

MAPPING LOW-CARBON METHANOL OPPORTUNITIES

SPEAKERS



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Power-to-X



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**Methanol Institute
(Ex-MAN Energy
Solutions)**



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Chief India Representative
Methanol Institute

MODERATOR



November 22, 2023, Wednesday



1500 IST | 1030 CET | 1730 SGT



TOPSOE



**MINISTRY OF FOREIGN AFFAIRS
OF DENMARK**
The Trade Council



OPENING REMARKS



**MINISTRY OF FOREIGN AFFAIRS
OF DENMARK**
Denmark in India

ESKE BO KNUDSEN ROSENBERG
Consul General of Denmark in Bengaluru



Amassing Feedstocks: Mapping Low-Carbon Methanol Opportunities

November 22nd, 2023

Singapore | Washington | Brussels | Beijing | New Delhi

MI History

- The Methanol Institute (MI) was established in 1989
- More than three decades later, MI is recognized as the trade association for the global methanol industry
- We facilitate methanol's increased adoption from our Singapore headquarters and regional offices in Washington DC, Brussels, Beijing and Delhi



Members



Tier 1



Tier 2



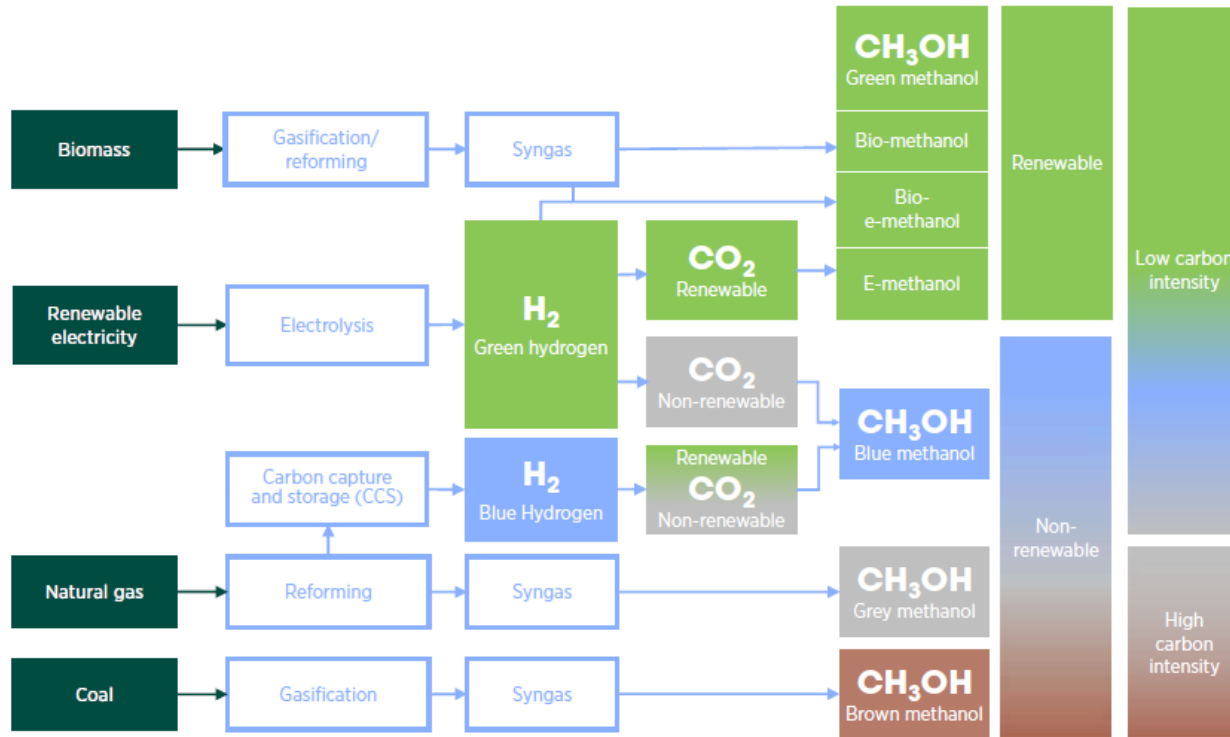
Tier 3



Tier 4



Production Pathways



- Interest in methanol is growing due to its ability to be an extremely low-carbon fuel and chemical
- IRENA projected that by 2050, 250 MMT of e-methanol and 135 MMT of bio-methanol will be produced annually
 - Current global production capacity: ~100 MMT
- As a liquid fuel, methanol's handling and utilization is not very different from conventional fuels, allowing end users an accessible fuel that can offer a transition pathway to lowering GHG emissions
- GHG LCAs ascertain the low GHG intensity of methanol allowing end users to know the exact amount of GHG savings that they accrue by utilizing methanol produced from different pathways
 - Promotes accountability and enables reporting mechanisms for GHG savings

TOPSOE EMETHANOL

Nikolaj Knudsen
Head of Business Development, Power-to-X

22 November 2023

TOPSOE



TOPSOE AT A GLANCE

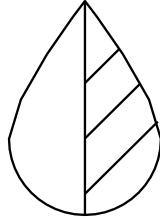
Topsoe is a leading developer and provider of solutions and technologies to produce fuels and chemicals essential to the energy transition.

For more than 80 years, we've been perfecting chemistry to help industries produce more efficiently. Today, it's our ambition to lead the global transition of hard-to-abate sectors to a zero-carbon future.

Guided by our purpose, 'Perfecting chemistry for a better world', we work to deliver solutions that will leave the world in better shape for future generations.

#1

In renewable fuels



#1

In Ammonia



6,845

In revenue
(DKK million)

+500

Patent families

8.6%

Of revenue
invested in R&D

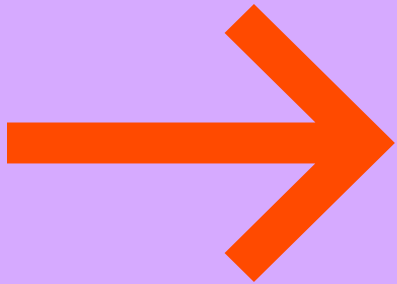
2,242

Employees

PROJECTS DEFINING THE FUTURE OF DECARBONIZATION

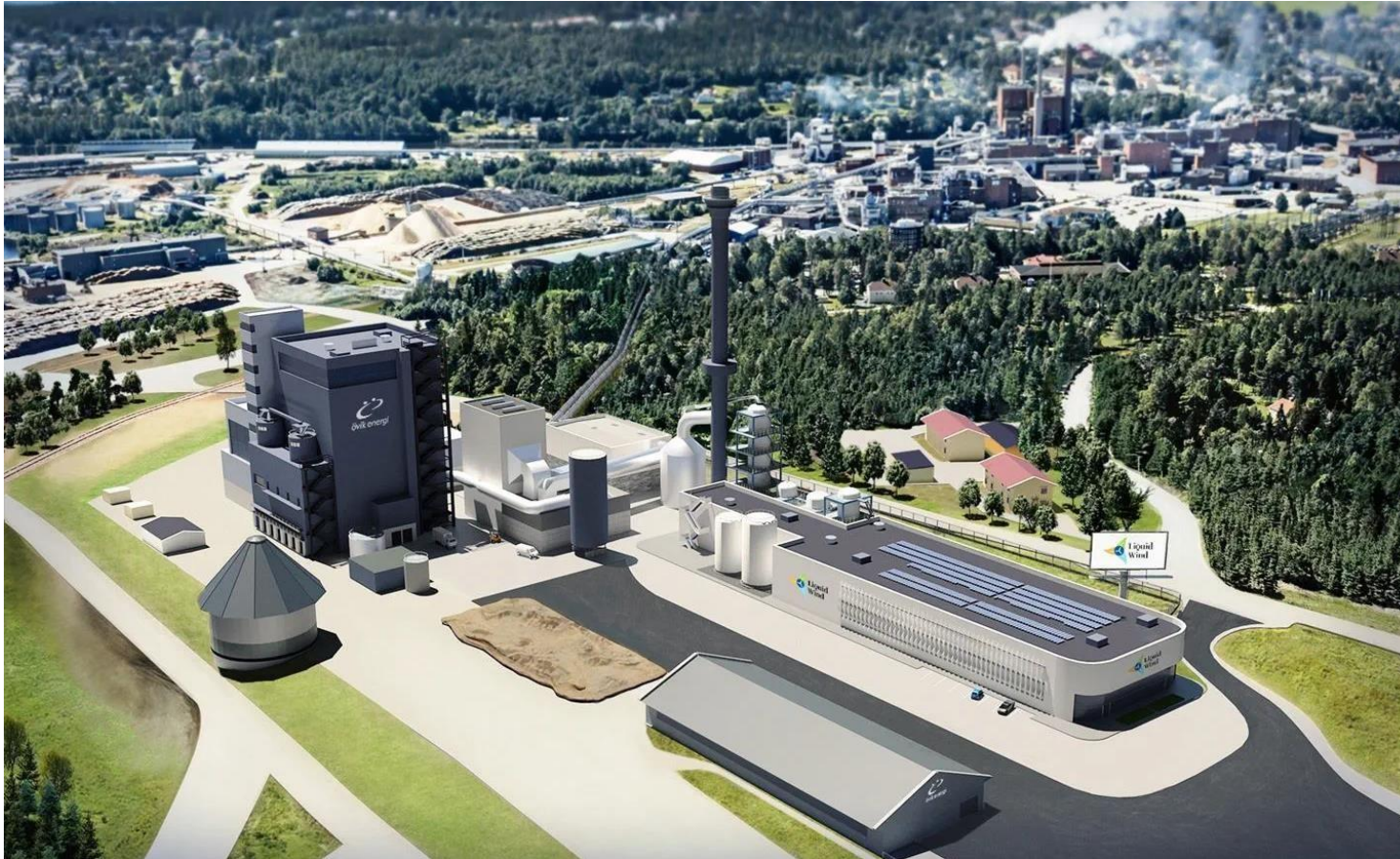
with industry leading carbon emission reduction technologies from Topsoe

SELECTED GLOBAL PROJECTS



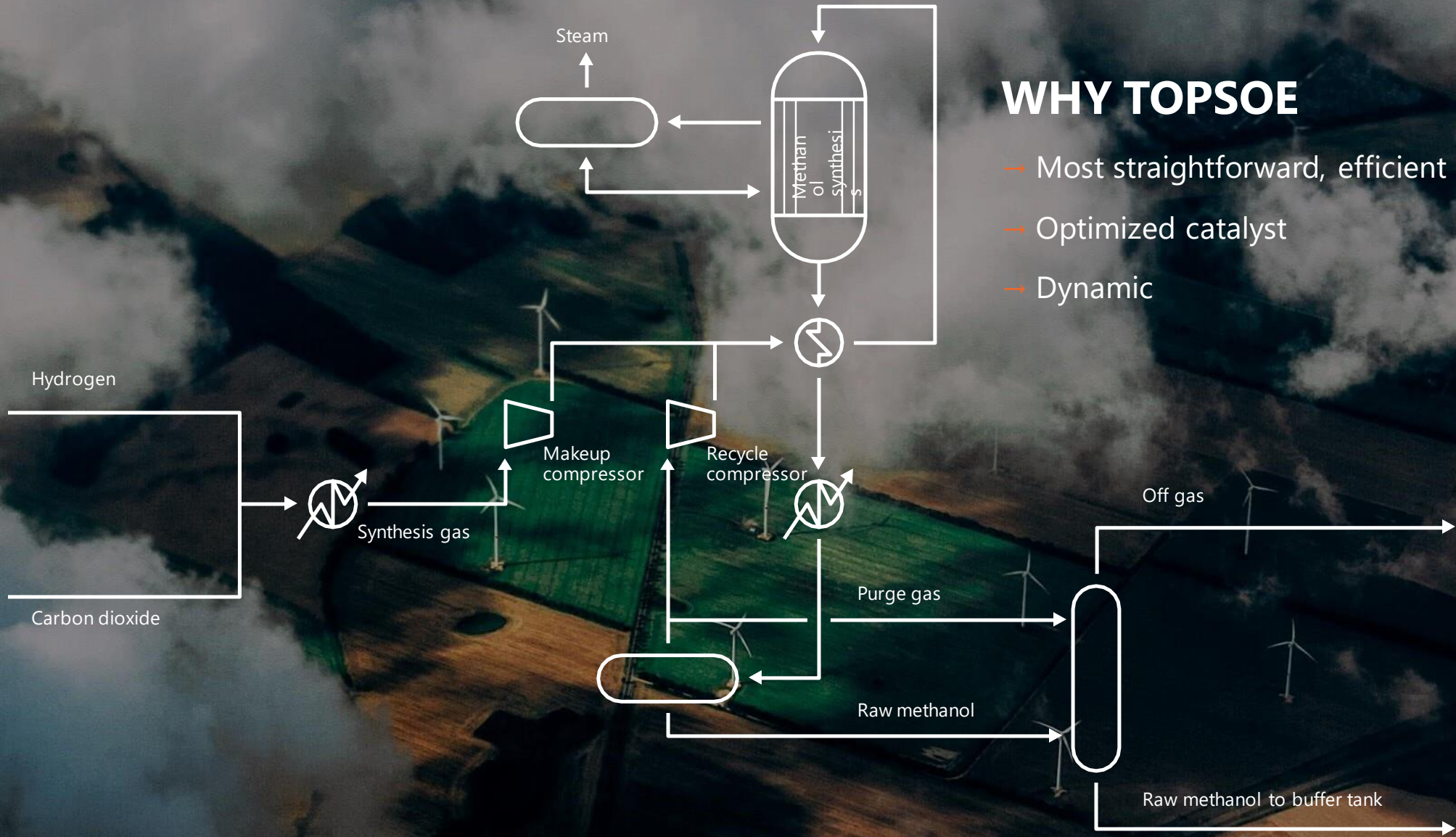
<p>Topsoe will deliver a 1650 MTPD green ammonia loop to World Energy GH2 in Canada</p>	<p>Topsoe will deliver technology to the first dynamic green ammonia plant in China, build by Mintal Hydrogen Energy Technology.</p>	<p>Topsoe will deliver a 4000 MTPD Dynamic green ammonia loop to Neom in Saudi Arabia</p>
<p>Topsoe is collaborating with Skovgaard Energy & Vestas to develop, build and operate the first fully dynamic green ammonia demo plant in Denmark, coupled directly to wind and solar power.</p>	<p>Topsoe is technology partner in FlagshipONE, Europe's largest production facility for green fuel for the shipping industry.</p>	<p>First Ammonia will be using Topsoe's solid oxide electrolyzer cells (SOEC) technology to produce green ammonia in the US.</p>
	<p>Exxon is building the world's largest low carbon hydrogen facility in the US, running on Topsoe technology.</p>	

FLAGSHIP1 BY LIQUIDWIND



- *50,000 ton per year grade AA eMethanol*
- *CO₂ from biomass heat/power plant*
- *Carbon Capture by CarbonClean*
- *PEM electrolyzers by Siemens Energy*
- *ModuLite™ eMethanol loop by Topsoe*

TOPSOE METHANOL LOOP



WHY TOPSOE

- Most straightforward, efficient process
- Optimized catalyst
- Dynamic

MK-417 SUSTAIN™

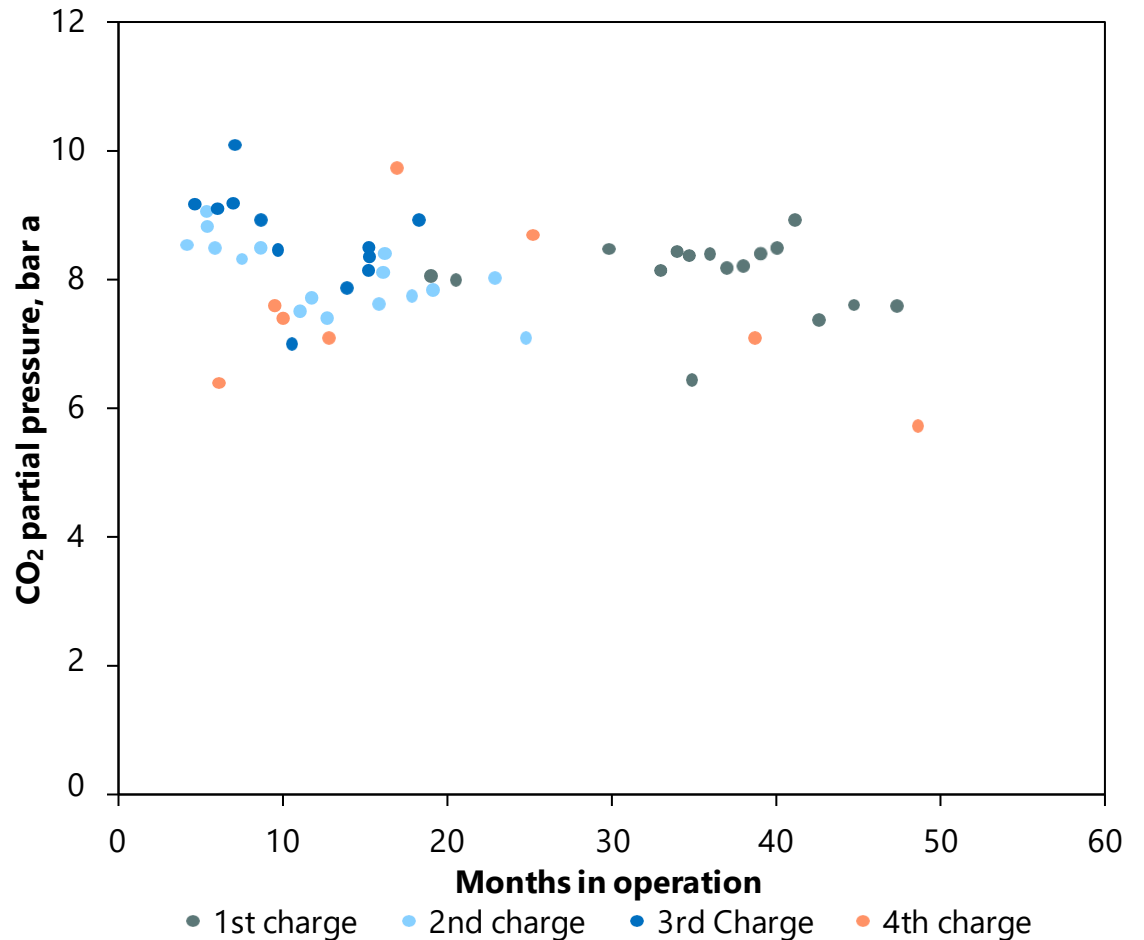
an even better choice FOR CO₂ rich feeds

TOPSOE

MK CATALYSTS – EXPERIENCE WITH CO₂ RICH FEED

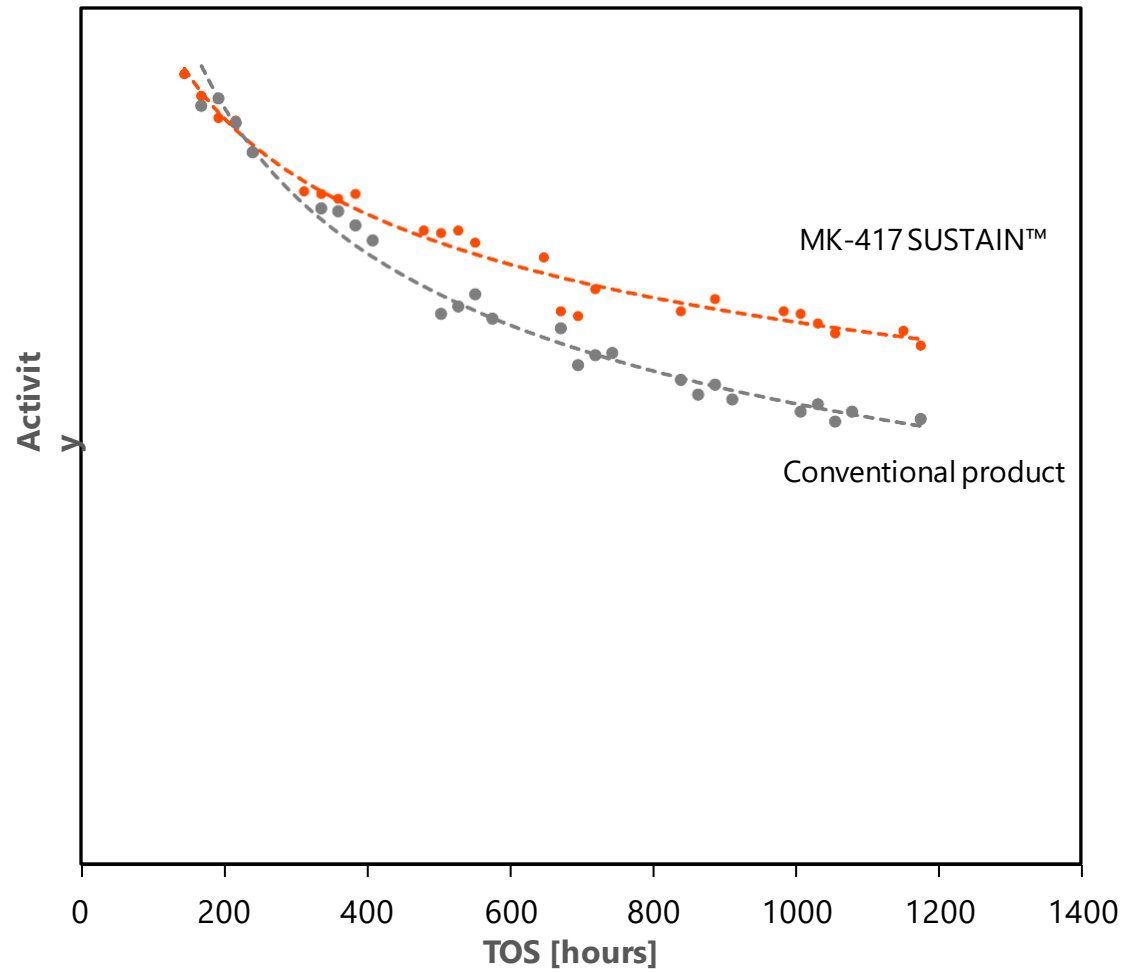
MORE CO₂ IS USED IN CONVENTIONAL PLANTS AND CONVERTED TO METHANOL WITH RENEWABLE H₂

- Inlet CO₂ partial pressures:
 - Conventional converters: 1.5-7 bar
 - Green methanol converters: 5-11 bar
- Previous generations of Topsoe MK catalysts in a plant with a CO₂ rich feed



MK-417 SUSTAIN™ – AN EVEN BETTER CHOICE FOR CO₂ RICH FEEDS

STABILITY IS DECISIVE IN CO₂ RICH FEEDS



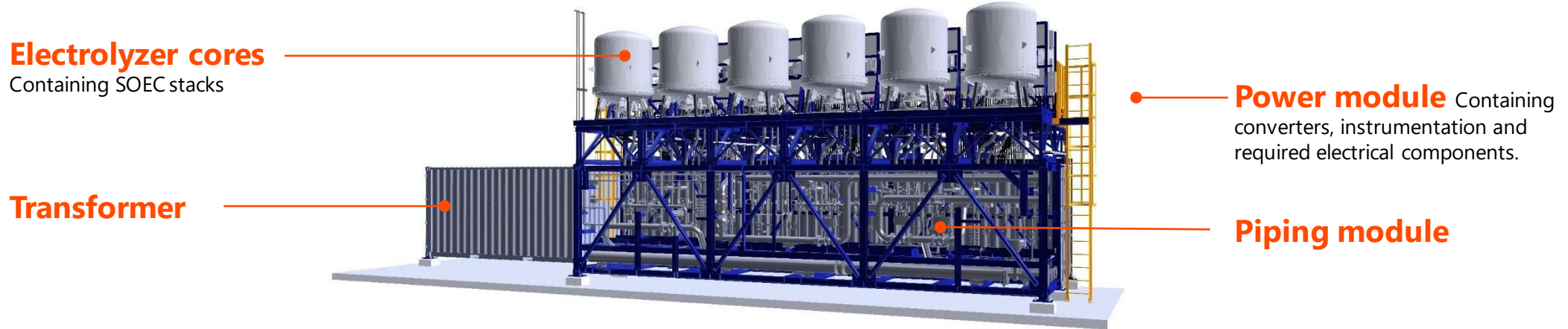
TOPSOE EMETHANOL

Advanced process layout

TOPSOE

SOEC - FROM CONCEPT TO NEXT GENERATION

HOW WE GOT HERE AND WHAT COMES NEXT



DEVELOPMENT TIMELINE

1980

Solid Oxide Fuel Cell (SOFC) developed
SOFC cell and stack can also be used as SOEC
Electrolysis of both water and CO₂

2013

Focus Shifts to SOEC
Demonstration and industrial SOEC units since 2015
Continuous optimization & innovation
Market leading efficiencies

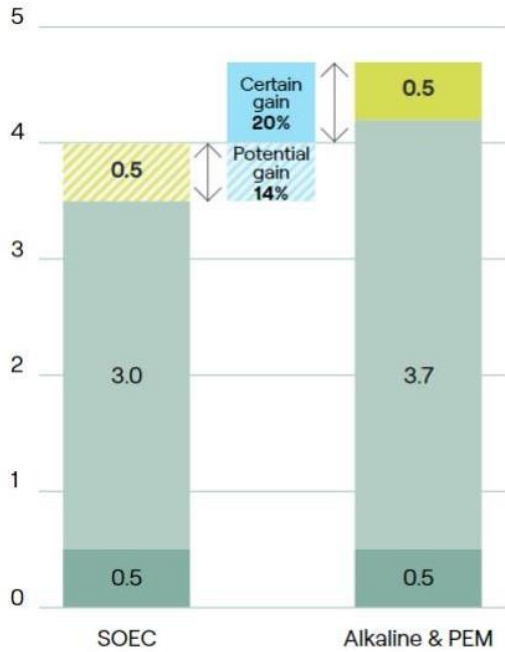
2025

Worlds biggest SOEC manufacturing facility
Initial 500 MW annual production capacity
Expansion to 1,2GW Annually by 2031
Planned expansion to USA

THE CHEMISTRY BEHIND OUR SOEC ELECTROLYSIS PROCESS

SOEC'S ADVANTAGE OVER ALKALINE AND PEM TECHNOLOGIES

Efficiency in kWh/Nm³ of Product Hydrogen



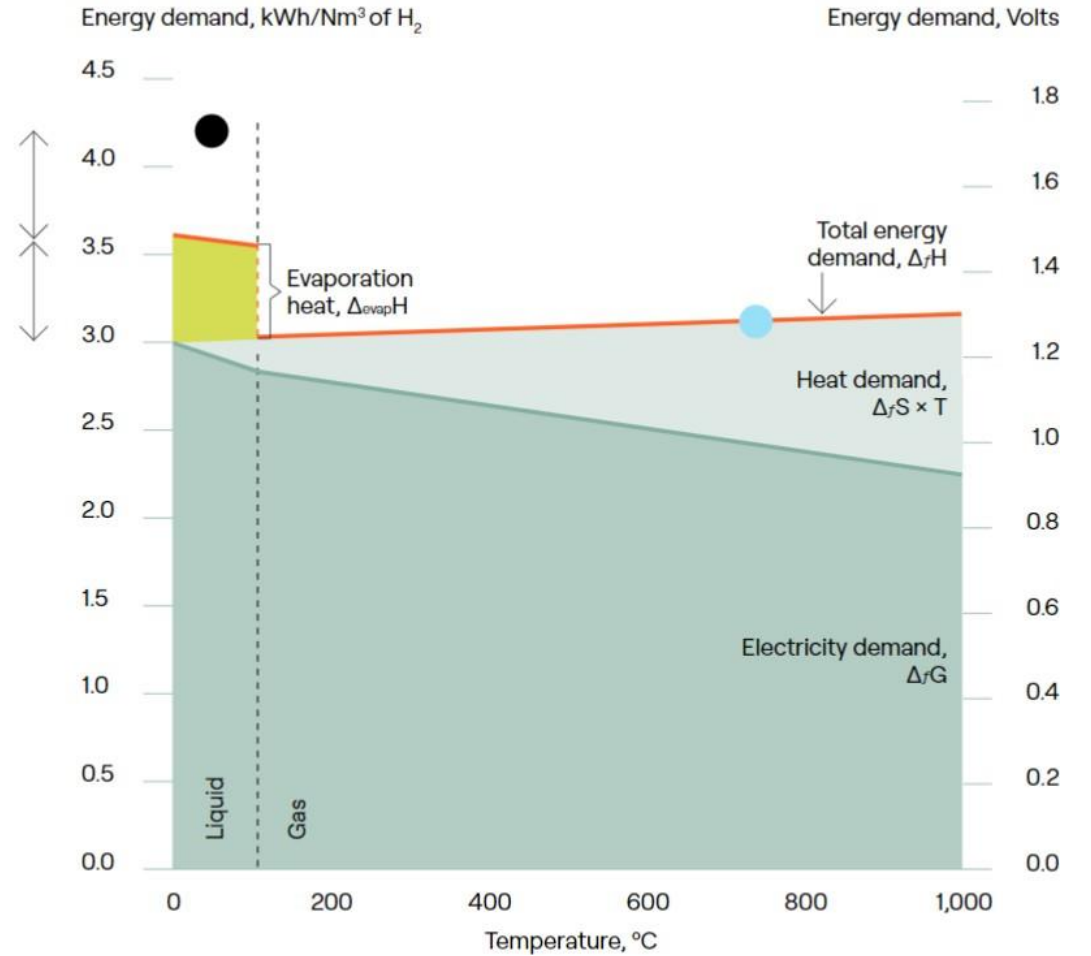
- Balance of plant
- Electrolysis
- Heat of evaporation

ENERGY DEMAND FOR THE ELECTROLYSIS OF WATER EXCLUDING BALANCE OF PLANT

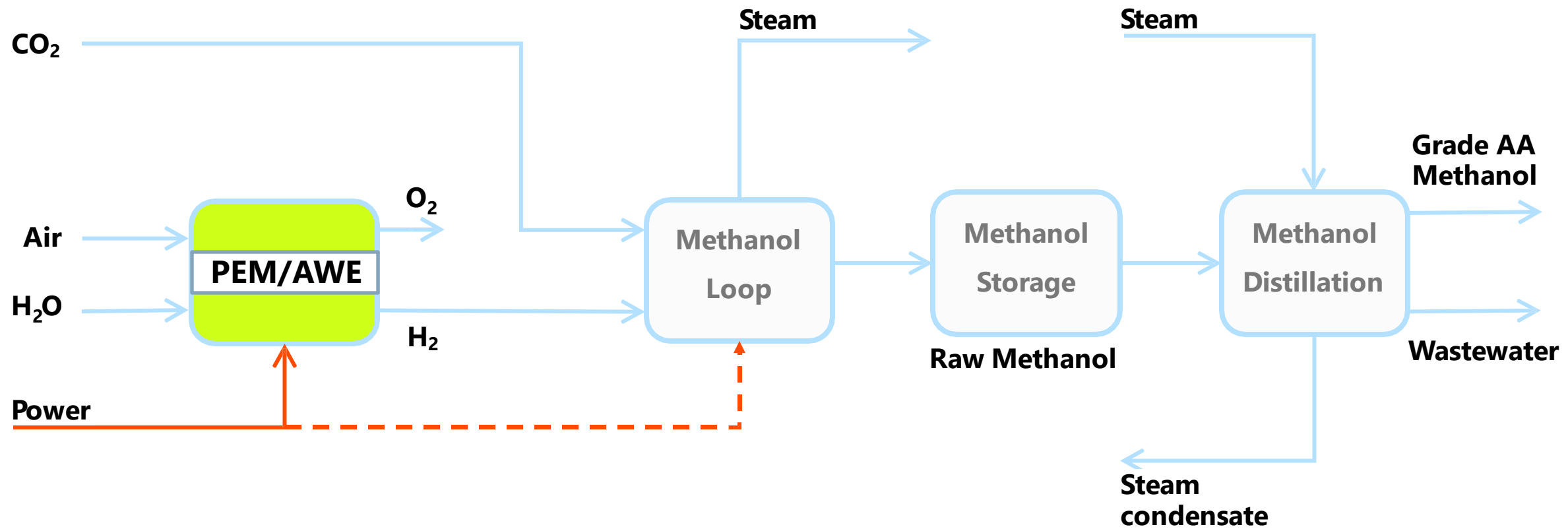
Certain gain due to operation at better kinetics and conductivity

Potential gain if steam is imported

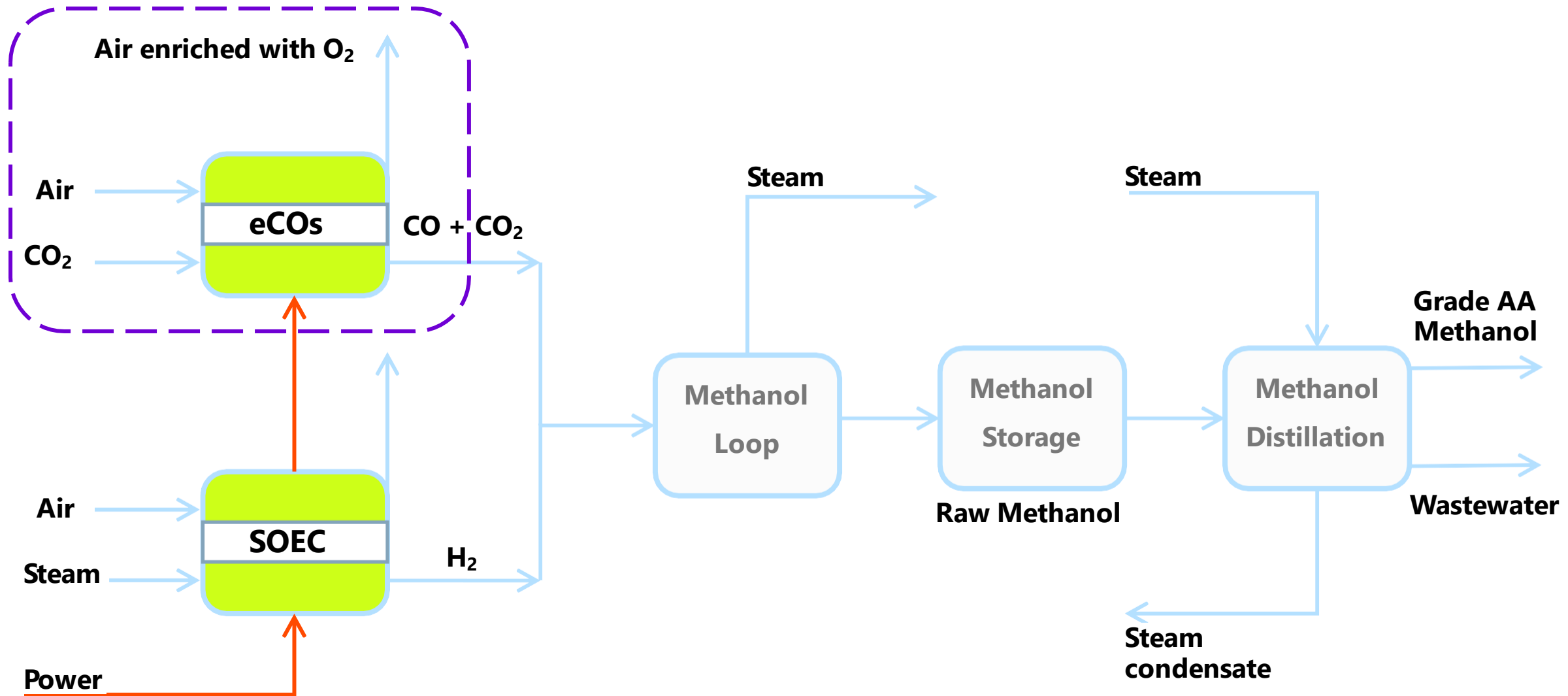
- Total energy demand, $\Delta_r H$
- Alkaline & PEM
- SOEC



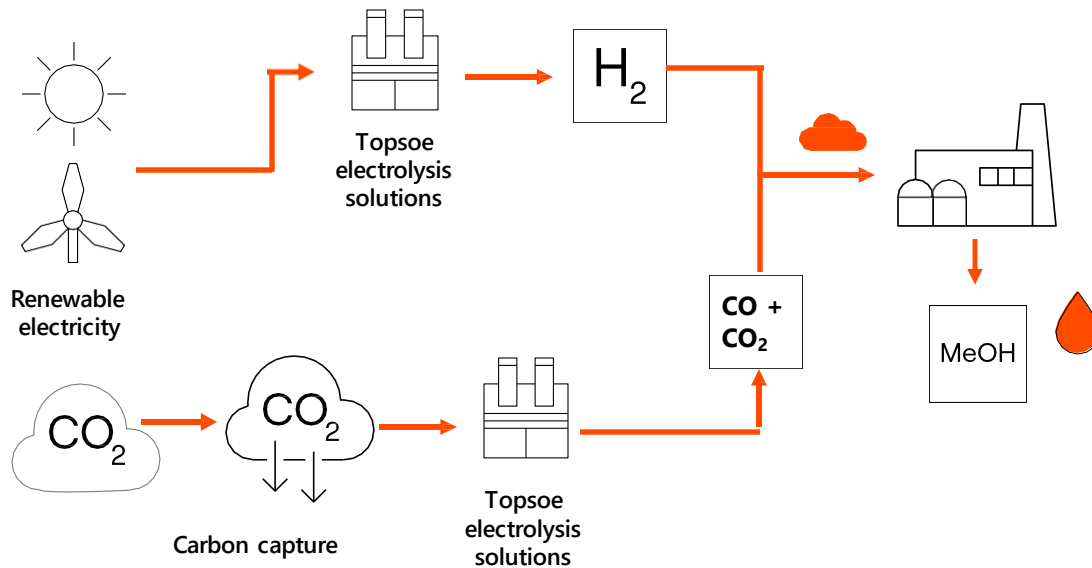
PRODUCTION OF METHANOL FROM CO₂ AND WATER USING PEM/AWE TECHNOLOGY



CARBON MONOXIDE PRODUCTION FROM CARBON DIOXIDE AND RENEWABLE POWER



GREEN METHANOL BY SOEC WITH CO2 ELECTROLYSIS



- Benefits

- More aggressive gas gives less water formation
- Smaller MeOH loop for same production
- Reduced hydrogen consumption
- Reduced equipment size for equipment handling water in distillation section

	H2 SOEC	H2 SOEC + eCOs	PEM
Electricity consumption	77.4%	77.6%	100%
Catalyst volume	100%	78.5%	100%
Cooling water consumption	60.9%	60.7%	100%



E-methanol in Kassø, Denmark

(Solar Park @ Kassø, Aabenlää municipality, Denmark)

November 22nd, 2023

Mitsui & Co., Ltd. Methanol & Ammonia Div. Todd HOSHINO

T.Hoshino@mitsui.com



MITSUI & CO.



Agenda

1. Introduction
2. **E-methanol** plant in Kassø Denmark
3. Danish **green transition**
4. Mitsui **Global Energy Transition**

1. Introduction

Mitsui & Co., Ltd.

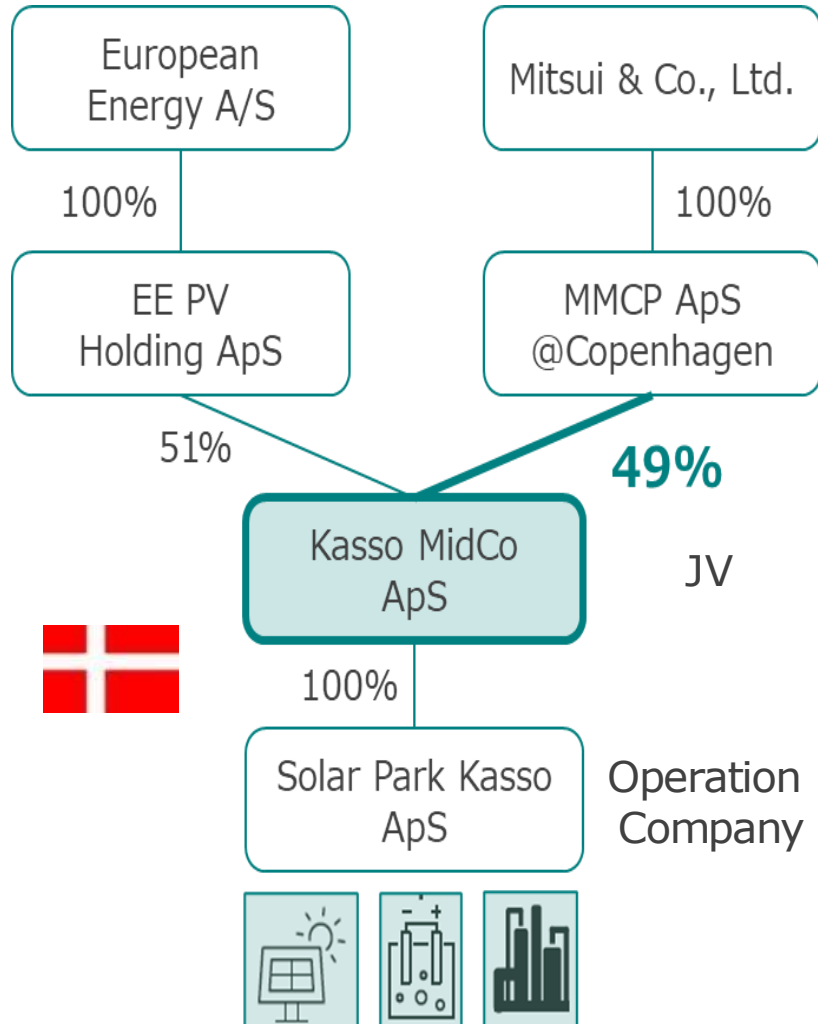
- Established: July 25, 1947
- Operation Segments: Mineral & Metal Resources, Energy, Machinery & Infrastructure, **Chemicals**, Iron & Steel Products, Lifestyle, Innovation & Corporate Development
- Office: 128 offices in 63 countries/regions including **6 offices in India**
(New Delhi, Mumbai, Chennai, Kolkata, Hyderabad, Bengaluru)

Todd HOSHINO

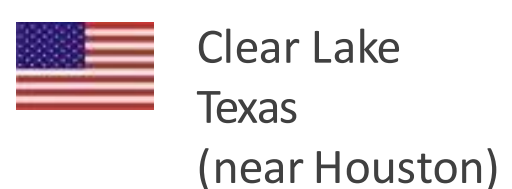
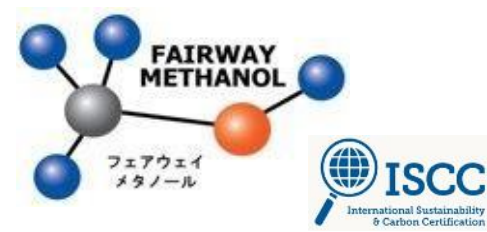
- Joined in Mitsui: April 1994
- Deputy General Manager in **Methanol** & Ammonia Div.
Chair of Policy Committee in **Methanol** Institute
Member of **Carbon Recycle** Roadmap Review in Japanese METI, 2023
- Led **e-Methanol** in Kassø, Denmark and **Fairway Methanol** in TX, USA

1. Introduction

E-methanol



Mitsui methanol biz



- Conventional methanol
- Recycled carbon methanol
- Annually 1.5 mil tons
- 35% via JAMC*

- Conventional methanol
- **Bio-methanol (EU,PLUS)**
- Recycled carbon methanol (to be operational soon)
- Annually 1.63 mil tons
- 50% via MMTX*

* JAMC: Japan Arabia Methanol Company owned by Mitsui at 55% MMTX: MMTX Inc. owned by Mitsui at 100%

1. Introduction

European Energy at a glance – End of 2022

Employees

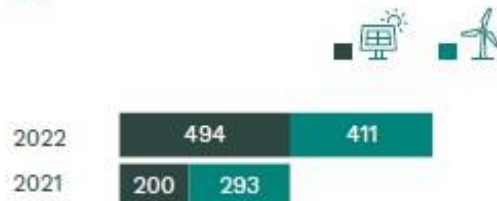
Head count



We hired 268 new employees in 2022. We employed 550 end of year 2022, which is a 60% increase compared to 2021 (343 employees).

Power production assets

MW



Our power producing capacity almost doubled compared to 2021, as a result of 655 MW of renewable energy farms being successfully grid-connected in 2022 and a slightly longer holding period of assets due to the high power prices

Profit before tax

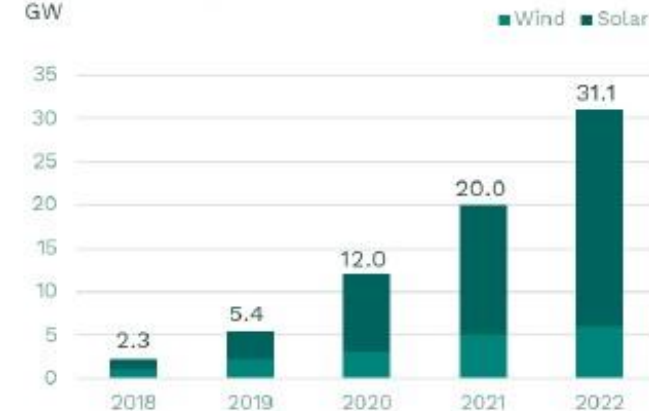
EURm



Profit before tax increased to EUR 110m, a growth of almost 75% and exceeding the outlook of EUR 100m.

Development pipeline

GW



Solar power



Onshore wind



Offshore wind



Downstream technologies



GW per regions

- Southern Europe
- Northern Europe
- Rest of the world
- Central Europe
- Denmark



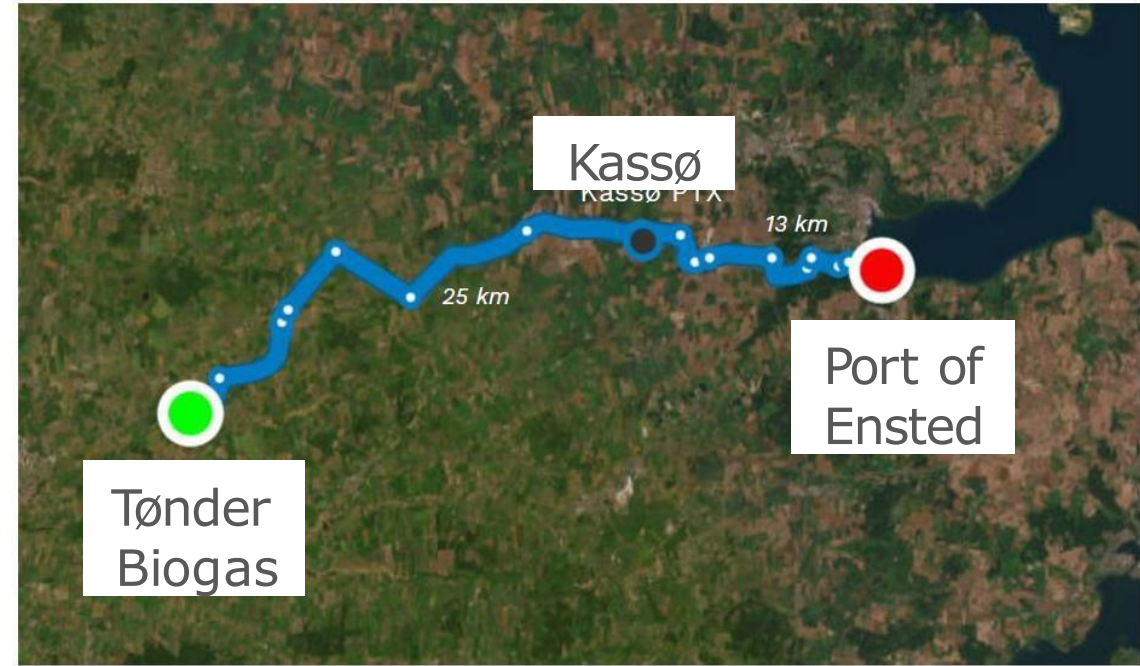
E-methanol plant in Kassø Denmark



2. E-methanol plant in Kassø Denmark



2. E-methanol plant in Kassø Denmark



January 2023



October 2023



CO2-storage tanks

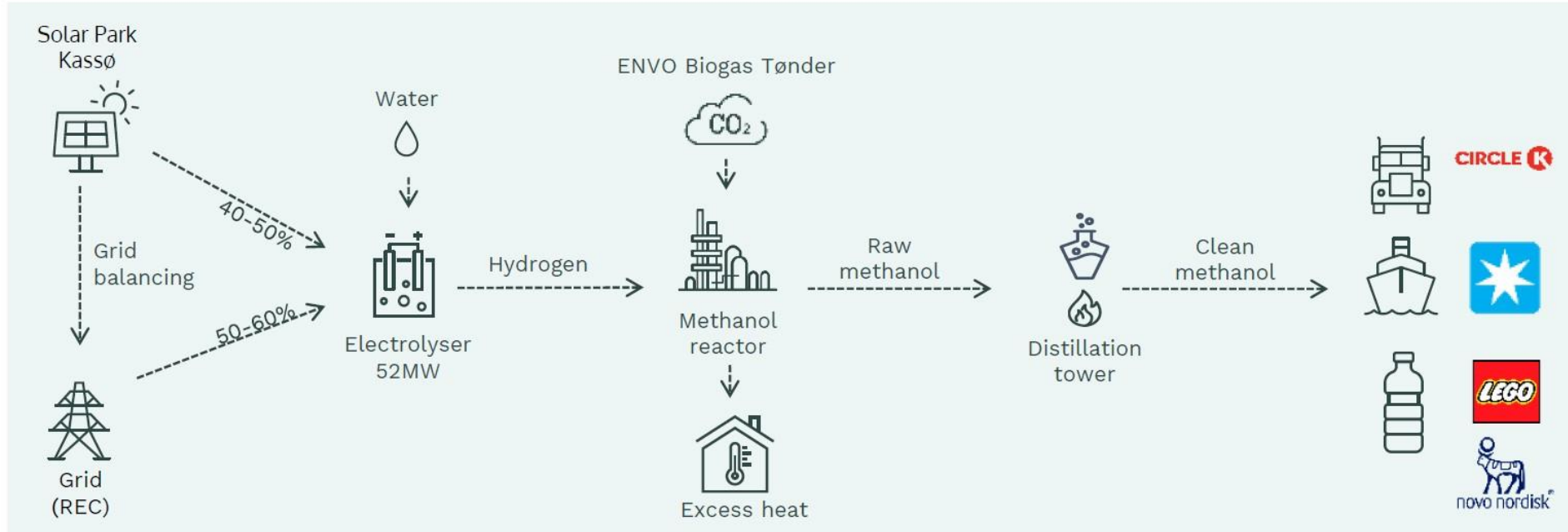


2nd electrolyzer (out of 3)

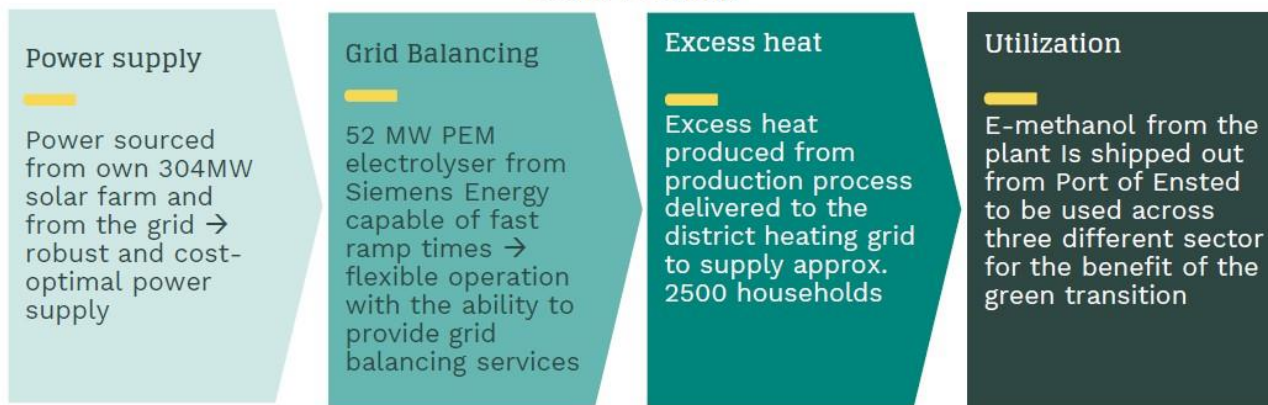
2. E-methanol plant in Kassø Denmark

How we produce e-methanol in Kassø

Input (consumption)	
Water	~90.000 tons
Electricity	~360-380 GWh
Biogenic CO ₂	~45.000 tons
Output (production)	
Hydrogen	~6000 tons
Raw methanol	~50.000 tons
Clean methanol	~32.000 tons (nom. cap. 42.000)
Excess heat	~50 GWh



Sector coupling



Milestones

- ✓ Final Investment Decision
- ✓ All permits secured
- ✓ Offtake agreements signed for e-methanol
- ✓ Methanol plant detailed design completed
- ✓ Construction initiated and on-track
- ☐ First methanol, COD 2024

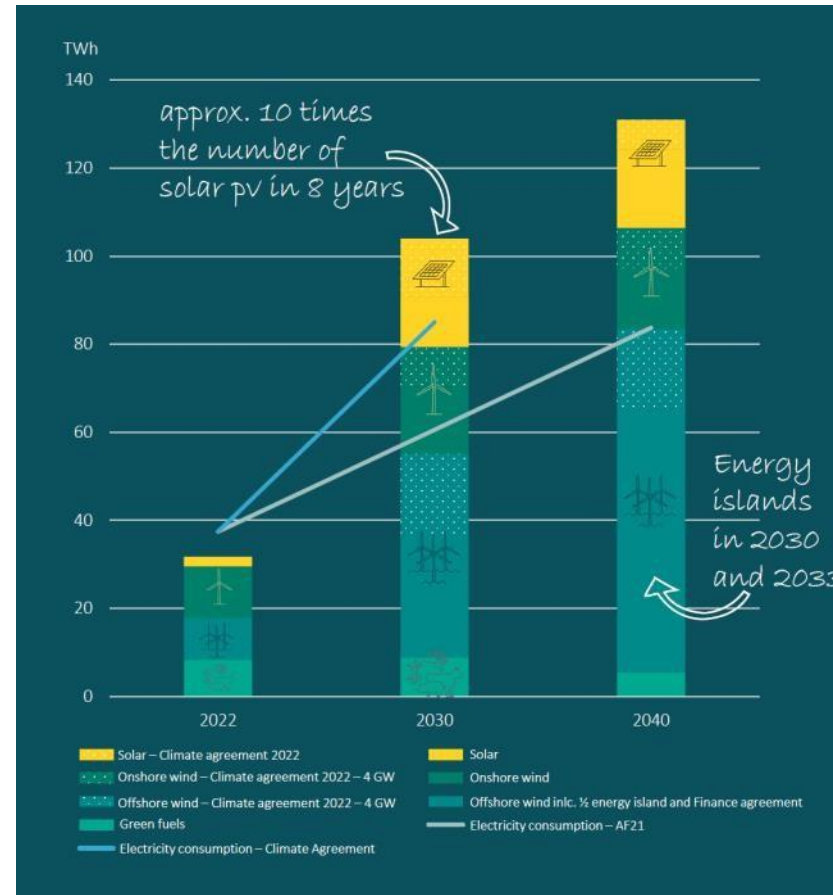
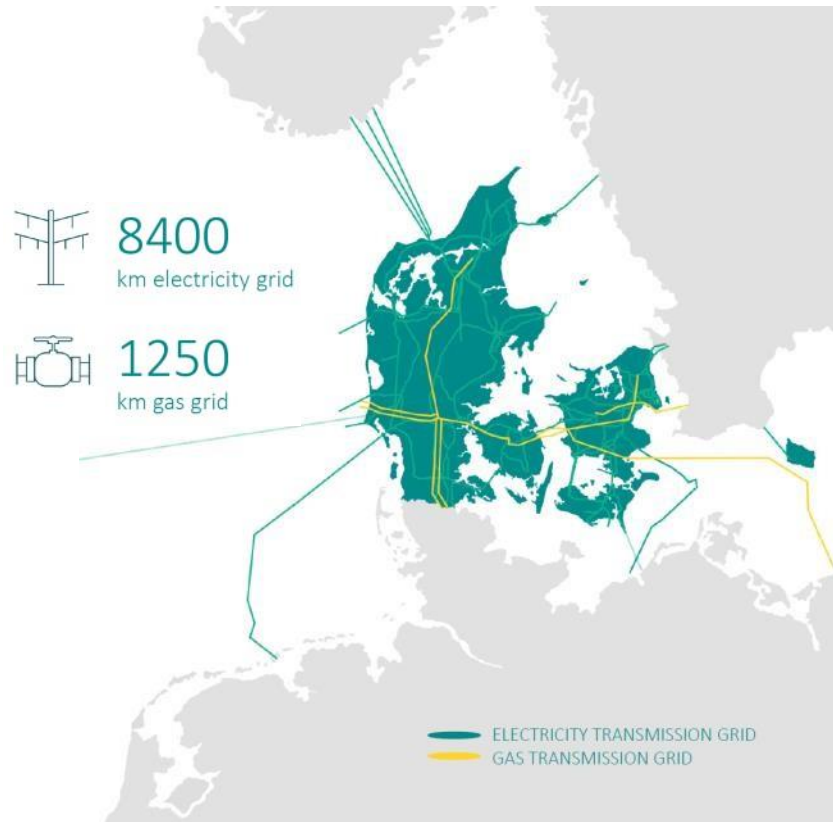
3. Danish green transition

Status 2022: **wind and solar power 59.3%, biogas 34%**

Target 2030: **70% reduced emissions**

Target 2050: **100% climate neutral society**

ENERGINET

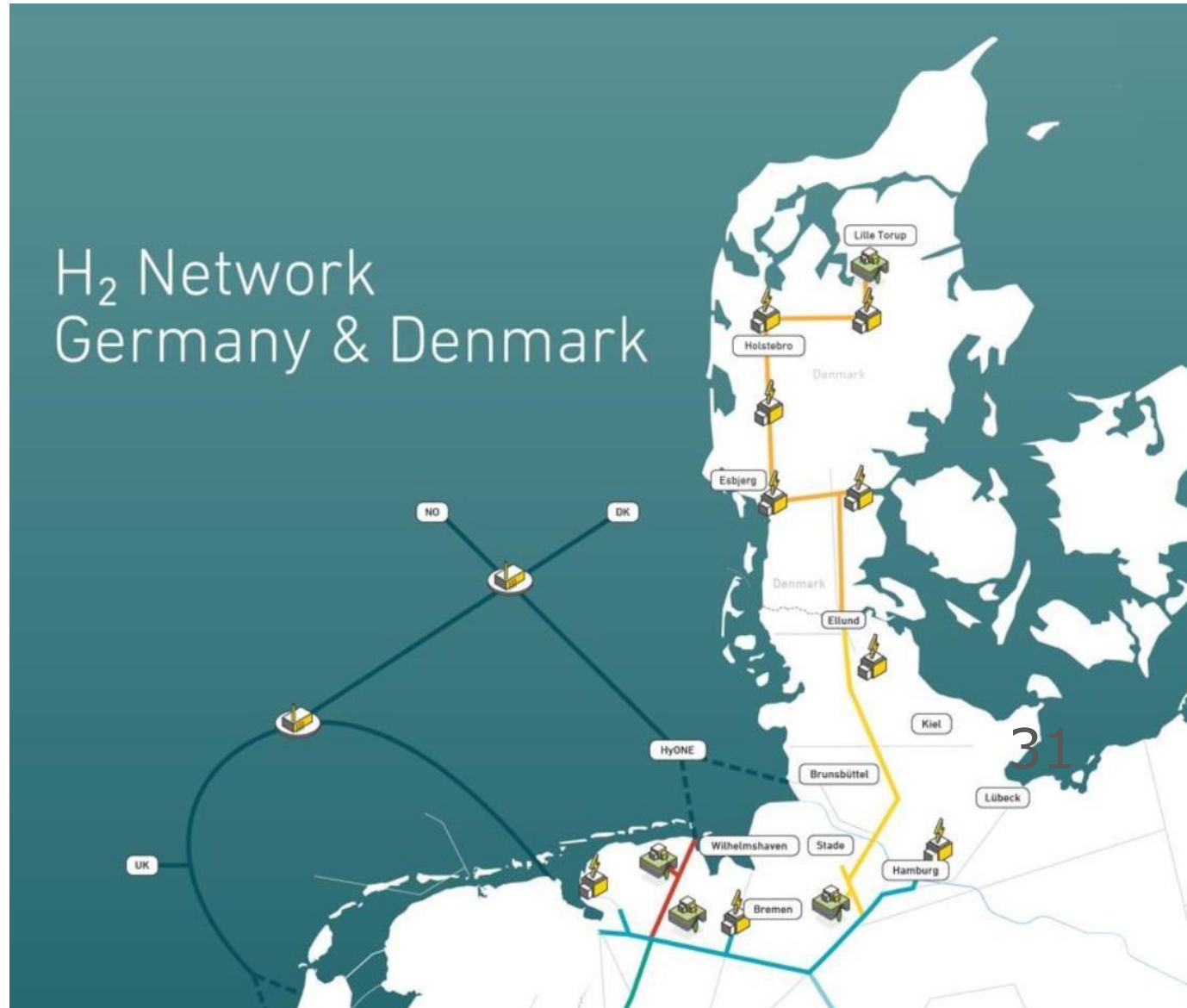


DENMARK'S CONSUMPTION AND PRODUCTION CLIMATE AGREEMENT 2022

- Electricity production from onshore wind and solar pv is quadrupled before 2030.
- Minimum 4 GW offshore wind is realized no later than in 2030.*
- Offshore wind from energy islands is expected to be installed in 2030 (Bornholm) and 2033 (North Sea)
- PtX-capacity increases from fra 1 GW (in AF21) to 4-6 GW in 2030
- The transport og heat sectors are electrified to a greater extent.

*On the condition that the offshore wind does not negatively affect the state finances.

3. Danish green transition



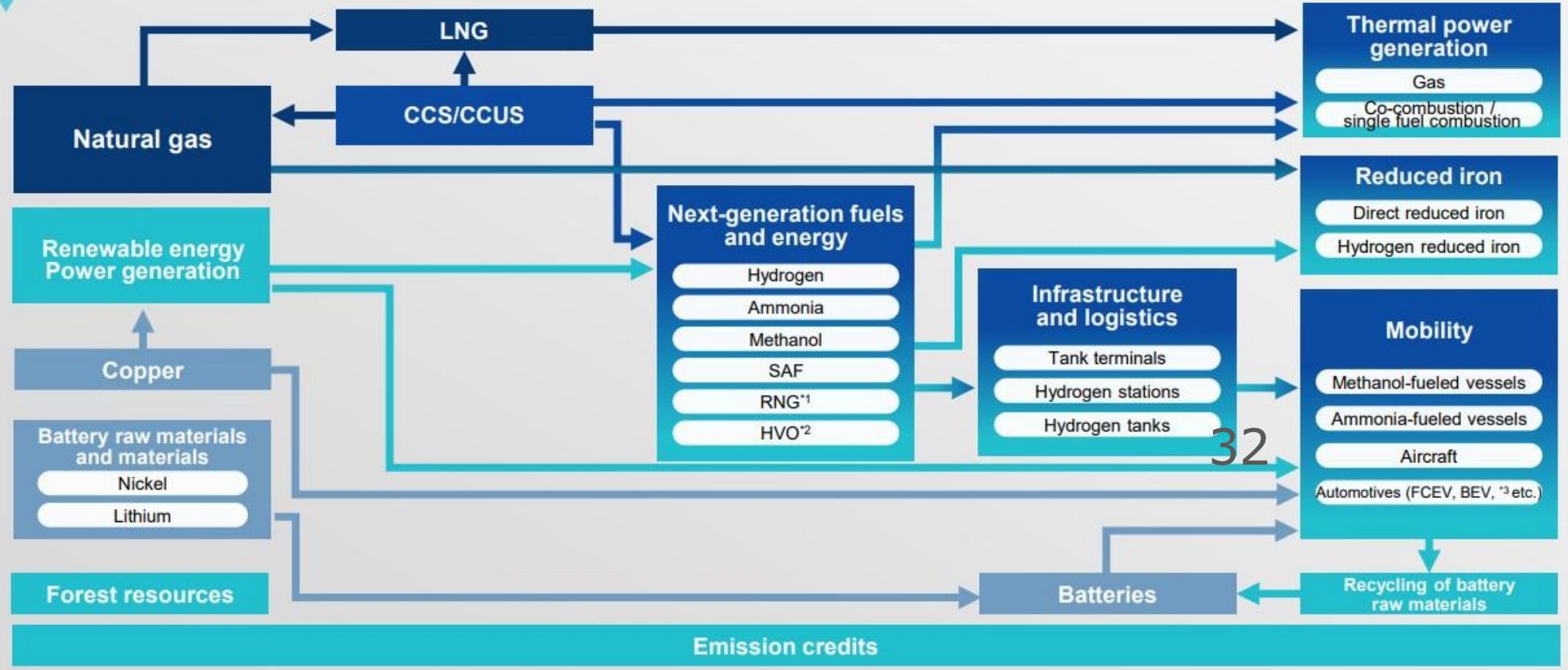
4. Mitsui Global Energy Transition

Global Energy Transition

Key Strategic Initiatives Global Energy Transition



Create value chains that expands into next-generation fuels and direct reduced iron



*1 Renewable Natural Gas *2 Hydrotreated Vegetable Oil *3 Fuel Cell Electric Vehicle, Battery Electric Vehicle

4. Mitsui Global Energy Transition



- HVO: annually 250kmts (operational for SAF)
- at Sines refinery
- Start: 2025
- Owned by Mitsui at 25%



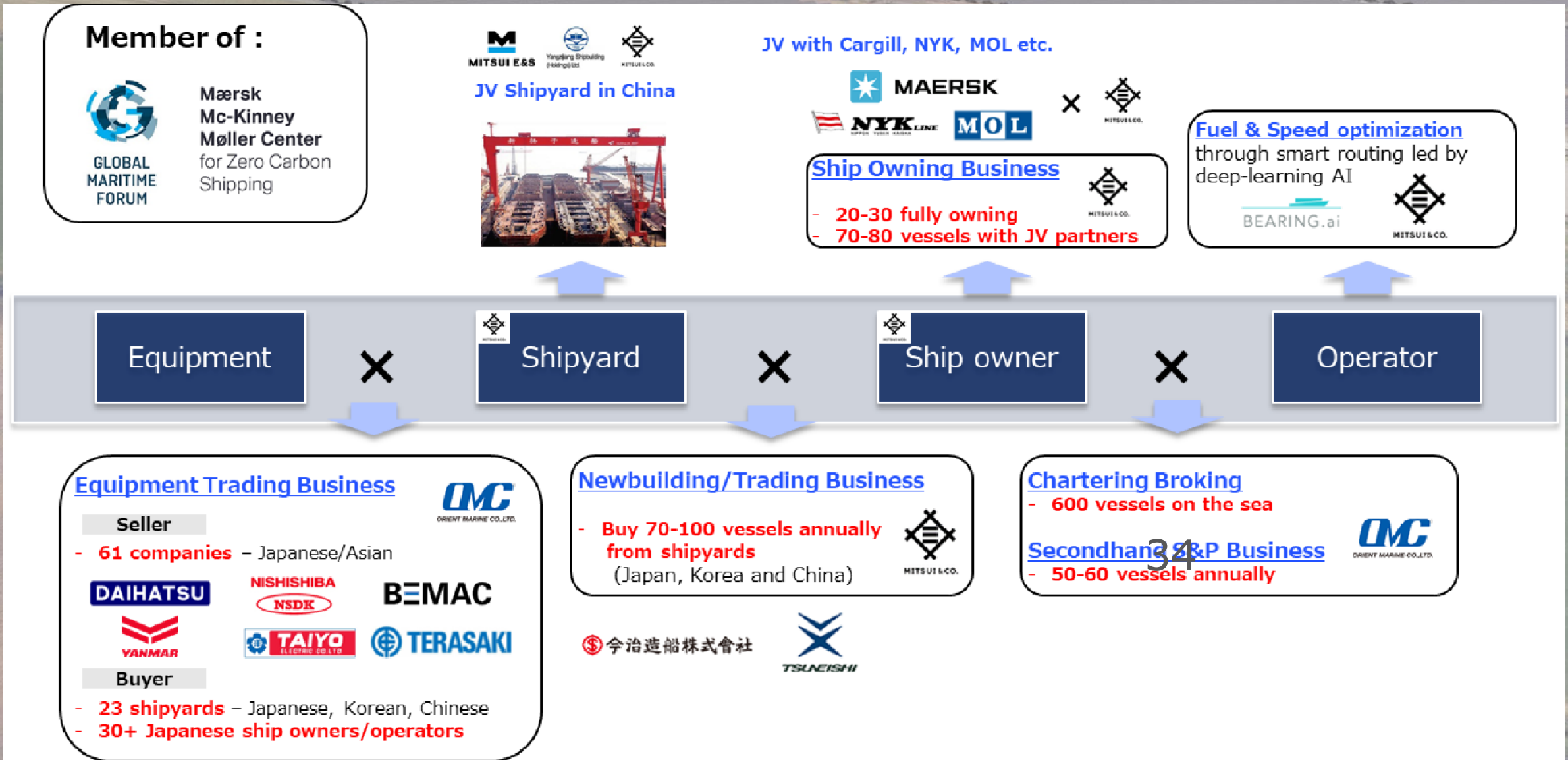
TOPSOE



- RNG from Landfill
- 5 plants (operational) in USA & Canada
- Owned by Mitsui at 33.3%



4. Mitsui Global Energy Transition



Theme of Medium-term Management Plan **2026**

Creating Sustainable Futures

Unearth social issues in all industries from the perspective of global sustainability, produce new business innovation and create strong business clusters and new industries



360° business innovation.



MITSUI & CO.



GLOCAL GREEN

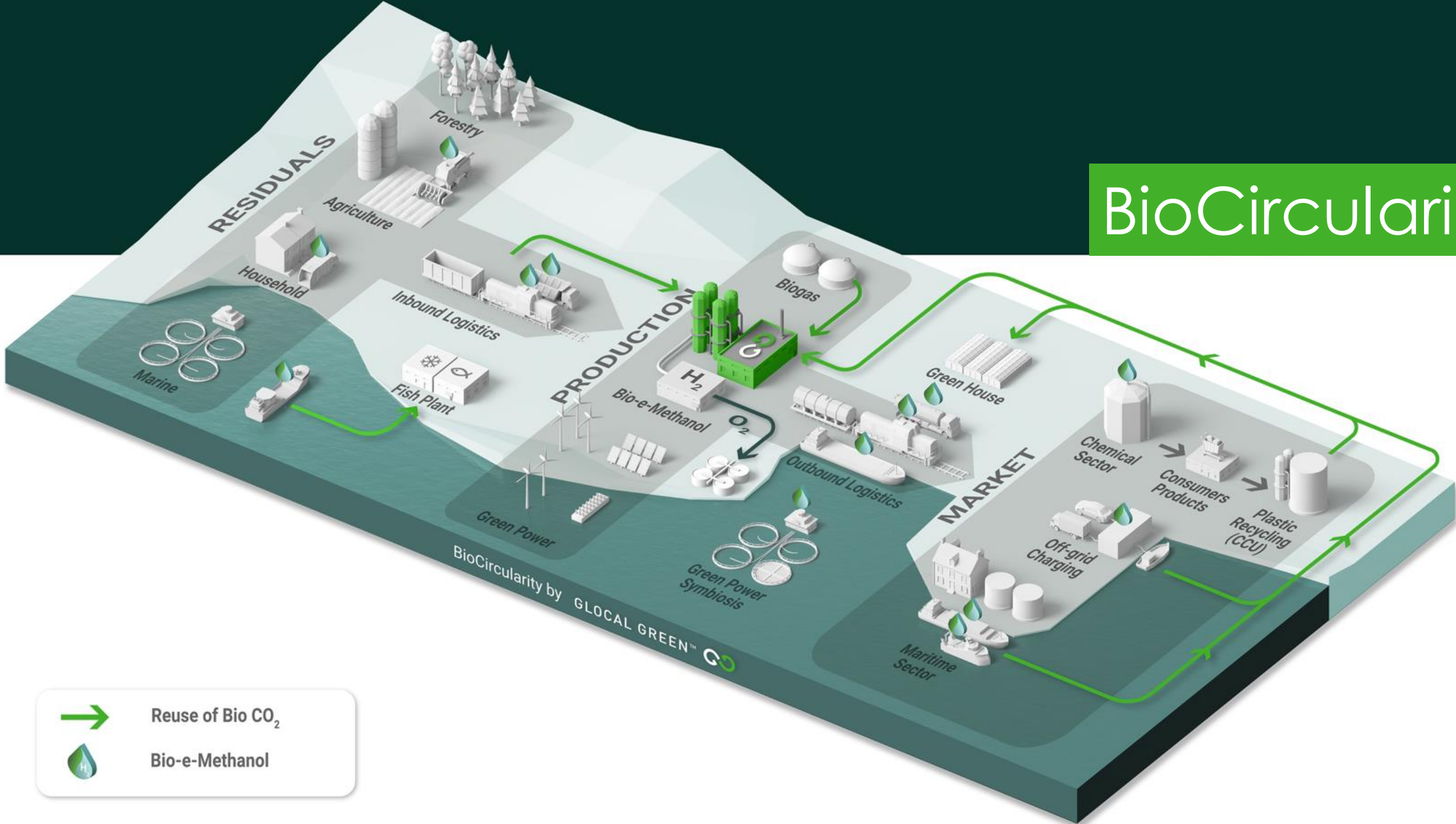
Bio-e-methanol

Bio + PtX = the rational pathway
for hydrogen

November 22th. 2023

Meth₂anol™

BioCircularity



 Reuse of Bio CO₂

 Bio-e-Methanol

AN ENVIRONMENTAL WINNER

Zero-emission production and value chain



GROT



RESIDUES FROM WOOD



FISH SLUDGE

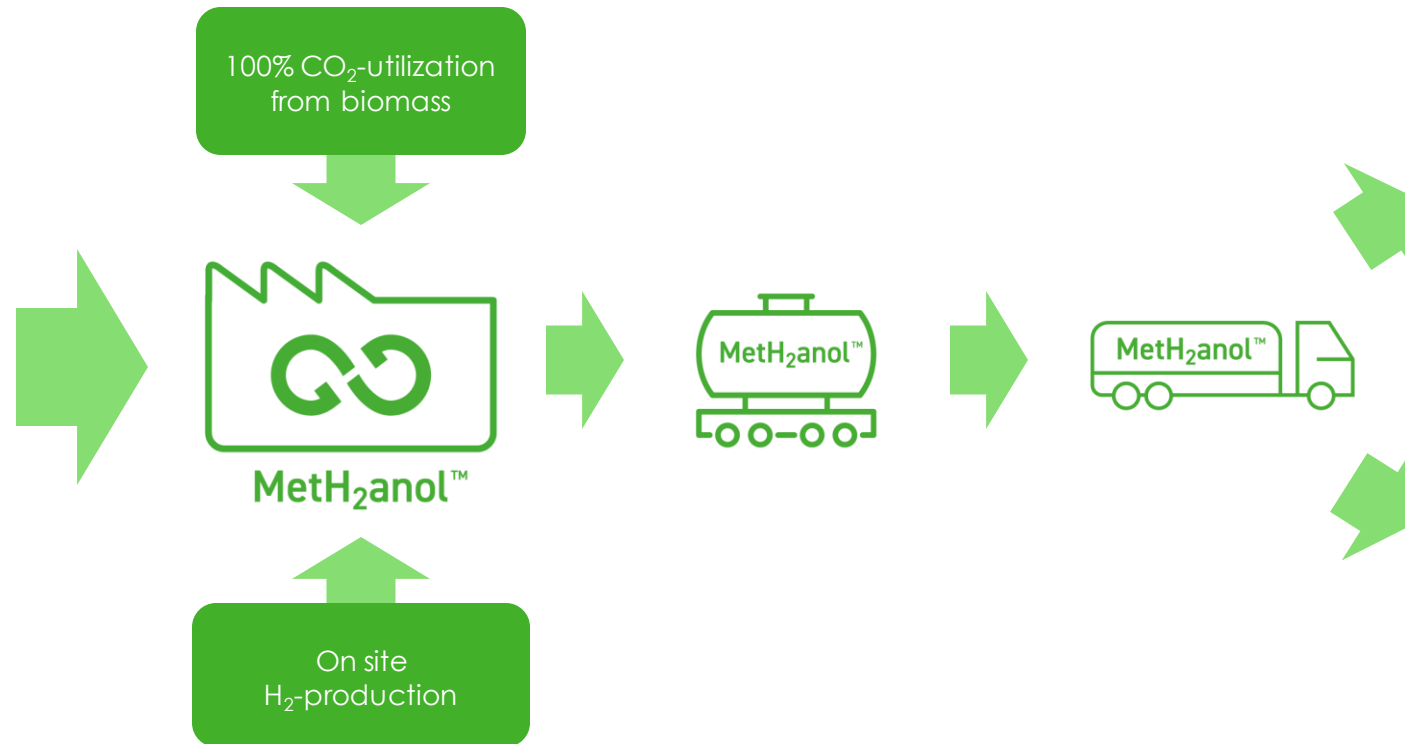
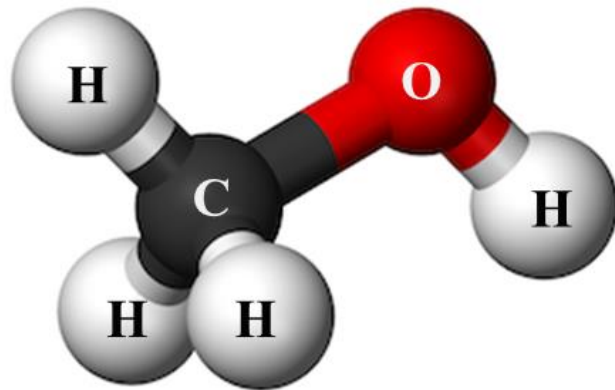


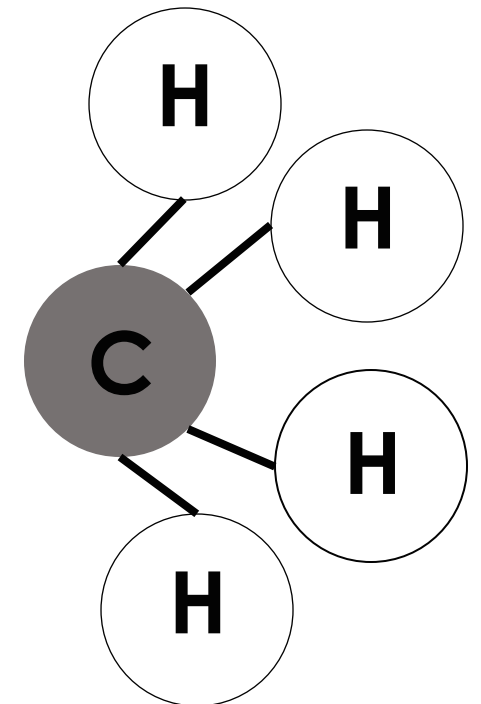
Illustration: Glocal Green

THE OPTIMAL HYDROGEN CARRIER

Methanol - best liquid H₂ carrier

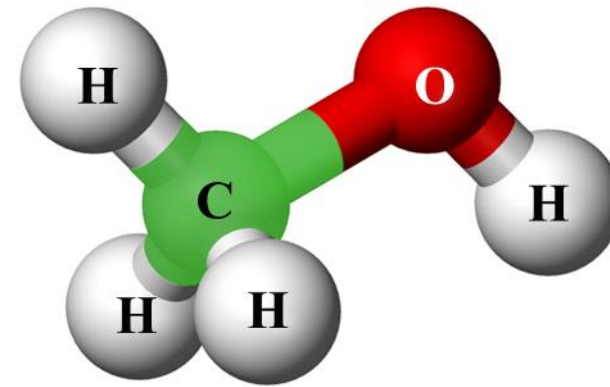
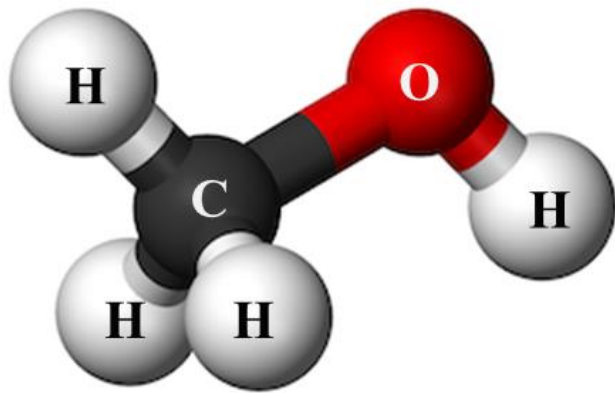


- Liquid at normal temperature and pressure
- Low risk
- Burns completely clean
- Existing infrastructure and user solutions

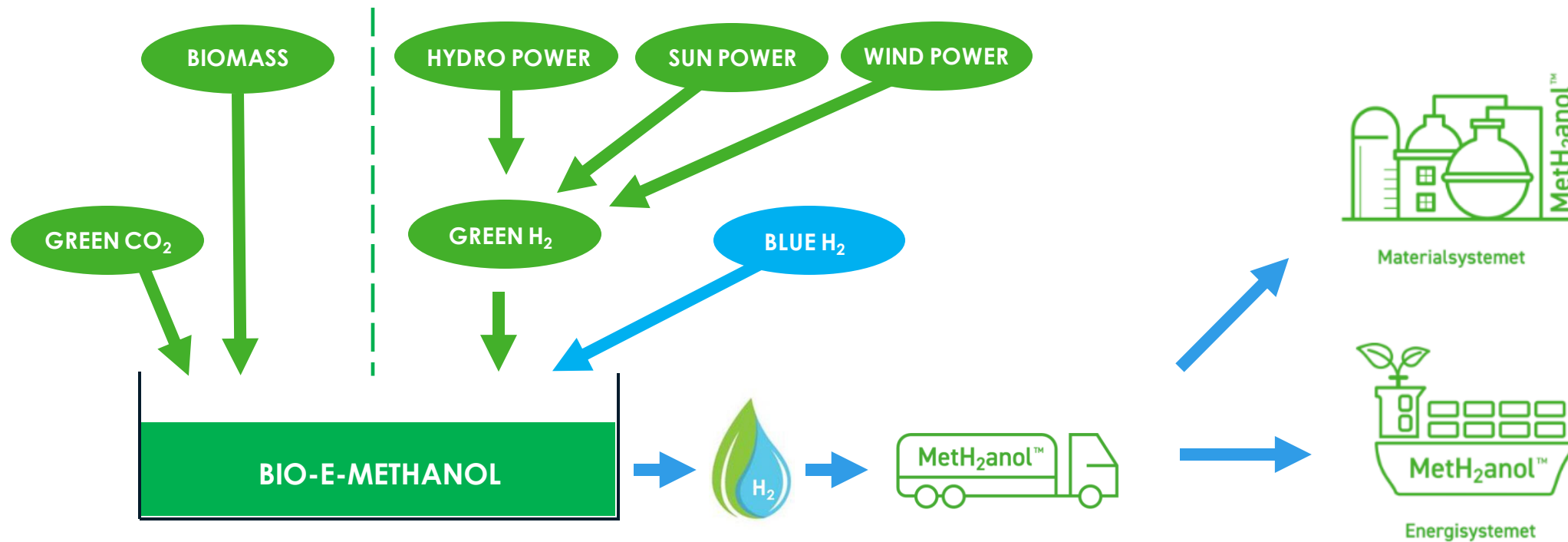


PUTTING GREEN CARBON TO WORK

Methanol - same but different



GREEN TRANSITION

The “battery” for storage & transportation of H₂

Development plant



**Existing
development facilities
for
completing our concept**



GLOCAL GREEN



Fra avfall til grønn energi

THEORETICAL PROOF OF CONCEPT

Technoeconomic analysis

- Ref. **Technoeconomic analysis** done together with Sintef Energi and partners;

Calculation of MFSP	CASE I	CASE IB	CASE II
Produced methanol	51 200 t/h	61 872 t/y	24 320 t/y
MFSP	0.6987 €/kg	0.5782 €/kg	0.6664 €/kg

Table 7: Annual operating cost and calculation of the minimum fuel selling price to achieve break even.

3 different operating scenarios that show different results depending on the supplied amount of H₂, and carbon utilization. Overall system utilization is set to 80%.

Case I = 80% H₂ boost and carbon utilization

Case II = no H₂ boost

Case IB = full H₂ boost and carbon utilization

- With following sensitivity analysis;

	CASE I				CASE II			
		Investment cost				Investment cost		
		50 %	100 %	150 %		50 %	100 %	150 %
Operating costs	20 %	0.1621	0.1993	0.2365	20 %	0.1699	0.2308	0.2918
	50 %	0.3494	0.3866	0.4238	50 %	0.3332	0.3942	0.4551
	100 %	0.6615	0.6987	0.7359	100 %	0.6054	0.6664	0.7273
	150 %	0.9736	1.0108	1.0481	150 %	0.8776	0.9386	0.9996

Table 8: Sensitivity study for a variation of the investment and operating costs

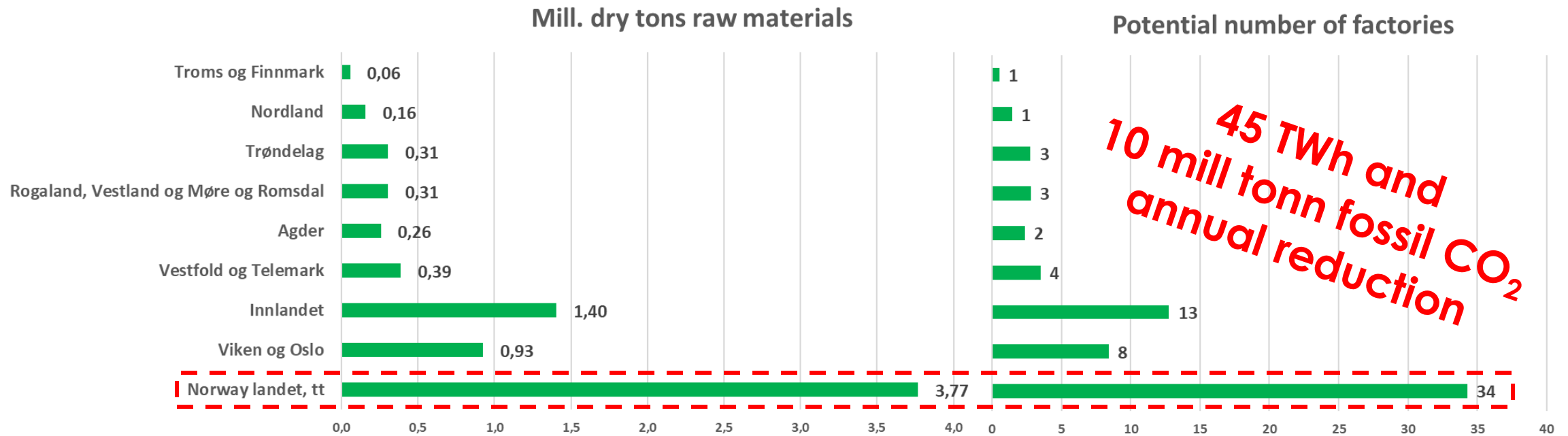
Glocal Green's planned first factory on Øyer will have a capacity equal to **2x30MW=60MW**, which implies an annual production of up to approx. 155,000 tons.

Minimum fuel selling price (MFSP) is Ex. Works on Øyer. (Price/litre by multiplying stated price/kg by 0.791.) Calculations are based on market-based Opex and Capex, and 10-year price estimate for biomass and electricity prices.

Techno-economic analysis confirms the company's prospects.

RAW MATERIAL BASE - NORWAY

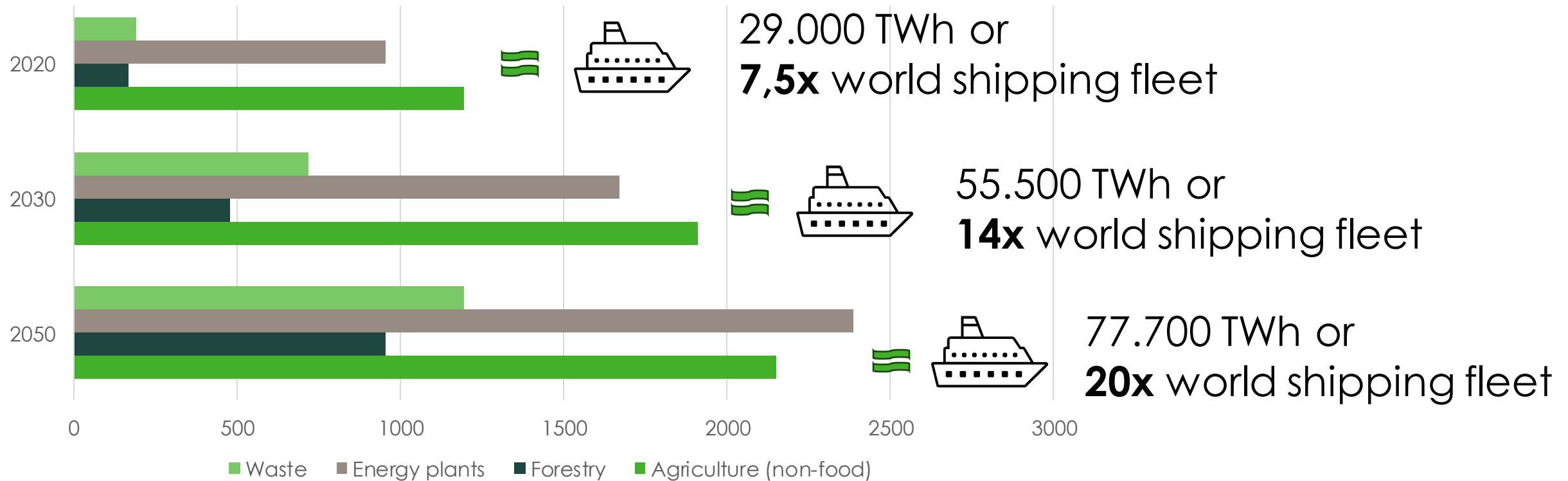
Available feedstock from forestry



RAW MATERIAL BASE - GLOBALLY

Theoretical – in a bio-e-methanol perspective

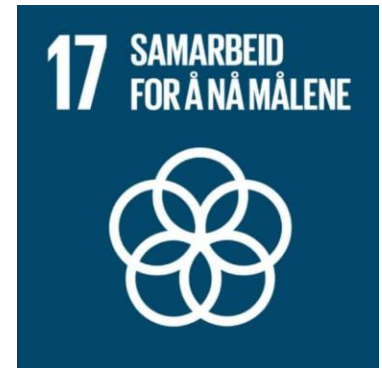
Mtoe per annum, world



Kilde: Marine Methanol, MI 2023

OUR VISION

A local solution to a global challenge



LARGE MARKET PROVIDES A BASIS FOR HIGH DEMAND

The future fuel and essential ingredient in green conversion



There are almost endless possibilities and needs for climate-neutral biomethanol. It will be used as an ingredient in the green transition (chemical input factor), will be an important piece in power production and storage, from, for example, offshore wind, and as a fuel for transport purposes - both on land and on water.



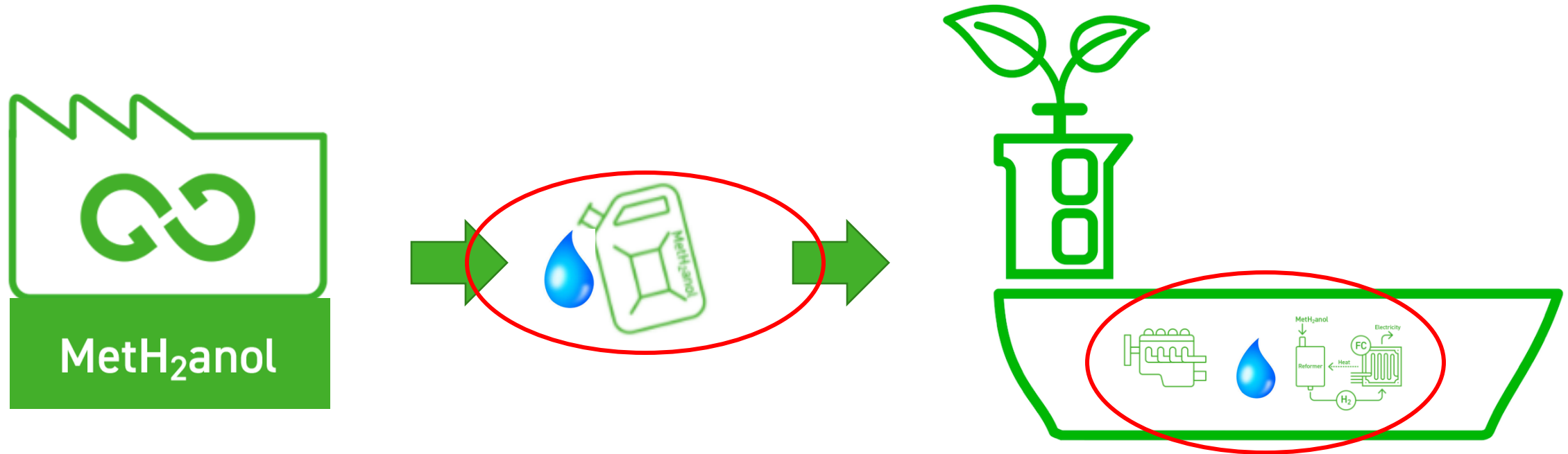
“Pioneers like you are shaping our future’s economy. This is not just a big step for Mærsk and Europe. It’s a big step for the whole world”

Ursula von der Leyen

President of the European Commission

LIQUID LOW RISK

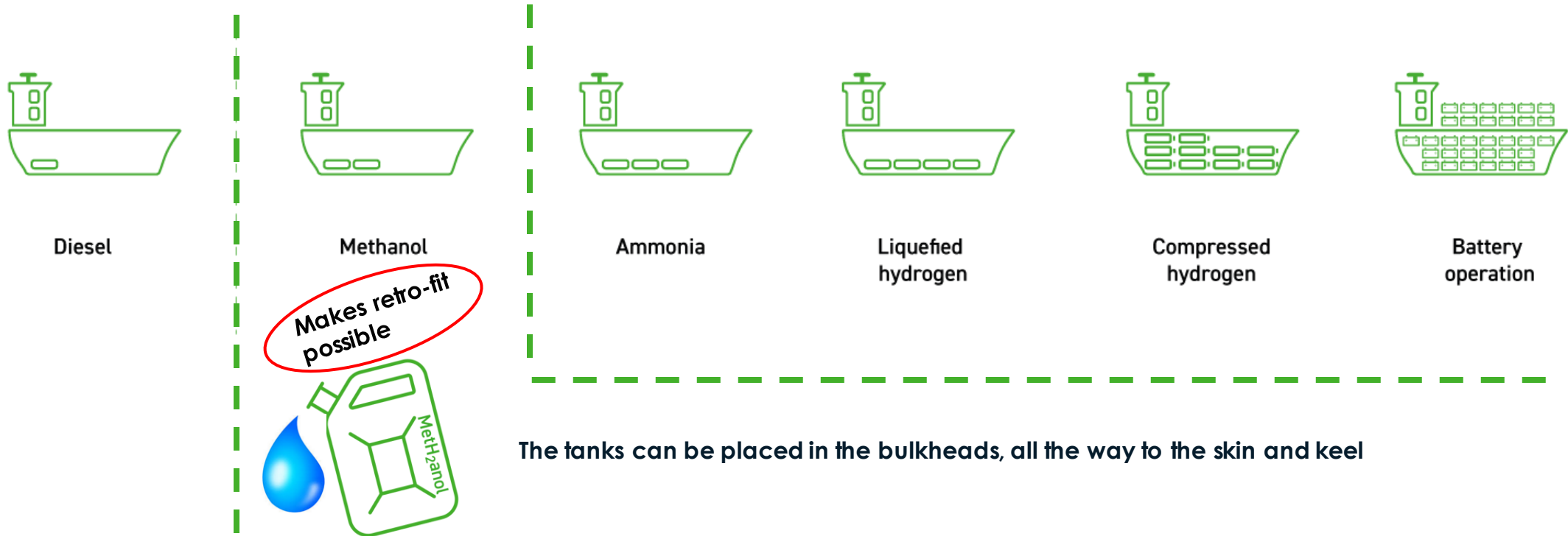
The regulations are in place from A to Z



Today, all FC and engine suppliers focus on methanol solutions

LIQUID LOW RISK EFFICIENCY

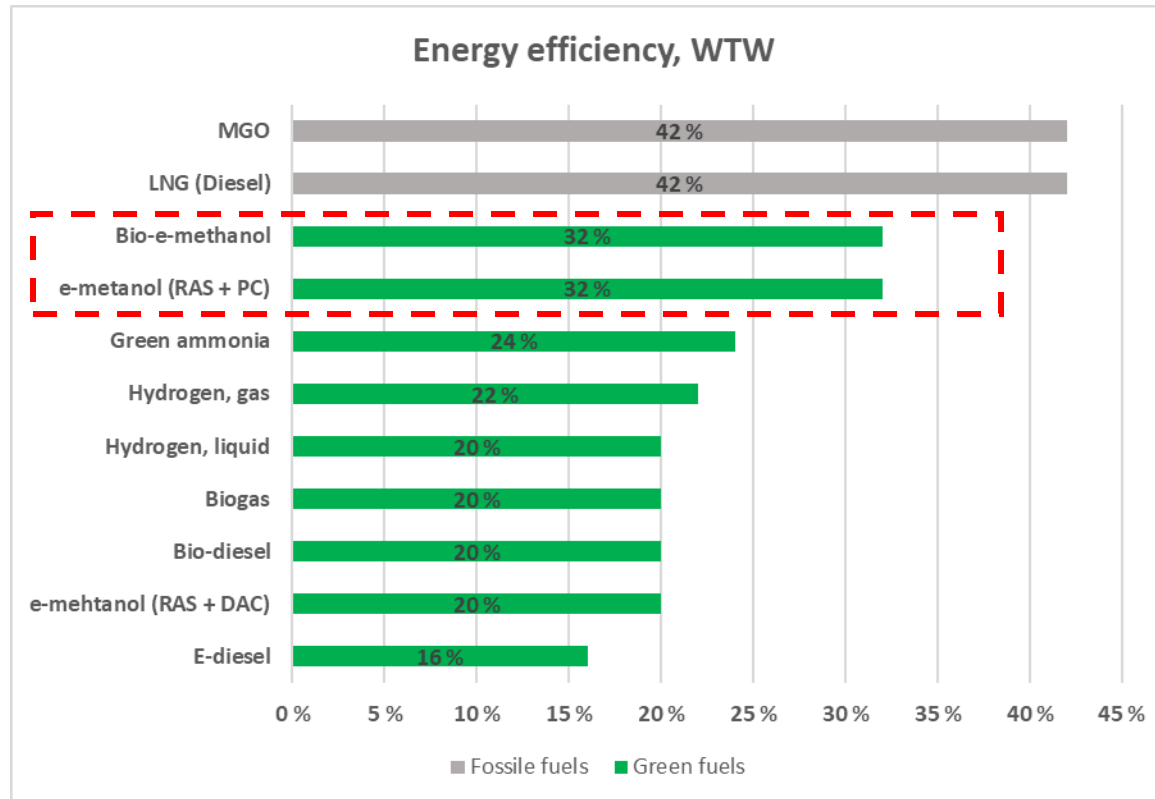
Ideal for new construction and retrofit



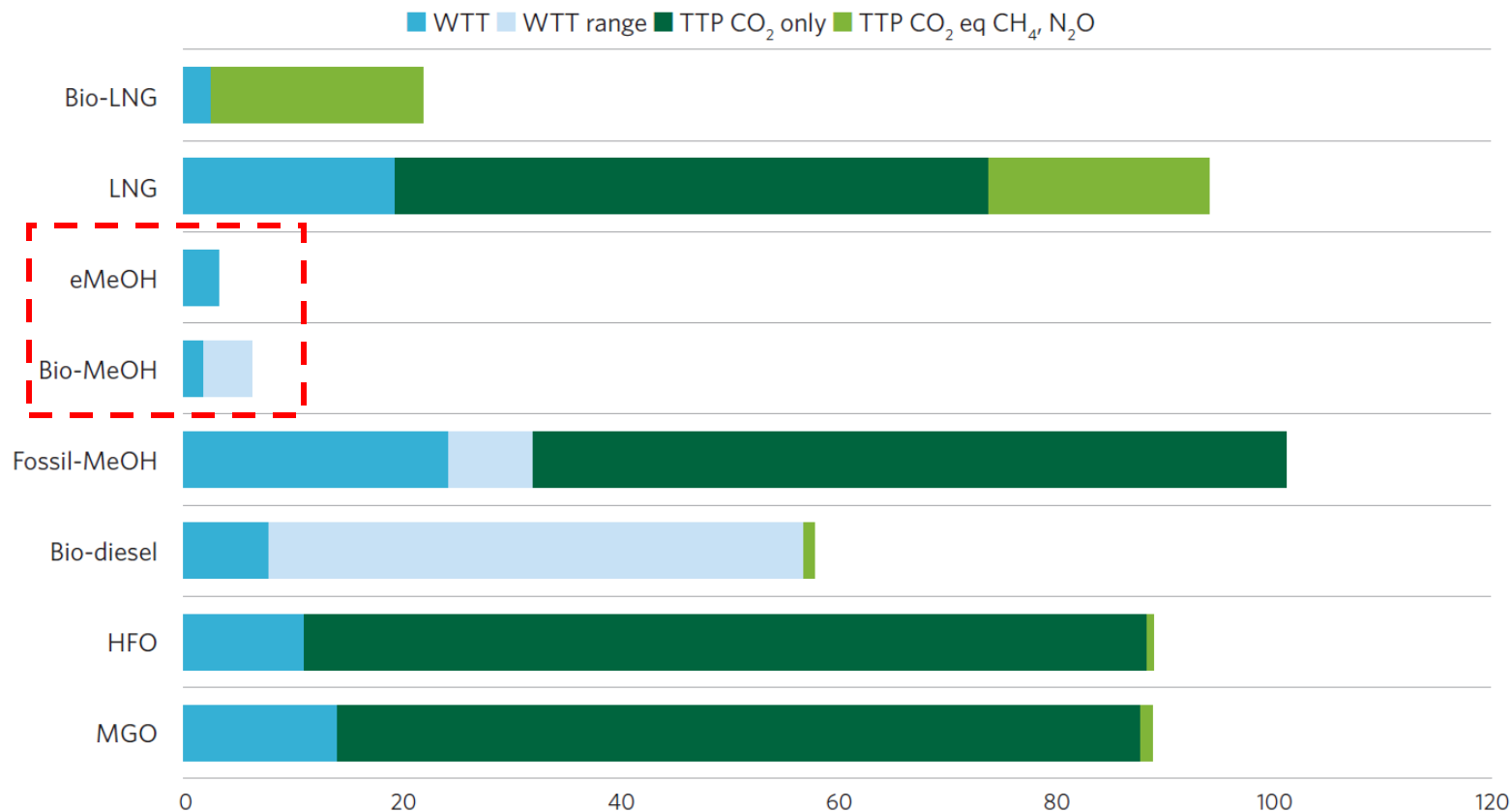
Illustrates short and deep sea vessels

Illustration: Glocal Green

Energy efficiency, Well-to-Wake



A climate winner



Bio-methanol and e-methanol (MeOH) have no potent methane or nitrous oxide emissions, (CO₂eq CH₄, N₂O)

WTP (Well-to-propeller) utslipp målt i gCO₂eq/MJ. (WTT: Well-to-tank; TTP: Tank to propeller). Kilde: Green Marine Methanol Consortium

SHIPPING LEADS THE WAY

Stena Germanica on methanol since 2015



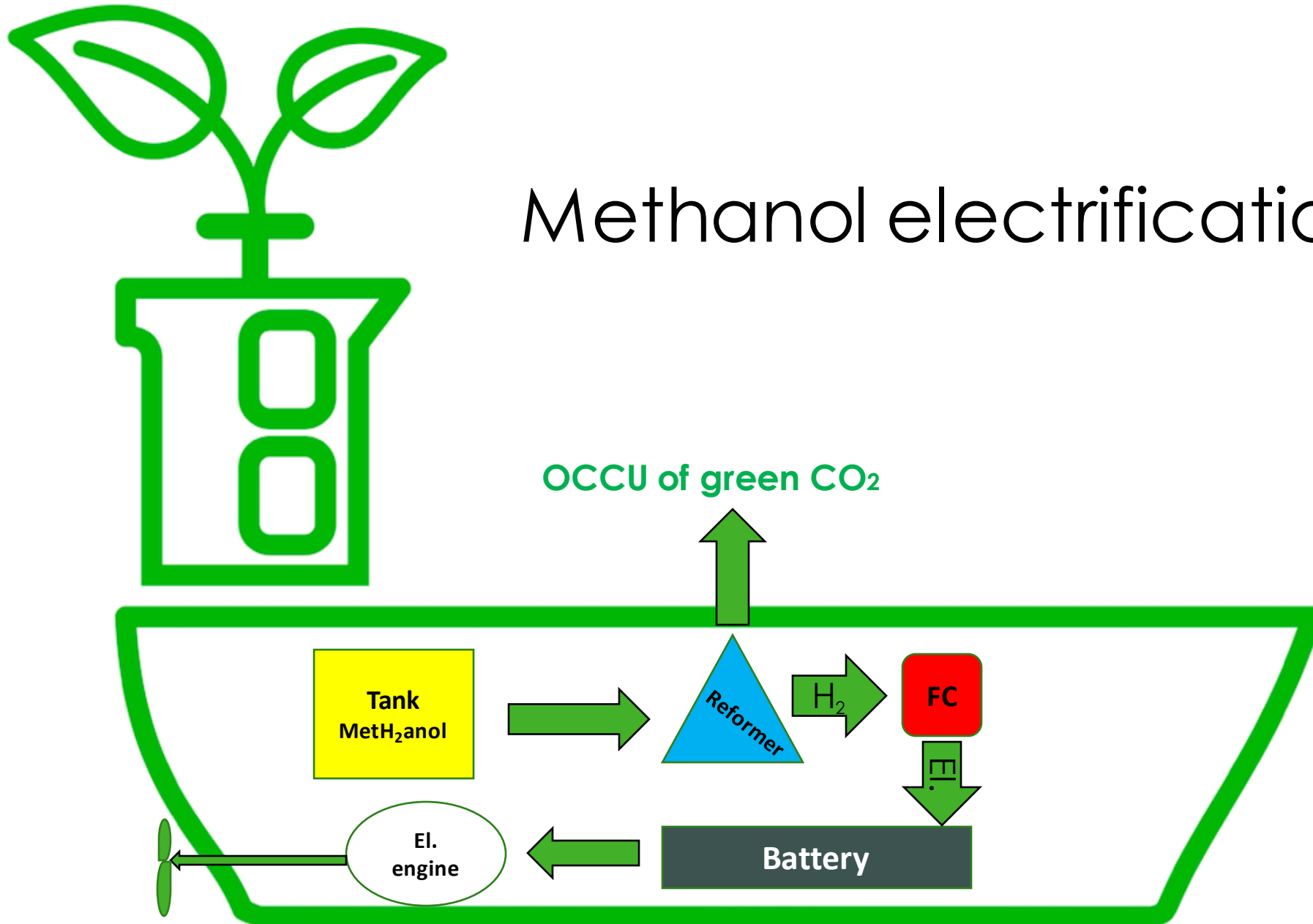
PILOT AND INSPECTION VESSELS

Motorized by Scania methanol engines



**Swedish
and
Norwegian
coastal
authorities**

Methanol electrification



STATIONARY ELECTRICITY PRODUCTION FROM METHANOL

H₂-to-electricity



Storage for methanol

Reformer /
H₂ generator

Buffer tank for H₂

FC for H₂

Battery

INFRASTRUCTURE

Bunkering systems



Distribution in Norway

Volume	
Per factory:	170.000 tonn/year 3.270 tonn/week = 1 tanker
Factories:	50
Total potential:	8.500.000 tonn/year

De-centralized production and distribution.
Tanker/bunker vessel to local stations

Additionally distribution from inland production
Oslo-Bodø

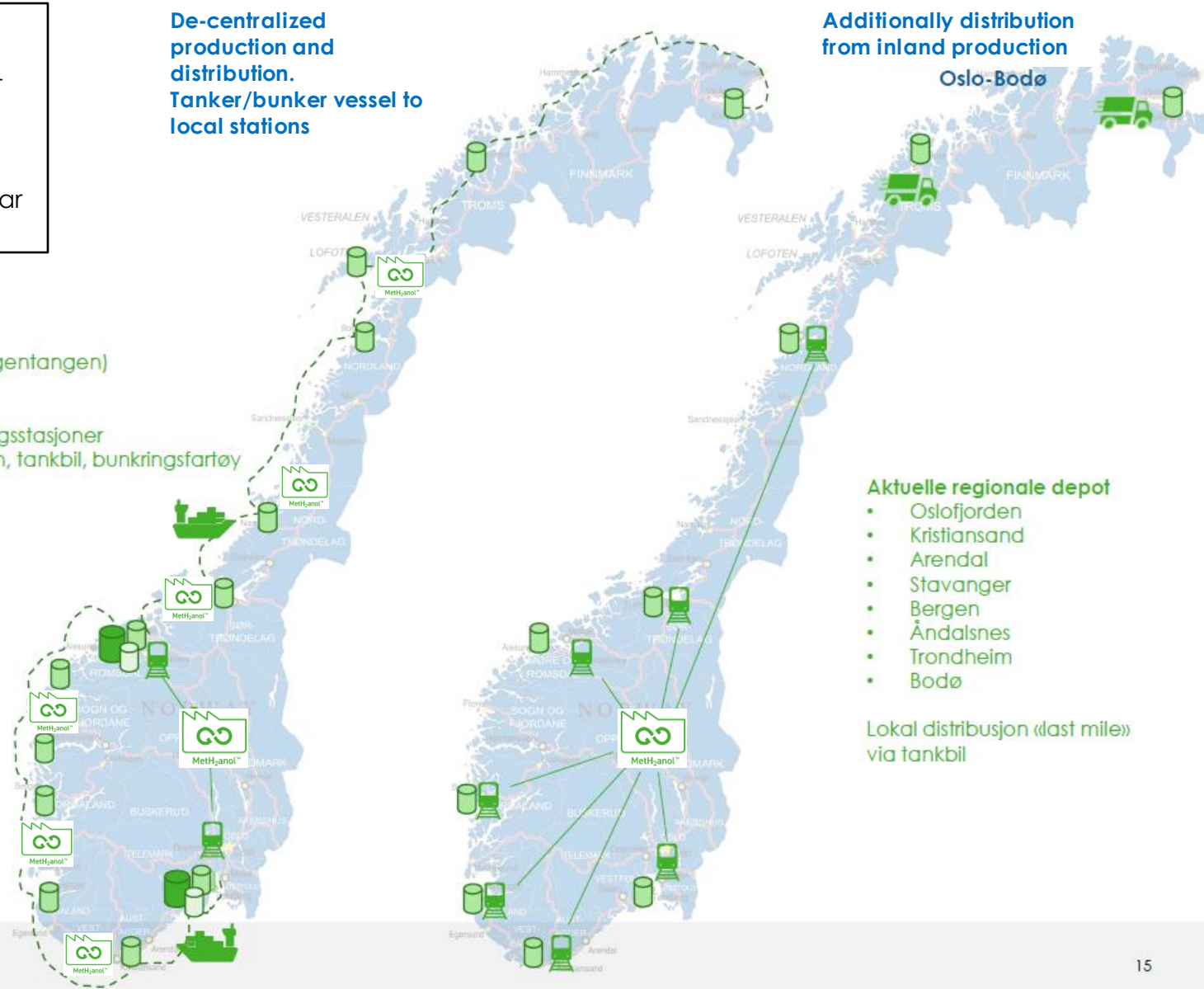
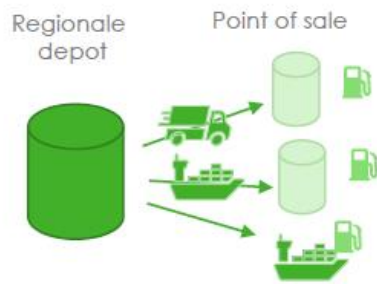
Regionale depot

- Oslofjorden (Slagentangen)
- Åndalsnes
- Tankbåt til bunkringsstasjoner
- Bunkring fra stasjon, tankbil, bunkringsfartøy

Aktuelle regionale depot

- Oslofjorden
- Kristiansand
- Arendal
- Stavanger
- Bergen
- Åndalsnes
- Trondheim
- Bodø

Lokal distribusjon «last mile»
via tankbil



Distribusjon i Europa

Fokus på det europeiske markedet

Viktige havner:

- Skagen
- Rotterdam
- Hamburg
- Østersjøen
- Southampton
- Algeciras
- Las Palmas
- Gibraltar

Bunkring i Norge:

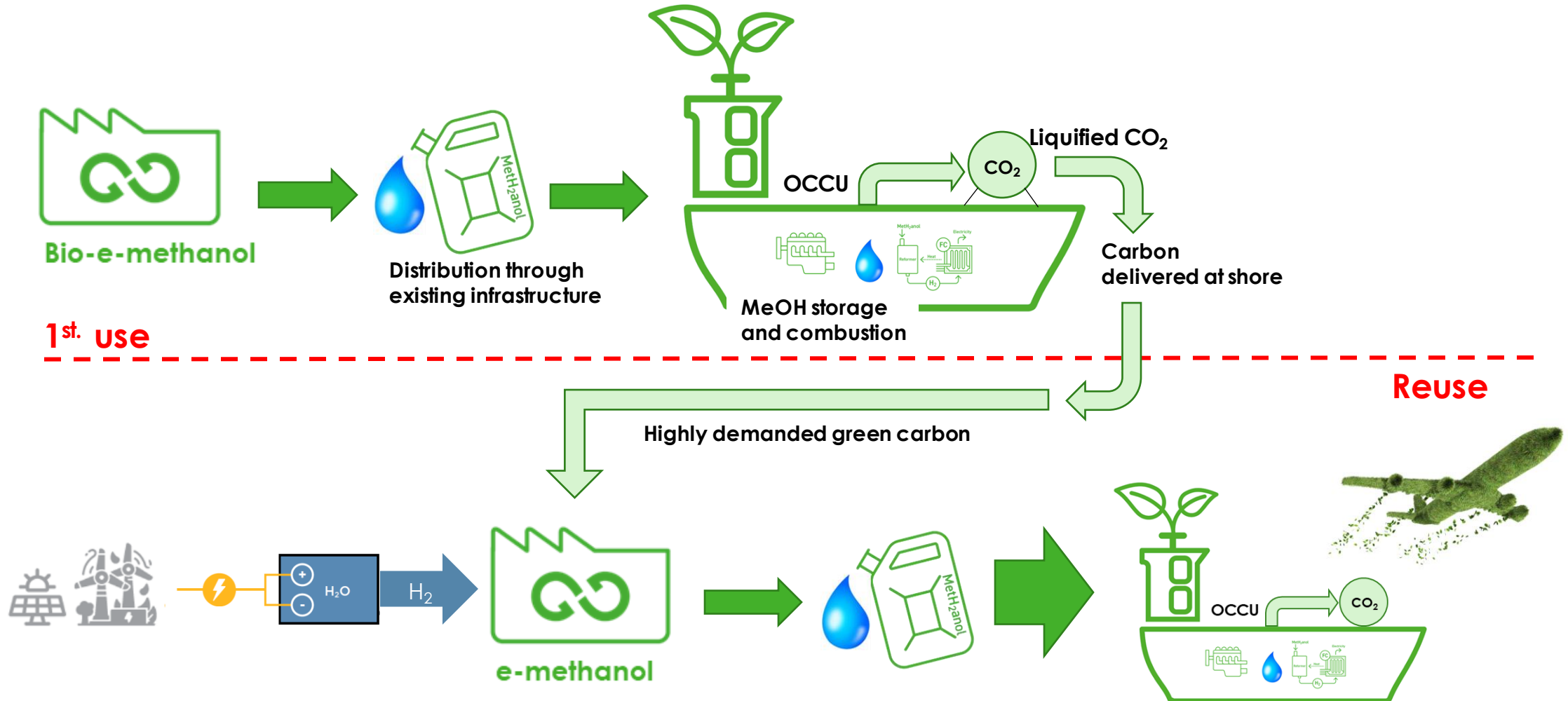
- bunker barge (større skip)



Nordsjøen – Østersjøen: Green Methanol Corridor ?

OCCU OF GREEN CARBON

Looping – simply rises the potential



INTERACTIONS

Close dialogs creates solutions



RAMBOLL

LTU Green Fuels

RISE

SINTEF



KYSTVERKET



MAERSK



CIRCLE K



SALMON EVOLUTION*



Bertel Steen
Power Solutions



MQWI



samskip





GLOCAL GREEN

www.glocalgreen.com



MAN Energy Solutions
Future in the making

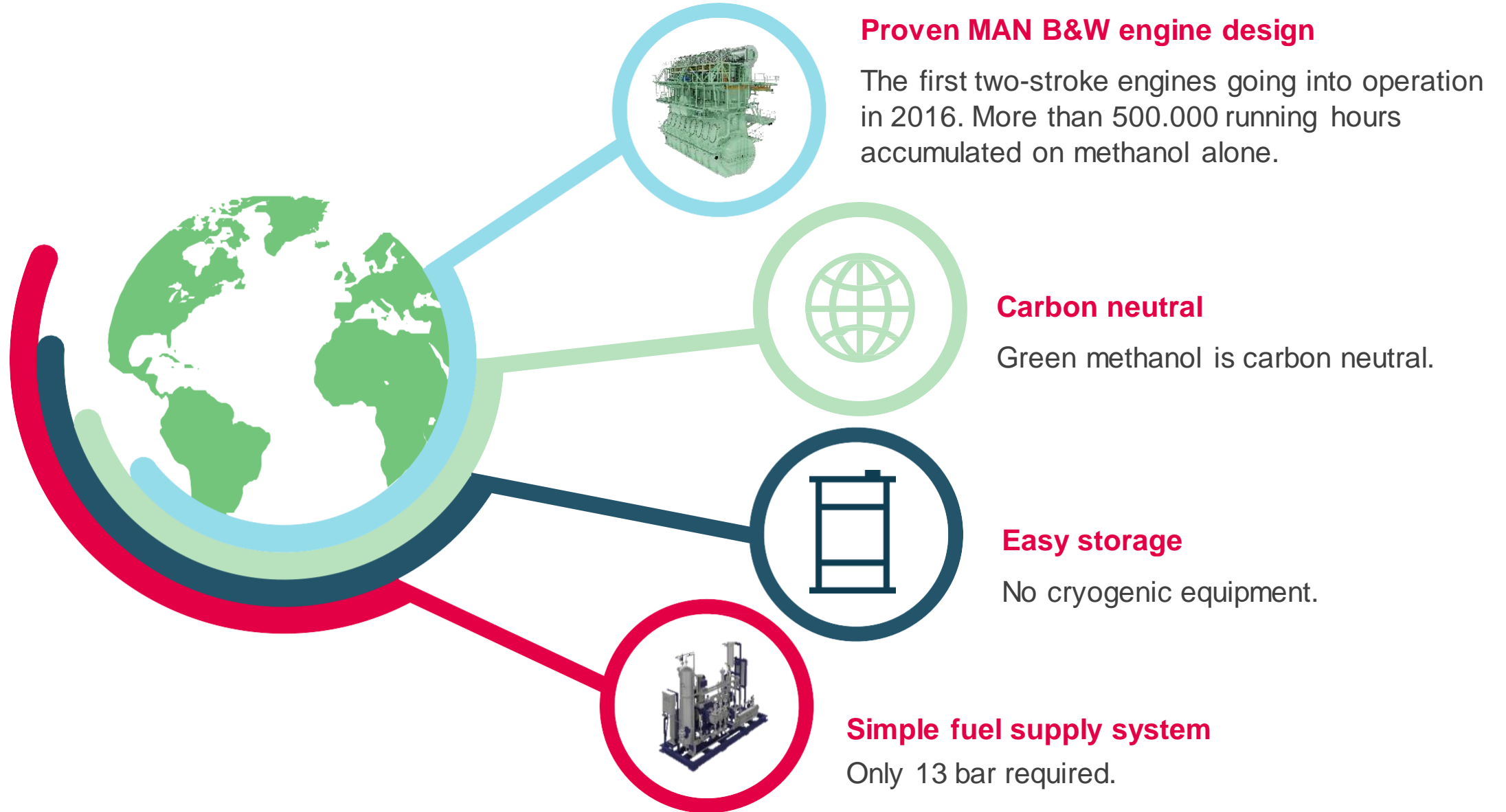
Scalable energy transition

MAN B&W ME-LGIM series - world's first methanol two-stroke engines



Presented by retired MAN-ES
employee Kjeld Aabo.
Now senior consultant for MI.

Methanol as a marine fuel

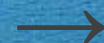


Powering sustainable shipping by opening clear routes

Methanol
ME-LGIM
154

Ethane
ME-GIE
51

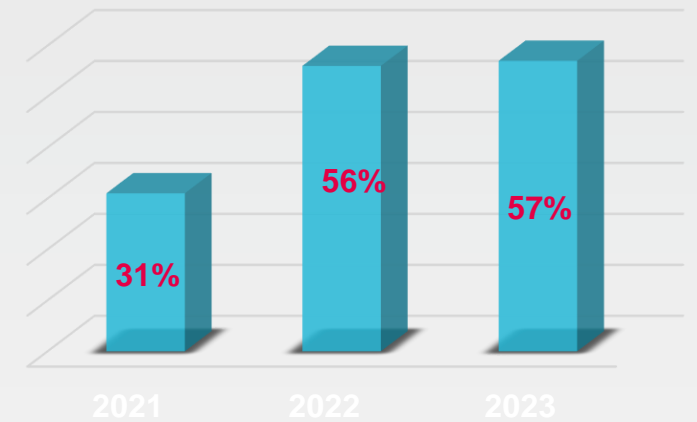
Ammonia



Methane
ME-GI & ME-GA
621 - 268

LPG
ME-LGIP
164

1250+



Two-stroke dual-fuel share of total newbuilding market

dual-fuel engine orders

154 X MAN B&W ME-LGIM references



**Methanol and
product tankers**
32 X 50-bore



Container vessels
70 X 95-bore
13 X 80-bore
23 X 50-bore

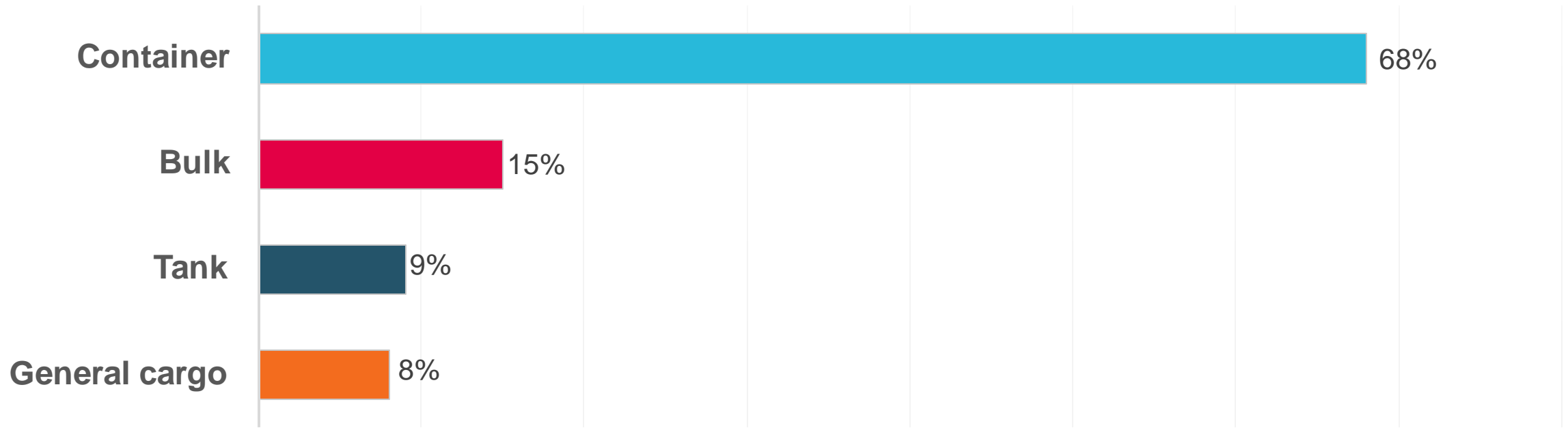


Bulk carriers
14 X 50-bore



PCTC
2 X 60-bore

Methanol – 30% of total newbuilding project pipeline



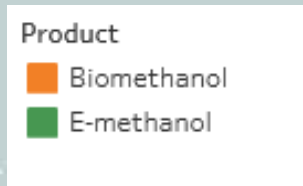
Newbuilding pipeline fuel distribution based on engine power: 30% methanol, 36% methane, 32.3% fuel oil, 1.5% LPG, and 0.2% ethane.

Let's go back in time - Green methanol projects as of Q1 2022

In Q1 2022, 55 X MAN B&W ME-LGIM engines were in the order book

Green methanol production projects as of Q1 2022:

- Yearly total production capacity from **e-methanol** and **bio-methanol** plants from 2024-2025 onwards, where production capacity was already published:
≈ **2.6 million tons of green methanol**



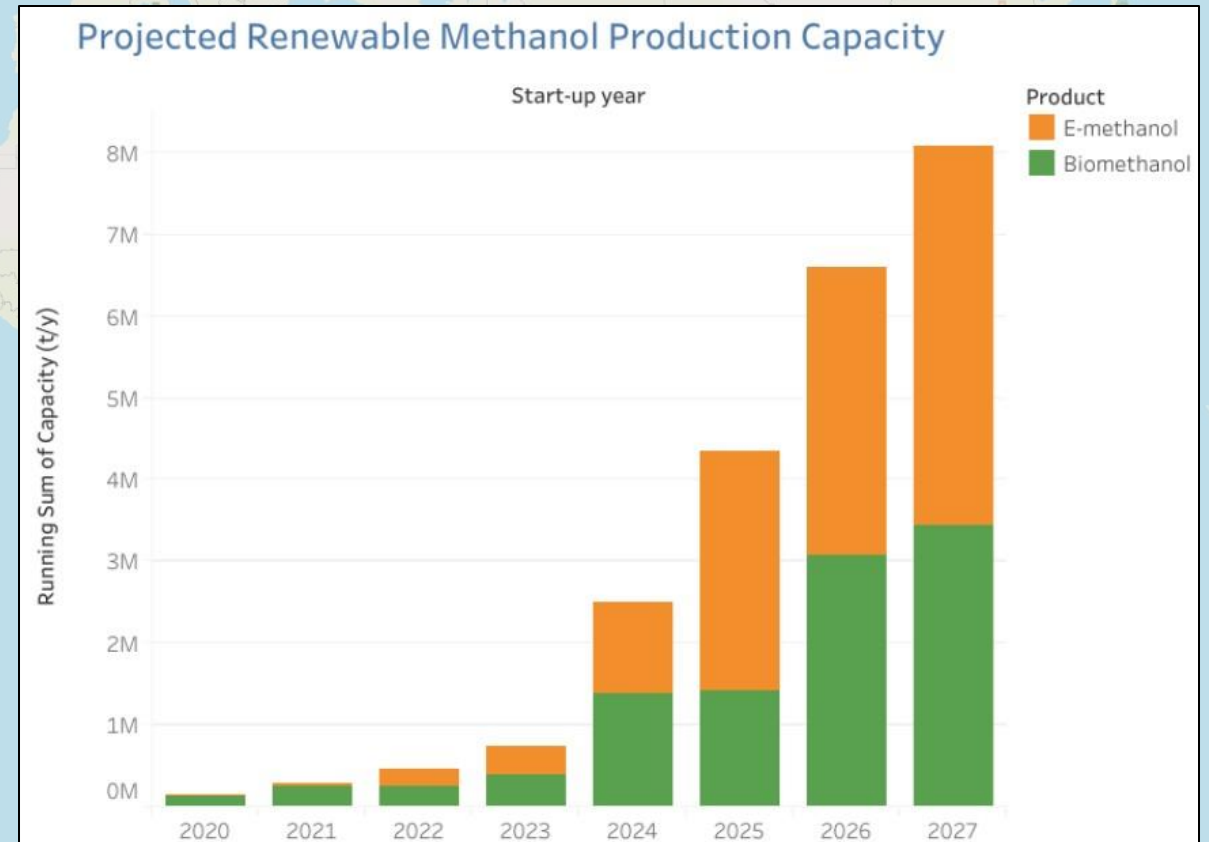
Source: <https://www.methanol.org/renewable>

Green methanol projects as of Q1 2023

Today, 110 X ME-LGIM engines are in the order book.

Green methanol production projects as of Q1 2023:

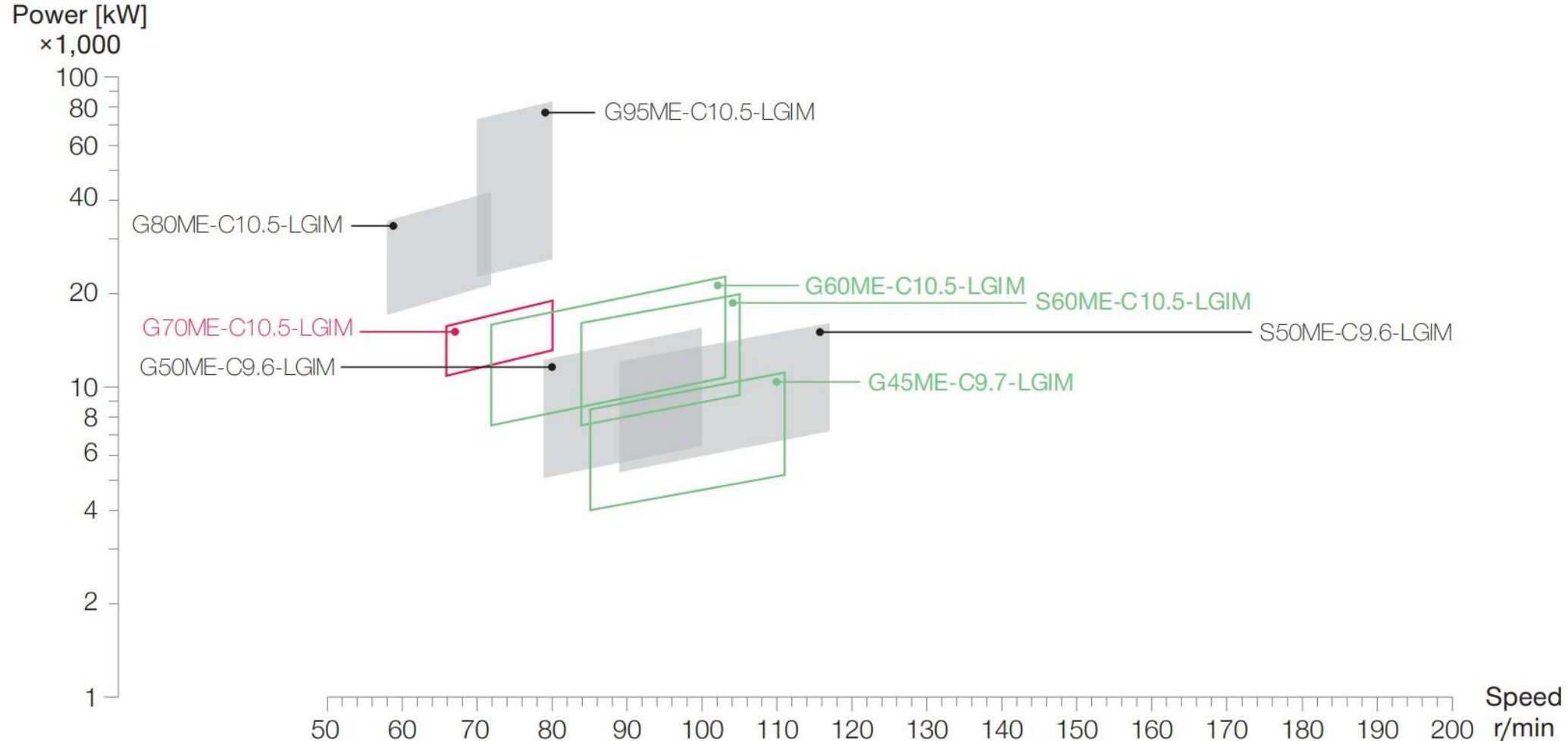
- Projects are since Q1 2022 increased as:
 - from around 2.6 million tons a year
 - to upwards of 8 million tons a year in 2027
 - across more than 80 projects



Source: Methanol Institute Renewable Methanol Database of Current/Announced projects, <https://www.methanol.org/renewable/>

MAN B&W Methanol engines

Existing S50, G50, G80 and G95-LGIM engines, alongside the new G45 and S/G60, as well as the G70 LGIM engines, of which design plans have been published.



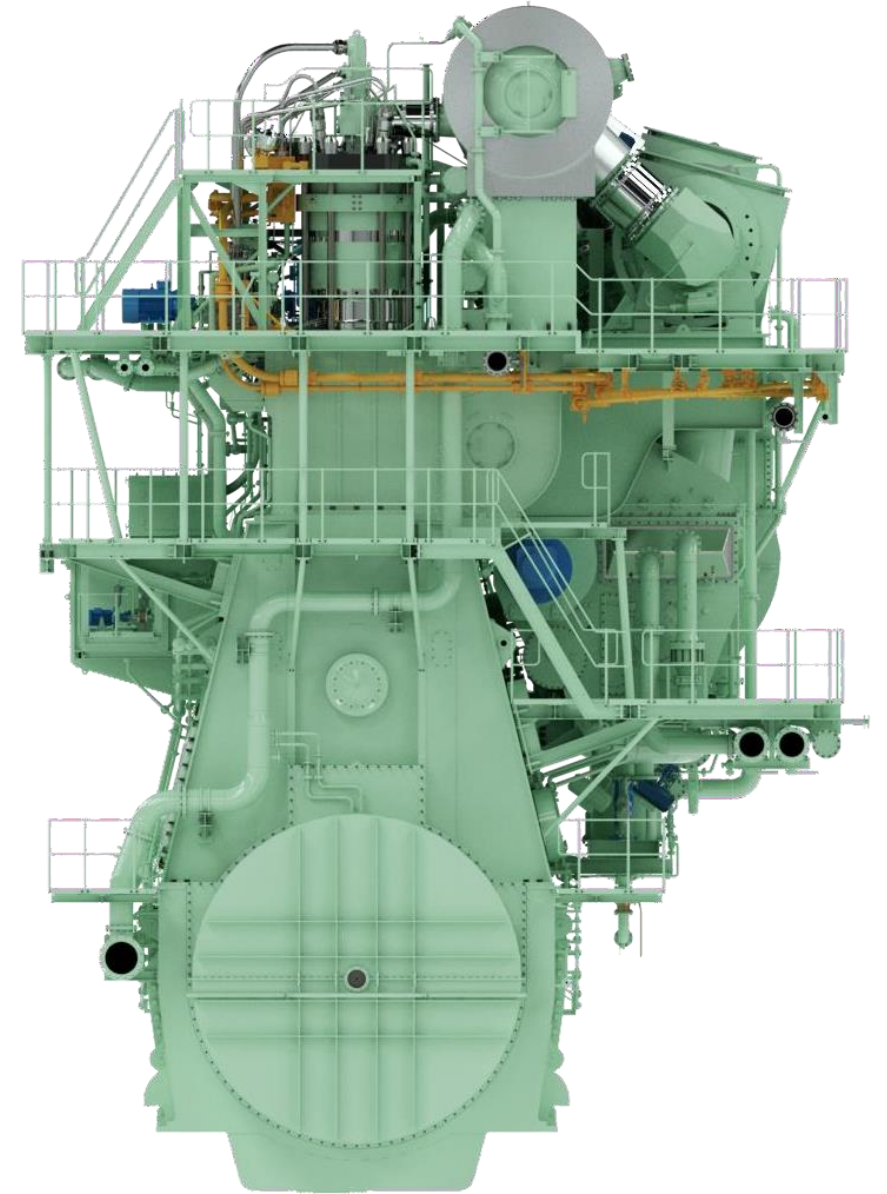
MAN B&W ME-LGIM Engine

Based on

- Proven high efficiency Diesel Cycle.
- Merits of ME-C, ME-GI and LGIP engines.

Key specifications

- 13 bar supply pressure.
- 600 bar injection pressure.
- 5% pilot energy fraction (any compliant fuel oil).
- Operation on methanol from 10-100% load.
- Same high efficiency in methanol and fuel oil modes.



LGIM components on engine

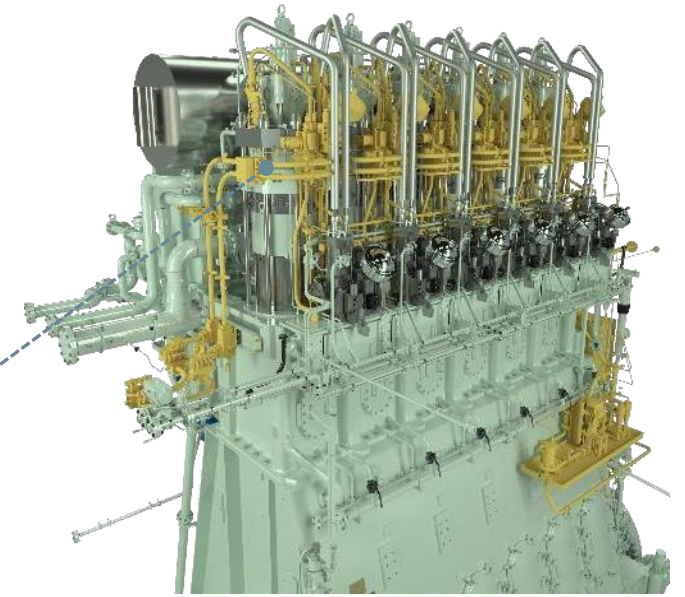
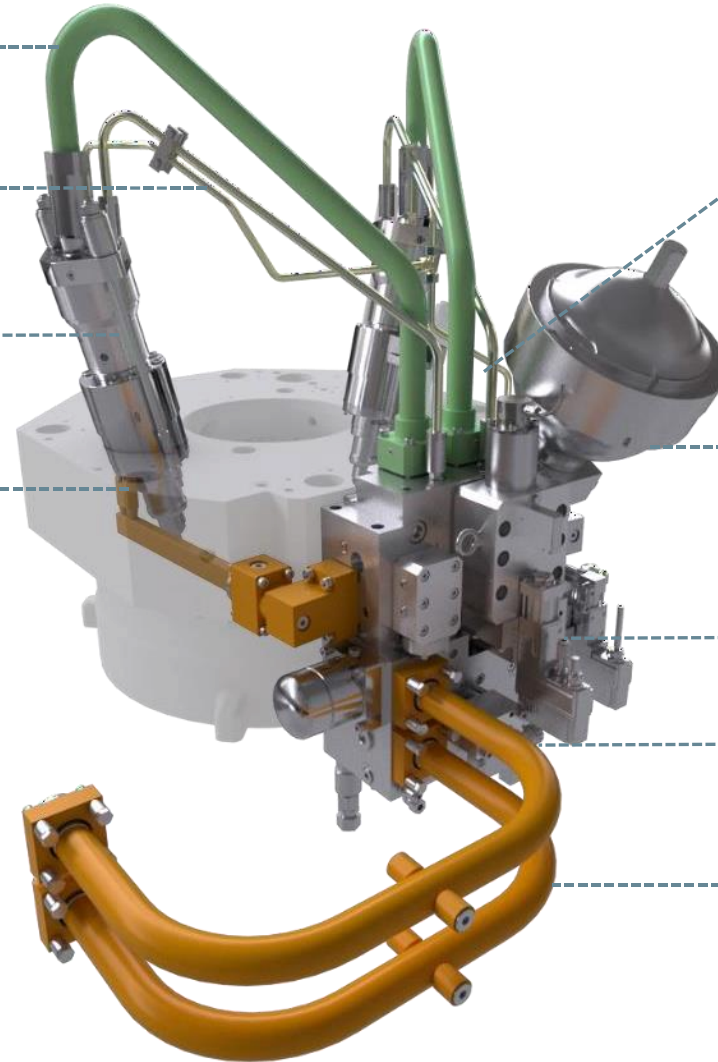
The latest generation LGIM engine components

Hydraulic oil

Sealing oil

FBIV-M

Methanol supply



Hydraulic accumulator

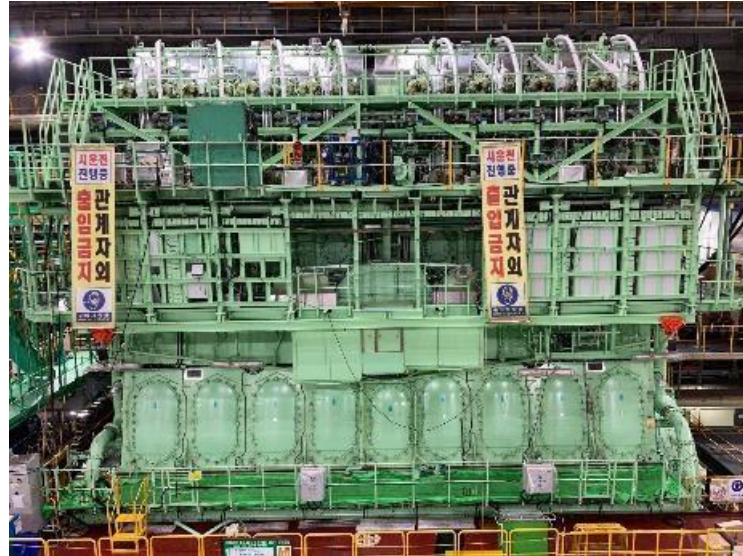
Hydraulic control valves

Double-walled pipe inlet

Double-walled pipe outlet

First 8G95ME-C10.5-LGIM EGRTC engine

First 2 X 8G95ME-C10.5-LGIM engines delivered to shipyards already. First vessel delivery 3rd of January 2024.



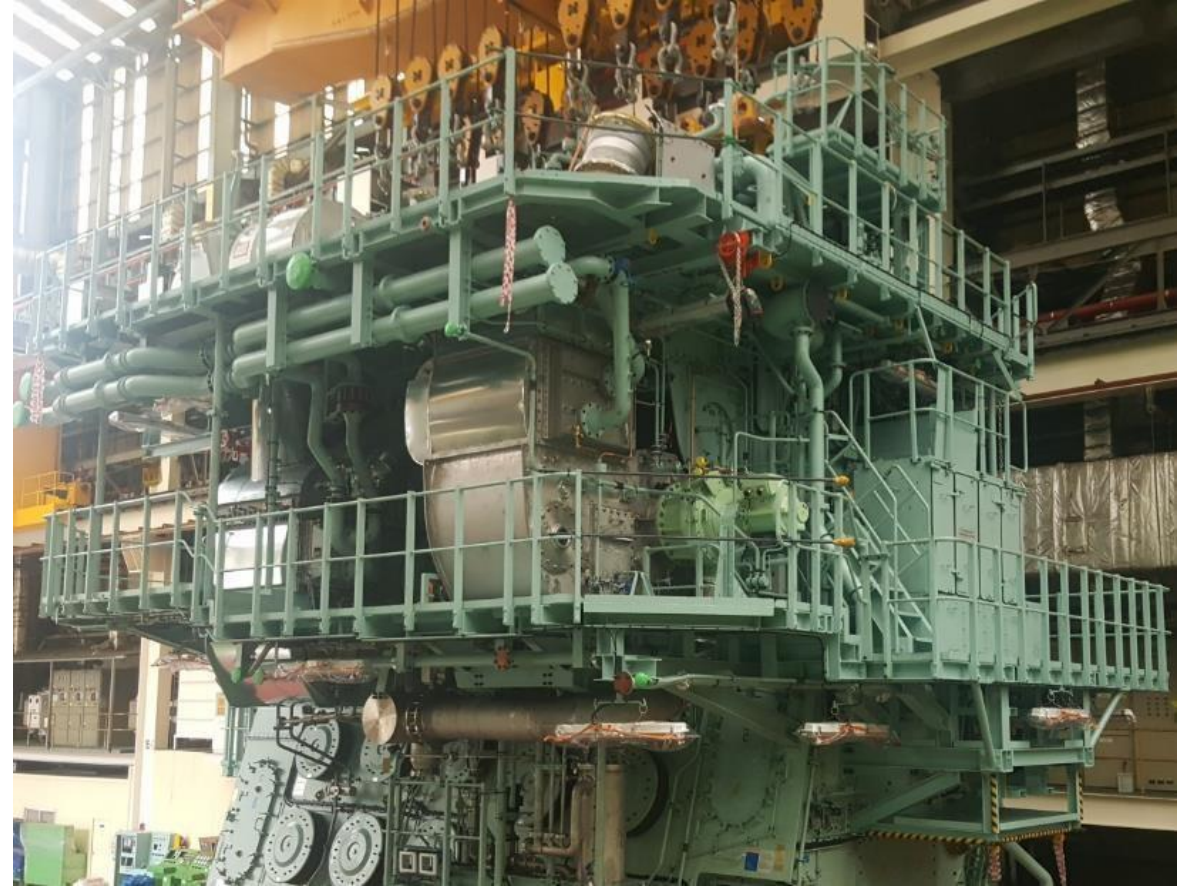
Tier III compliance by EGR and SCR

EGR: A matured technology on MAN B&W engines.

Commercial service experience since 2012

- 1100+ EGR engines on order.
- 200+ EGR engine in service.
- 10 years+ design refinement.
- 10 years+ cost optimization.
- Well-proven and compact design.
- A Tier III measure on both ME-C and dual-fuel variants.

EGR contributes positively in terms of engine tuning and thereby potential fuel optimization for a high-priced fuel.



G70 Engine equipped with EGR.

Methanol as marine fuel

What is the expected CAPEX for methanol-fueled vessels?

Example

Standard design for methanol powered product-tanker

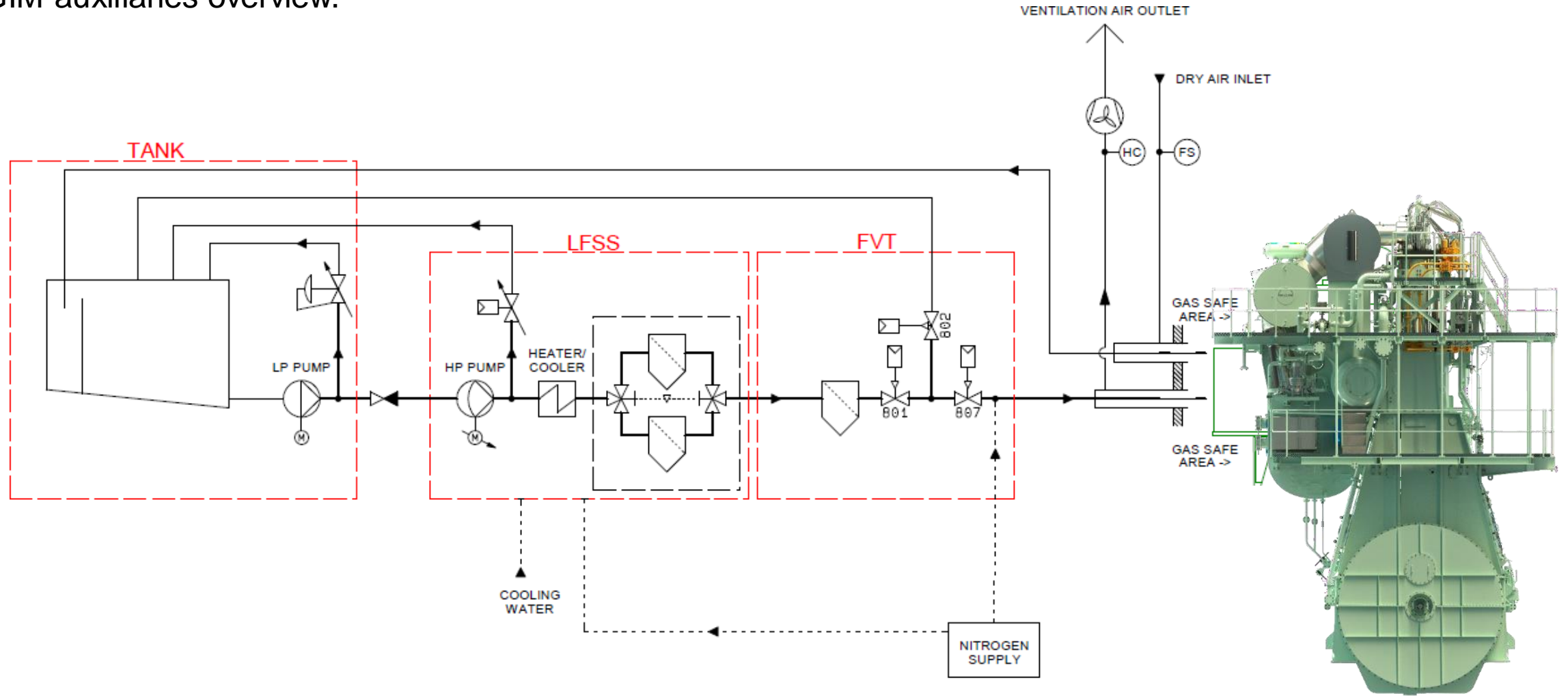
- Design developed by HMD, MAN ES, DNV GL and methanol institute.
- Featuring our proven G50 LGIM engine with more than 120.000 running hours on methanol.
- Additional newbuilding cost of just **10%** compared to **22%** of LNG dual-fuel.



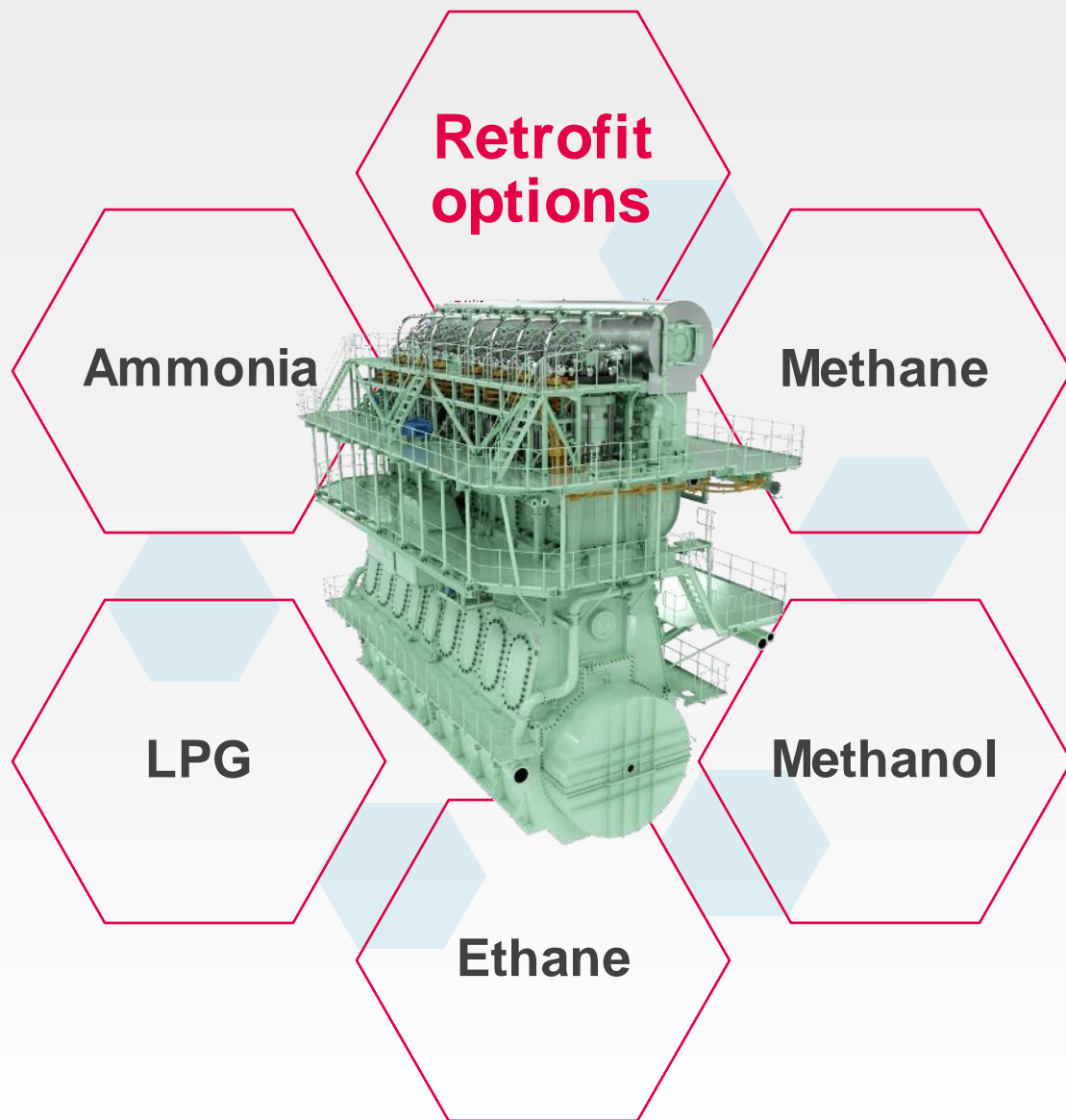
Source: <https://www.offshore-energy.biz/four-partners-develop-standard-design-for-methanol-powered-product-tanker/>

Fuel supply system

ME-LGIM auxiliaries overview.



Modular design enables extensive retrofit options



Retrofitting is a proven concept for MAN Energy Solutions engines

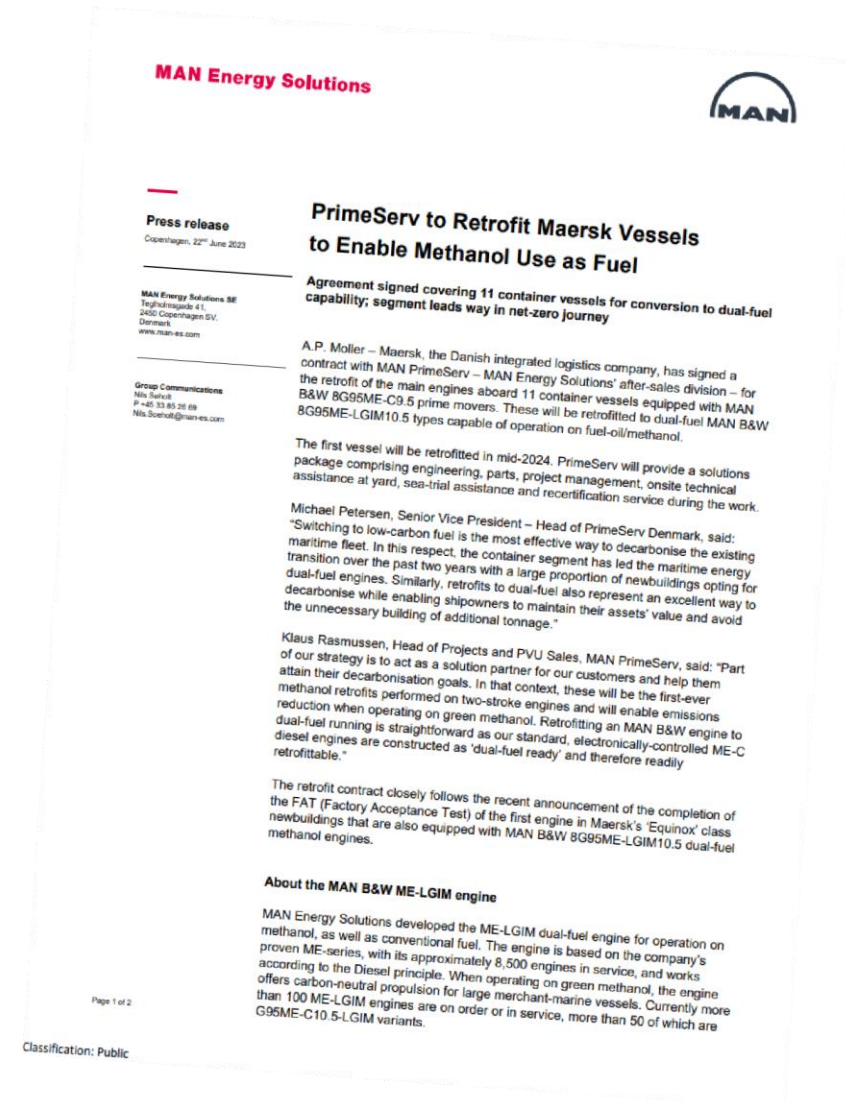
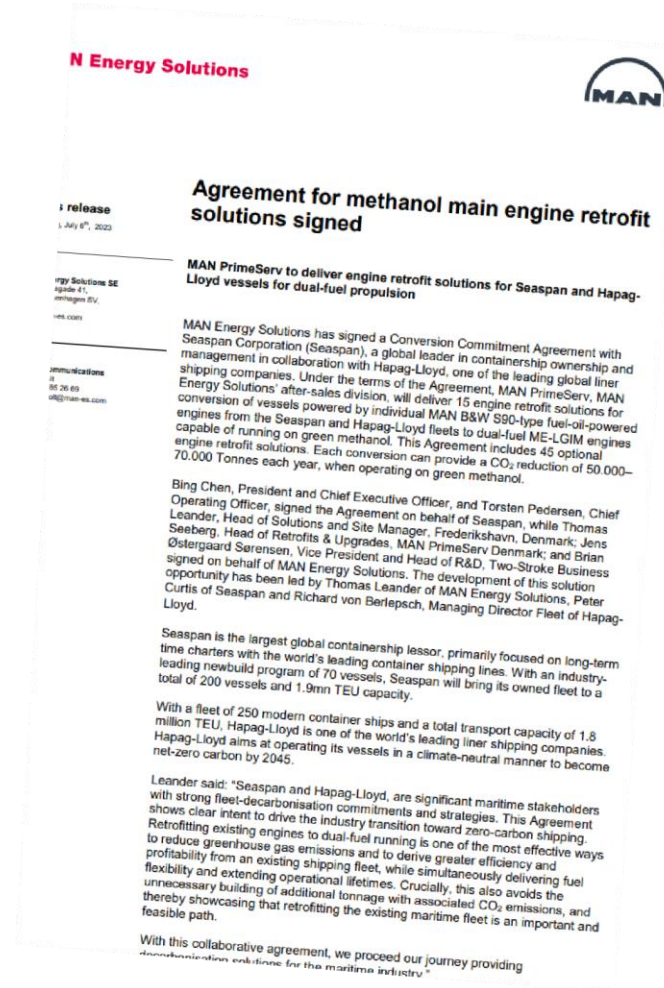
- ✓ 19 Two stroke engines retrofitted
- ✓ 4 Four stroke engines retrofitted

Two-stroke retrofit pipeline of contracted ME-LGIM projects

Selected orders from 2023

Seaspan & Hapag-Lloyd
15+45 X S90-LGIM

APM Maersk
1+10 X G95-LGIM



Disclaimer

All data provided in this document is non-binding.

This data serves informational purposes only and is especially not guaranteed in any way.

Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.



Q&A



Thank you