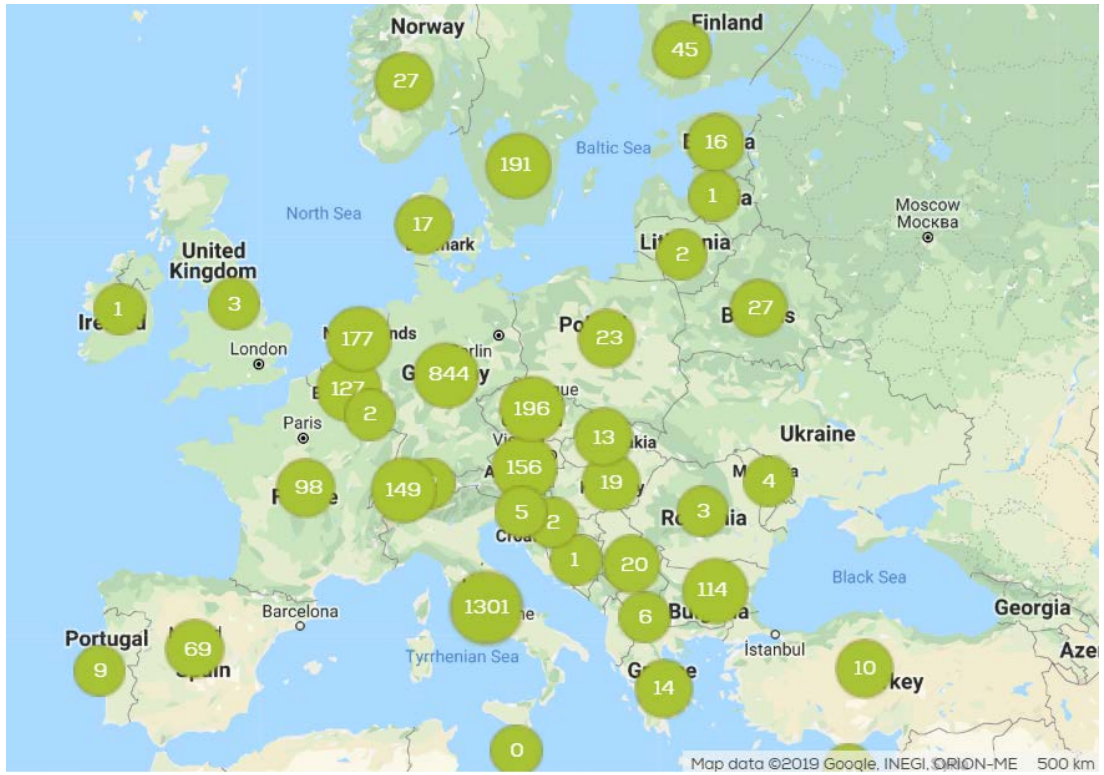
Opportunities for a drop-in bio replacement growing

Transport segment for CNG / LNG is growing, due to heavy trucks opportunity, but with big differences across Europe (also for incentives)



LNG stations



CNG stations

Data from NGVA Europe

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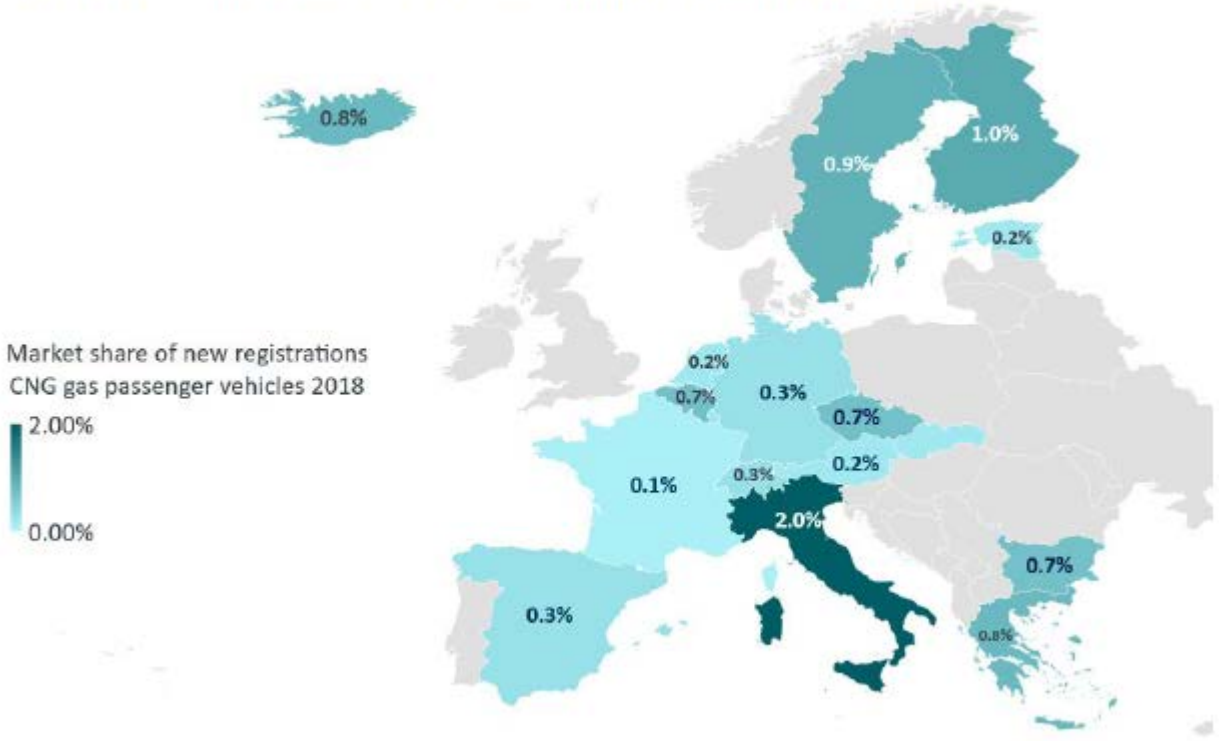
Focus on: transport market

Even for passenger vehicles there are still new registrations of CNG.

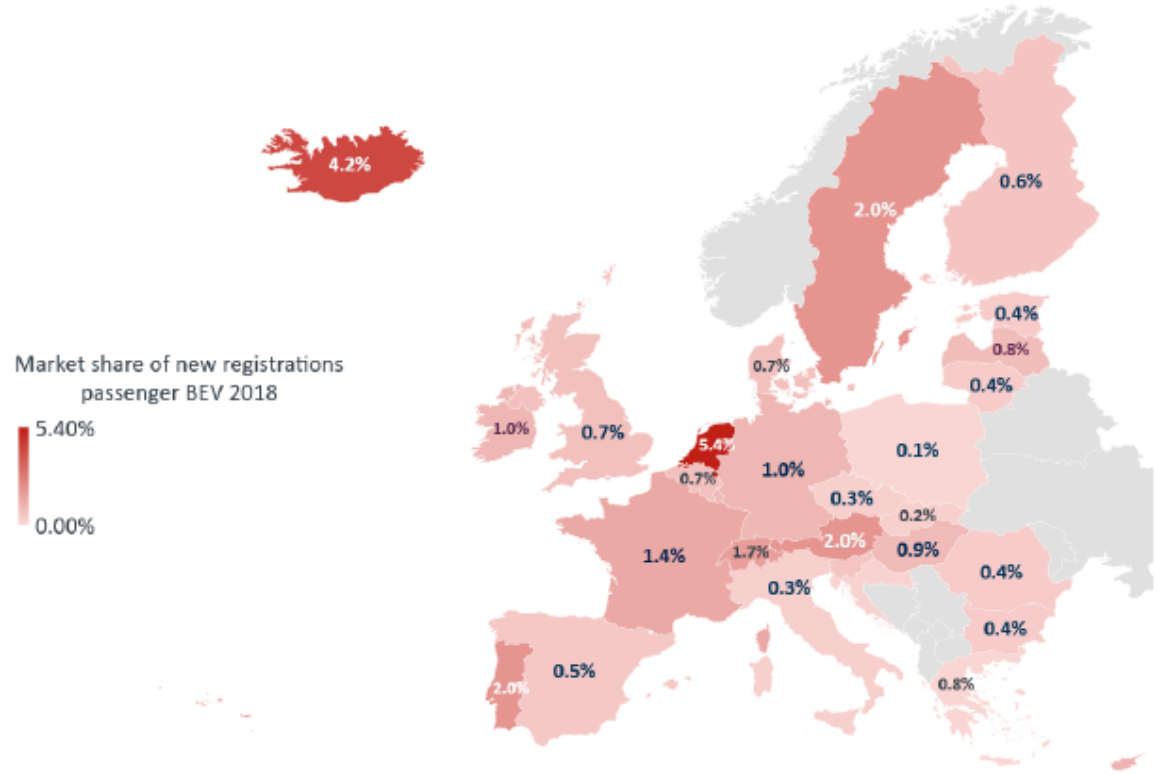
High ratio of EV does not imply availability of renew electricity

Figure 62 Share of CNG vehicles in new registrations (2018)



Source: *Frontier Economics based on European Alternative Fuels Observatory*

Figure 63 Share of battery electric vehicles in new registrations (2018)



Source: *Frontier Economics based on European Alternative Fuels Observatory*

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Back to the origins: biogas overview

Biogas production from Anaerobic Digestion is a mature technology, there are ≈18.000 plants in EU (60% in Germany). 97% of biogas plants are for Power Generation

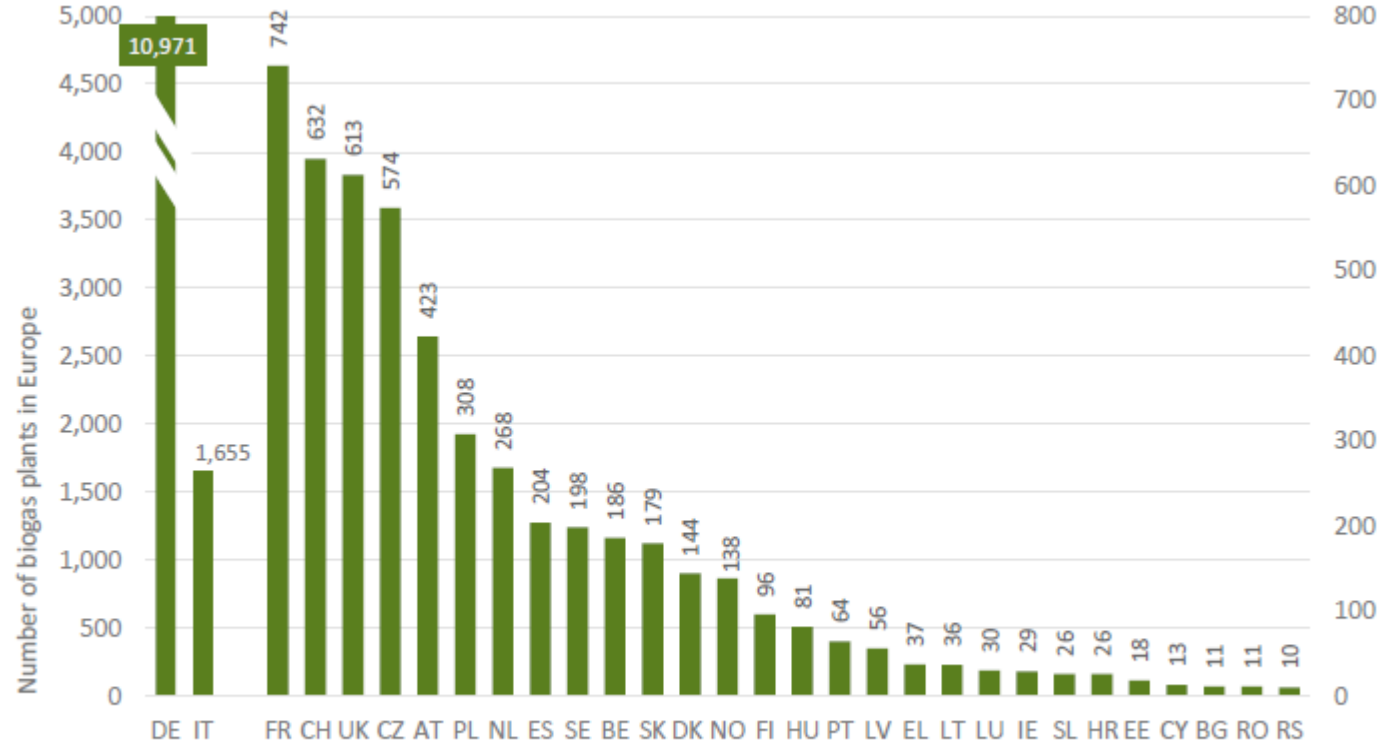
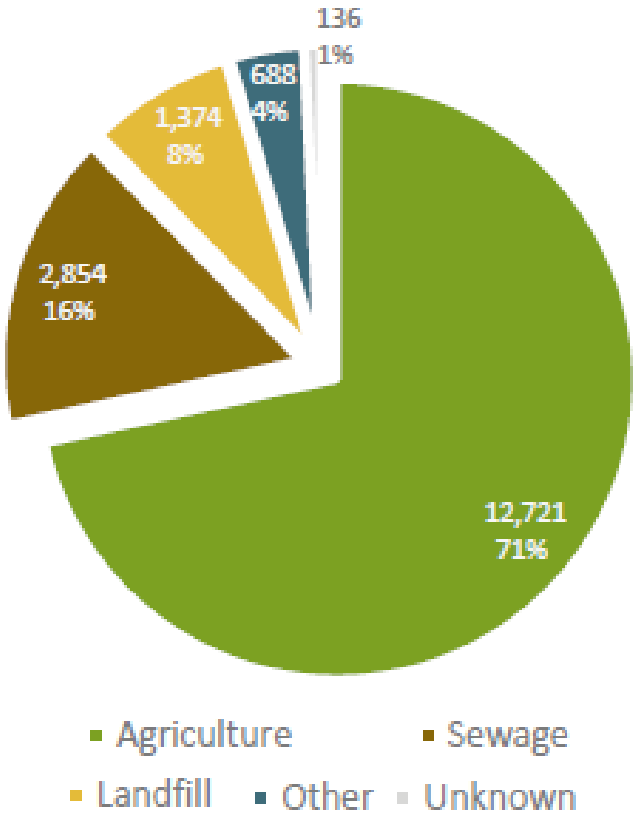


Figure EU-2: Number of biogas plants in European countries, arranged in descending order



Data from EBA 2018 Report

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A step further: biomethane

Biomethane production is already at commercial scale, but more than 95% of the plants are injecting into natural gas grid (Sweden is the only exception < 15%).

Most part of the current biomethane is from agriculture feedstock (residues / crops)

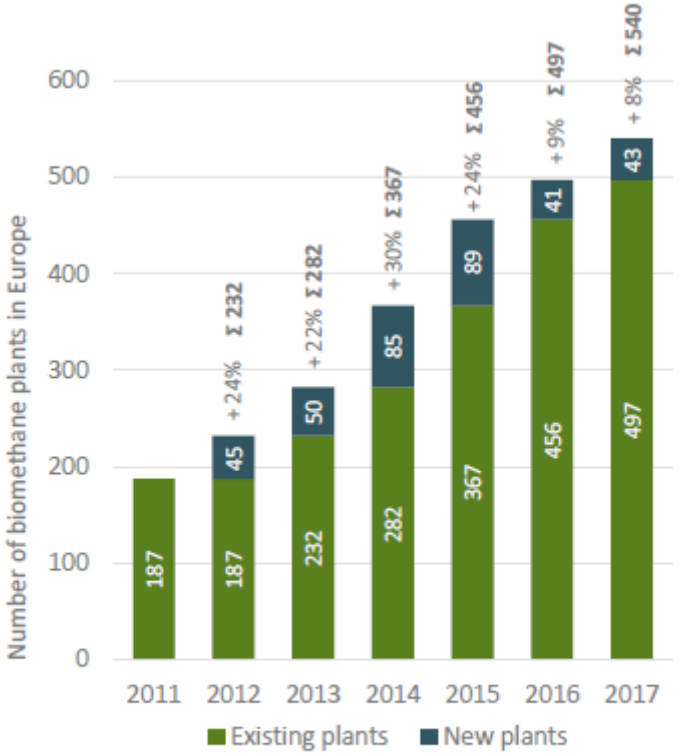
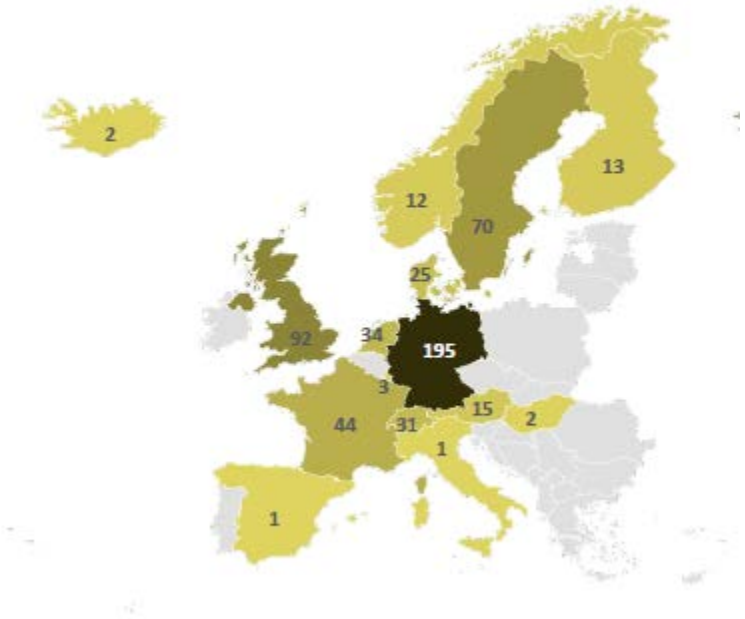
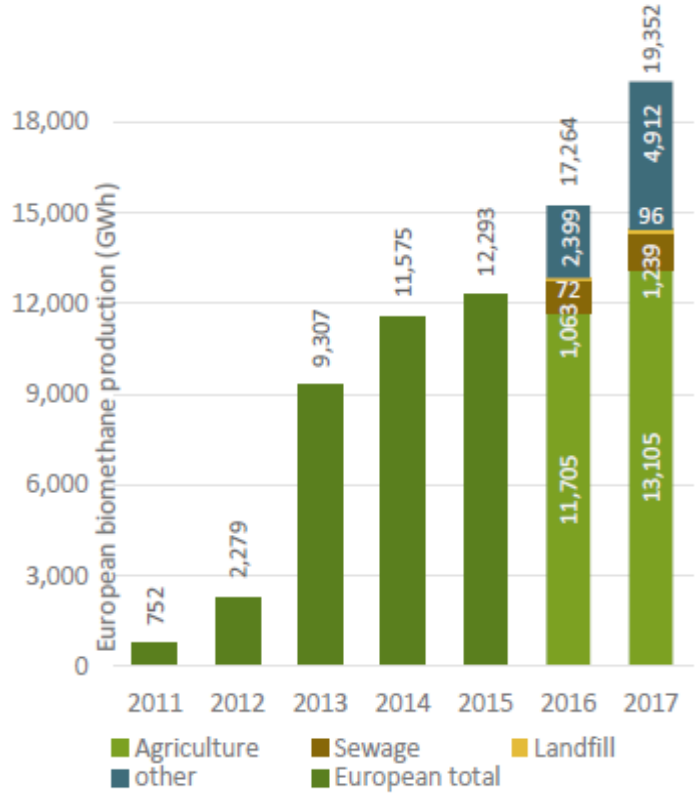


Figure EU-12: Development of the number of biomethane plants in Europe



Number of biomethane plants in European countries



Data from EBA 2018 Report

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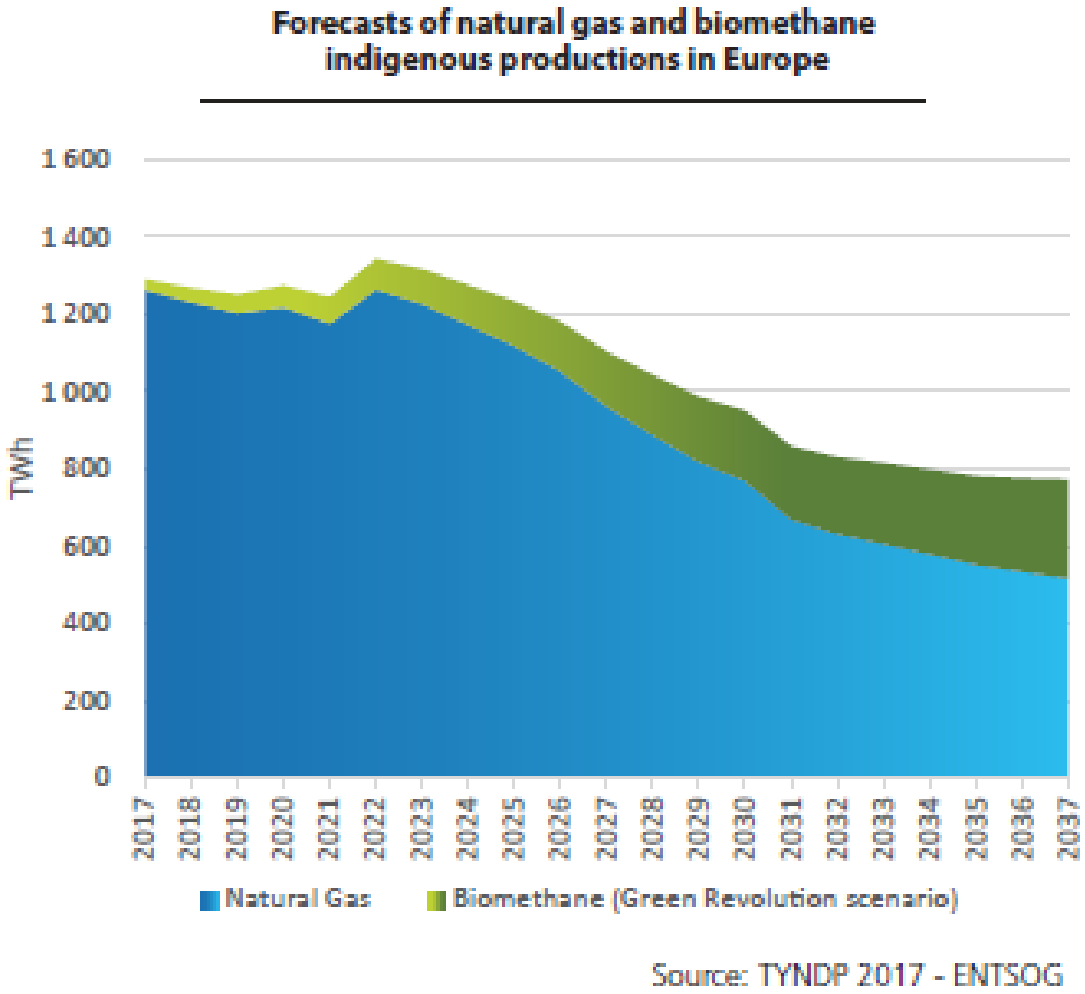
Potential evolution of biomethane

- Green Revolution scenario of ENTSOG's forecasts that biomethane will represent a third of the European indigenous production by 2037

- 15% of biogas plants are assumed not to be economically connectable to the grid



Source: TYNDP 2017 - ENTSOG

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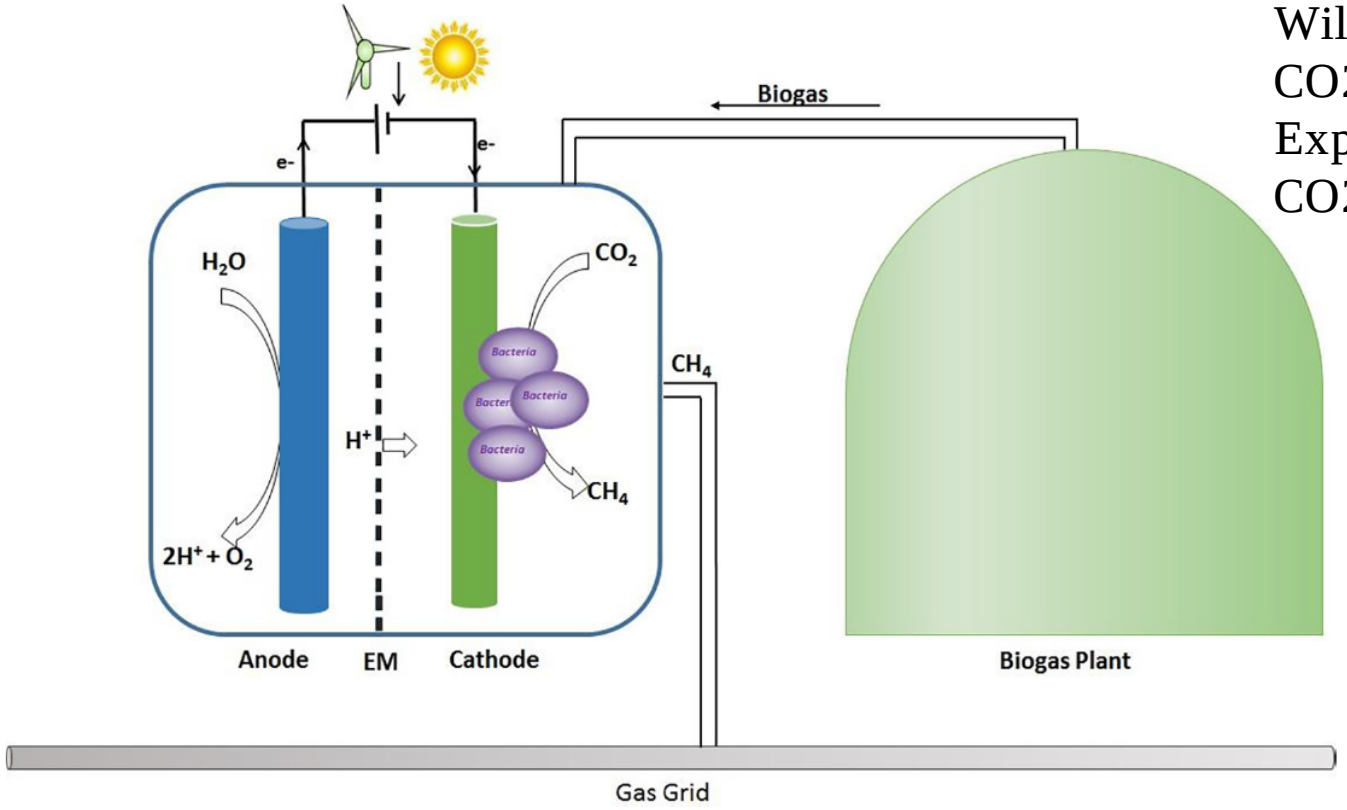
Power to Gas - Bioelectrochemical biogas upgrading



Will the release of biogenic CO2 from biogas be allowed in the future?
Exploit (constrained) electricity to methanate CO2 in biogas in microbial fuel cells

$$CO_2 + 8H^+ + 8e^- \rightarrow CH_4 + 2H_2O$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$$

Fig. 3. Bioelectrochemical CH_4 enrichment phenomena discussed in this review, where EM represent Exchange membrane, electrochemical oxidation reaction takes place at the anode to generates O_2 and H^+ and electrochemically active microorganisms utilize the cathode as electron donor and CO_2 from biogas to produce CH_4.

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Biogas enrichment in anaerobic digestion

N. Aryal et al.

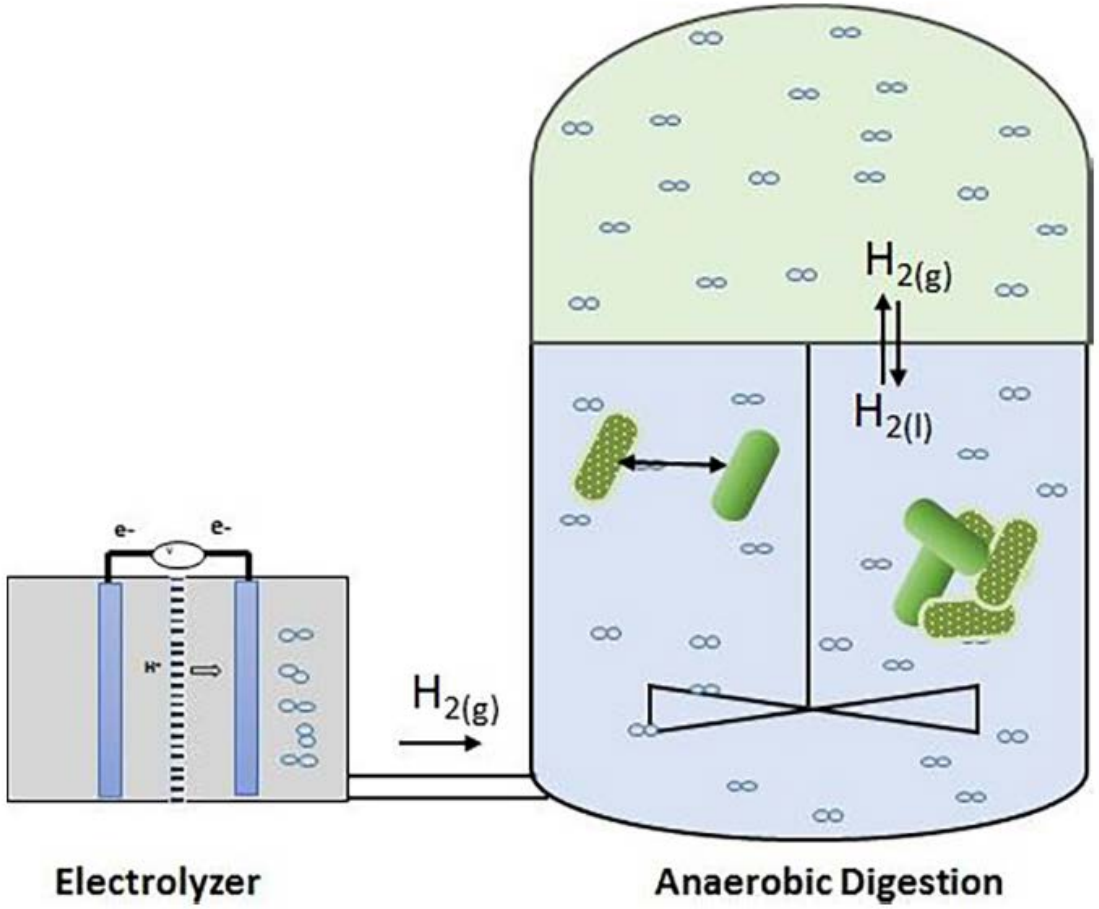

Fig. 2. Hydrogen (H_2) uptake in AD supplied from electrolyzer where "∞" is $H_{2(g)}$ represents in gaseous phase, and $H_{2(l)}$ in the liquid phase.

Hydrogen from a conventional electrolyser injected into digester and methanates CO2 in biogas

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BioLPG

BioLPG - long term strategic low carbon option

- Available in Europe now, initially 40ktpa from Rotterdam
- Drop-in replacement for LPG - Can be used in any ratio

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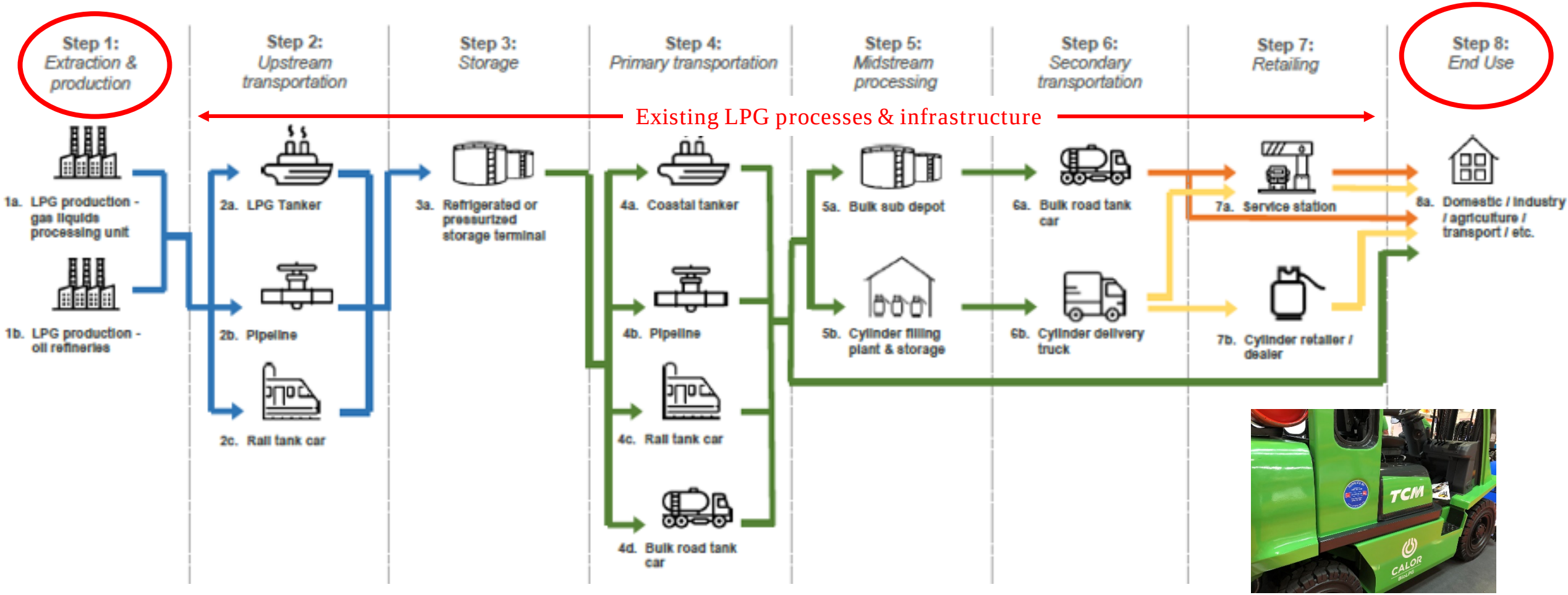
BioLPG… where is the difference?

Different upstream – no changes for distribution and most importantly the customer



BioLPG… where is the difference?

Using different feedstock totally changes the carbon intensity of the product we supply to our customers

Step 1: ~~Extraction~~ & production

Used cooking oil


Fish fat from fish processing waste


Crude palm oil


Rapeseed oil


Soybean oil

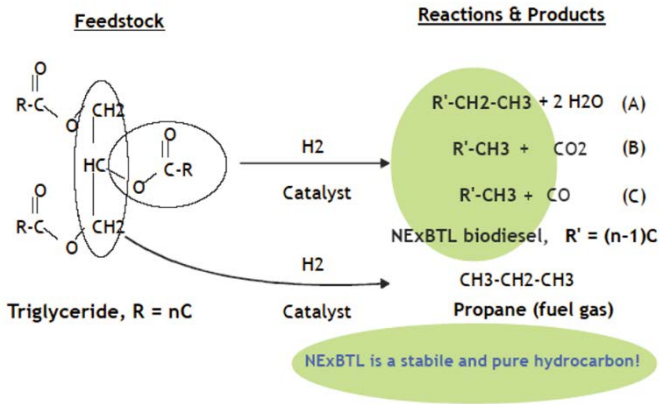
Feedstock is not ‘extracted’

Feedstock CO2 is already in our atmosphere!

≈ 80% CO2 reduction

Step 8: End Use

Simplified NExBTL Process Chemistry



Investing in the future

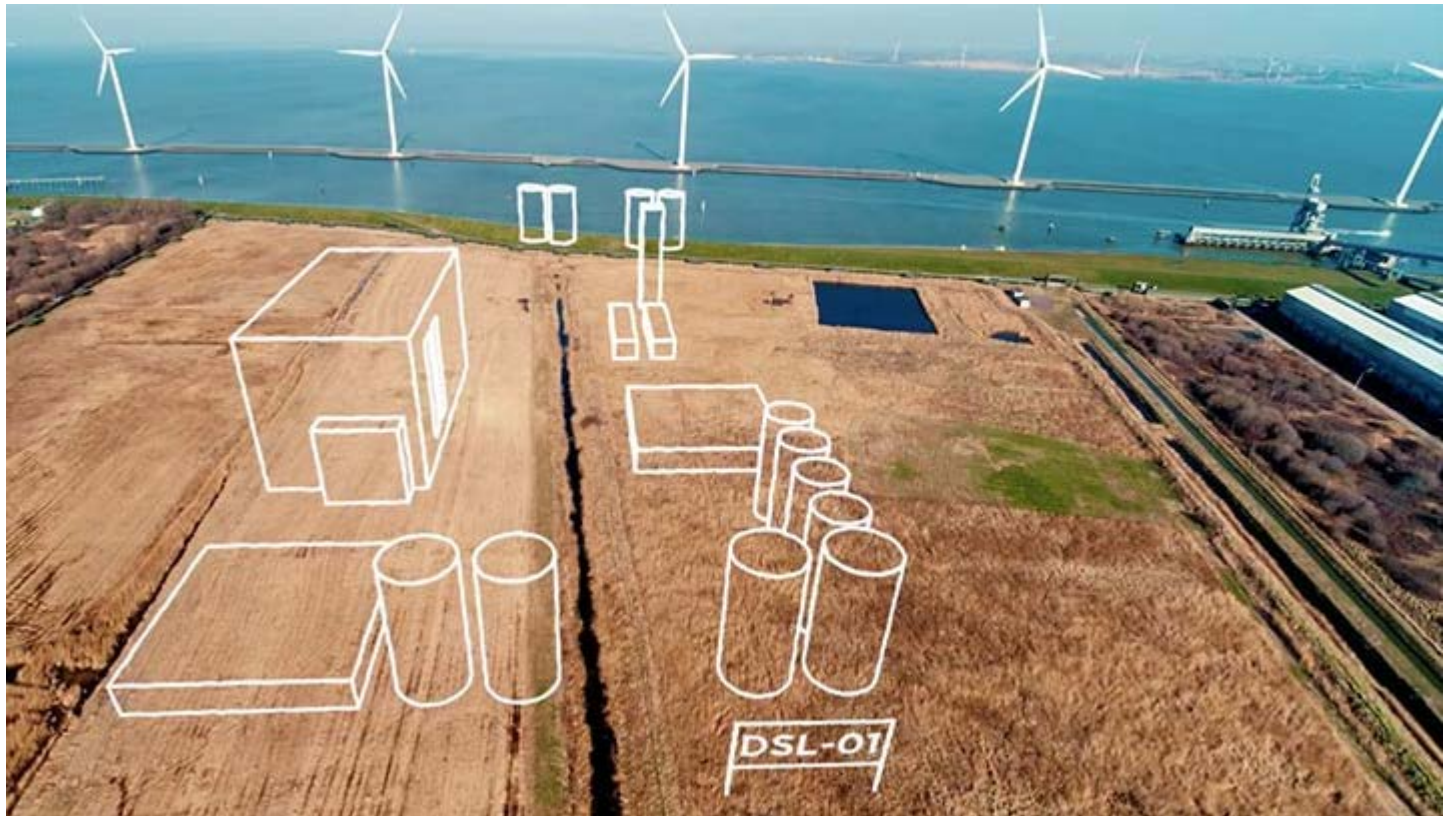
KLM, SkyNRG and SHV Energy announce project first European plant for sustainable aviation fuel

SkyNRG

KLM Royal Dutch Airlines

SHV ENERGY

- Agreement signed on May 27th 2019
- First dedicated plant for Sustainable Aviation Fuel in Europe
- Regional waste based feedstocks RSB certified
- 15.000 tpa of BioLPG



Multiple pathways to a 100% renewable future

Feedstock	Conversion technology	Biofuels
Vegetable oils / animal fats	Hydrogenation	5-8 % propane as co-product HVO diesel
Glycerine	Dehydration / hydrogenation	95% propane from glycerine
Bio-Isobutanol	Dehydration / hydrogenation	Isobutene / Isobutane
Organic Residues (from farms or MSW)	Anaerobic Digestion	bioLNG or rDME (via methanation)
Solid biomass → Syngas	Methanol to DME	DME as the main product (further DME to propane possible)
	Methanol to Gasoline (MTG)	10-30% propane + butane as co-product of gasoline
	Fischer Tropsch (FT) synthesis	1-2% propane + butane as co-product of diesel + kerosene
	Methanation	BioLNG or rDME + Potential fractions of propane + butane
Solid biomass	Pyrolysis / hydrogenation	2-3% LPG components as co-product of pyrolysis + hydrogenation oils
Glycerine / aqueous phase of pyrolysis oil	Aqueous phase reforming	Various fuels including LPG
Sugar / starch / solid biomass	Supercritical water / biological hydrolysis	Propane
Sugar / starch / solid biomass	Hydrolysis / fermentation	Isobutanol

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High

Low

Feedstock Potential

Carbon Capture Utilisation

Biological Conversion Of Sugars

Alcohol to Gasoline

Biomass/MSW Gasification Fischer Tropsch

(Plastics) Pyrolysis

Fats and Oil Hydrotreating

Biomass/MSW/Waste Gasification to DME

Glycerol Conversion

Conversion Selectivity to bioLPG

Our approach to Research and Development

Academia
Knowledge Development

Collaboration
Technology Development

Industry
Business Development

DISCOVERY *OPTIMISATION* *PILOTING* *DEMO* *FOAK/NOAK* *COMMERCIAL*

1 : Basic research	2 : Concept definition	3 : Feasibility	4 : Proof of Concept	5 : Lab validation	6 : Test validation	7 : System demo	8 : Operational deployment	9 : Commercial operation
€5k – 150k		€50k – 250k	€100k – 2.5M		€10M+	€50M+		€1B+

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New developments in transport

SHV ENERGY

UK Rigid Truck Types

2 axle <18te

18-26te 3 axle

8 x 4 tipper 28-32te

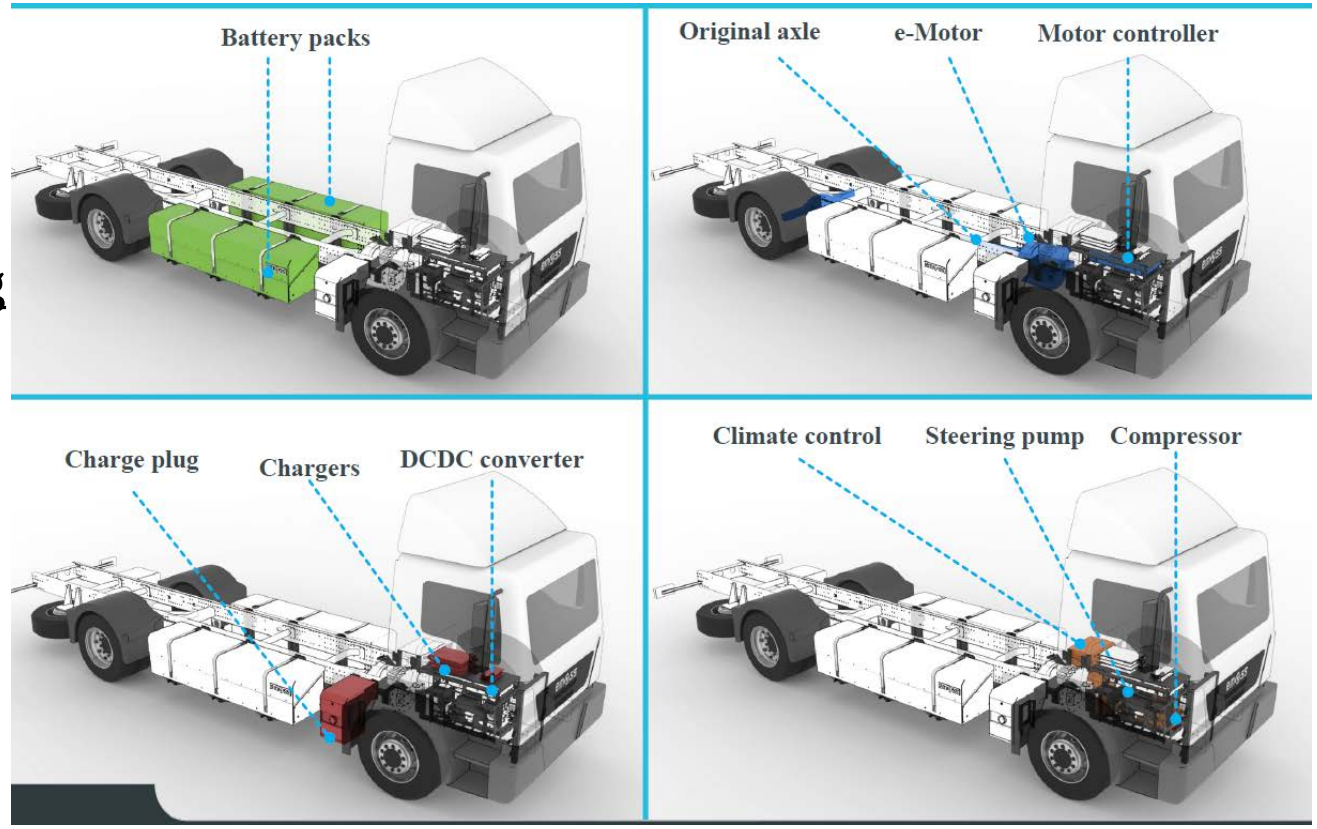
2 axle 16te Flatbed

3 axle Concrete mixer

Curtainsider

The World's 1st LPG Range-Extended Electric 16te Cylinder truck

- Military grade Li-Ion batteries
- 2 litre **LPG** steady state engine
- Plug-in charging
- 40 mile EV-only range **with GPS ring-fencing**
- 250 mile RE range
- Regenerative braking
- Cleaner
- Quieter
- Lower carbon

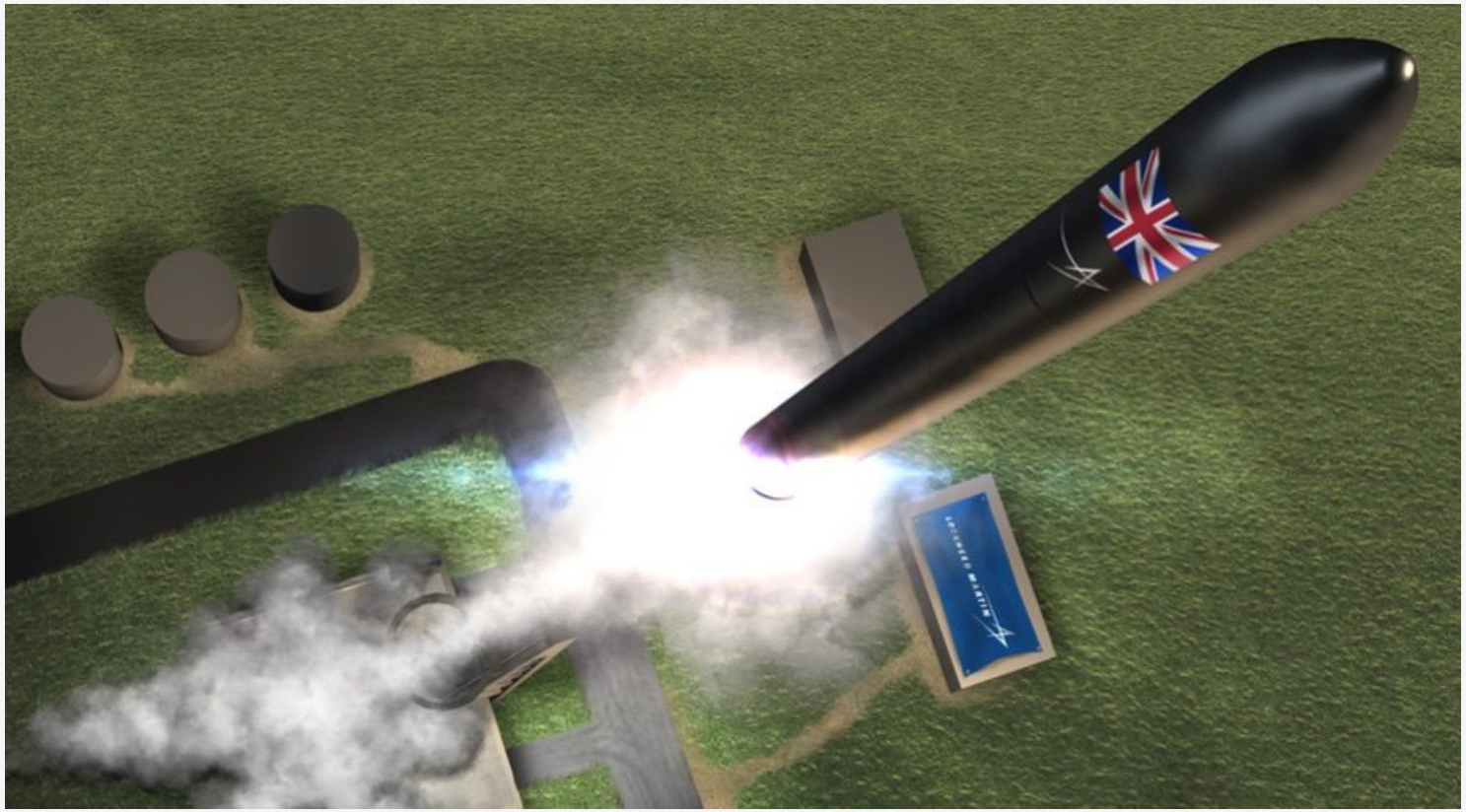


Emissions profile

On WTW basis:

- Standard Calor truck 48te CO_2 per annum
- LPG RE EV Truck 8.6te CO_2 per annum (82% saving)
- BioLPG offers up to 80% further CO_2 savings (94% overall reduction)
- NOx estimates to be 94% saving over Euro VI
- PM virtually eliminated
- Zero emissions in geo-fenced areas – Clean Air Zones or LPG facilities.

Biopropane to Infinity & Beyond!



Lockheed Martin and Orbex to launch UK into new space age

July 16th 2018 – Farnborough International Air Show

*"Their orbital launch vehicle, called Prime, will deliver small satellites into Earth's orbit, using a single renewable fuel, **bio-propane**, that cuts carbon emissions by 90% compared to hydrocarbon fuels."*

https://www.gov.uk/government/news/lockheed-martin-and-orbex-to-launch-uk-into-new-space-age

CALOR

Thank you

keith.simons@shvenergy.com

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