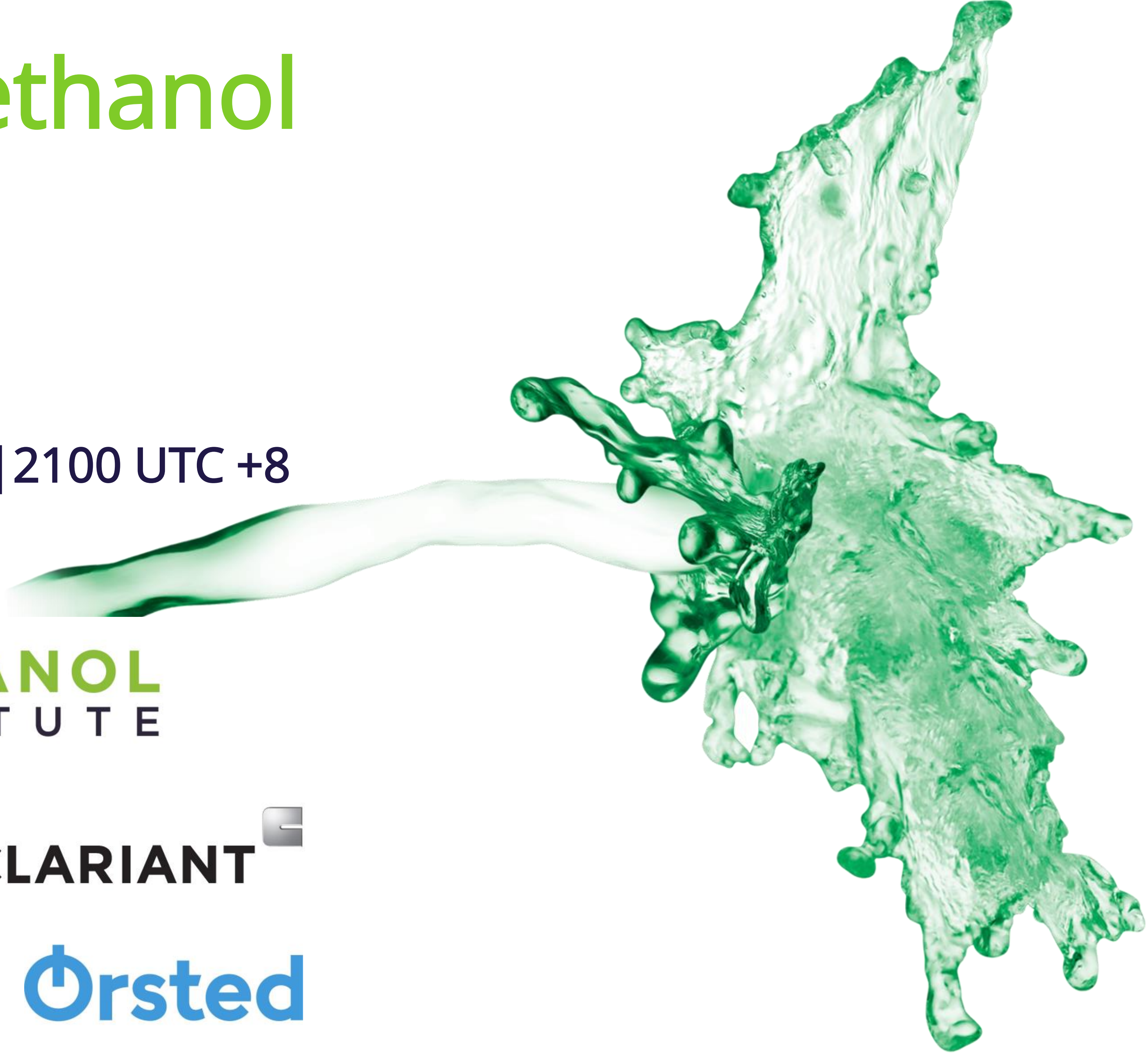
Renewable Methanol Webinar

August 5, 2020

0900 UTC -04 | 1500 UTC +2 | 2100 UTC +8



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METHANOL INSTITUTE

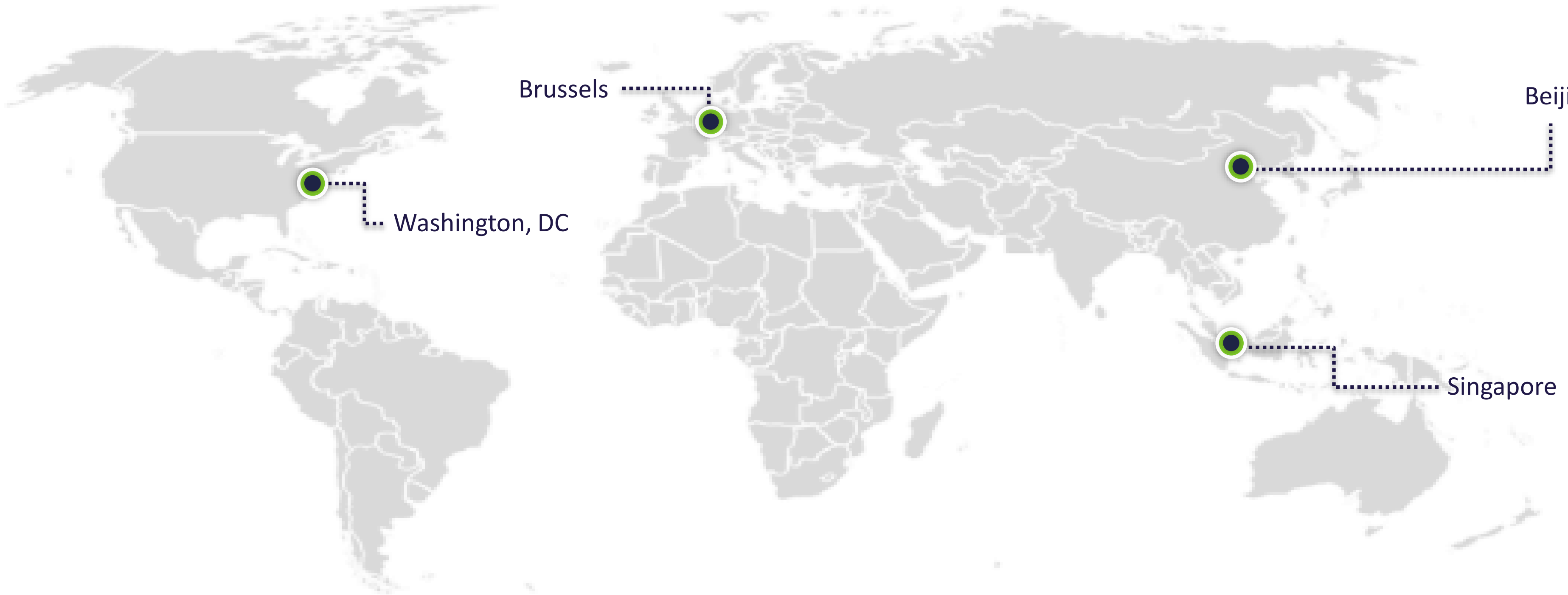
Renewable Methanol: A Net Carbon-Neutral Fuel

Tim Chan

Manager, Government Relations and Business Development
Asia & Middle East

MI History

- The Methanol Institute (MI) was established in 1989
- Three decades later, MI is recognized as the trade association for the global methanol industry
- Facilitating methanol's expansion from our Singapore headquarters and regional offices in Washington DC, Brussels, and Beijing



Members

METHANOL INSTITUTE

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MHTL

methanex the power of agility

سابك sabic

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Tier 2

Qatar Fuel Additives Company Limited

MITSUBISHI GAS CHEMICAL

ATLANTIC METHANOL

MITSUI & CO., LTD.

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Oman Methanol Company L.L.C.

Tier 3

eni ecofuel

سبكيم Sipchem Excellence everywhere

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OQ

Mitsubishi International Corporation

JM Johnson Matthey Inspiring science, enhancing life

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CARBON RECYCLING INTERNATIONAL

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SCC Southern Chemical Corporation

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YCI METHANOL ONE

FUELSAVE GREEN TECHNOLOGY

GasTechno ENERGY AND FUELS

mmsa

neo-H2

IMTT

Palcan

NU INNOVATION WORKS

IGPMethanol

TRICON ENERGY

GANE ENERGY

OLAHMOTORS

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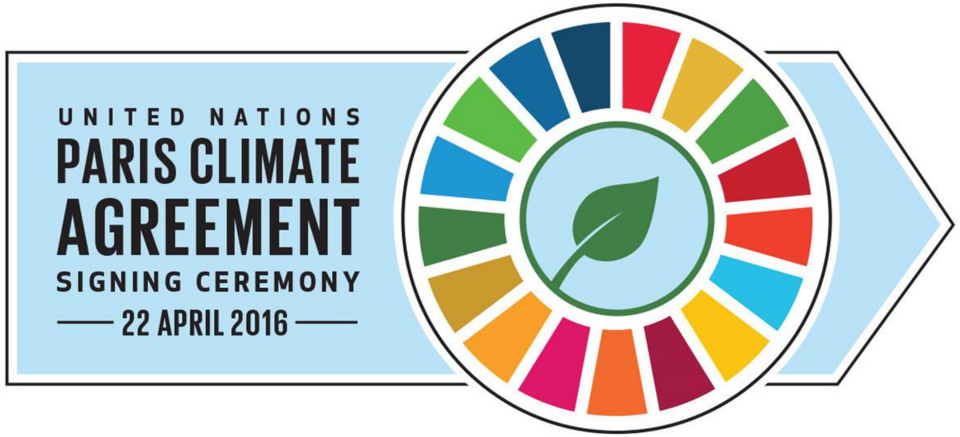
Nebraska Public Power District

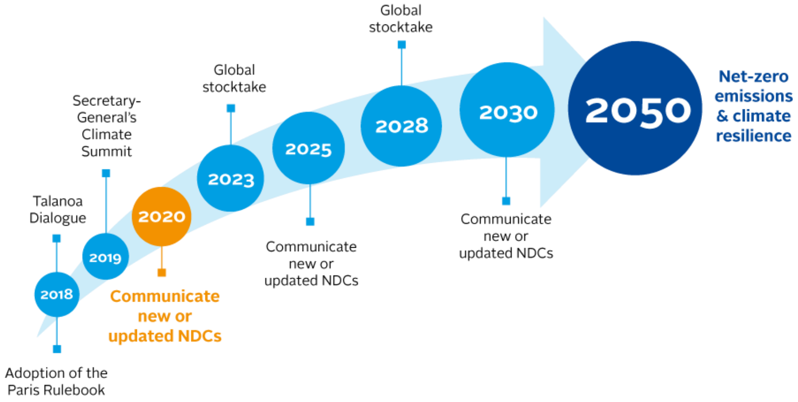
Facilitating Increased Sustainability

- MI supports the spirit enshrined in the UN Sustainable Development Goals (SDGs) and UN Paris Climate Agreement by
  - Acknowledging the need for public-private partnerships that foster sustainability of environments, economies, and societies;
  - Advocating for the recognition of alternative fuels as well as their commercial viability driven by government policy to "*level the playing field*"
  - Support technological developments that enable sustainable production of methanol



- Methanol is largely produced from natural gas, an important starting point for the transition to clean and sustainable fuels for marine and land transport, as well as feedstock for petrochemicals in the circular economy.

AMBITION MECHANISM IN THE PARIS AGREEMENT



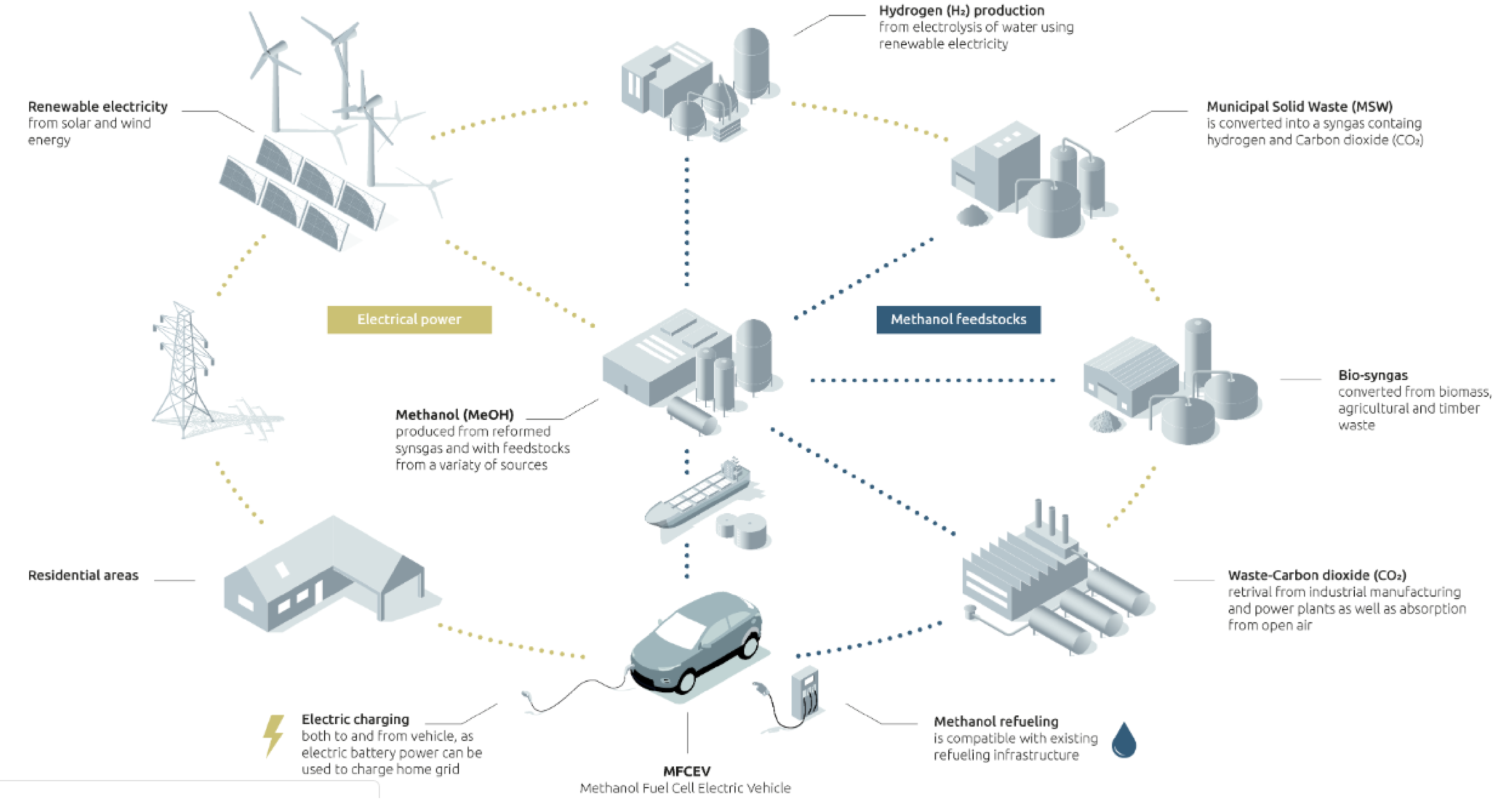
Source: wri.org/publication/NDC-enchancement-by-2020

Carbon and Waste Circularity

Lowers greenhouse gas emissions through carbon capture

Diversifies waste management by diverting waste from landfills and incinerators

Value creation



MI Materials on Methanol Production

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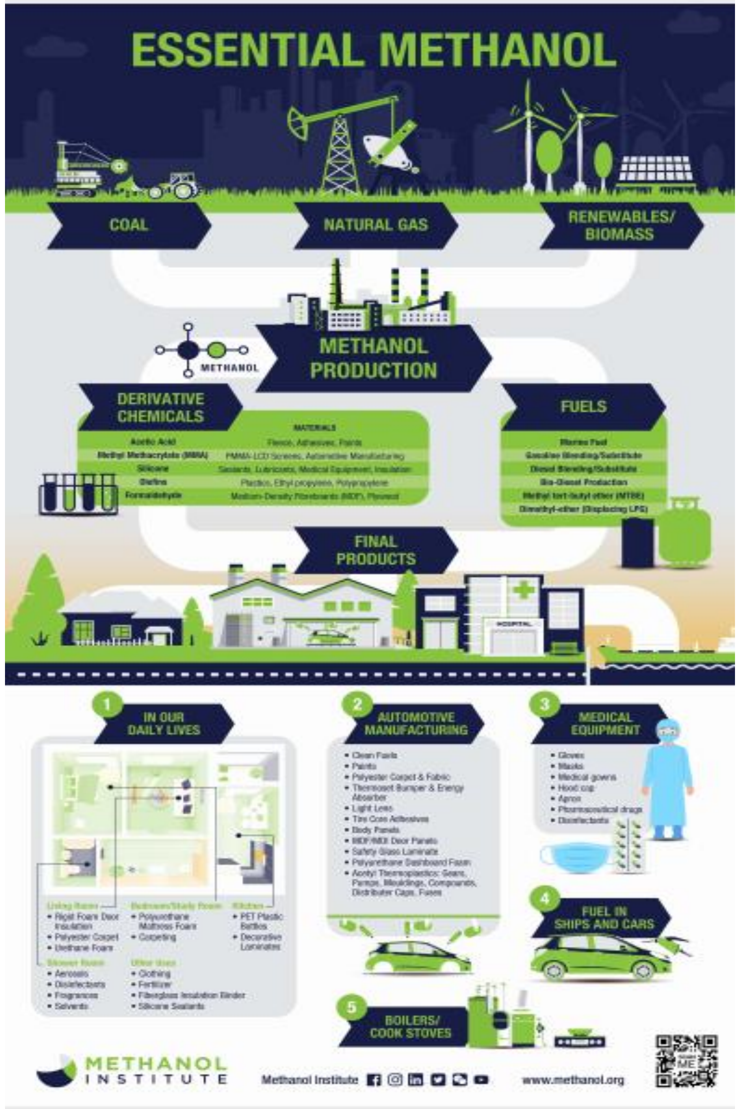
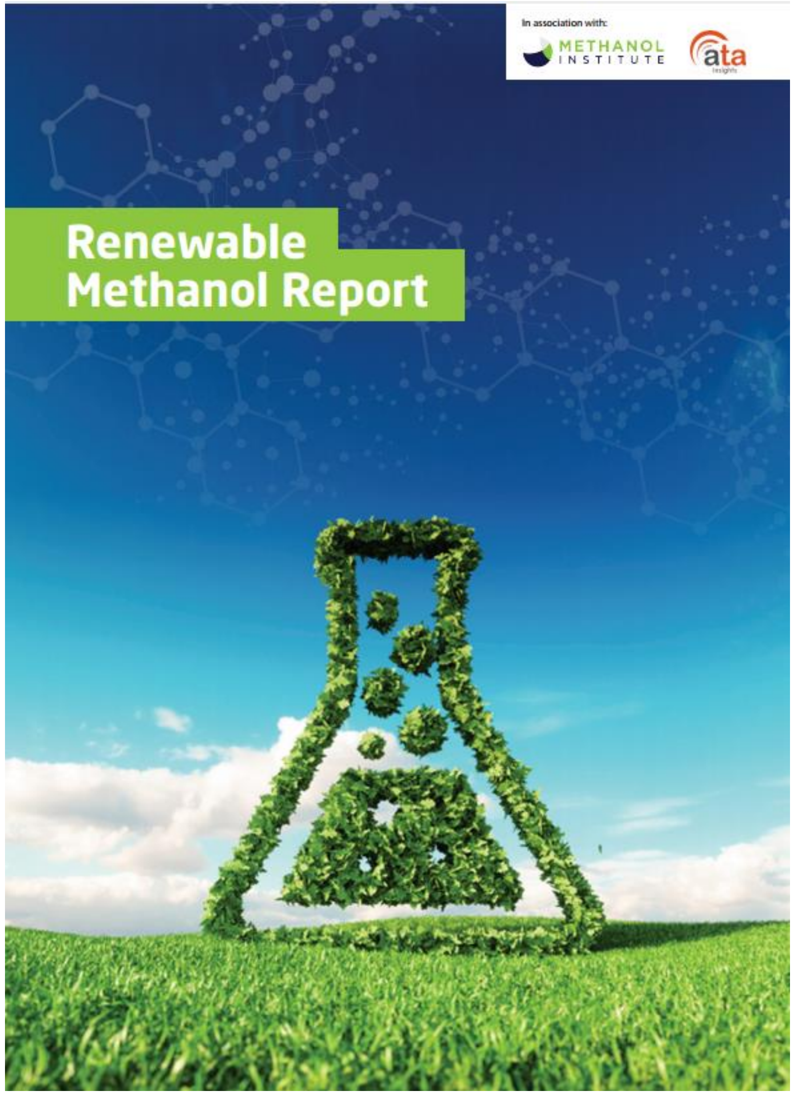
MI materials are ready for download from the GoToWebinar control panel, under ‘Handouts’ drop-down menu.





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Catalysing Renewable Methanol

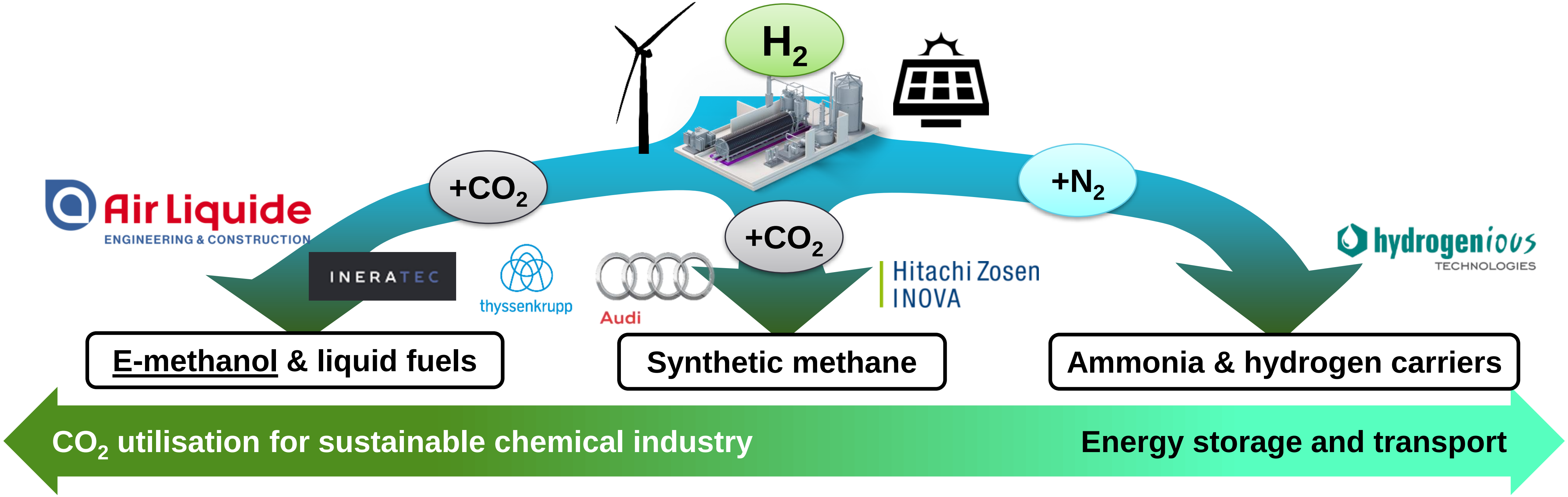
THOMAS COTTER

CLARIANT CATALYSTS

what is precious to you?

CLARIANT

Together with partners, Clariant offers solutions across the Power to X landscape



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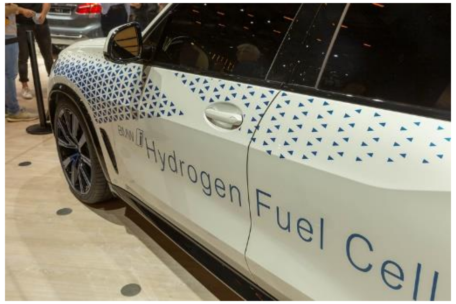

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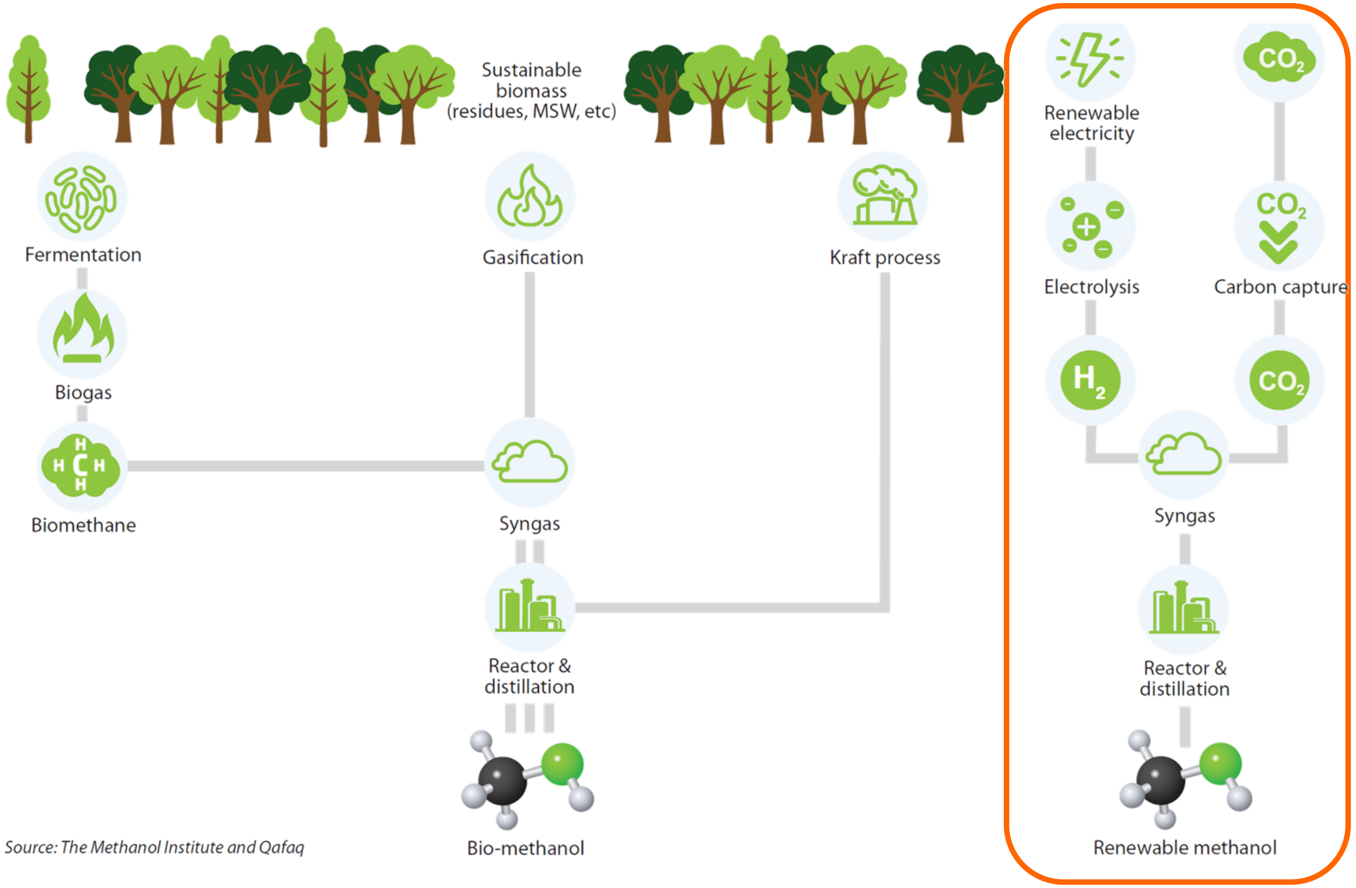
We will see significant growth in renewable methanol as synthetic fuel markets mature



Source: The Methanol Institute and Qafaq

Power-based fuels are forecast to consume ~3000 TWh of renewable energy by 2050*

- Equivalent MeOH: 200-300 million MT/a
- 15-20% of green H_2 → liquid fuel production

2020s
- CO_2 from industrial sources
- First significant PtL projects 2025

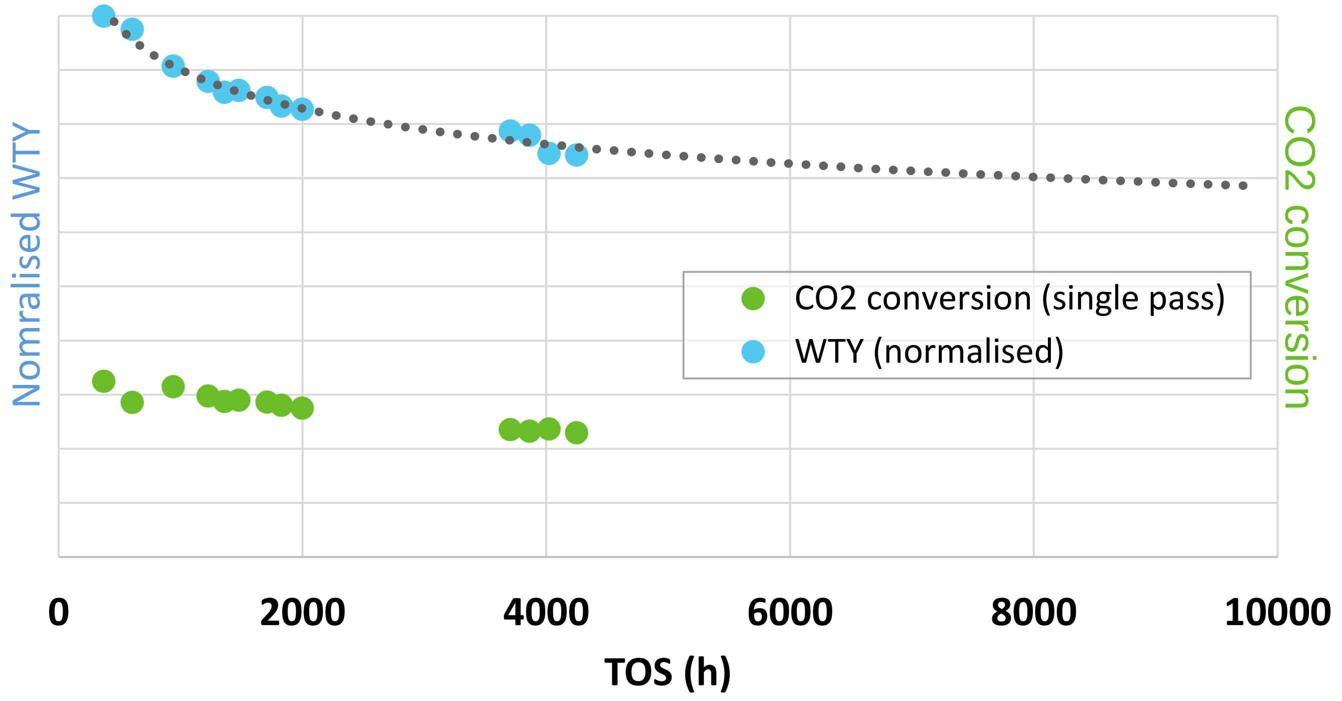
2030s
- CO_2 from MSW/biomass processes
- Strong growth in PtL with wind & solar

2040s
- CO_2 from Direct Air Capture
- PtL dominates due to biomass limitation and fossil phase-out

*ETC report (2018): Mission Possible - Reaching net-zero carbon emissions from Harder-to-abate sectors by mid-century

Clariant's MegaMax® 800 is THE commercial catalyst for CO_2

MegaMax® 800 operating in CO_2/H_2 conditions at Air Liquide



- MegaMax® 800 demonstrated over >4000h using pure H_2/CO_2 feed at Air Liquide pilot unit
- Commercial catalyst design for constant productivity and long lifetime
- Expected lifetime performance > 2Y
- Guarantees available for agreed process conditions

- Clariant is ready to offer catalyst in new processes for CO_2 to methanol
- We support adaption of existing methanol processes
- Commercial output and reliability under flexible conditions

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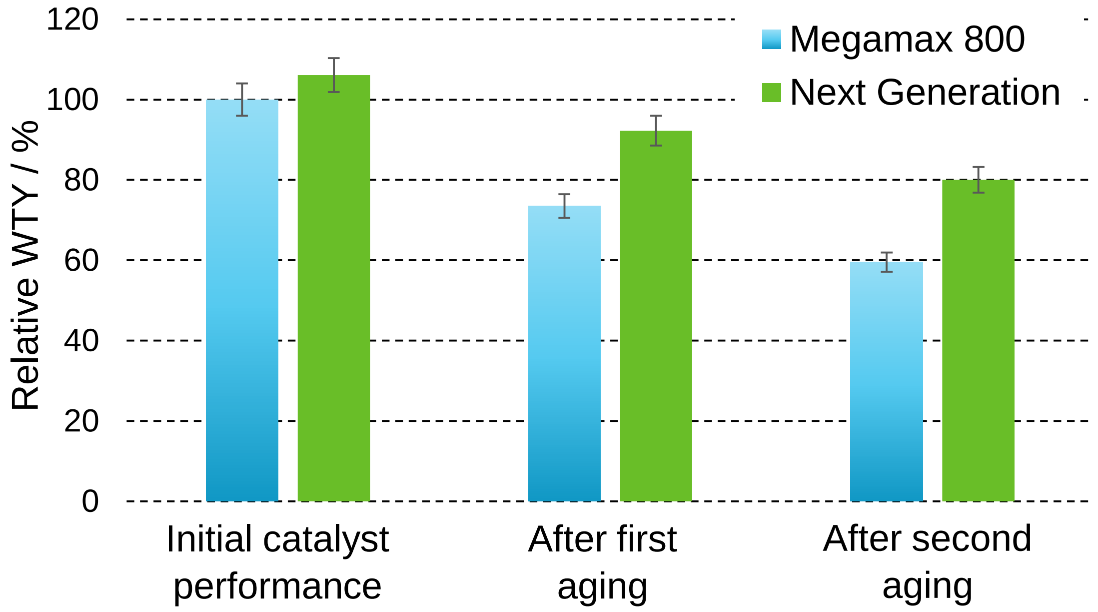
Clariant's next generation catalyst enables lower cost operation with improved productivity and lifetime

Benchmark performance of Clariant CO_2 → MeOH catalyst



- Piloting and lifetime testing
- Customer sampling and feedback
- Scale up and process demonstration

Clariant's offering

New CO_2 → MeOH catalyst:

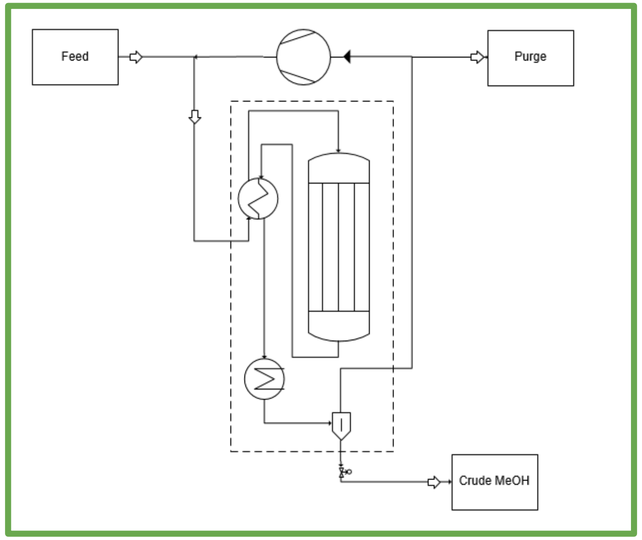
- **Highest productivity** in new process designs
- New process designs: **lifetime 4 years**
- Drop-in potential >3 years with **increased productivity** compared to existing products

- Clariant's next generation catalyst for CO_2 based on new material composition
- Outperforms previous generations and benchmarks in accelerated aging conditions

<u>Piloting and customer sampling will be carried out in 2021</u>

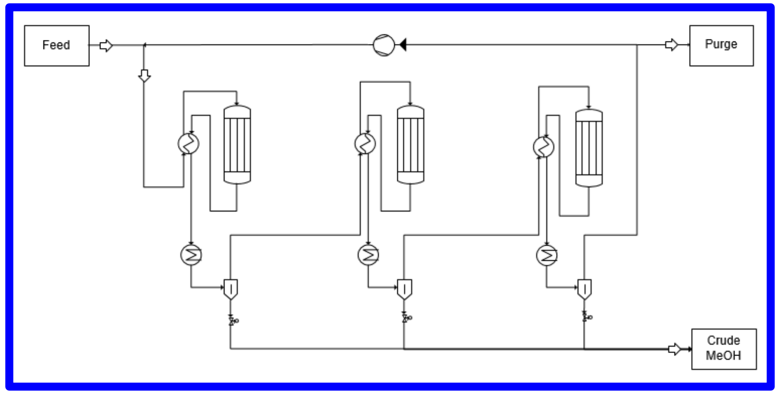
Air Liquide's 2nd Generation process using Clariant catalyst is the best choice for low-cost and high productivity

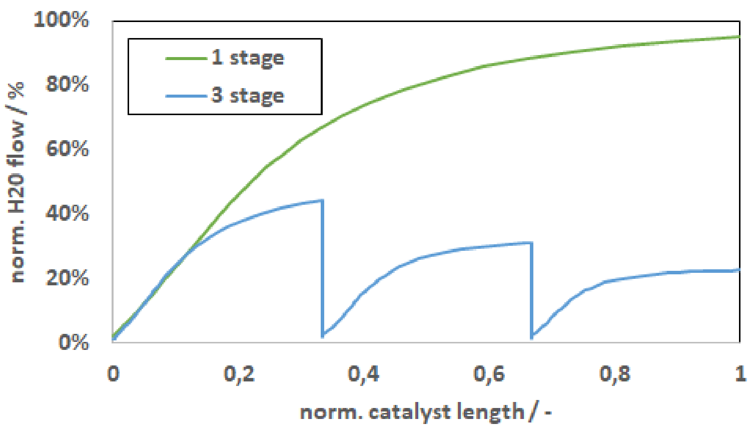
1 stage (1st generation)



Current process technology from Air Liquide with Clariant's MegaMax 800 is suitable for CO2 conversion with commercial performance and process stability

3 stages (2nd generation)





Multi-stage process with inter-condensation:

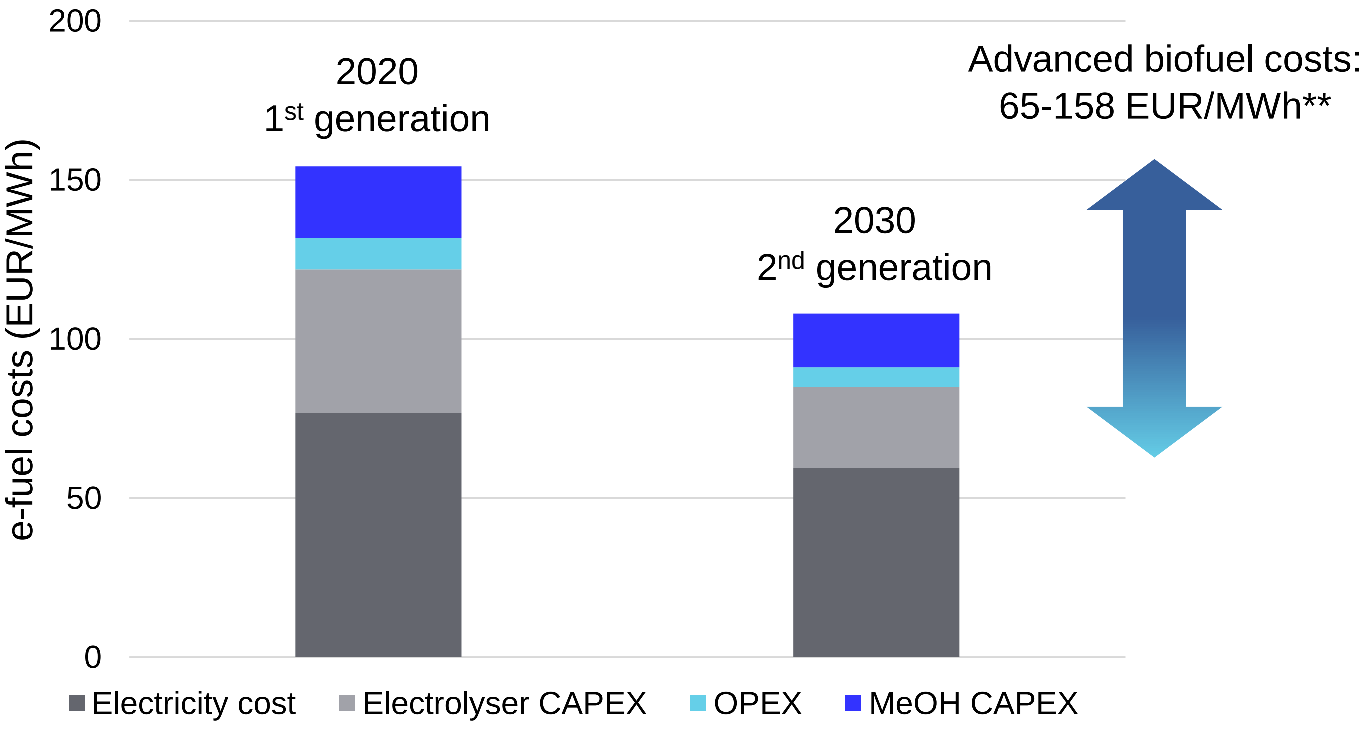
- higher (single pass) conversion
- lower gas recycle (4.6 -> 1)
- less H_2O flow on the catalyst
- smaller & standardized equipment

Air Liquide's 2nd Generation design:

- ✓ Dedicated for CO_2 and H_2
- ✓ based on maximum H_2 efficiency
- ✓ Cheapest green methanol solution with **20% lower CAPEX**
- ✓ Increased catalyst lifetime
- ✓ Increased space time yield

New catalyst and process technologies will enable PtL economics competitive with advanced biofuels

Case study: MeOH costs for 80kTa (100MW) P2MeOH plant



- Existing market in EU with growing mandates for transportation fuels set out in the Renewable Energy Directive (RED II)
- Advanced biofuel costs vary widely depending on technologies and feedstocks
- Demand for low-carbon fuels will exceed available supply of low-cost biofuel sources
- Process innovation and efficiency gains make power-based methanol an attractive investment

*Internal cost model. Assumptions: RE = 38€/MWh(2020) / 30€/MWh(2030)| EL_{CAPEX} = 1000€/kW(2020) / 600€/kW(2030) | η_{eff} = 75%(2020) / 80%(2030) | EOH = 8000h/a | Depr. 15y | Interest rate = 14%

**IEA Bioenergy: Advanced Biofuels – Potential for Cost Reduction: https://www.ieabioenergy.com/wp-content/uploads/2020/02/IEABioenergy-2pSummary-CostAdvancedBiofuels.pdf

Opportunities in Renewable Methanol

CO_2 → MeOH AVAILABLE NOW

MegaMax® 800 for new or existing plants

Drop-in solutions possible with modification

PROFITABLE PATH TO RENEWABLE MeOH

Power-based methanol production can compete with biomass derived fuels

No need for syngas generation or upgrading

Very low by-products → lower separation costs

HIGHER EFFICIENCY AND PRODUCTIVITY

Next gen catalyst offers standard process lifetimes with optimised performance

Air Liquide process technologies and Clariant catalyst offer lower total cost of ownership

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Sustainable Methanol Production

Yawar Abbas Naqvi, Business Development Director

Methanol Institute, 5th August 2020

HALDOR TOPSOE

Haldor Topsoe in brief

Full range of products & services

Chemical Processing

Hydroprocessing

Emissions Management

Process design, engineering & licensing + High-performance catalysts + Proprietary equipment + Business & technical services

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Drivers and Trend for sustainable methanol
Global energy transition and decarbonization

Necessity

- Environmental Drivers
  - Need to reduce CO_2
  - Need to control air pollution
  - Need to address water scarcity

Policy

- International agreement (G7 & Paris 2015)
  - Reduce subsidies to fossil fuel
  - Subsidised renewable technologies
  - Imposed efficiency targets
  - Increased taxes on fossil fuels and CO_2 emission
- Private sector action to drive decarbonization

Technology

- Ammonia, Methanol and Hydrogen energy source enjoy both rapid growth & technology driven learning curves
  - Wind, Solar PV, Li-on batteries intermediate enabler cost have been falling by 20%, for each doubling capacities.
  - Chemicals have a potentially important role in energy storage
  - Power-to-X fuels and chemicals can be immediately used in existing infrastructure, once they are technologically and commercially viable

eMethanol^{TM} across various sectors for greenhouse gas reduction

Industry

Feedstock for chemicals

Transportation

Ships

Trucks

Aviation

Energy

Energy carrier/long term power storage

Back-up power plant

How do we make Methanol?

Steps towards carbon-neutral production

NG Based: SMR

Coal Gasification

- Steam methane reforming of Natural Gas or Goal Gasification
- 95% of all current MeOH production
- < 0.3 Ton of CO_2 emission for each ton of MeOH

SMR: steam methane reforming

NG + RES + CC(U)S/CO_2 import: SynCOR

- Well proven concept, not yet practised, but significant attention lately
- Variable CO_2 emission for each ton of MeOH

RES: renewable energy source
CC(U)S: carbon capture utilization, sequestration

Renewable feedstock

Electrolysis, CC(U)S, Biobased, eSMR

- Water electrolysis is a derivative of proven chlorine electrolysis, with decade of experience
- Carbon neutral/negative MeOH production

eSMR: electrified steam methane reforming

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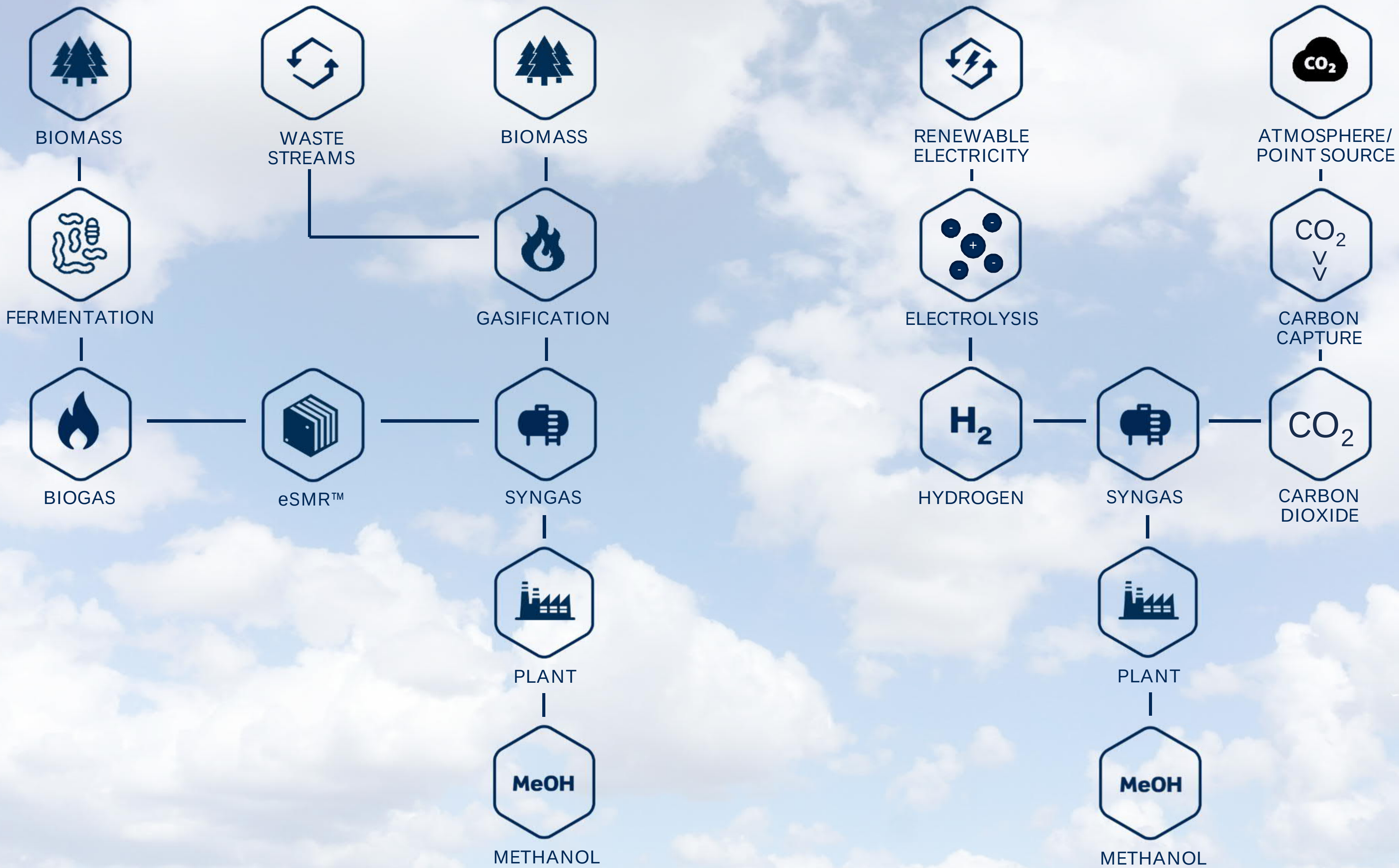
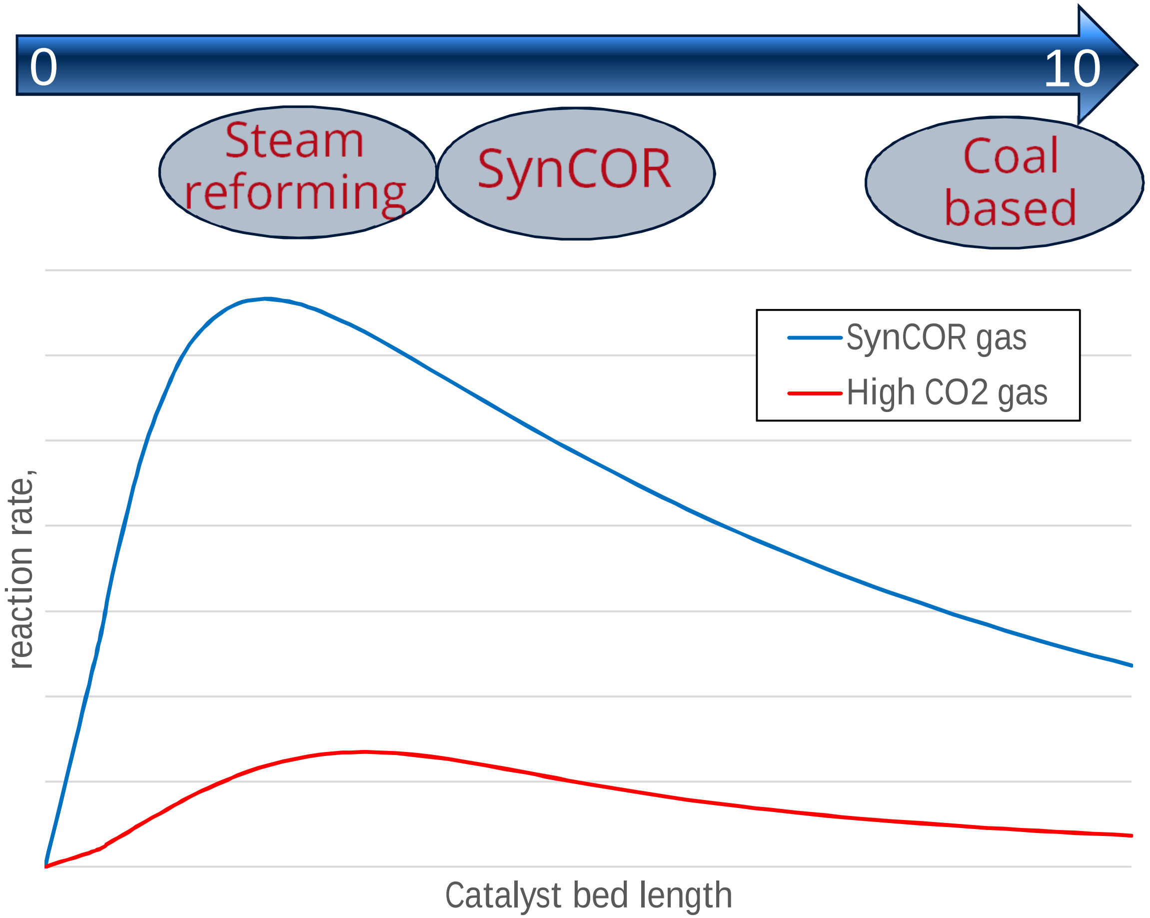
eMethanol™ processes from different feedstocks



eMethanol™ plant configuration and MK-317 SUSTAIN™
> 20 years of experience with CO_2-rich gases

Reactivity of feed gas - CO/CO_2



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Liquid Wind – Sustainable methanol based on eMethanol™

Methanol produced from captured CO_2 and Hydrogen from water electrolysis.

Based on Topsoe's eMethanol™ technology and dedicated catalyst MK-317.

Anchored in local community with available renewable power, local industry and Swedish framework for off-take.

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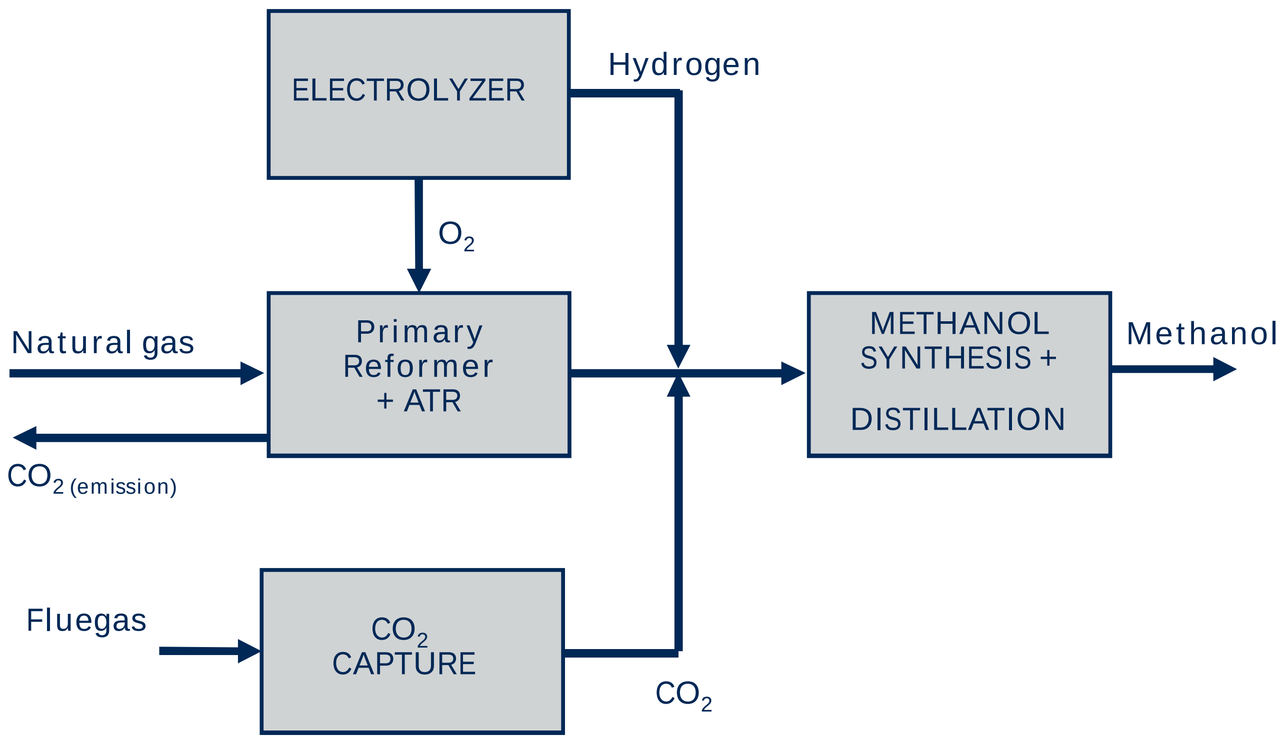
Case study – New Hybrid plant



Case	Hybrid plant	eMethanol CO_2+H_2
Electrolyzer	Same size	
CO_2 Capture	1 std unit	
NG frontend	Yes, 2-step	No
Scale, Methanol	1000 MTPD	280 MTPD
CO_2 emission (tons/tons MeOH)	- 0.1 (negative)	- 1.4 (negative)
Break Even price,	150 *)	300 *)

*) Approximative figures

Market price in Europe: 100 base (June 2020)

NG price = European

Electricity cost= 29 EUR/MWh

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Topsoe brings a wealth of competences for renewable chemicals and fuels

- Topsoe Fuel Cell
- Commercial CO_2 electrolysis technology
- Demonstrated water and co-electrolysis

- Technology Licensor and catalyst supplier for existing fuel market
- Has technology and catalyst for future fuels

- Long standing relationship with ICE OEMs

- Experience from more than 20 pre-projects and project developments (renewable technologies)

- > 50% for renewable diesel
- > 50% for ammonia
- > 30% for methanol

- Technology licensor & Catalyst provider for SkyNRG, Red Rock biofuels
- Selected as Technology licensor and catalyst provider for Hylios, Liquid wind projects

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Thank you for your attention!
To find out more or get in contact please visit
info.topsoe.com/emethanol

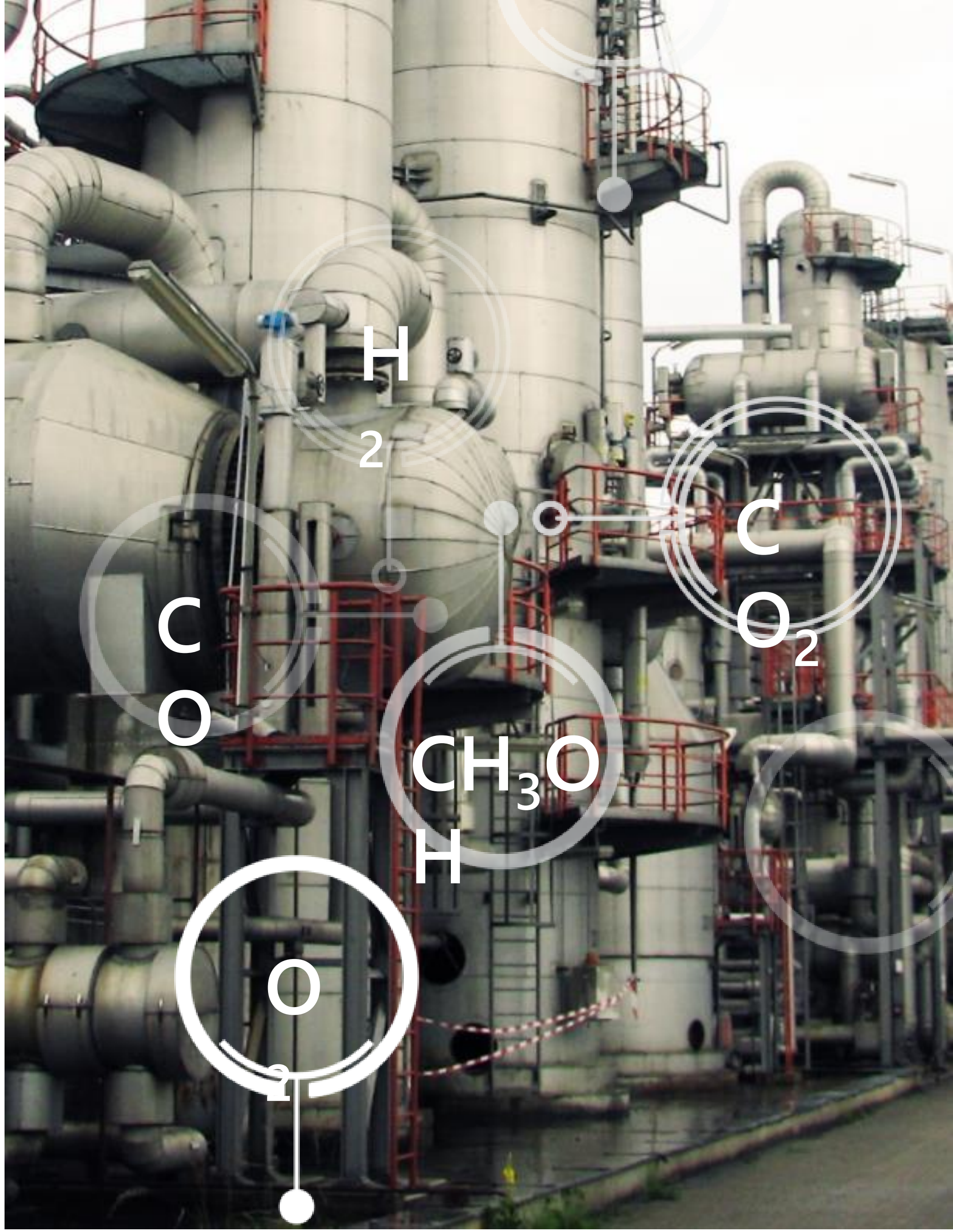
Renewable Methanol

Webinar by Methanol Institute

05/08/2020, bse Engineering Leipzig GmbH

Content

- Developments Decarbonisation in Europe
- Methanol Acceptance in the Transport Sector
- Flexible Methanol Production
- Pricing Mechanism



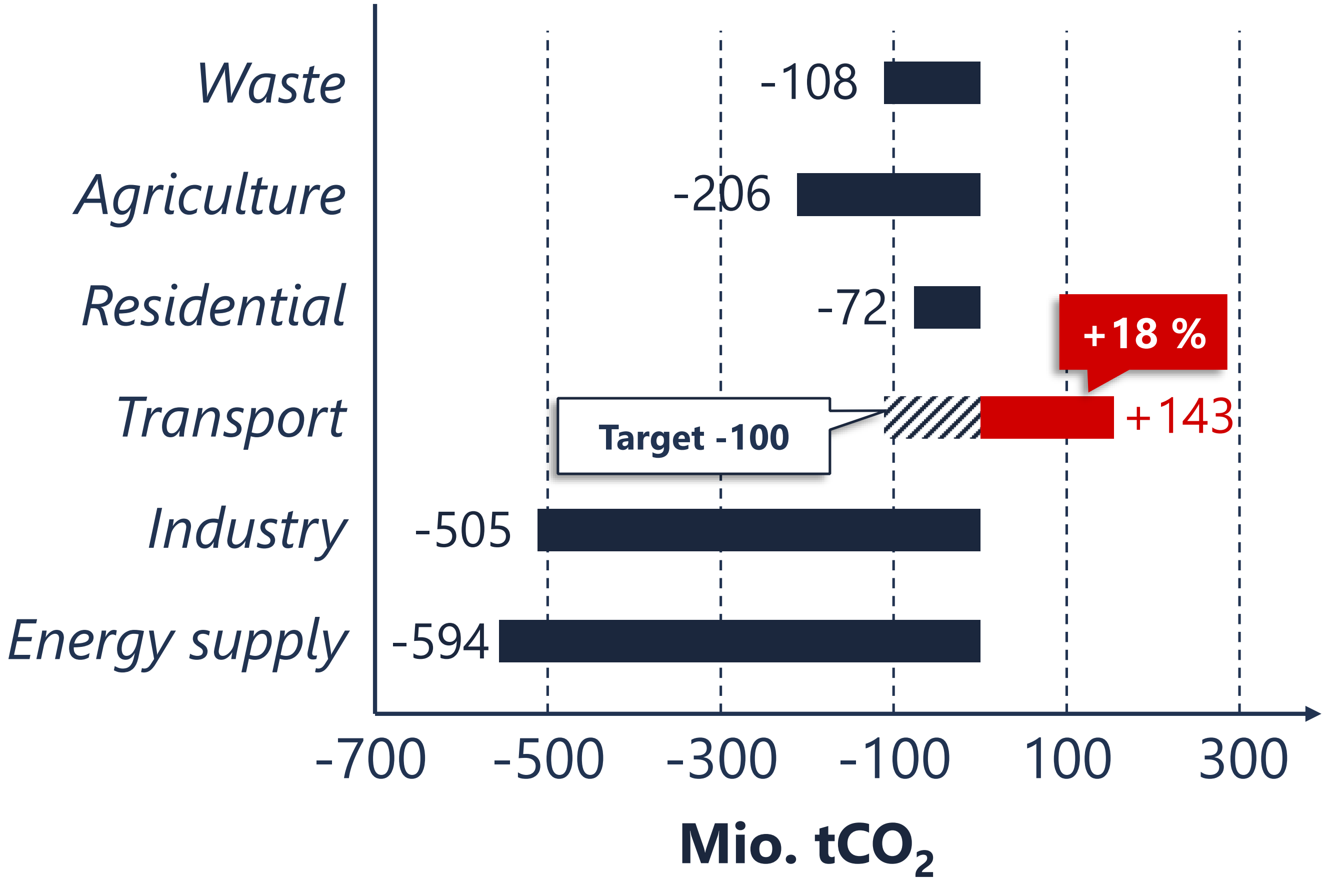
Developments Decarbonisation in Europe

Challenge Transport Sector

Requirement of Significant Emission Reduction

- The transport sector missed the 10 % saving target.
- From 1990-2016 emissions raised by 18 %.
- The focus is decarbonisation of the transport sector.
- Options are e-mobility and synthetic fuels (PtL).

EU-28 GHG Emission 1990-2016
-1,377 Gt CO_2 (-24%)



Regulatory Landscape EU Decarbonization

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Emission Trading System

2005 - 2007	2008 - 2012	2013 - 2020	2021 - 2030
Phase I	Phase II	Phase III	Phase IV adopted
Carbon leakage rules		CCU on member state level	**Continuation, Fewer EUA avaible, CCU practice in EU**

General Trends:
- Less Emission Certificates available
- Carbon Leakage Rules continue
- Combination of sectors Electricity-Fuel-Industry
- Fuel Blending Mandate increase
- 2nd gen. Feedstocks
  - CO_2
  - Waste (fossil and biologic)
  - Renewable Power

Renewable Energy and Fuel Regulations

2009 - 2017	2017 - 2020	2021 - 2030
RED/FQD	Amended RED/FQD in place	RED II adopted
Biofuels and GHGS-Methodology	E-Fuels	**Continuation, Clarification E-Fuels CO_2 and power source**

Megatrends Post-2020

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Low-Carbon Economy 2050 (Update Green Deal)

- Cost-efficient reduction of yearly GHG emissions **50-55%** (by 2030), 60% (by 2040), 80% (by 2050)
- Power sector can almost totally eliminate CO_2 emissions; Industry must achieve 80%

Circular Economy

- Minimise landfilling of waste and increase recycling and energetic utilisation
- Concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material (C-Recycling)

Resource Efficiency

- Turning waste into a resource
- Ensuring efficient mobility

Reindustrialisation and Green Recovery

- Increasing the manufacturing sectors' share in GDP and building up added value in EU

Renewable Energy Sources and Hydrogen Initiative

- Extent the gross energy consumption from 12% to 32% within 10 Years
- **Hydrogen, Sector Coupling, Power-to-X**

Regulatory Landscape Decarbonization in Germany

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Wissenschaftliche Dienste

Deutscher Bundestag

Dokumentation

Dekarbonisierung und Sektorkopplung

Deutscher Bundestag (Federal German Parliament) about **Power-to-X synthetic fuels 2017 to 2050**:

„[…]
Need of electrolyser to generate hydrogen with a capacity of 15 – 30 Gigawatt **and synthesis plants to convert hydrogen into synthetic gases and fuels with a capacity of 15 – 45 Gigawatt**." Page 23

BEHG - Fuel Emission Trading Act
The supplier of fossil fuels is obligated to pay a CO_2 fee from 2021 on (price 10 – 25 €/t). By 2026 the trading system as semi-fee market shall be established in the range of **35 – 60 €/t CO_2**.

This makes the business case of methanol production from renewable electricity more viable.

National Hydrogen Initiative
Ambition: The Federal Government expects that around 90 to 110 TWh of hydrogen will be needed **by 2030**. In order to cover part of this demand, Germany plans to establish **up to 5 GW of generation capacity including the offshore and onshore energy generation facilities** needed for this.

Source: Publication from 18th June 2018, File code: WD 8 – 3000 – 064/18

Public Acceptance Power-to-X

Author	Publication	Position
CDU/CSU Bundestag Fraction	*Renewable fuels as a contribution to a technologically open mobility of the future* / 07-2019	The Majority of the Federal Parliament acknowleges the need of E-Fuels and supports the implementation beside electric cars.
Global Alliance Powerfuels / DENA - German Energy Agency	*Powerfuels: A missing link to a successful global energy transition* / 04-2019	The technologies for powerfuel production are market-ready. An international powerfuels market provides value for everyone - producers, consumers and enabling countries.
Power to X Allianz	*Market Introduction Program for Power-to-X Technologies* / 04-2019	Power to X achieves effective climate protections and a sucessful technology and industry policy.
World Energy Council	*International Aspects for Power-to-X Roadmap* / 10-2018	Power-to-X is an integral part of the global transition of energy systems.

Conclusion Megatrends

- Wind and photovoltaic electricity is generated regardless of the demand
- Power becomes temporary an unused resource
- Carbon dioxide is an available unused carbon source

- Options to use power when available in:

Battery	Power Storage
Power-to-Heat	Power Sink
Power-to-Fuel	**Transport Sectoral Coupling**
Power-to-Gas	Power Storage for Repowering
Power-to-Chem	**Re-Industrialisation**

Methanol Acceptance in Transport Sector

Why Methanol in the Transport Sector?

Chemical Power Storage

1 cubic meter of liquefied power (E-Methanol) compares with **222** BMW i3 (full electric car)!*

1 m³ Methanol

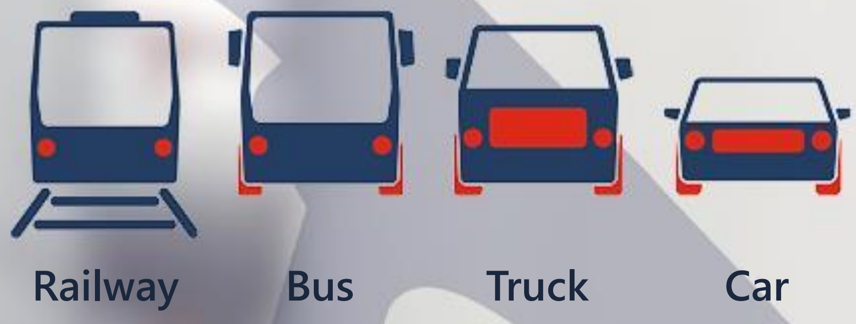
=

*Storage capacity of one BMW i3 first generation battery is 21,6 kWh.

Advantages Renewable Methanol

Value Chain

- Cascade usage of fossil CO_2 and climate-neutral usage of CO_2 from green, air and waste sources
- Contribution to EU blending mandates
- DIN EN 228 conformity with existing use of Methanol in the gasoline sector:
  - Direct Blending as M3 without any adjustments possible
  - Methyl-tert-butylether (MTBE)
- Further fuel applications:
  - Fuel Cell
  - Biodiesel
  - Dimethylether (DME)
- Utilisation without adjustments of the infrastructure possible
- Substituting fossil fuels and biofuels from crops



Methanol is already applicable as fuel without adjustments

Upgrading Methanol

There are different options to upgrade methanol in a refinery:

- Methanol to DME – TRL 9

$$2\,CH_3OH \rightarrow CH_3OCH_3 + H_2O$$

- Methanol to Olefine (MtO) – TRL 9

$$CH_3OH \rightarrow CH_3OCH_3 + H_2O \rightarrow (CH_2))_2 + 2\,H_2O$$

- Methanol to Gasoline (MtG, ExxonMobil-Process) – TRL 9

$$2\,CH_3OH \rightarrow CH_3OCH_3 + H_2O \rightarrow C_2 - C_5 \rightarrow \text{Alkanes, Cycloalkanes, Aromatics}$$

- Methanol to Diesel (via OME) – TRL 3-4

$$CH_3[OCH_2]_nOCH_3$$

Methanol Fuel Passenger Cars

Methanol from Renewable Energy for Mobility with Plug-In Hybrid Cars (PHEV)

MEEMO Objectives:

- Suitability test of eMeOH (M15-M100) in modern gasoline engines
- Examination of exhaust behaviour
- Specification of eMeOH composition
- Component and system adjustments (PHEV)
- Process optimization of eMeOH production acc. to application requirements
- Technical, economical, ecological overall consideration
- Definition of infrastructure requirements for implementation

Project duration:

- 2018-09 – 2021-09

DAIMLER Continental IFKM KIT Karlsruher Institut für Technologie bse engineering

In Cooperation with: BASF We create chemistry

Supported by: Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

Source: www.bse-engineering.eu/methanol-plug-in-hybrid.html

Methanol Fuel Derivates Road Transport

Closed Carbon Cycle MOBILITY
Klimaneutrale Kraftstoffe für den Verkehr der Zukunft

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Closed Carbon Cycle – Mobility Objectives:

- Suitability test of Methanol and Methanol derivates OME/DME in modern gasoline engines
- Examination of exhaust behaviour
- Specification of eMeOH composition
- Component and system adjustments
- Process optimization of eMeOH production according to application requirements
- Technical, economical, ecological overall consideration
- Definition of infrastructure requirements for implementation

Project duration:

- 2018-10 – 2021-10

In cooperation with:

Methanol as Maritime Fuel

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MethaShip

Project Conclusion: „One central result of the project is that synthetic methanol in particular is a **fuel with a future** which offers the potential for implementing an ambitious maritime climate protection strategy. A few technical and financial details still need to be clarified until methanol can be used continuously in shipping.“

Source: www.meyerwerft.de

FuelEU Maritime – Green European Maritime Space

Key Messages: „… ramping-up the production, deployment and uptake of sustainable alternative transport fuels" "… **Energy Taxation Directive** along with a proposal to extend **European emissions trading** to the maritime sector …" "… liquid biofuels and electrically synthesised hydrocarbons have the highest energy density … These fuels are **compatible** with the existing assets and infrastructure (liquid … and can therefore be deployed immediately in existing … vessels."

Source: www.ec.europa.eu

IMO

Acceptance of methyl alcohol (Methanol) as fuel according to the Interim Guidelines for Safety of Ships.

Source: www.imo.org

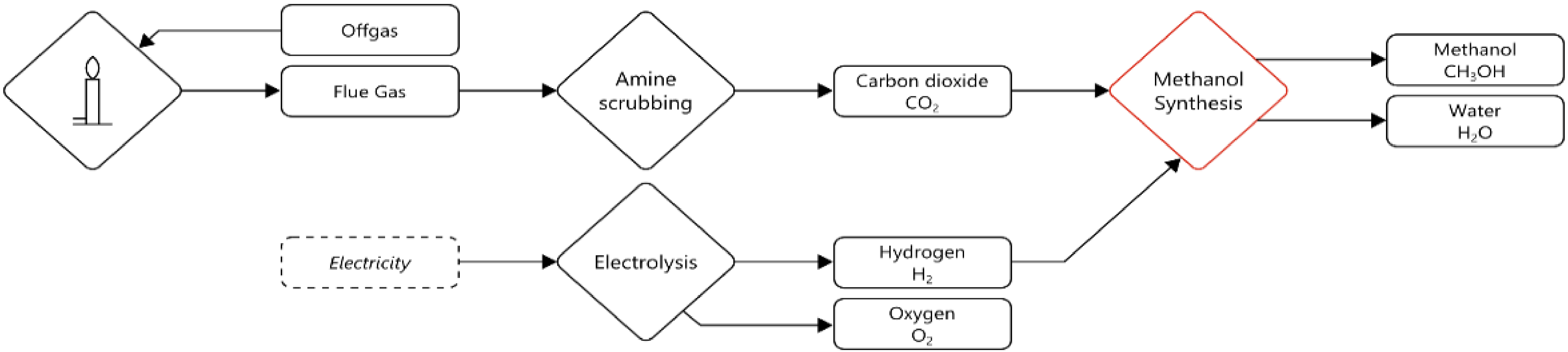
Flexible Methanol Production

Methanol Production from Power

Process Steps of FlexMethanol Synthesis

- Green Power and water is used to produce pure hydrogen and oxygen via electrolysis
- Purification of CO_2 out of the flue gas via amine scrubbing
- Pure gases H_2 and CO_2 get feed to the state of the are methanol synthesis
- No waste streams

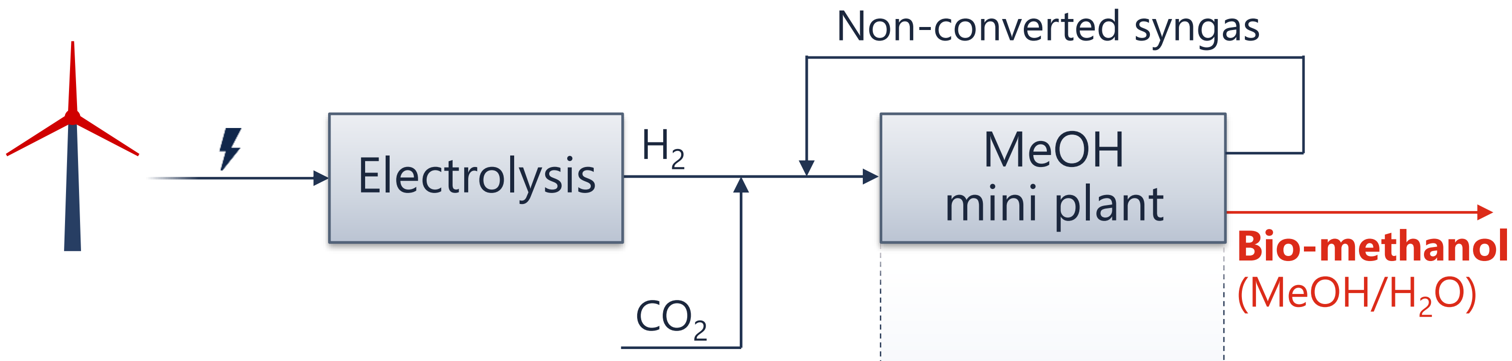
Simple Process – Low Invest – Use of existing Assets



Operating mini plant

Bio-methanol production at IRES (Stralsund, Germany)

- One year operation of dynamic methanol production over BASF catalyst (started May 2020)



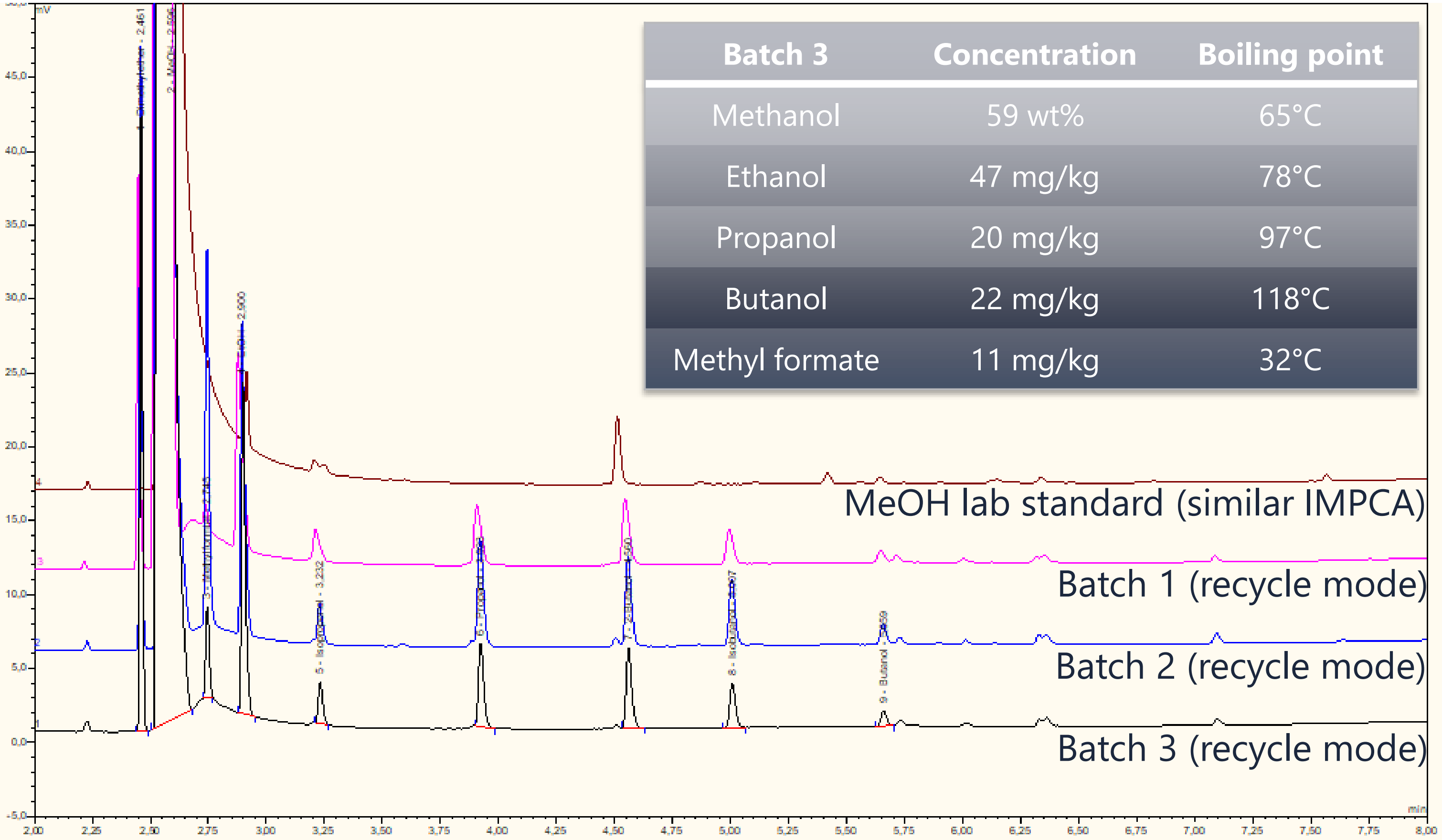
Conditions

- 240°C, 40 bar, H_2/CO_2=3, GHSV up to 7000 h^{-1}
- Recycle loop of non-converted syngas
- 28 l bio-methanol per day
- Dynamic feed supply according to power generation

Operating mini plant

Analysis of produced bio-methanol

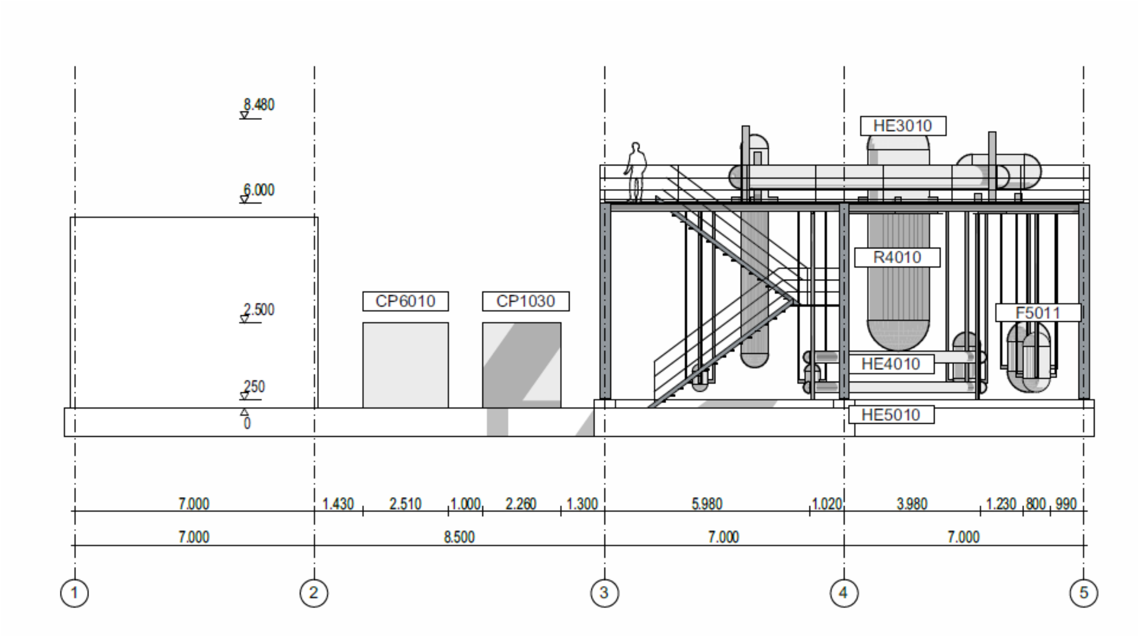
- Crude methanol analysis (GC-FID) in recycle mode



Batch 3	Concentration	Boiling point
Methanol	59 wt%	65°C
Ethanol	47 mg/kg	78°C
Propanol	20 mg/kg	97°C
Butanol	22 mg/kg	118°C
Methyl formate	11 mg/kg	32°C

Methanol Synthesis

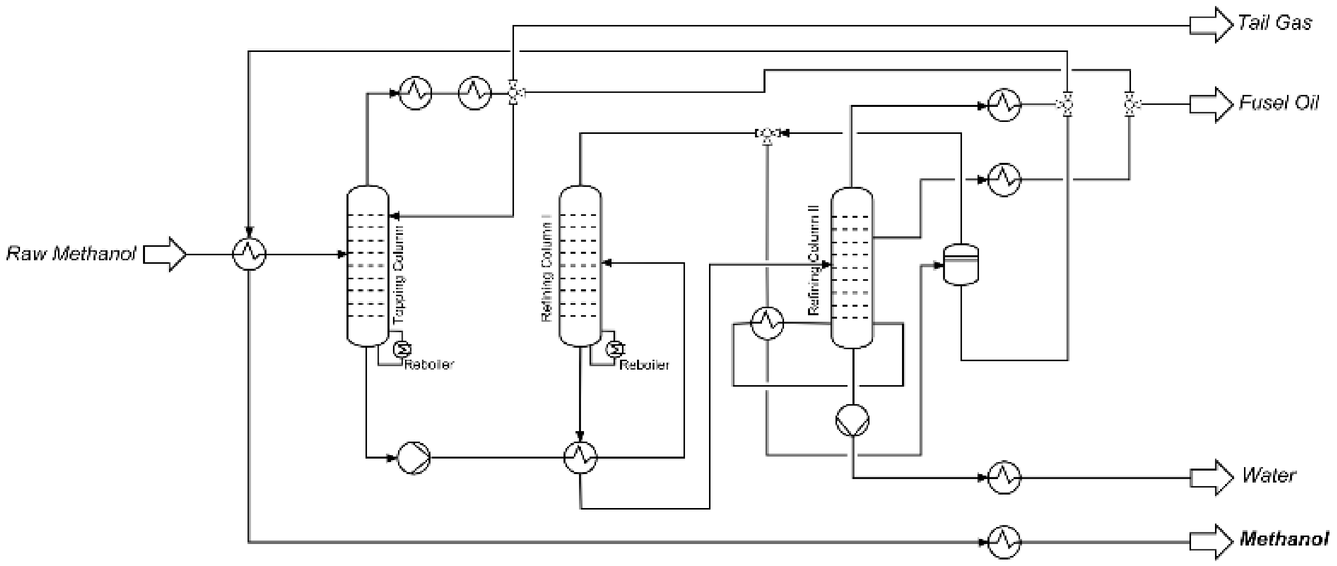
Catalytic exothermic reaction of CO_2 and H_2 to raw methanol



Elevation

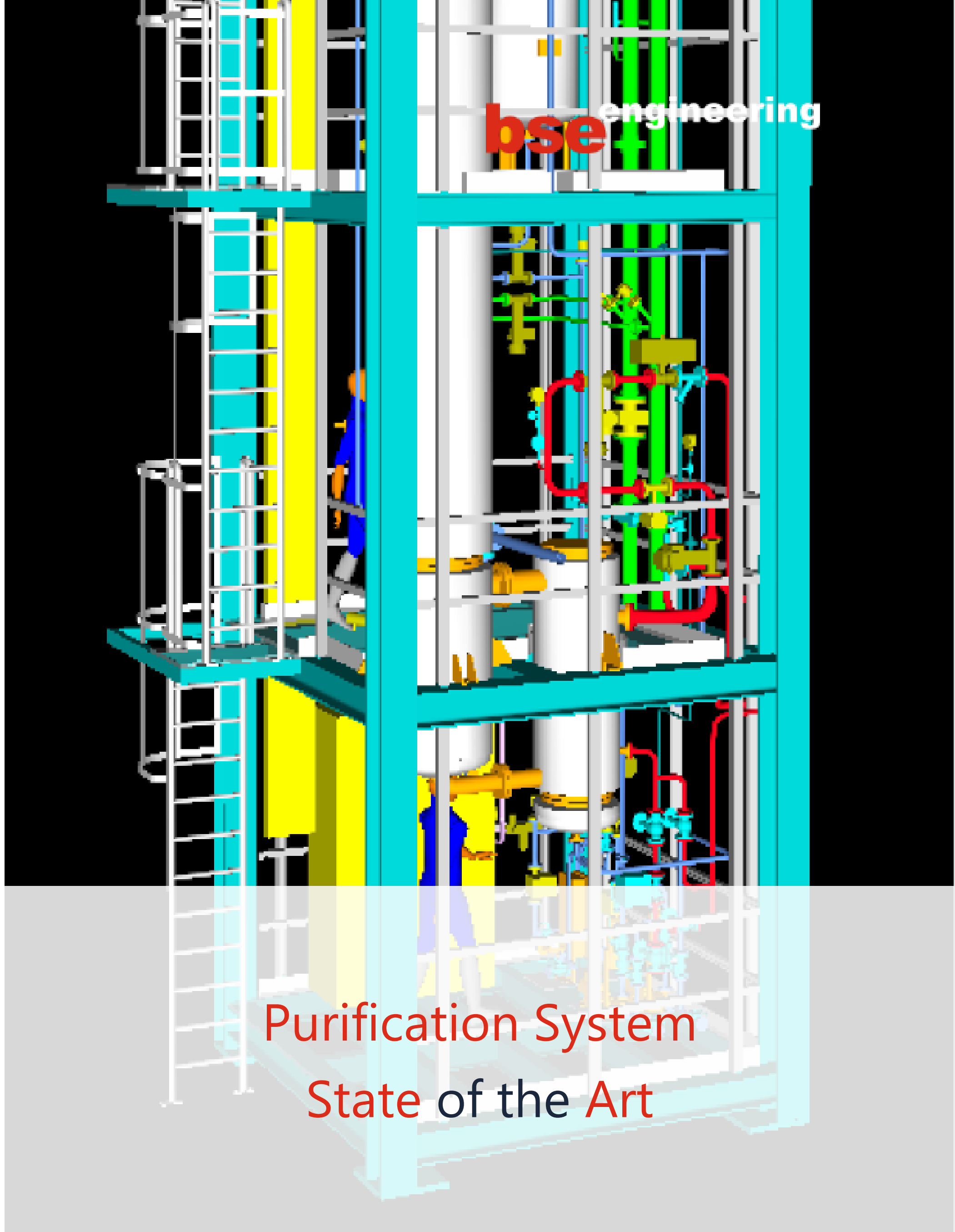
Flexibility range: 10 – 120 %

Methanol Distillation



Topping plus two stage refining distillation
Methanol according IMPCA specification (> 99.85 %w/w)

Flexibility range: 70 – 120 %



Purification System
State of the Art

bse Methanol GmbH

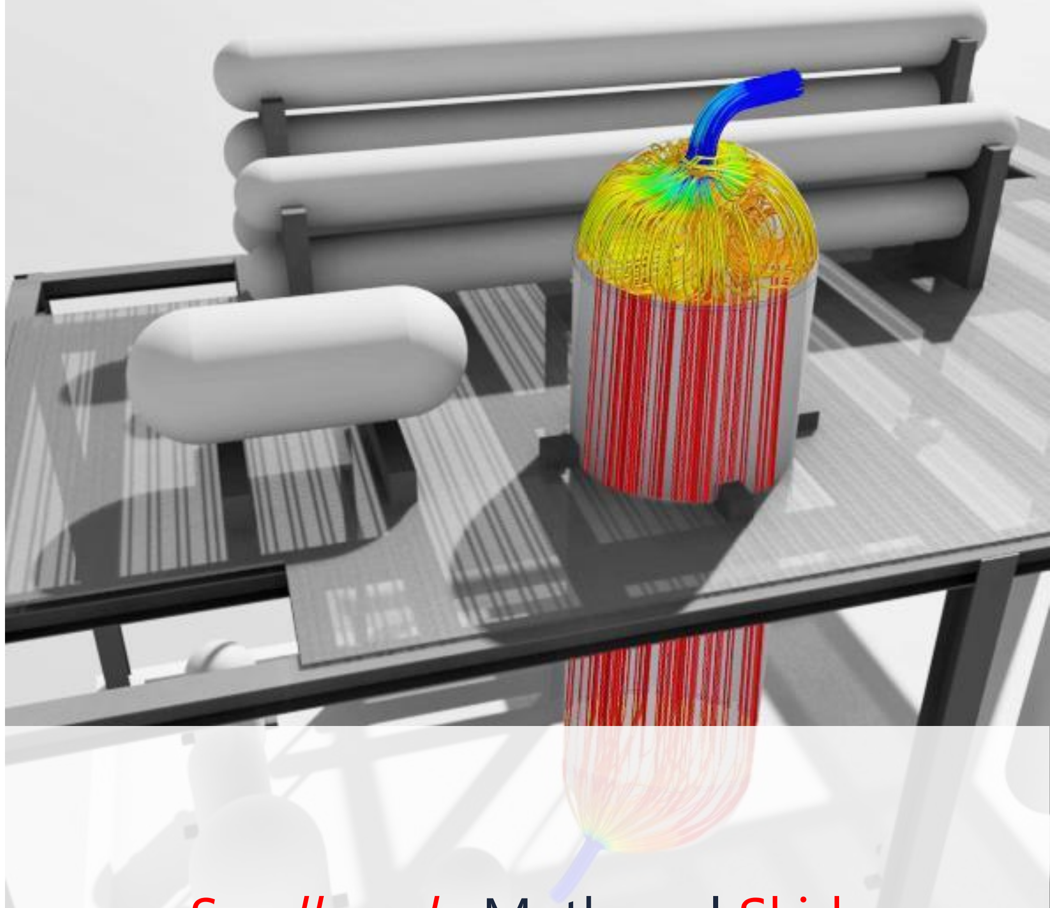
Announcement of Foundation

After six years of development of the business case „Renewable Methanol“ we have now founded
bse Methanol GmbH.

We are sure that now „Power-to-Methanol“ creates a real business case for our clients and that we will supply the Small-scale Methanol as Skids FlexMethanol 10 and FlexMethanol 20.

You are able to reach us now also under

office@bse-methanol.eu



Small-scale Methanol Skids

*Flex*Methanol 10 & 20 by BSE

bse engineering

Ready. Proven. Profitable.

10 – 20
Megawatt
Electricity

€
up to 100
€/MWh
Value of power
on generator

12,000 – 24,000
Tons/year
Carbon Dioxide savings

8,200 – 16,400
Tons/year
Methanol

13,000 – 26,000
Tons/year
Oxygen

17,500 – 35,000
MWh/year
Heat Potential

Scalable plant for your needs!

*Flex*Methanol by BSE

bse engineering

Ready. Proven. Profitable.

Mild process conditions
Low pressure 40 bar, 240 °C

No water-gas shift reaction
There is no need for capital cost intensive Steam Reforming

Proven methanol catalyst from BASF exclusive delivered by BSE
Supply secured over aftersales contract

No hydrogen compression
Electrolyzer works on pressure stage of methanol synthesis

Skid-mounted & pre-fabricated units
Thus short construction time and short start-up time

4 industrial available process steps
Reduction of technical and operational risks

No tars, no waste
Methanol synthesis works on pure gases without any impurities

Price Mechanism

Methanol Pricing Mechanism

bse engineering

Green Premium in Germany

The value of Renewable Methanol is determined by Article 37 Immission Control Act (BImSchG).
The specific penalty of non-compliance with the blending mandate of Renewable Fuels in the transport fuel sector amounts 0,47 €/kg CO_{2equ}. Taking the Greenhouse Gas Saving of Green Methanol into account, then the premium for Renewable Methanol is 831 €/t plus energetic value.

Comparison of the Cost Price for Biomethanol from Biomethan

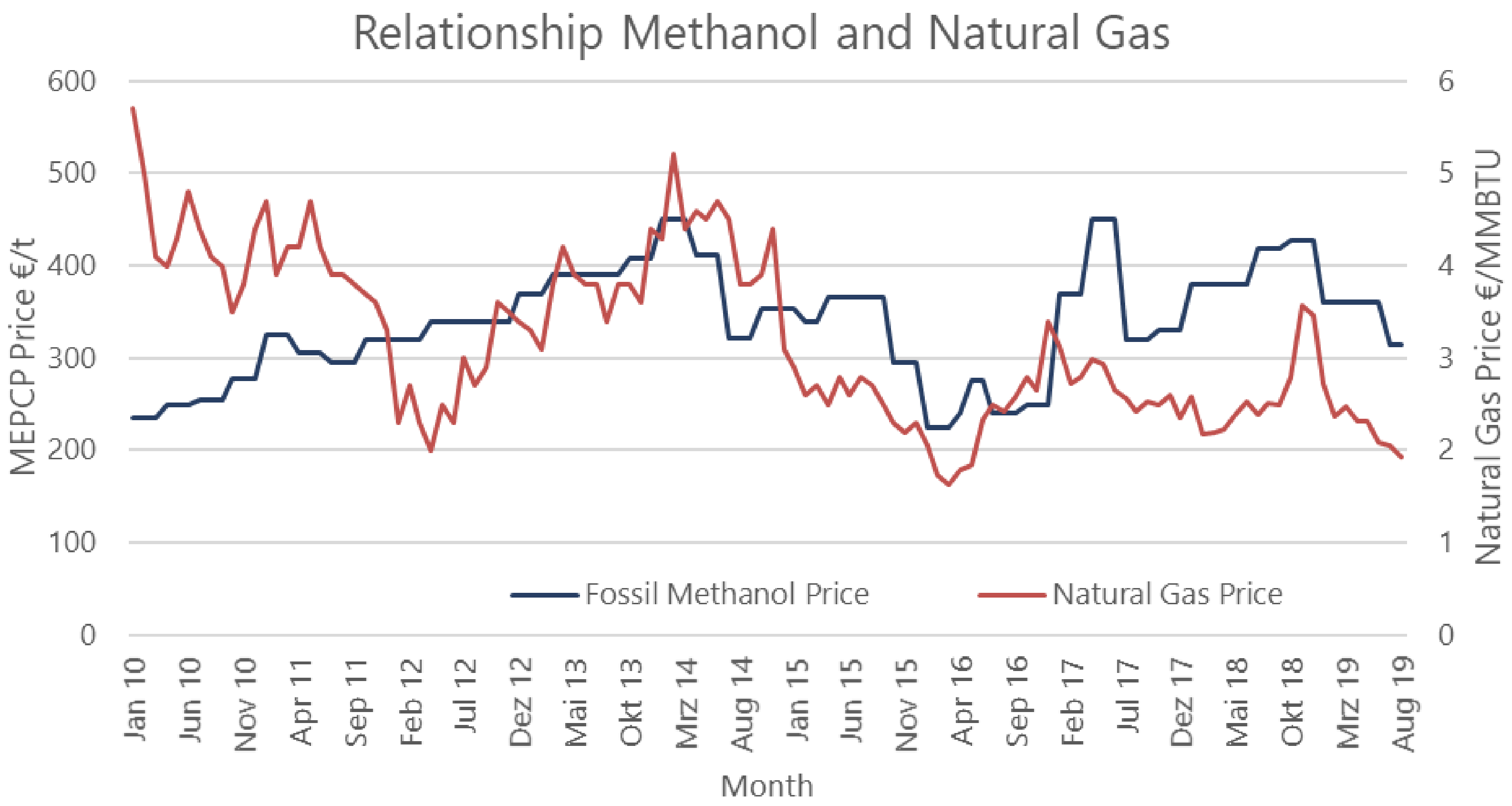
Feedstock	Price	Efficiency	Feedstock Costs	OPEX Methanol	Cost price Biomethanol
Renewable					
Biomethane	70.00 €/MWh	70 %	551.00 €/t	130.00 – 150.00 €/t	681.00 – 701,00 €/t

Methanol Pricing Mechanism

bse engineering

Interaction between methanol price and natural gas price is not applicable for Renewable Methanol.

To learn more about the pricing of Renewable Methanol or to create a Busines Case contact us!



We are supported by

DECHEMA

Methanol Institute

DLR Deutsches Zentrum für Luft- und Raumfahrt

IHS Markit

Bundesministerium für Bildung und Forschung

Bundesministerium für Wirtschaft und Energie

Umwelt Bundesamt

Our Partners

In cooperation with BASF We create chemistry

AkerSolutions

SULZER

bse Engineering

Thank You

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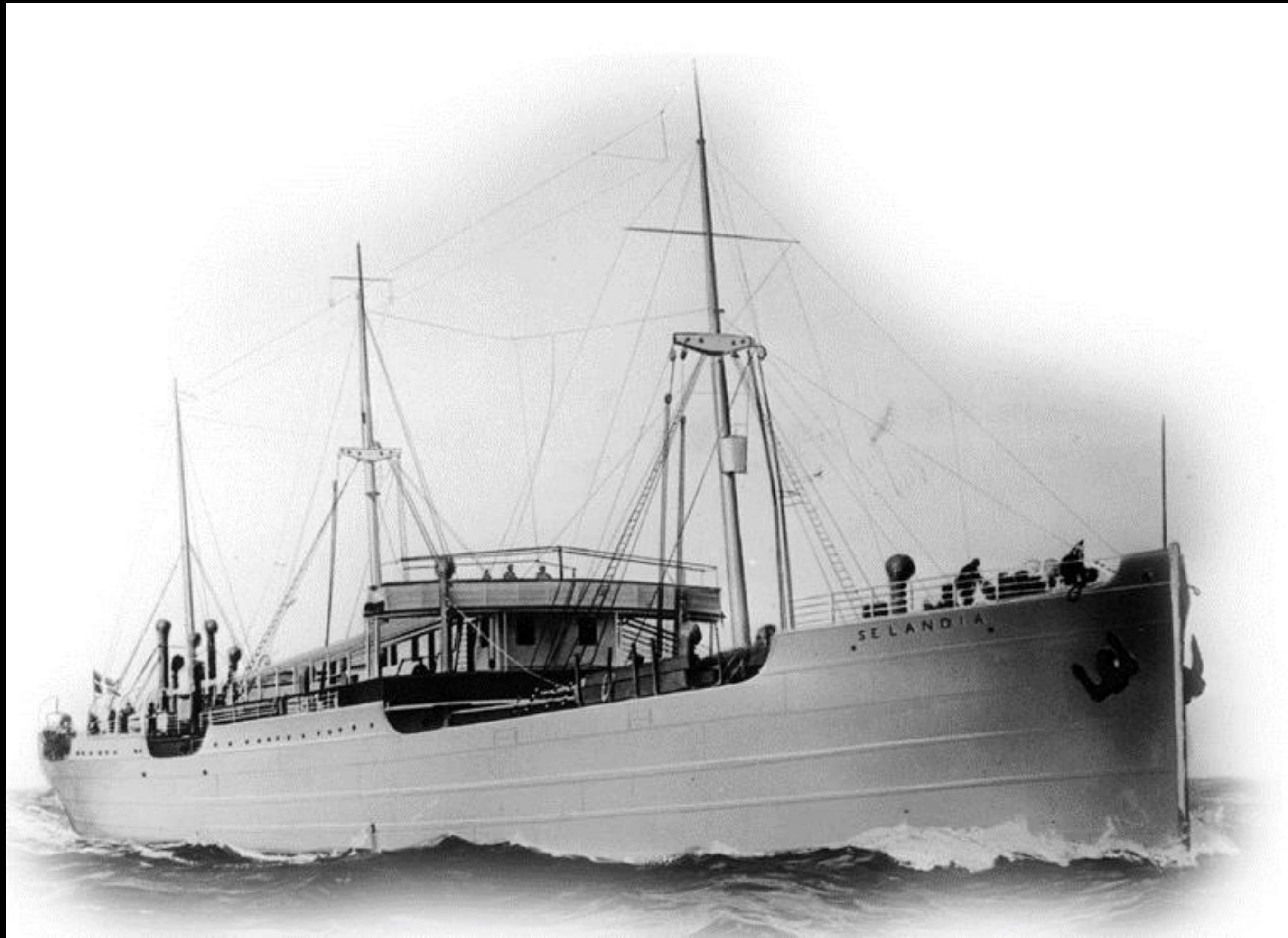
Electro Fuels Generational Innovation

A ship to change the world

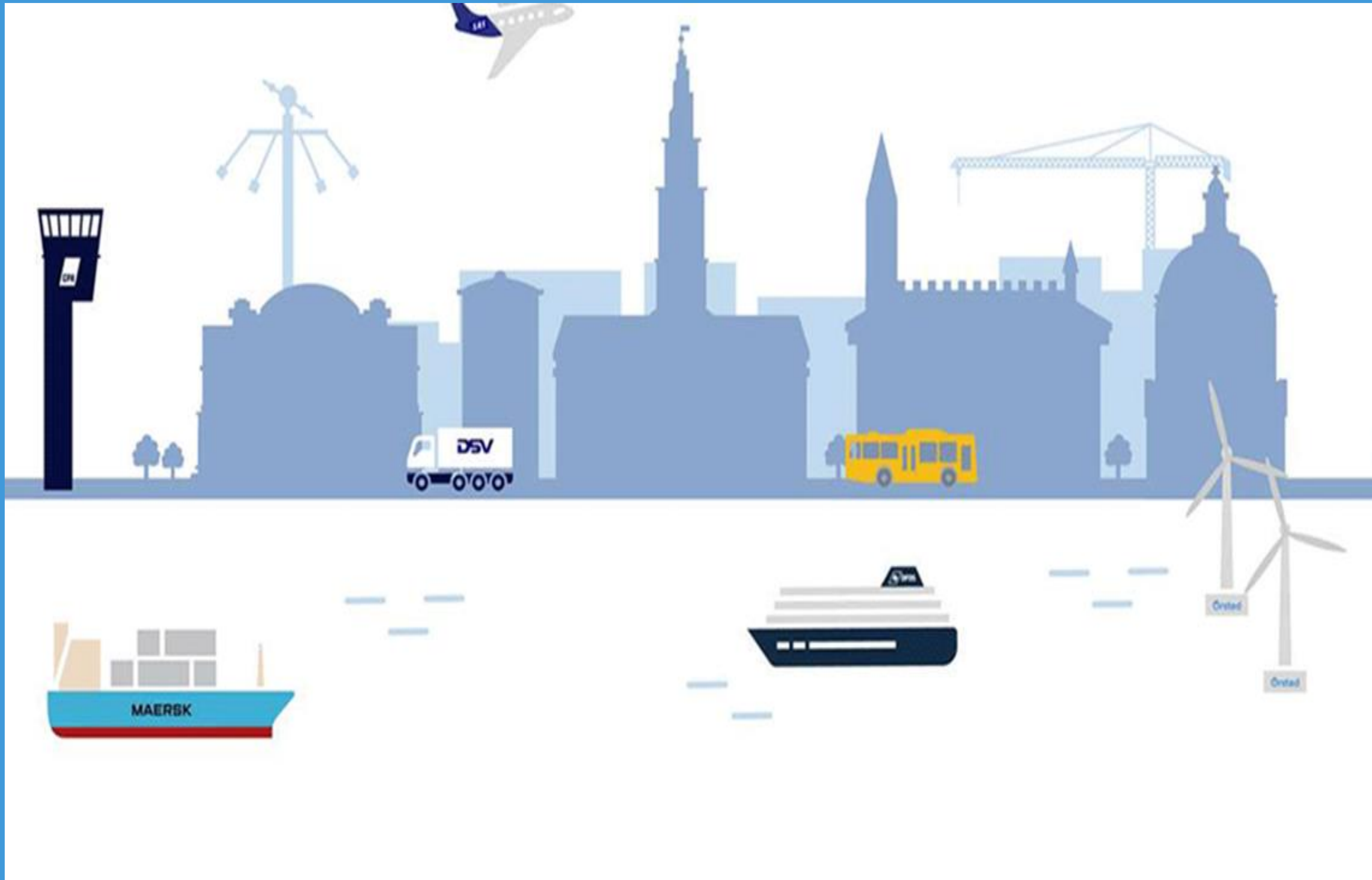
Denmark 1912



1912 the Selandia first sailed from Copenhagen, ushering in the bunker fuel innovation, and made the old coal burning steam ships out-of-date

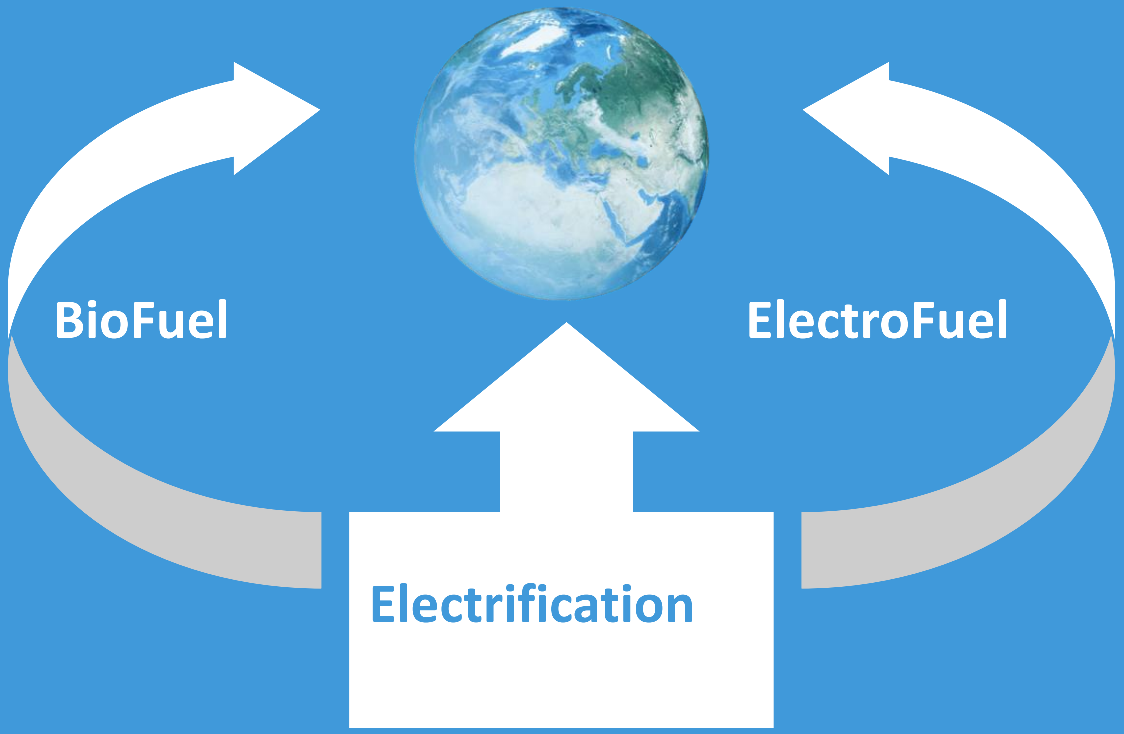
A vision to inspire the world

Denmark 2020



Ørsted partnership with transport companies Copenhagen Airports, A.P. Moller - Maersk, DSV Panalpina, DFDS, and SAS, rests on a shared vision to develop an industrial-scale production facility in the Copenhagen area to produce sustainable fuels for road, maritime and air transport

a world that runs entirely
on green energy



Harvesting the power of the wind and the sun to create a fuel

eHydrogen – eMethanol - eAmmonia

Today transport is dominated by fossil fuel

Heavy Fuel Oil is an antique

A bottom of the barrel remnant from crude oil cracking

One of the most polluting fuels

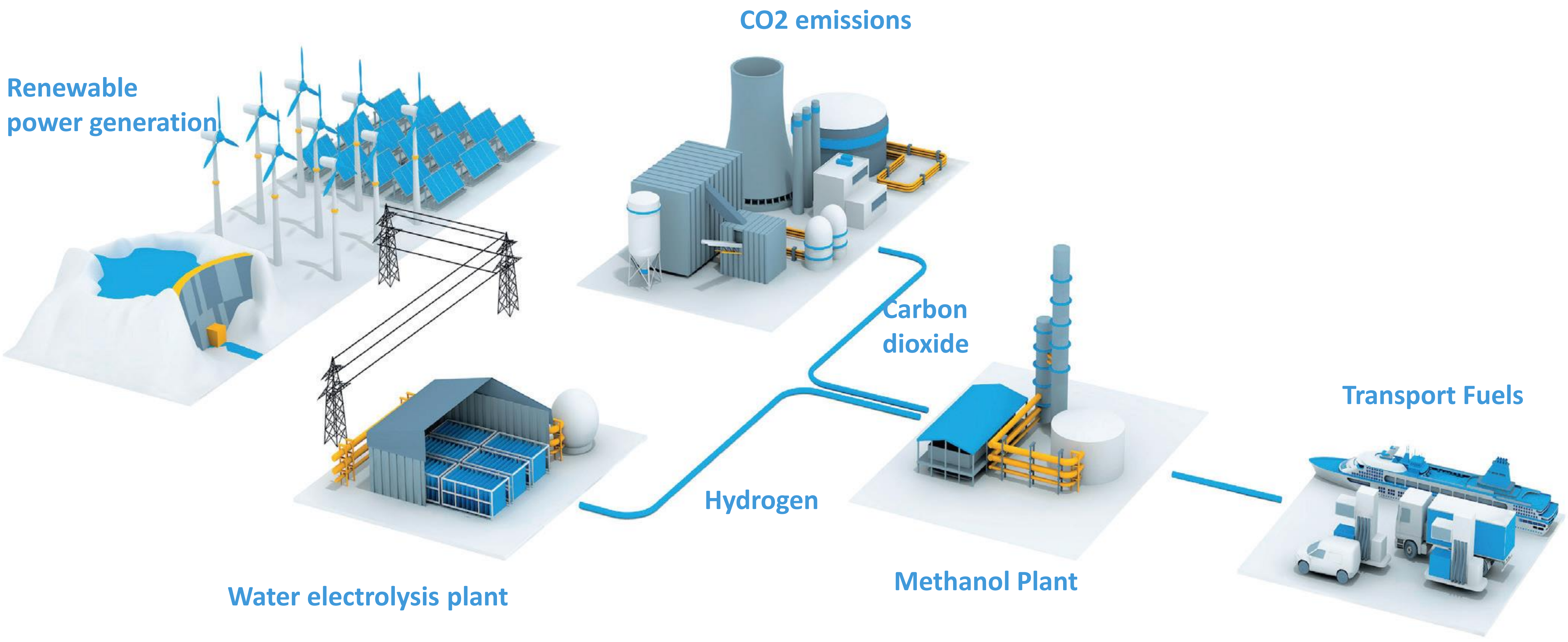
Yet today this antique fuel accounts for approximately 90% of energy consumption by international shipping

300 million tonnes of Heavy Fuel Oil a year

800 million tonnes of CO_2 emissions a year and rising

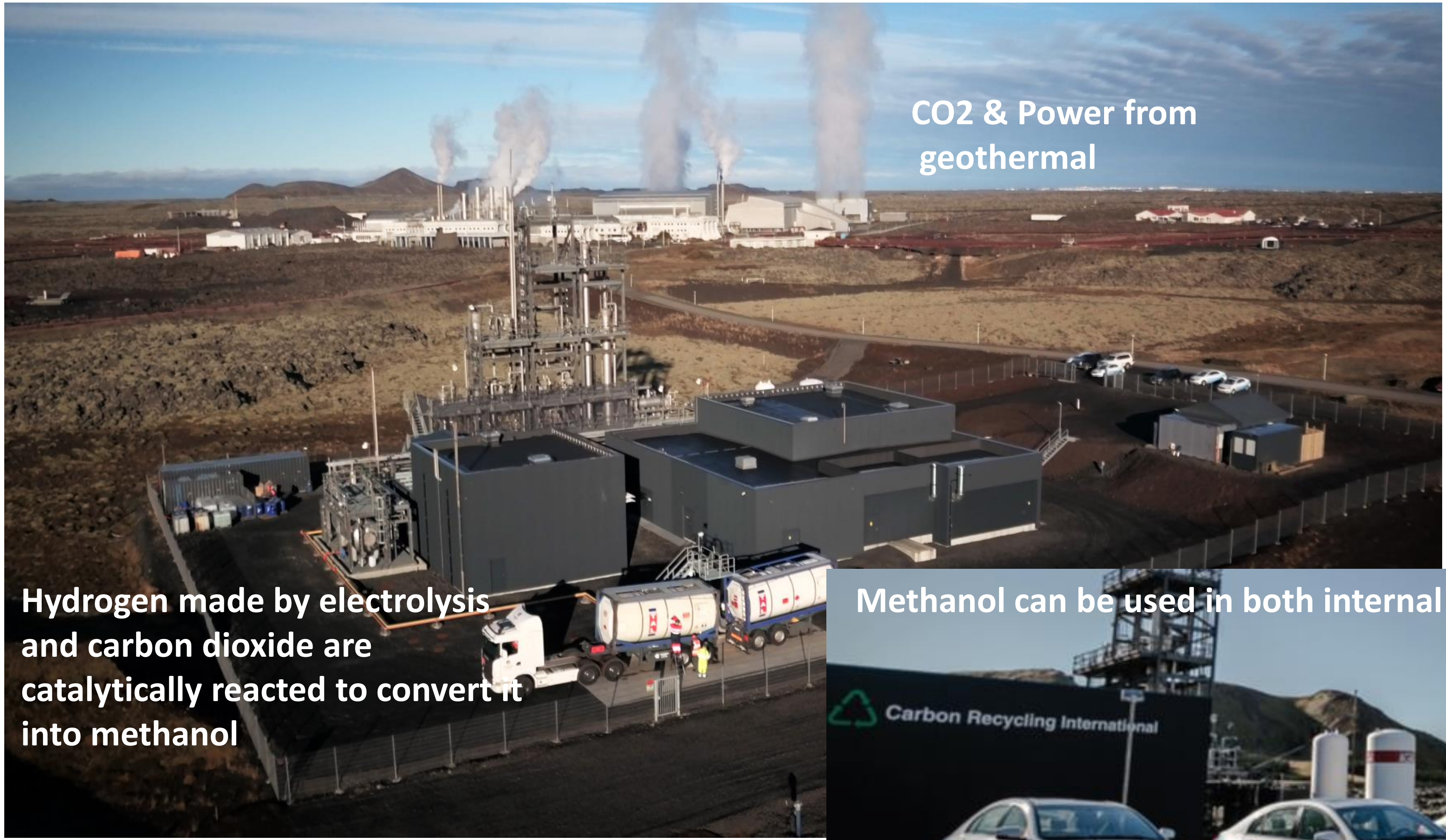
Ørsted

eMethanol



Creating a fuel from Wind - Water - Waste

eMethanol today



Vulcanol

Renewable methanol produced by CRI since 2012

Chemically identical to fossil methanol

CRI has sold Vulcanol commercially to clients in Europe and China

Carbon Recycling International Renewable Methanol Plant Iceland

Ørsted

Applications at scale

Waterfront Shipping operates the largest methanol ocean tanker fleet in the world

Stena Germanica one of the world's largest ferries was converted to run on methanol in 2015

Clean fuel demand presents a huge wave of growth for eFuels & eMethanol

- **Timing** is right
- **Technology** is now available
- Opportunity is **tangible**

Ørsted