How ship-based CCS supports the transition to future fuels

18 August 2021 • 14:00-14:45 BST

Presentation & supporting organisation documents:

Part of
Carbon Capture & Storage
Webinar Week

16-18 August 2021

#carboncapture

LNG SHIPPING & TERMINALS

marine propulsion & auxiliary machinery

Supporting organisations

MARLOG

METHANOL INSTITUTE

CONOSHIP
INTERNATIONAL

Capturing CO2, CH4 and NOx for ZERO-Emission LNG-fueled vessels

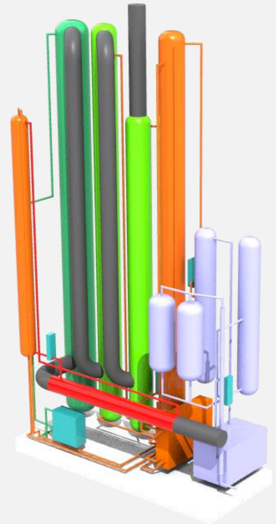
by Guus van der Bles

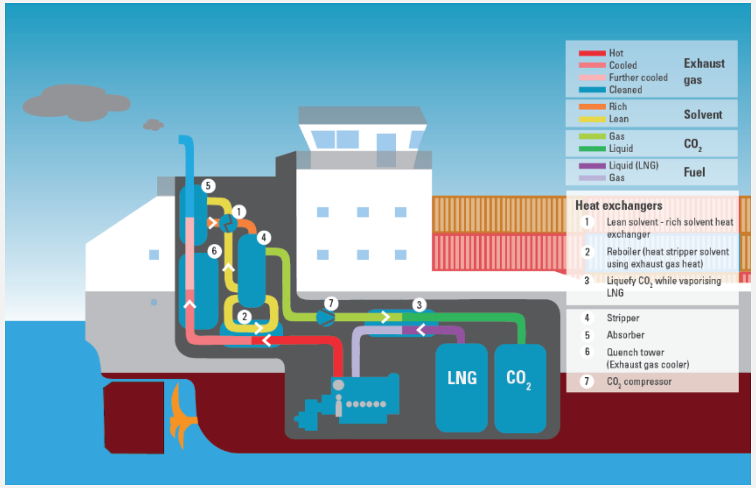
INTRODUCTION CONOSHIP INTERNATIONAL

Conoship Int. , Groningen, Netherlands

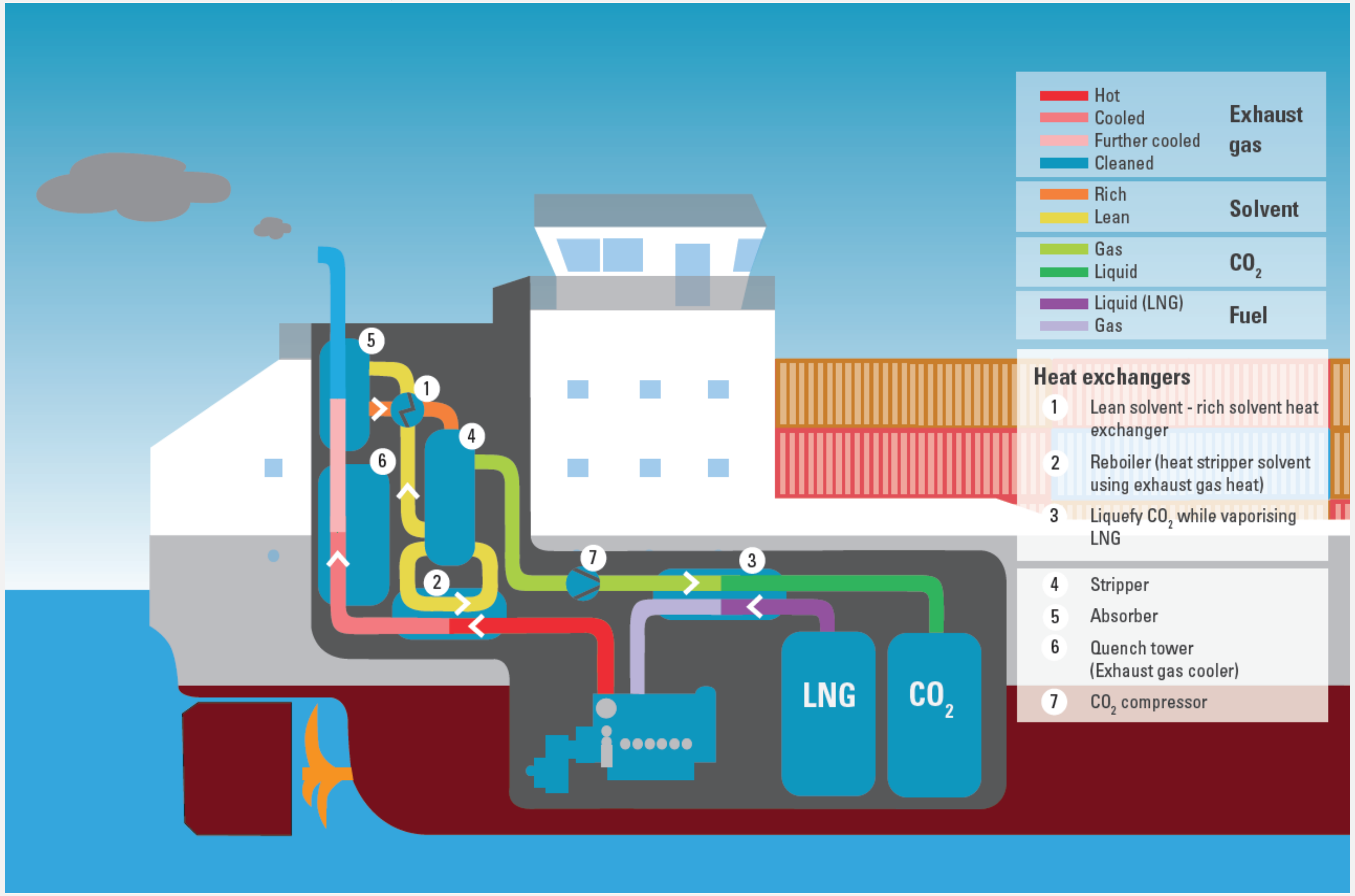
- Ship Design office started 1952
- > 2000 vessels built of our design
- **Focus R&D**: eCONOmy & eCOlogy
  - Reduction of fuel & emissions
  - Propulsion on LNG/MeOH/H2
  - Wind Assisted Ship Propulsion
  - **CO2 capturing on board**

⇒Practical applicable innovations





CHALLENGES: CAPTURING & STORING CO2 ON BOARD



TNO innovation for life

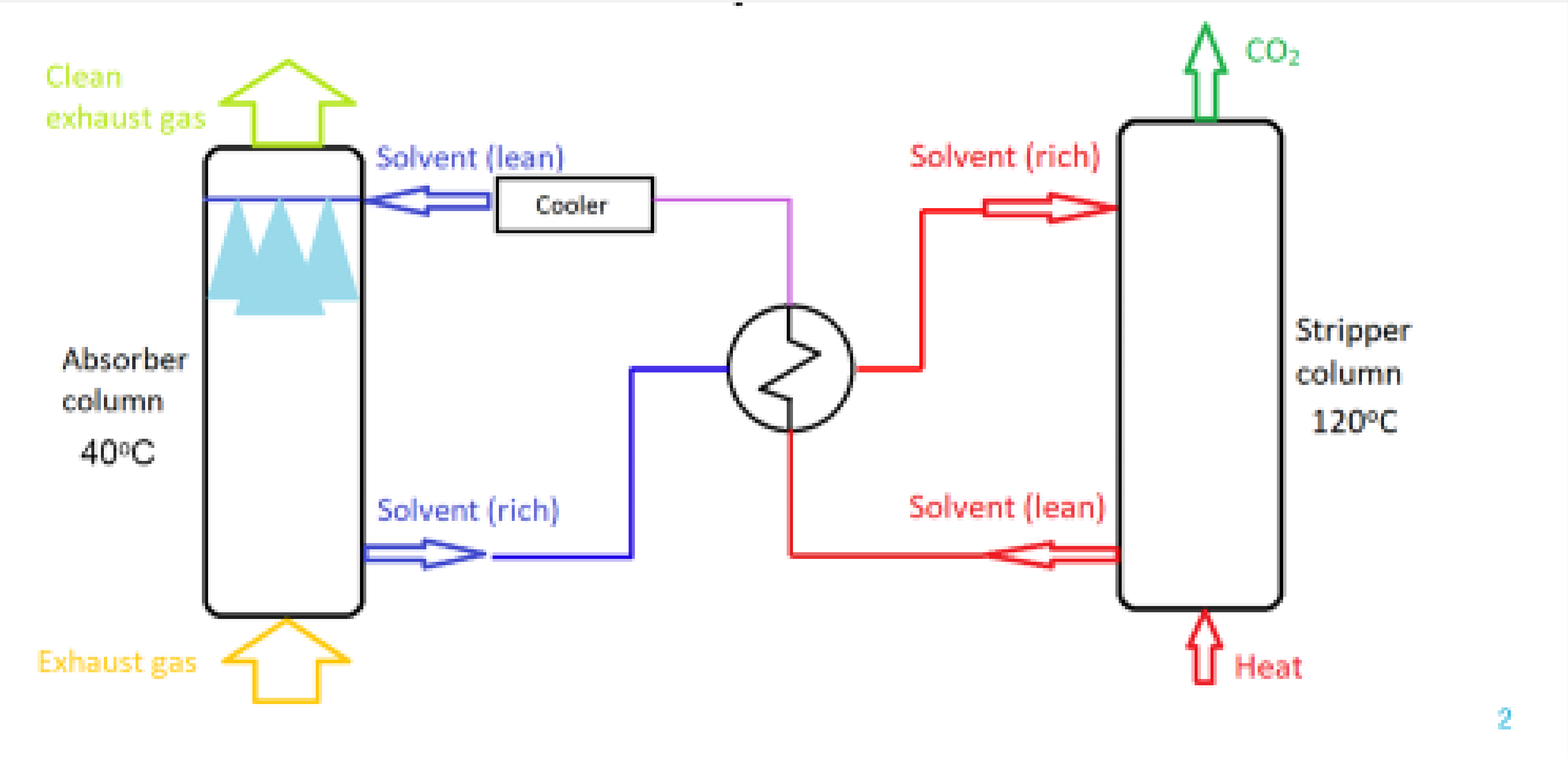
Capturing CO2:

- proven technology
- land-based plants:
- size/weight/roll&pitch-effects?

Storing CO2 on board:

- Liquid: -20 C @ 20 bar in tank(/-containers)
- Energy for cooling? => cool CO2 with LNG

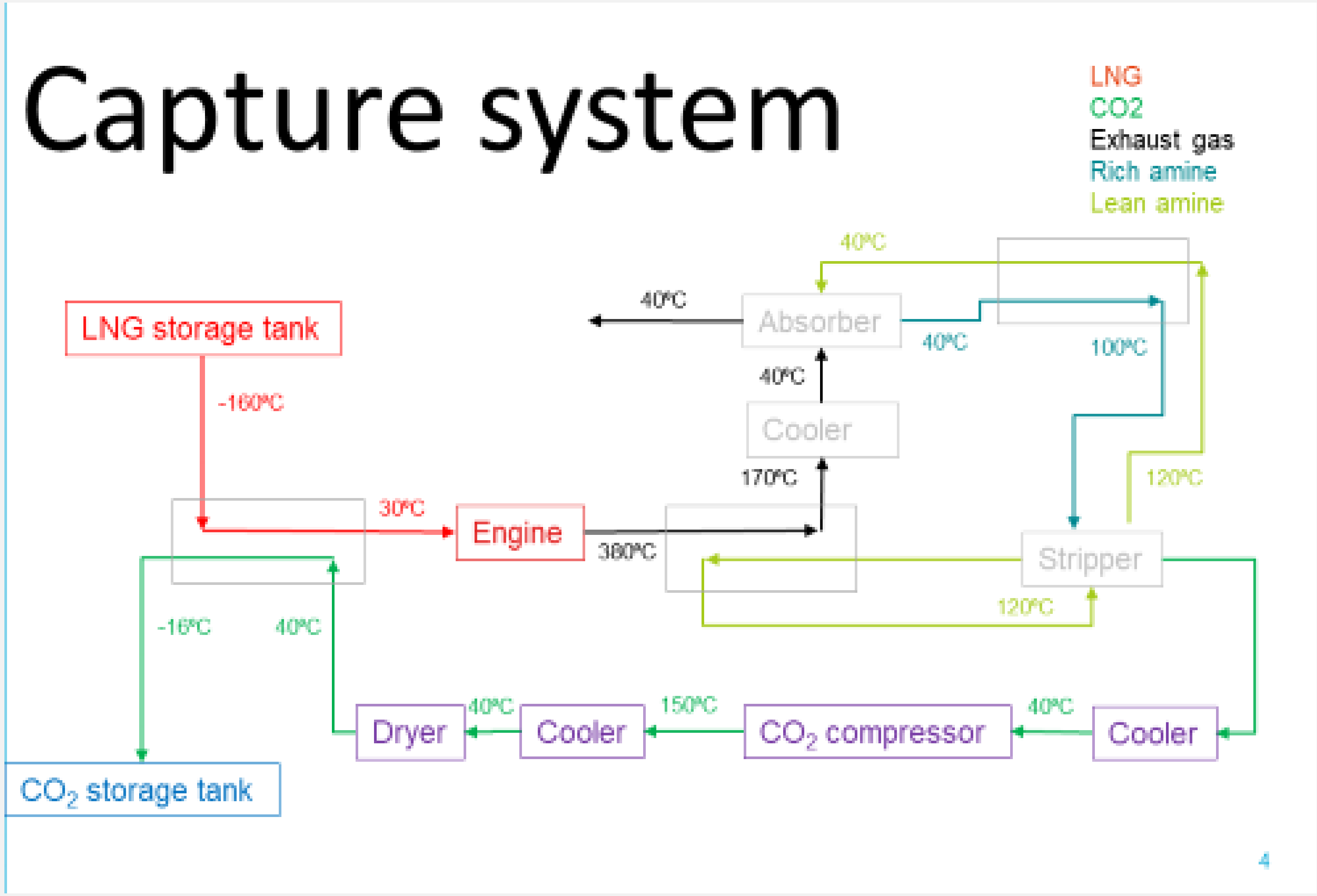
How does carbon capture work



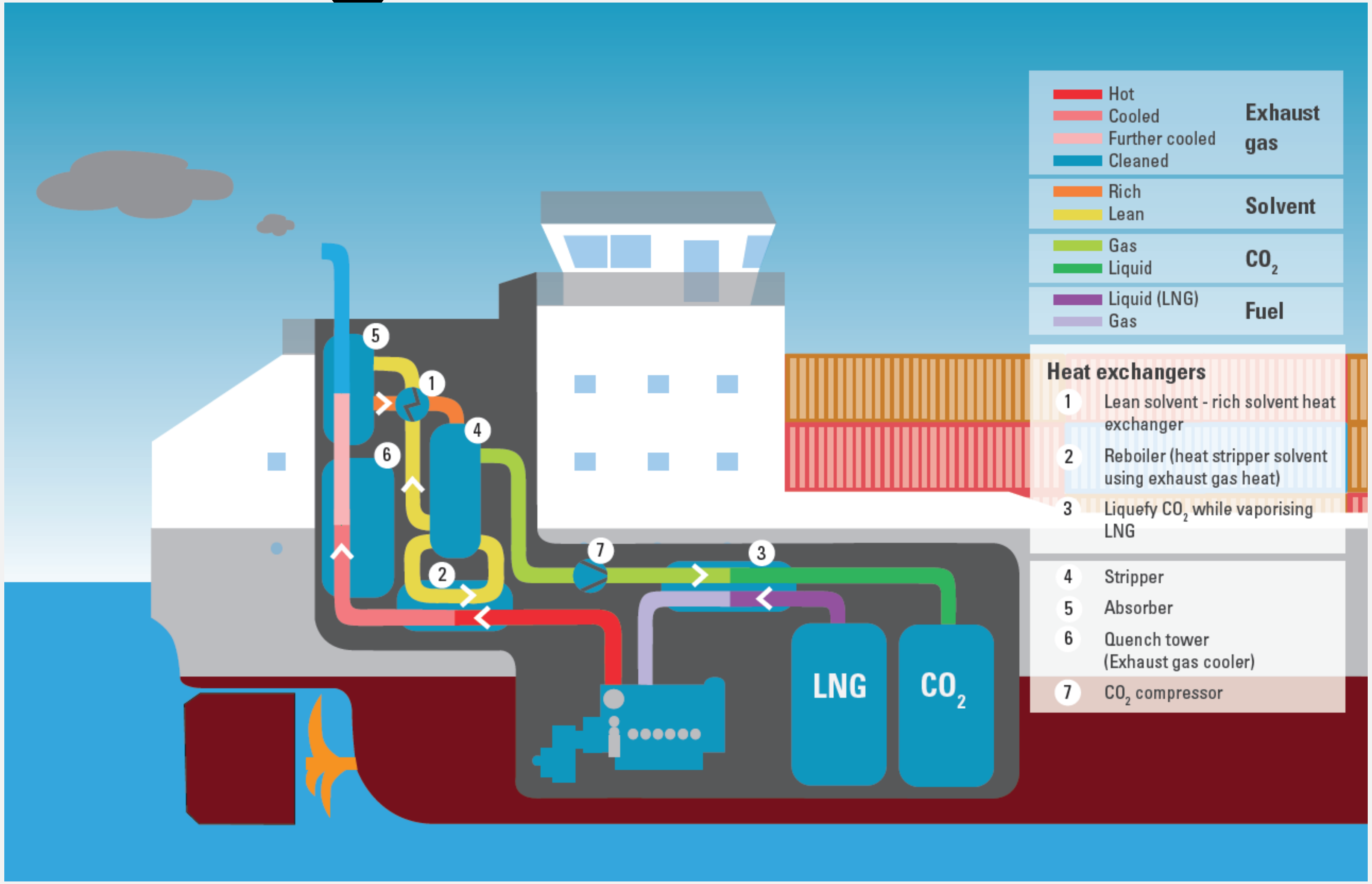
CO2 CAPTURE ON LNG VESSEL + LIQUIFY CO2 WITH LNG

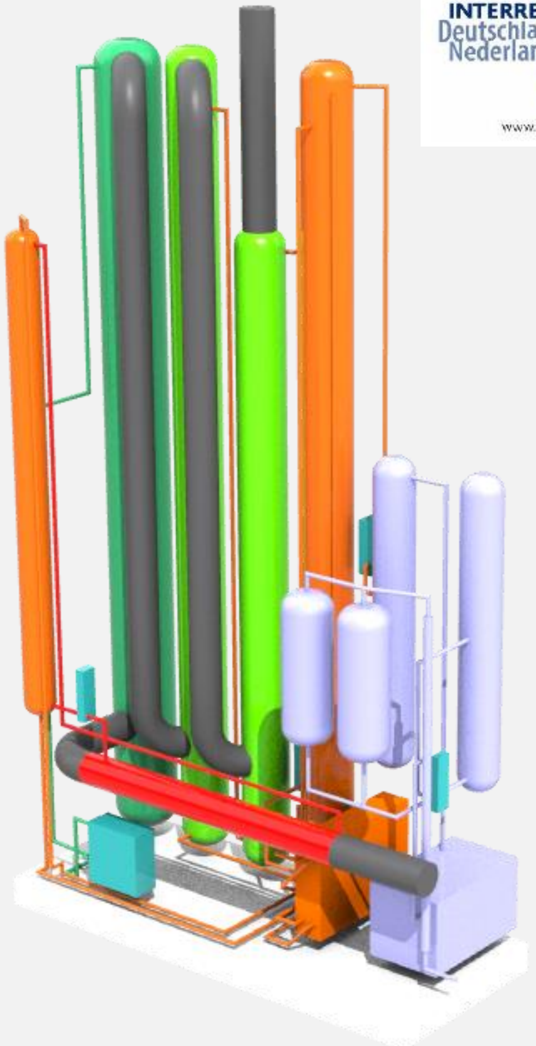
Combining carbon capture with LNG:

- Exhaust gases from LNG contain little contaminants (SO_x, NO_x, particulate matter) => less complicated capture
- CO_2 needs cooling to be stored: LNG is a cold source
  - 163 C -> -20 C @ 20 bar
  or -50 C @ 8 bar

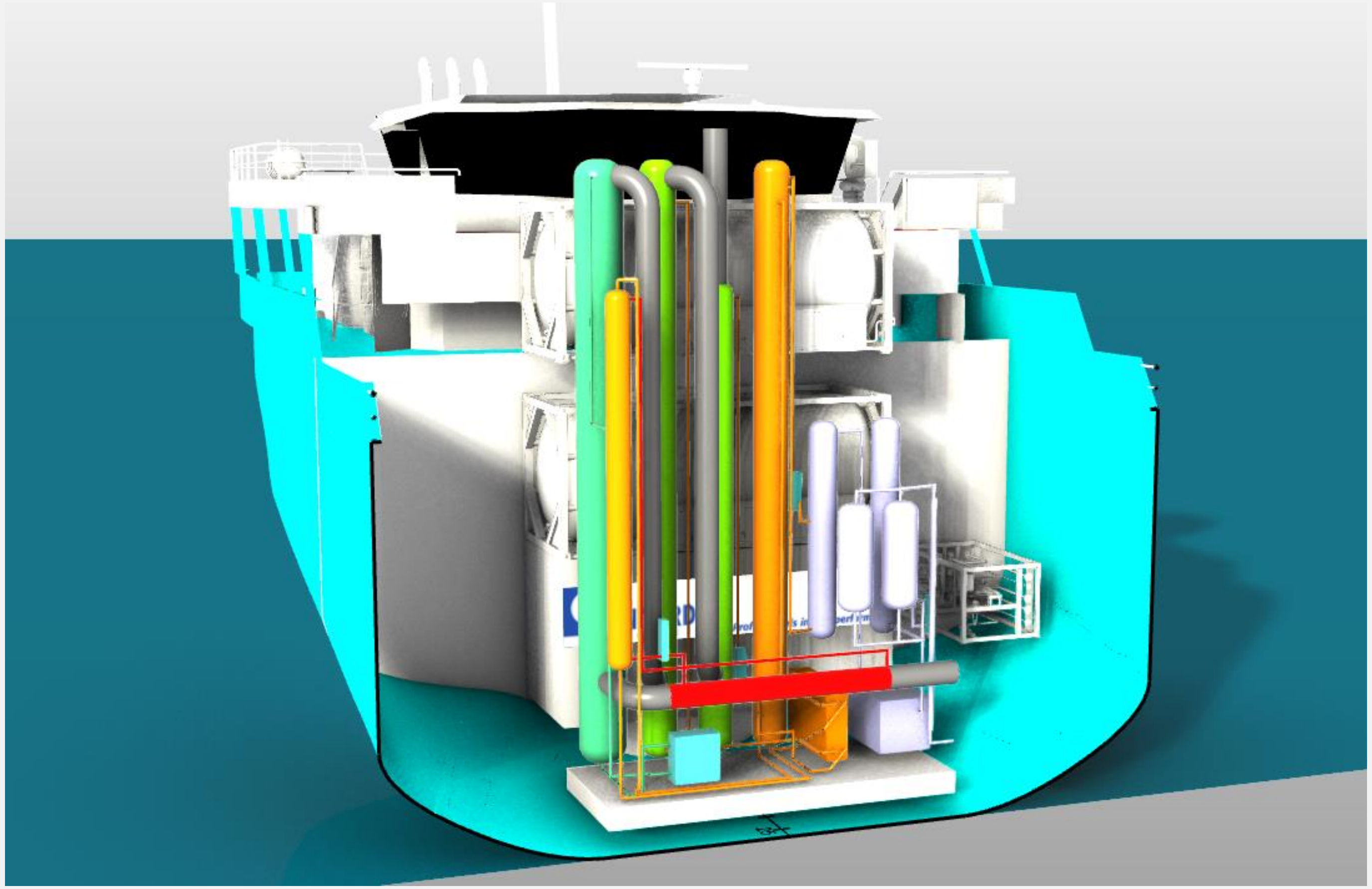


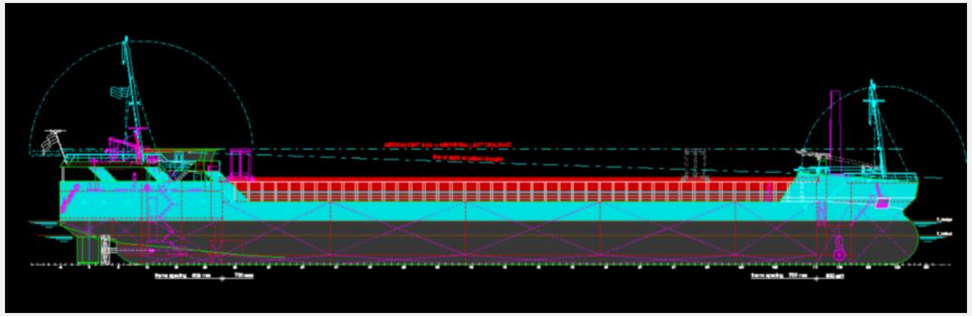
CAPTURING INSTALLATION IN SHIP





2019~2021 Feasibility studies on-board application

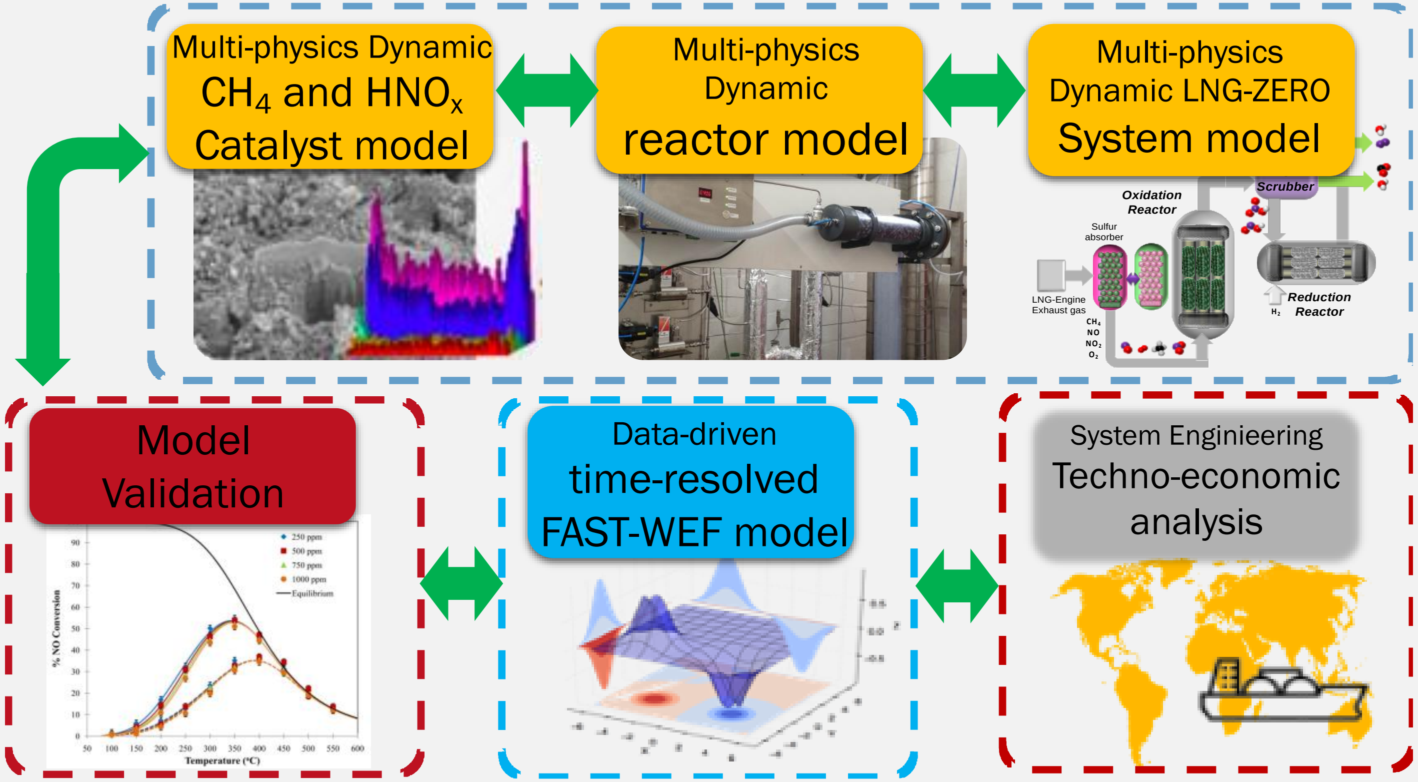




COMBINING CO2 CAPTURE WITH REDUCING NOX AND CH4-SLIP

R&D on combining CO2, NOx and CH4 capture:

- Oxidation of methane (CH4) and NO -> CO2, H2O& NO2 R&D Utwente on catalysts
- NO2 to be washed from gasses with water in Quench-tower of CO2 capture plant
- Catalyst to clean NO2 from H2O => N2
- **Capture rates: CO2 80 ~100%, CH4-slip 80% and NOx 95%**



CONOSHIP INTERNATIONAL

LNG-fueled vessels & CO2-capturing~ Closed Carbon Loop

Fossile LNG => ~ 85% Methane = **CH4**

CH4 in LNG-engine: => **CO2** + H20

⇒ **Capture CO2 on board + liquify + store** in CO2 tank (-containers)

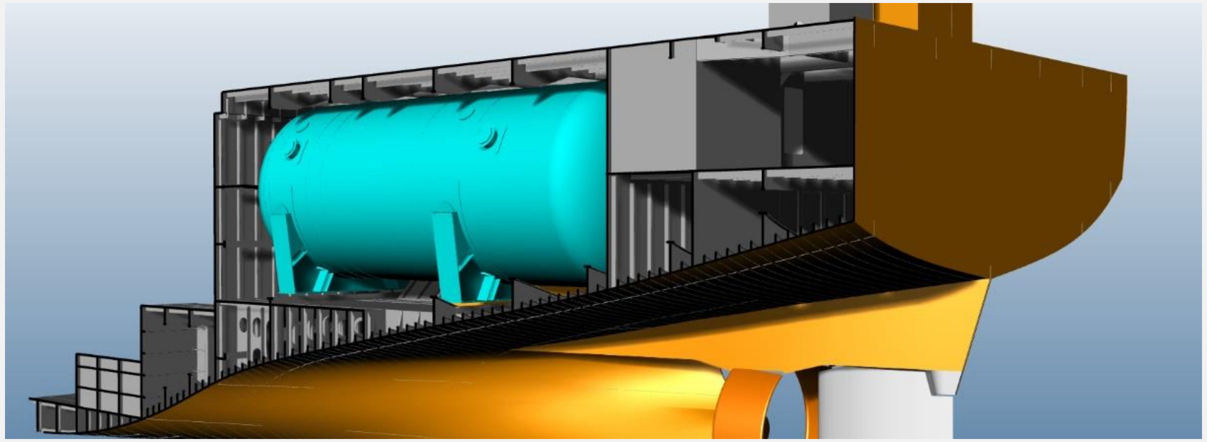
Unload & store in empty offshore gasfields f.e. NorhternLights

⇒ Fulfil **UN SDG 13 'Climate Action'!**

Future: sell tankcontainers **CO2…**

13 CLIMATE ACTION

SUSTAINABLE DEVELOPMENT GOALS



TURN CO2 EMISSIONS TO FEEDSTOCK FOR E-FUELS

Future: tankcontainers liquid **CO_2 => feedstock** for '**synthetic E-Fuels**'

Windenergy -> clean E-power -> 'green'H_2

H_2 + CO_2 -> **CH_4** + H_2O (Sabatier proces)

Example **E-Fuel CH_4** = synthetic Methane

=> liquifying => LSM ready to fuel LNG-vessel

⇒ **Actual LNG fueled vessels can be CO_2-neutral in future with Ship Based Carbon Capture**

MARLOG

Financed by Danmarks Erhvervsfremmebestyrelse

Co-financed by Uddannelses- og Forskningsstyrelsen

How ship-based CCS supports the transition to future fuels?

August 18th 2021, online webinar

Jan Boyesen

Senior Manager
Green Transition
MARLOG

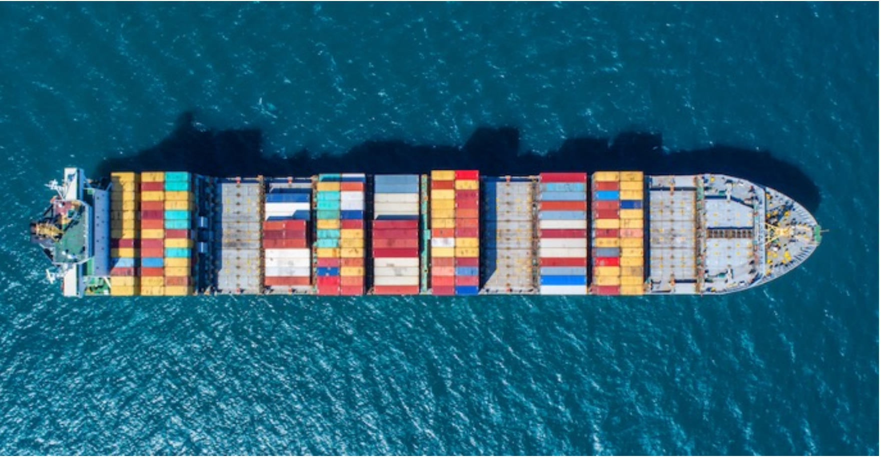
+45 2875 4081
jb@marlog.dk

www.marlog.dk
www.decarbonice.org

MARLOG

Financed by Danmarks Erhvervsfremmebestyrelse

Co-financed by Uddannelses- og Forskningsstyrelsen

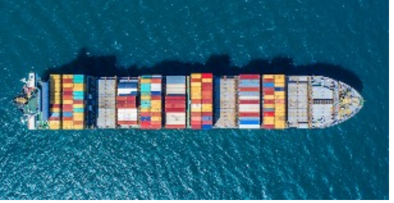


1) Can CCS decarbonize ship operations?

2) Can maritime CO_2 become a feedstock for new synthetic fuels?

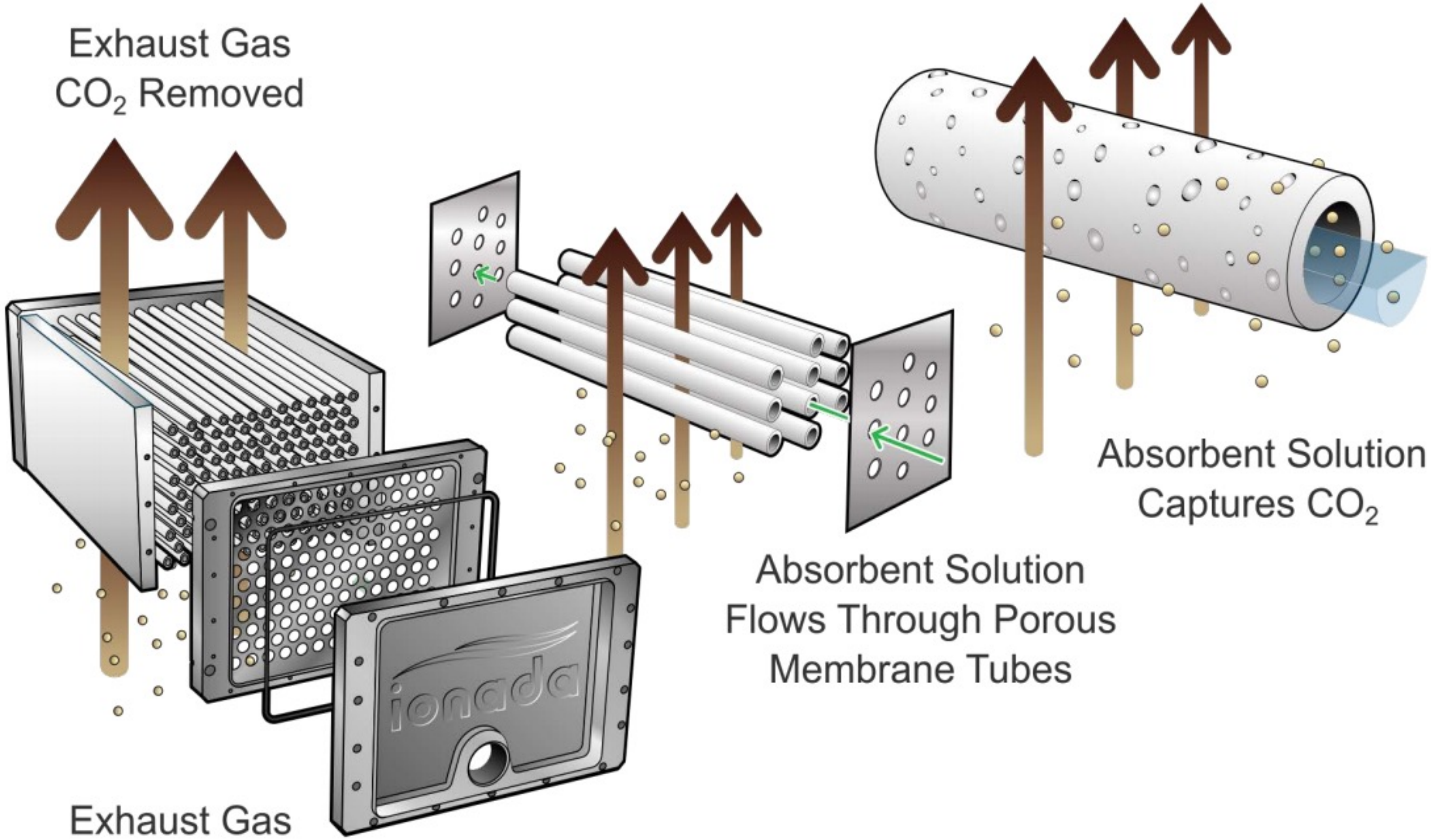
3) What is the potential for maritime CCS?

MARLOG

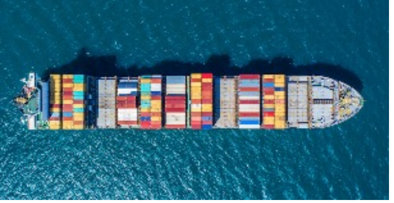


How It Works – Membrane Carbon Capture

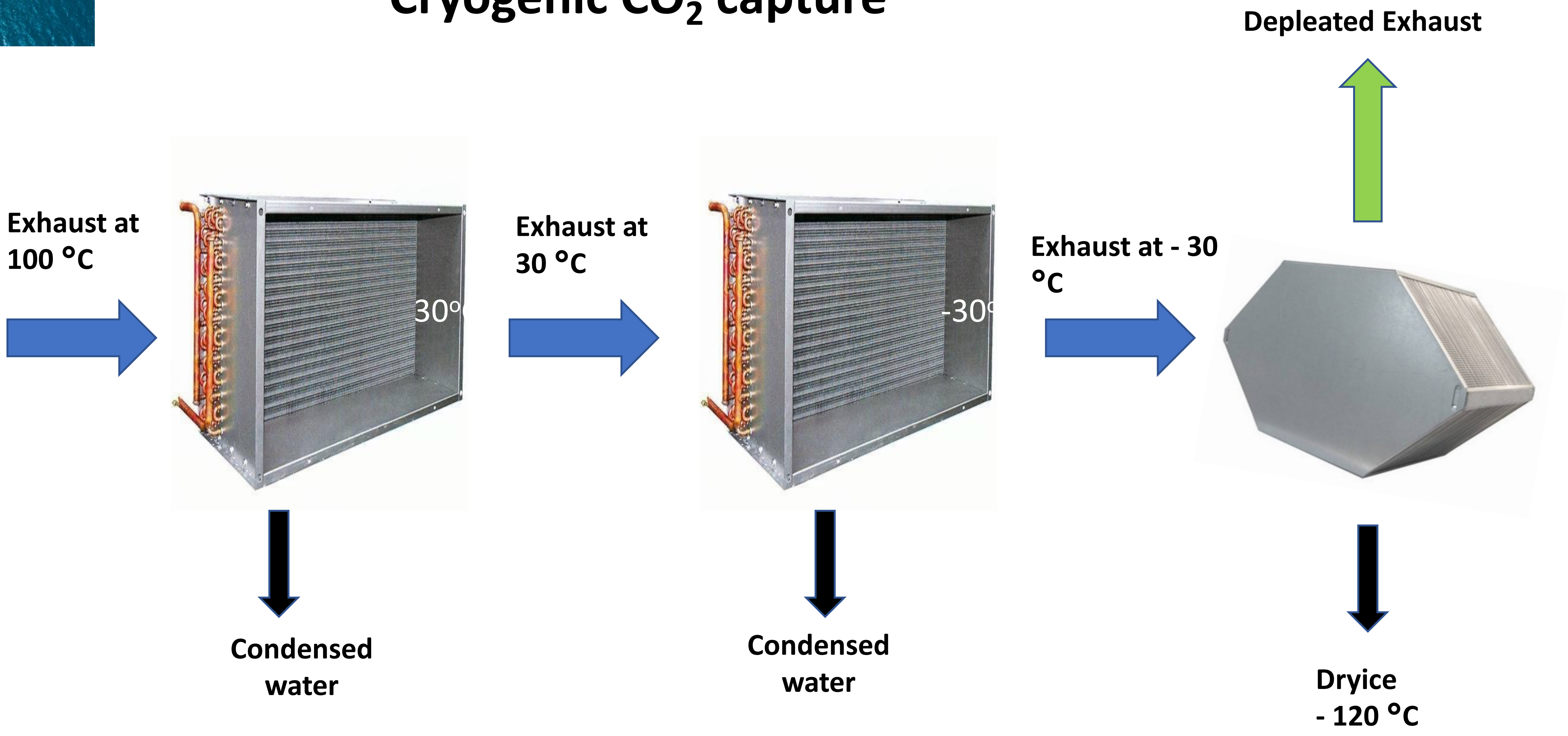
The key innovation is the use of hollow fiber nanotechnology membrane contactors with the amine or ionic liquid CO2 absorbents. Membranes offer significant increase in capture efficiency and reduced absorbent losses.



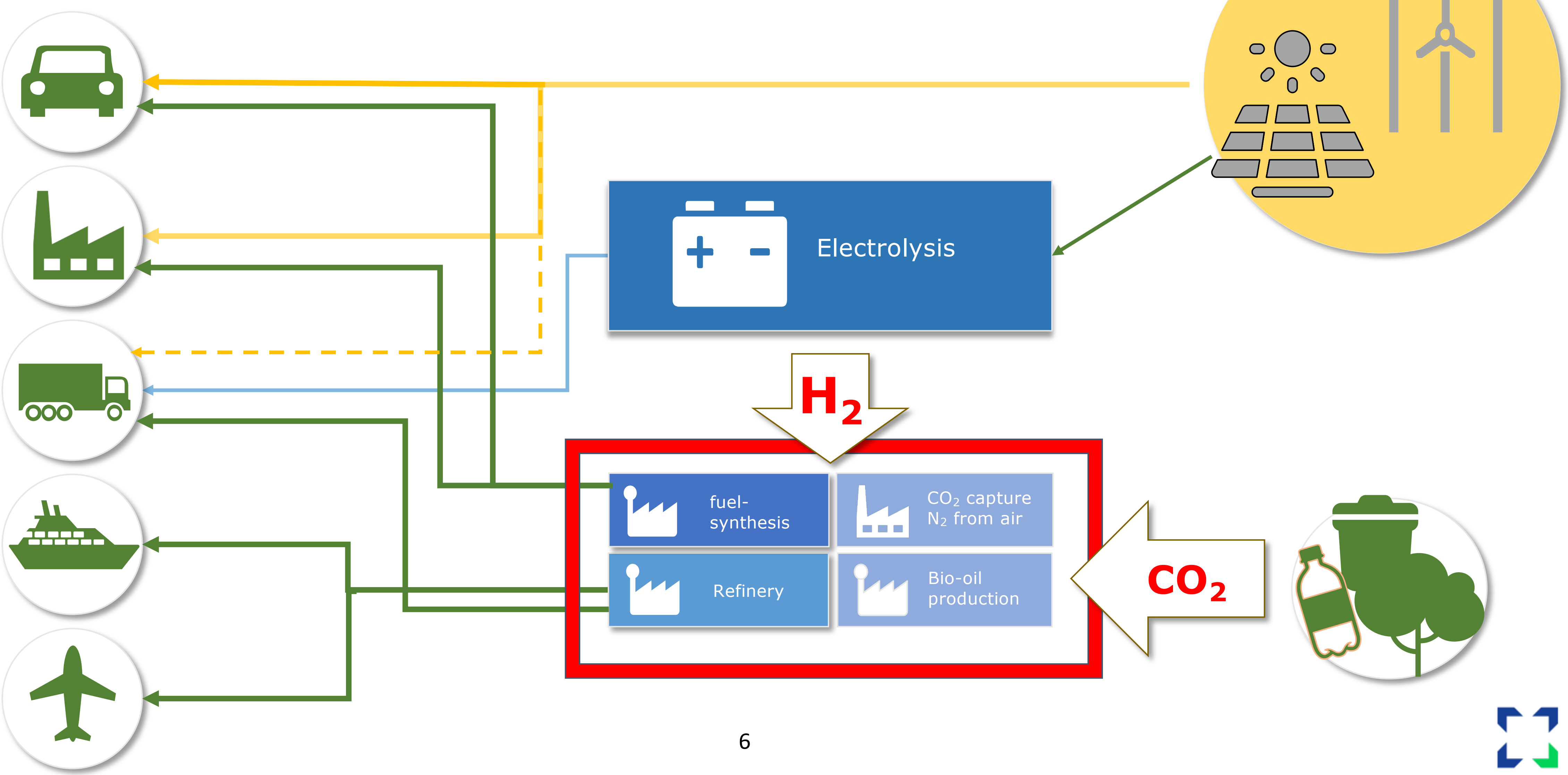
NO_2 -9,3



Cryogenic CO_2 capture

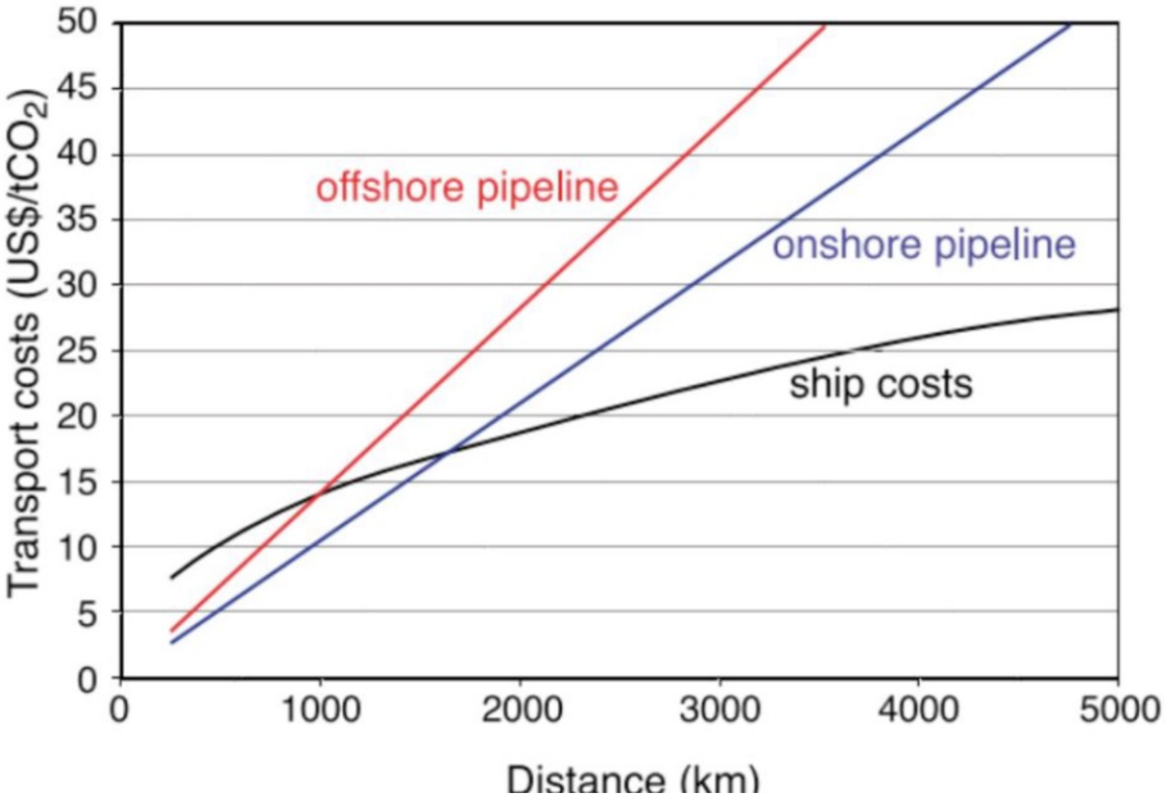


Power to X (C) fuels are relevant for several offtakers
- intermediary pathway (2030)



MARLOG

Why not produce C-fuels at point of emission?



MARLOG

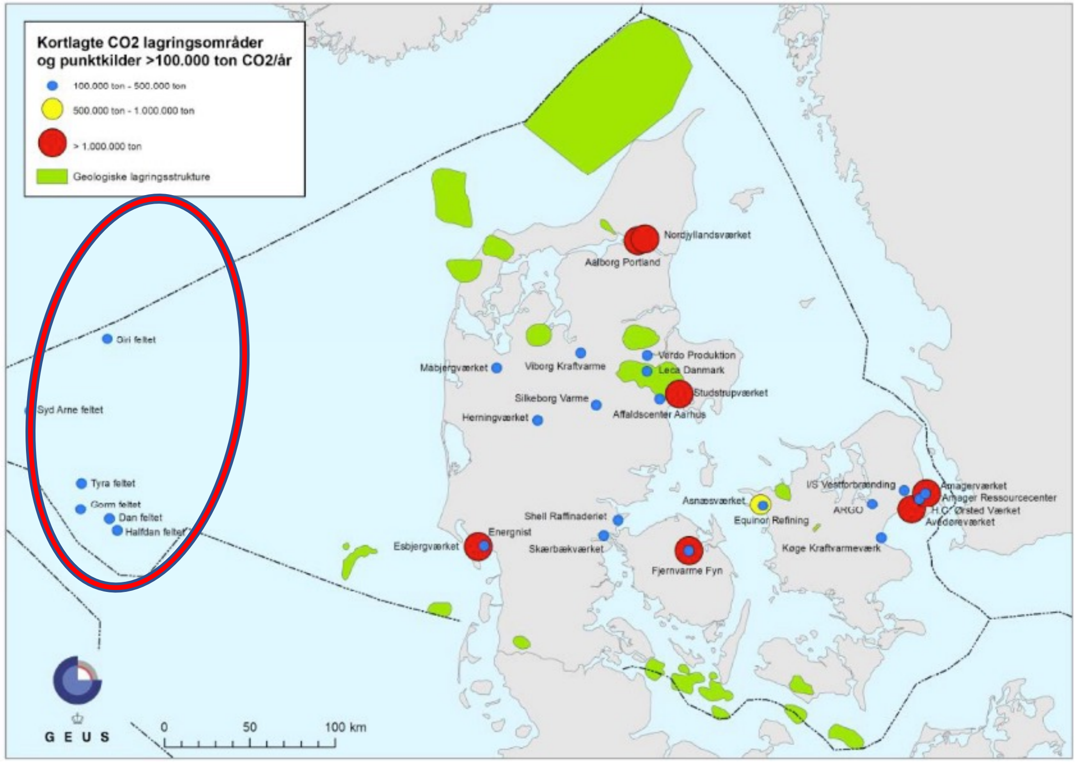
Geological CCS has huge potential

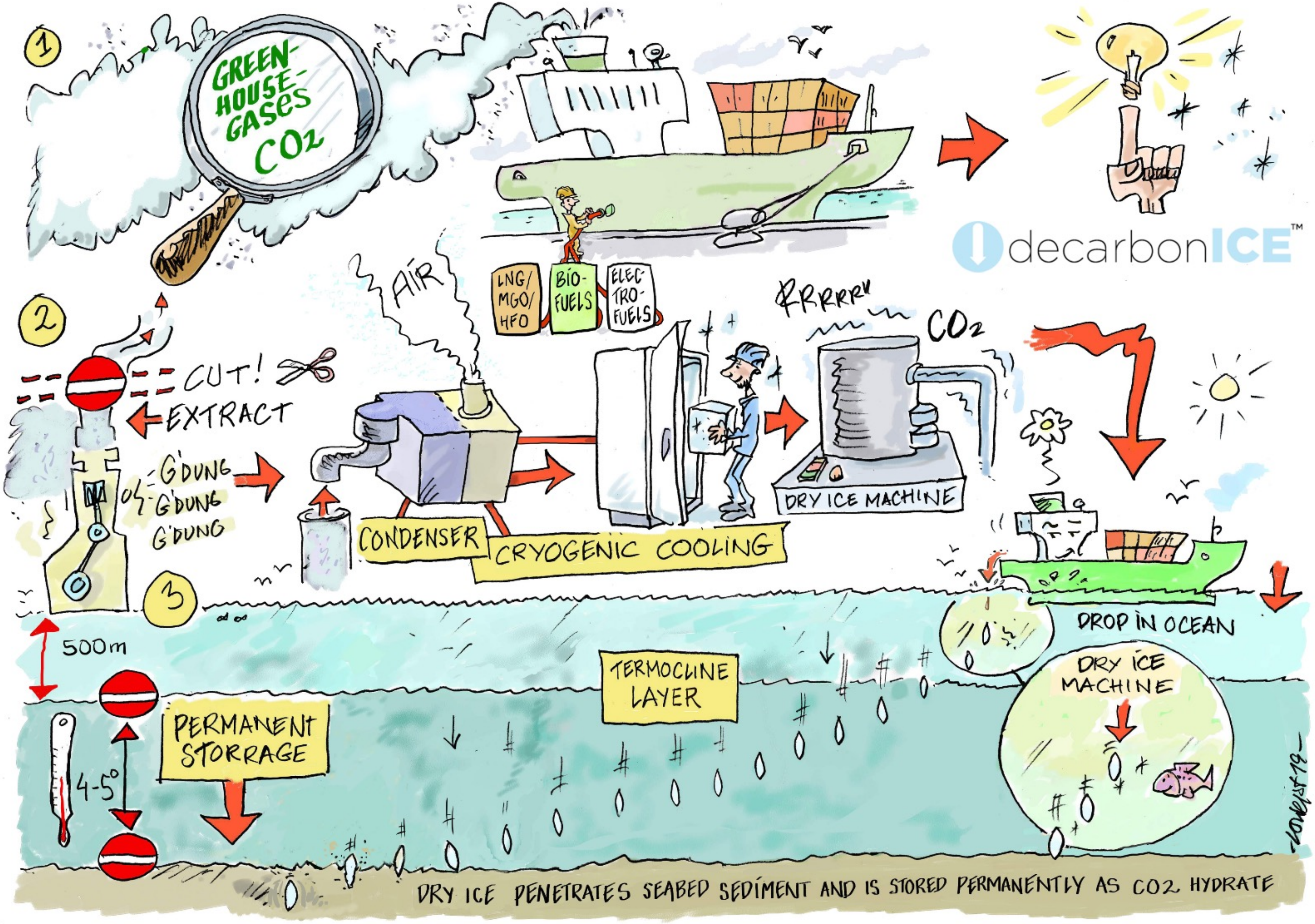
Capture potential – 11.2 megaton CO_2 /y

- Biomass power/heat plant 8.2 megaton
- Waste incineration 1.39 megaton

- Cement 1.2 megaton
- Other heavy industry 1.6 megaton

Storage capacity 22,000 megaton




1
GREEN-HOUSE-GASES CO2
decarbonICE™
2
CUT!
EXTRACT
G'DUNG G'DUNG G'DUNG
AIR
LNG/ MGO/ HFO
BIO-FUELS
ELEC-TRO-FUELS
RRRRR
CO2
CONDENSER
CRYOGENIC COOLING
DRY ICE MACHINE
3
500m
DROP IN OCEAN
TERMOCLINE LAYER
PERMANENT STORRAGE
4-5°
DRY ICE MACHINE
DRY ICE PENETRATES SEABED SEDIMENT AND IS STORED PERMANENTLY AS CO2 HYDRATE

CCS from shipping

decarbonICE™

- A **non-for-profit** project conducted in a spirit of **open innovation** to fight climate change
- Initiated and hosted by Copenhagen based Maritime Development Center (MDC)
- **10 shipping industry partners**
- **Project funding** comes entirely from the partner **shipping companies**

CLEAN MARINE

DSME

Knutsen OAS Shipping

NYK GROUP

MARLOG

PENSÉE OSHIMA

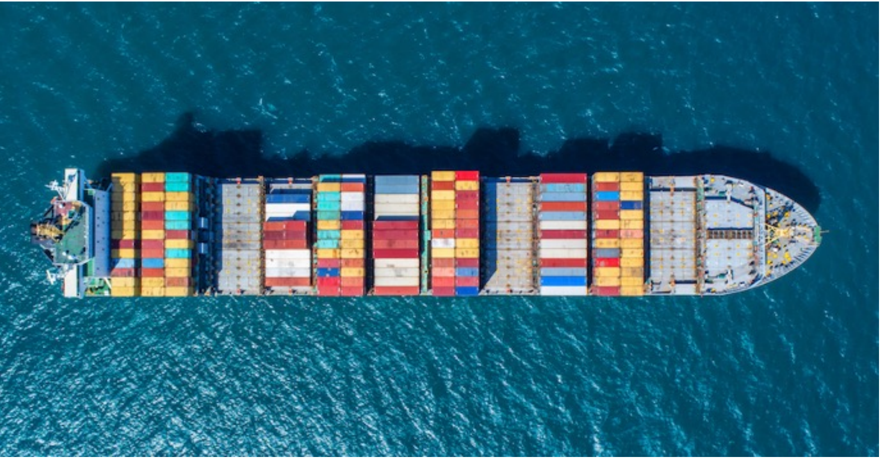
SCF Sovcomflot

TK

VALE

How can ship-based CCS support the transition to future fuels?

MARLOG



CCUS can decarbonize shipping at a low cost
- CCS can potentially be much cheaper than a fuels switch

Ship based CCU can provide carbon for new C-fuels
- On board CO_2 storage and carriers are the missing link

CCS can support carbon negative shipping
- If C-fuels are based on bio-feedstock or direct air carbon capture

MARLOG

METHANOL INSTITUTE

Methanol: How Shore & Ship-Based CCS Supports the Transition to the Future

Chris Chatterton, COO

RIVIERA

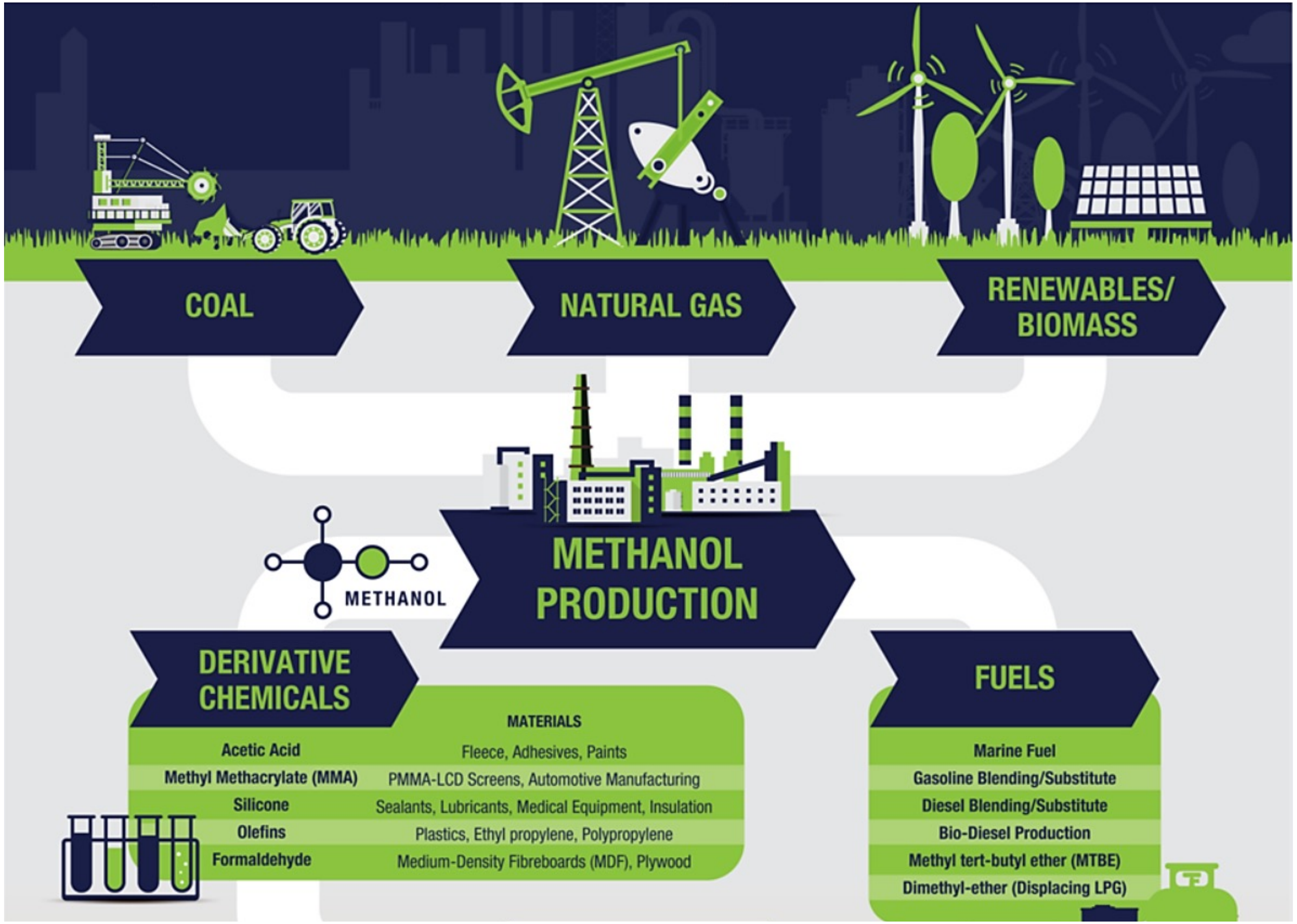
CARBON CAPTURE & STORAGE WEBINAR WEEK

August 18th, 2021

Singapore | Washington | Brussels | Beijing | Delhi

Feedstocks & markets

METHANOL INSTITUTE

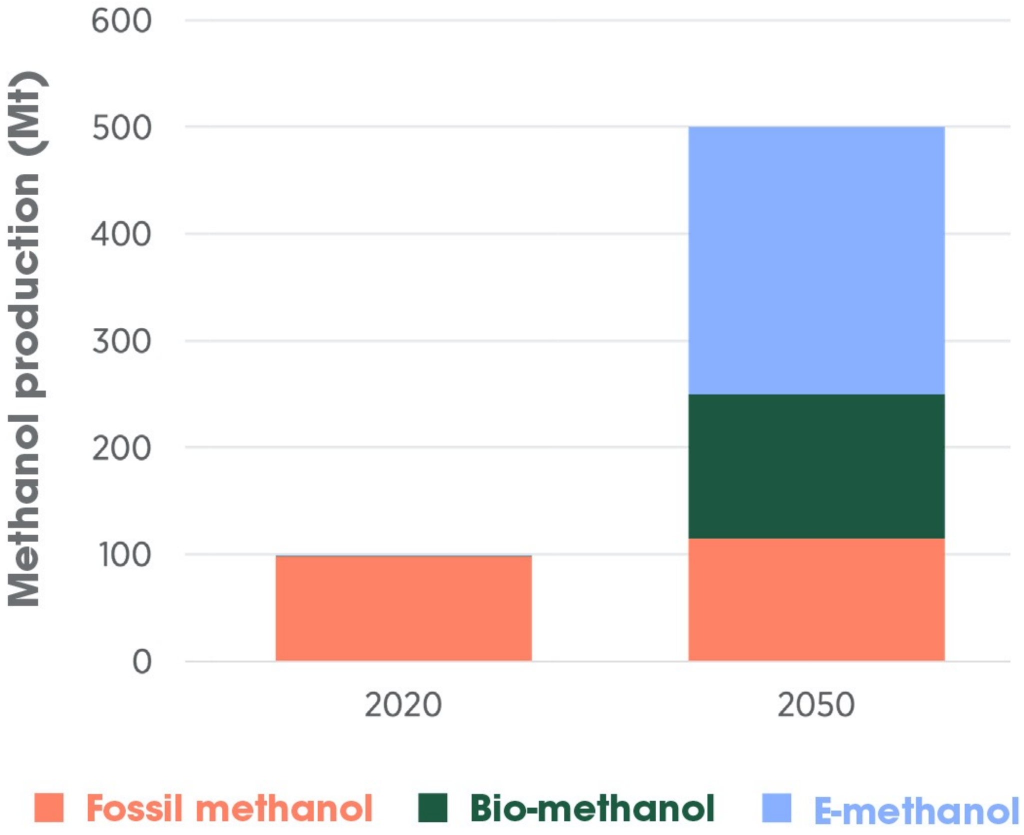


- Natural gas is still the predominant feedstock for the methanol industry ex-China
- Increasing number of projects utilize sustainable feedstocks such as captured CO_2 from industrial emitters and green hydrogen produced from municipal solid waste (MSW), forestry residues or agricultural waste
- Conventionally methanol goes into the production of **downstream chemicals** (~55% of global consumption)
- Increasingly, the fastest growing segment is where it is consumed as a **fuel,** in numerous applications (~45%)

2050: Potential 5-Fold demand increase

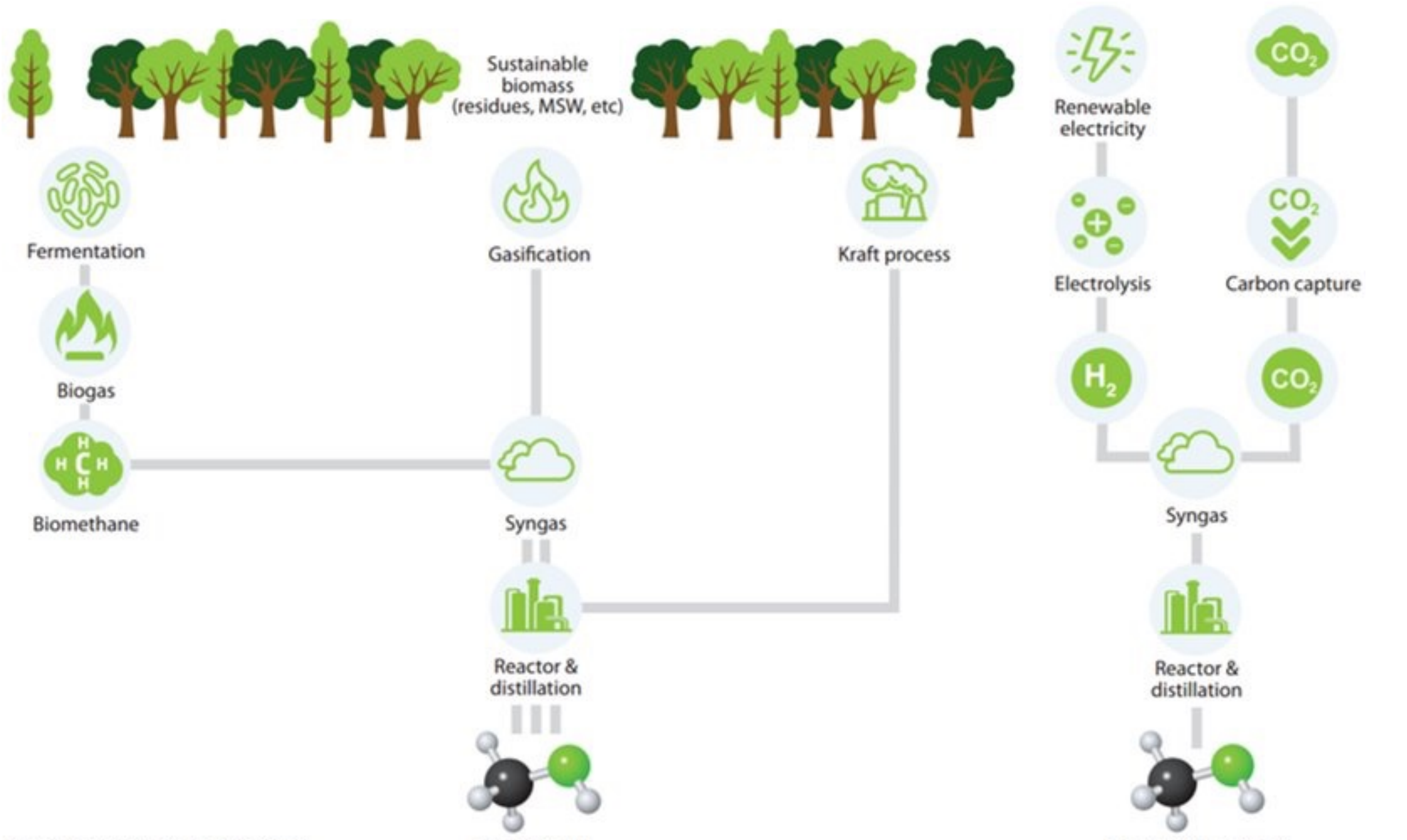
- According to IRENA, the uptake for both bio and renewable methanol is set to increase substantially
    - Existing infrastructure can be repurposed
    - Waste feed and CO_2 streams are readily available, allowing harder to decarbonize sectors to de-leverage
    - Cost effective

Figure 47. Current and future methanol production by source



https://www.irena.org/publications/2021/Jan/Innovation-Outlook-Re

Renewable methanol pathways

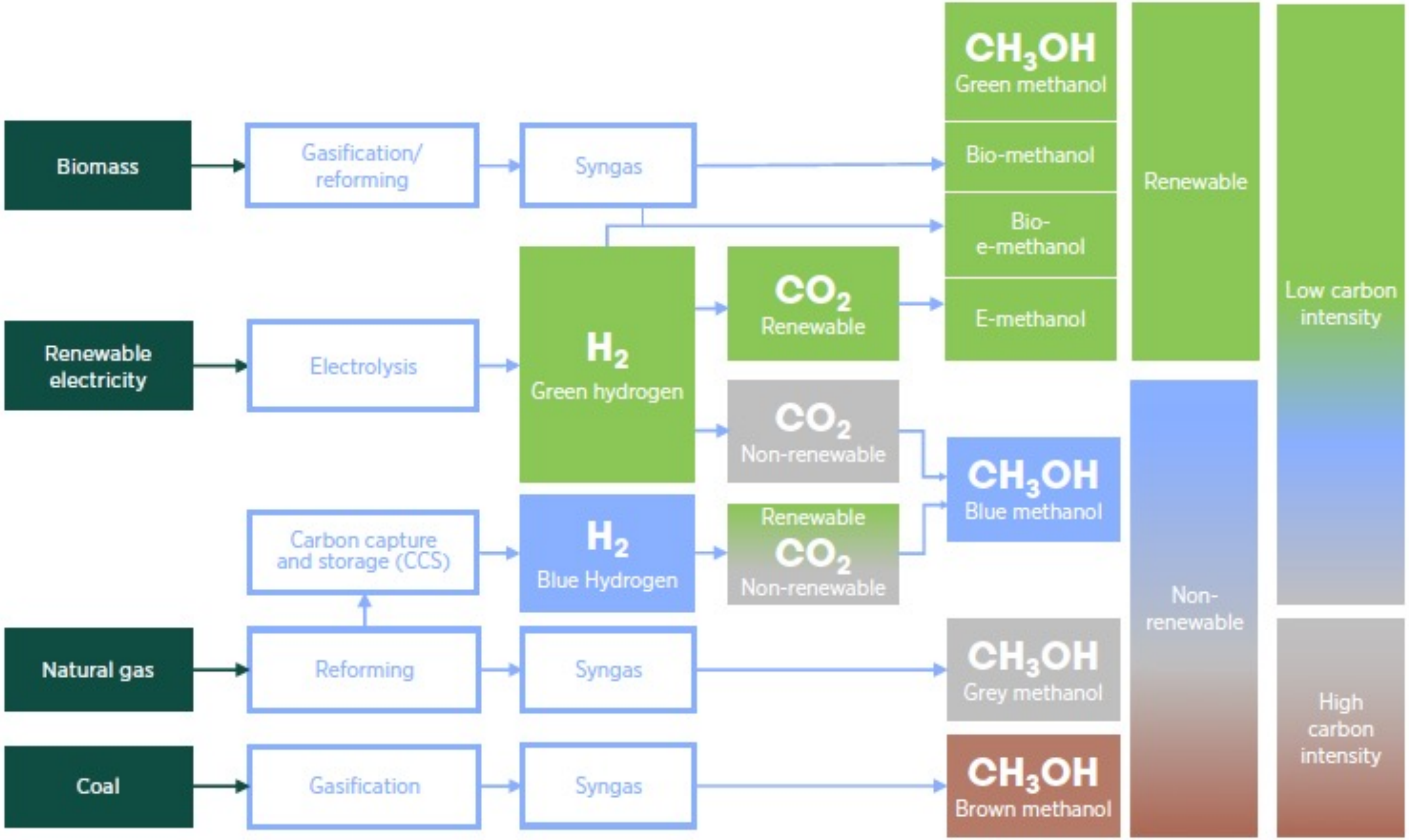


Source: The Methanol Institute and Qafaq

Brown, grey, blue, green

Renewable CO_2: from bio-origin and through direct air capture (DAC)

Non-renewable CO_2: from fossil origin, industry



Source: IRENA

Indicative cost of renewable methanol

METHANOL INSTITUTE

		Estimated Costs in USD		
		2015 – 2018	2030	2050
Cost of green H_2 (\$/t H_2) [a]		4000 – 8000	1800 – 3200	900 – 2000
Cost of CO_2 (\$/t CO_2) [c]		50 – 100	50 – 100	50 – 100
Cost of Methanol (\$/t MeOH) [b]	No Carbon Credit	870 – 1690	460 – 790	290 – 560
	Carbon Credit of \$50/t CO_2 [d]	780 – 1610	370 – 700	200 – 480
	Carbon Credit of \$100/t CO_2 [d]	700 – 1520	290 – 620	120 – 390

(a) Source: (IRENA, 2020)

(b) assuming \$50 per ton synthesis cost for e-methanol once the raw material, H_2 and CO_2 are provided

(c) Origin of the CO_2 will change over time as volumes increase

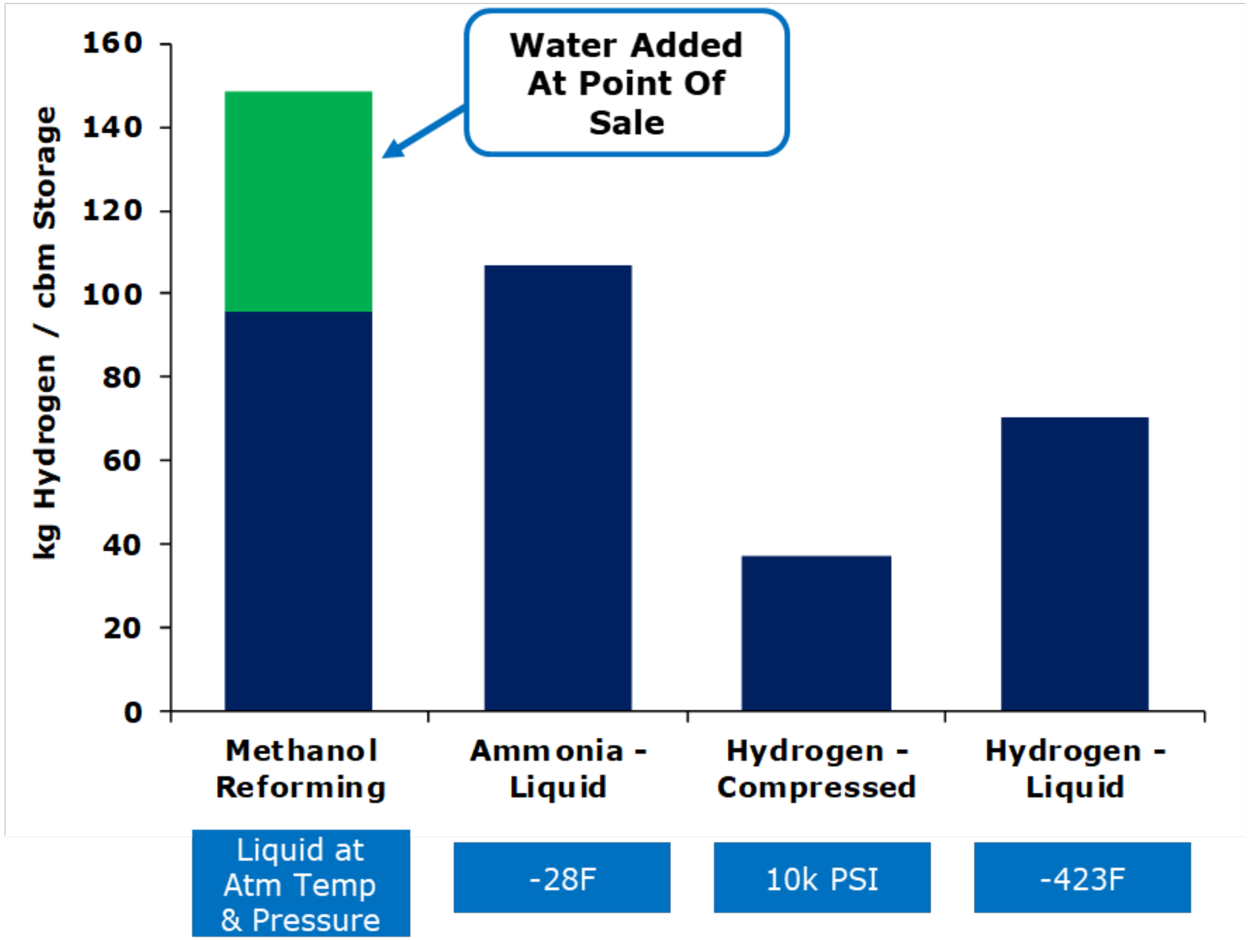
(d) The carbon credit per ton of e-methanol is based on the difference between the average CO_2eq emissions from methanol production from natural gas (95.2 gCO_2eq/MJ) and average CO_2eq emissions from e-methanol production from renewable CO_2 and H_2 (8.645 gCO_2eq/MJ). Considering a LHV of 19.9 MJ/kg for methanol, this corresponds to a 1.72 tCO_2eq of emission avoided per ton of e-methanol, compared to traditional natural gas based methanol.

SCAN ME

Superior Hydrogen Carrier

- Methanol combines with water at the point of sale to generate 30-40% more hydrogen than Methanol carries.
- Help lower the cost of storage and infrastructure needed to transport, store, and dispense hydrogen safely over long distances
- Traded extensively for the chemical industry which demonstrates considerable experience of safe handling and storing methanol
- As green methanol can be produced from biomass, waste streams and captured carbon dioxide emissions, the GHG emissions avoided due to the production of green methanol allows it to be a carbon-neutral or carbon-negative energy product

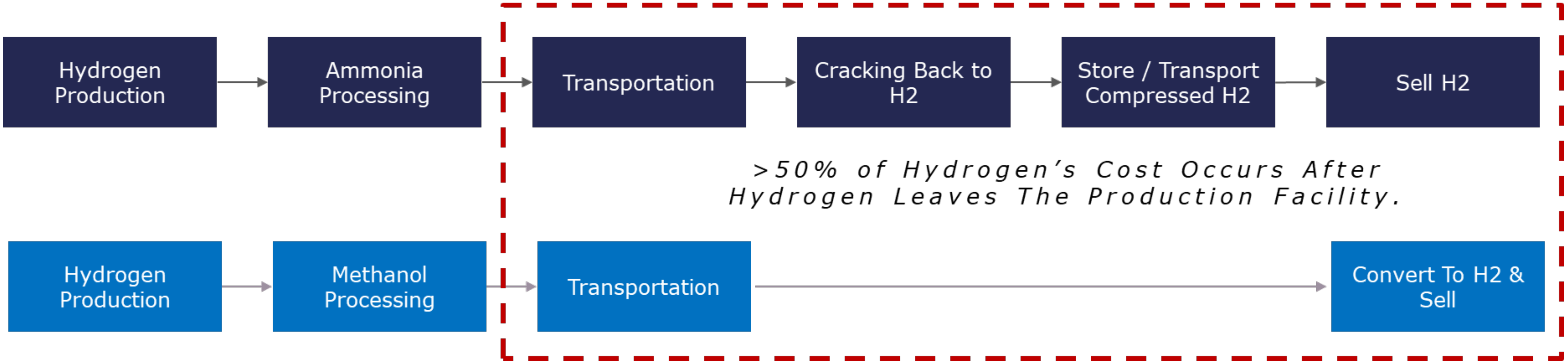
Hydrogen Logistics



Source: Webber Research and Advisory

Methanol vs Ammonia

Ammonia – Converting Ammonia to Hydrogen requires higher heat (600C to 900C = Outside Heat Source), more expensive equipment, and large centralized facilities for Hydrogen distribution to end users. Public spaces cannot currently convert Ammonia to Hydrogen without high costs and/or public safety risk.



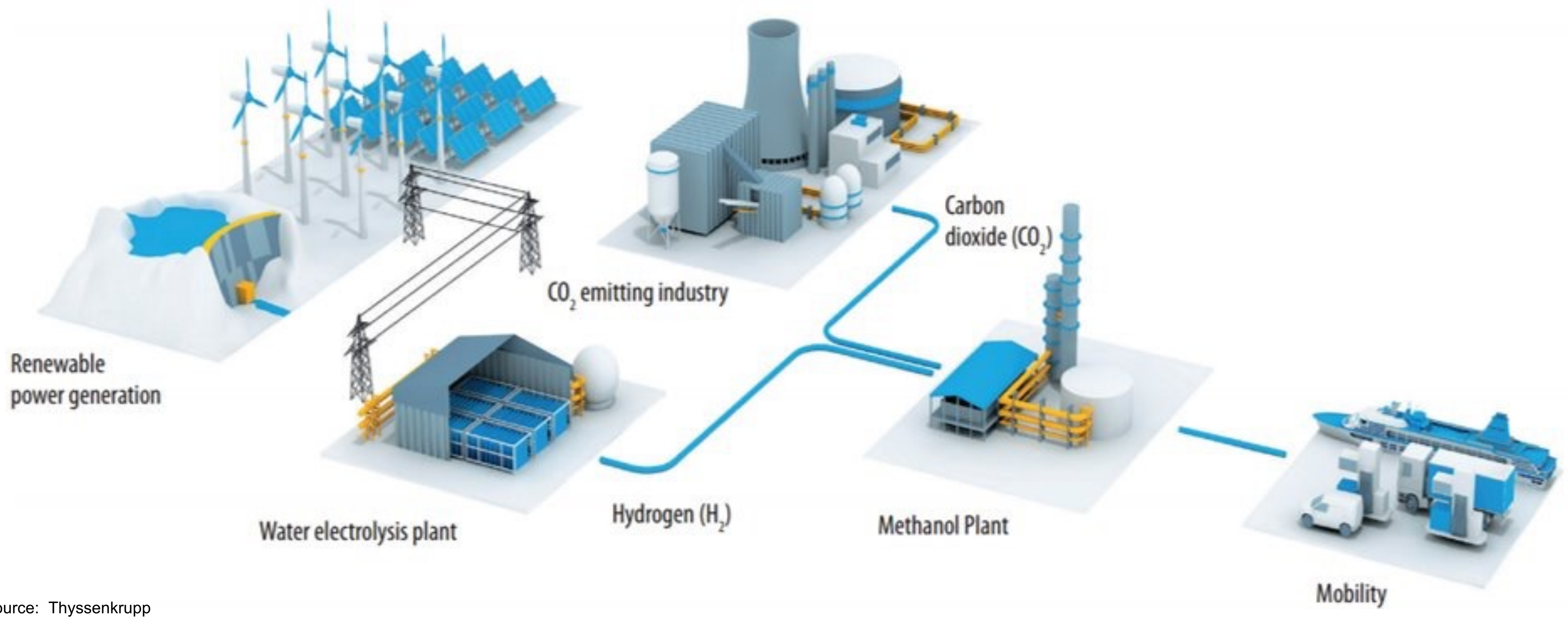
Methanol – Methanol can convert to Hydrogen at lower temperatures (300C to 450C). Methanol also leverages existing liquids infrastructure and converts to Hydrogen with proven technology that is less expensive, safer, and with a limited footprint.

Source: Webber Research and Advisory

Renewable energy and waste CO_2 model

METHANOL INSTITUTE

Thyssenkrupp is exploring ways to efficiently marry CO2 sources with green hydrogen for efficient methanol production



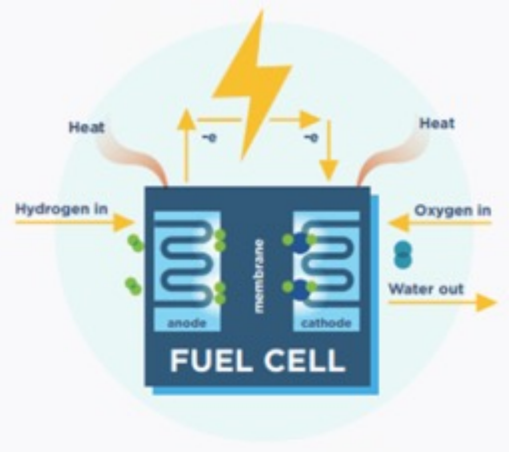
Source: Thyssenkrupp

Onboard methanol reformer: fuel cell scenario

METHANOL INSTITUTE

E1 L-series reformer: 65kg/day

Purified H_2



H2 fuel cells produce clean electric power which can be used in a wide array of applications

Clean power

- Nascent but growing interest – shipping companies are taking note
- Fuel cells or hybrid systems can be a more efficient pathway to produce power
- **Key driver is cost:**

	EU	N America	APAC	China
Cost of methanol $/MT	$308.94	$332.25	$275.00	$275.85
Cost for producing 1 kg H2	$2.38	$2.56	$2.12	$2.12

ENGINEERING

Why Intellectual Property matters when it comes to CC and the transition to future fuels

Colin Baker
Partner
18 August 2021

Forms of Intellectual Property

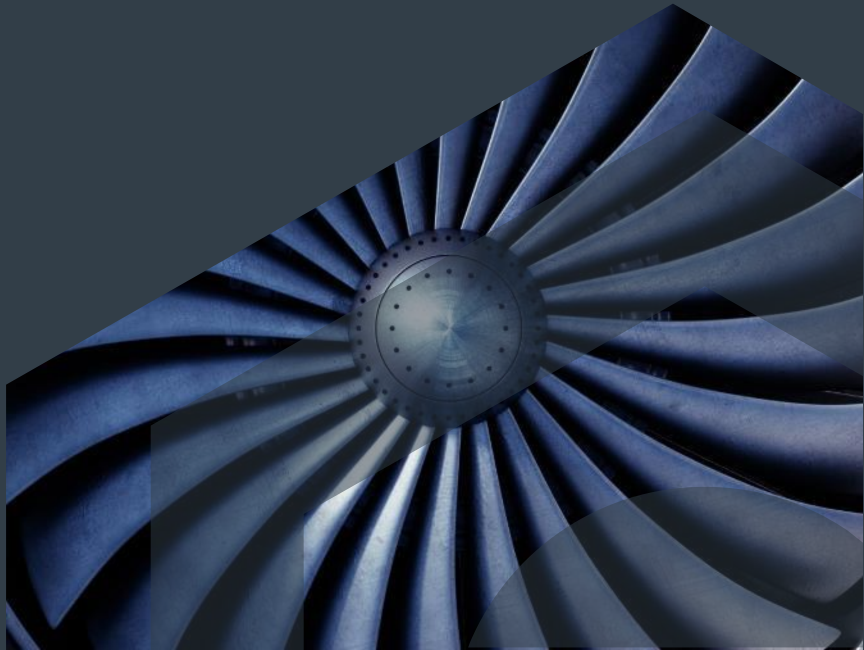
- \- Inventions (patents)

  \- Brands (trade marks)

  \- Designs (appearance)

  \- Copyright (copying)

  \- Trade Secrets (virtually anything!)



An Opportunity and a Threat!

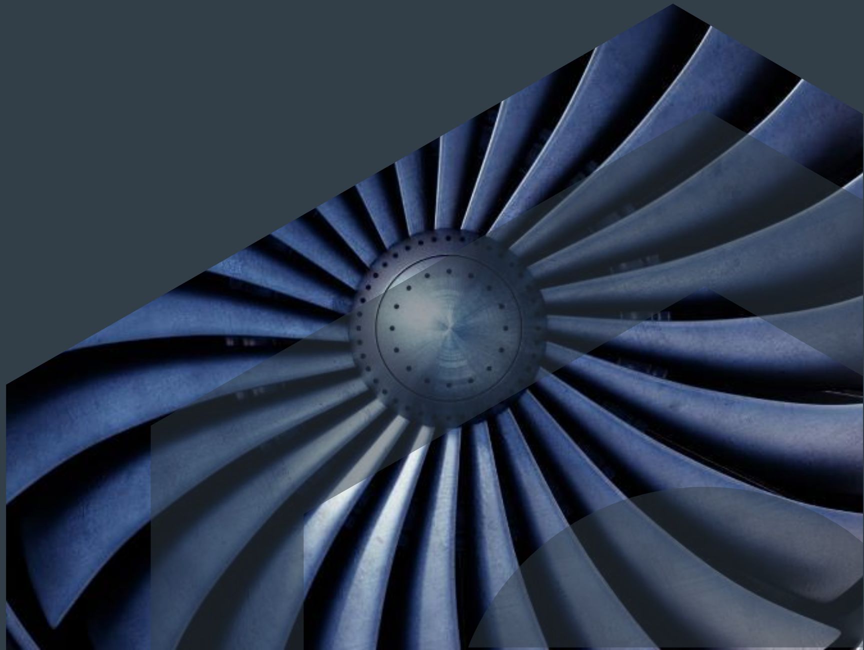
An Opportunity:

- Protect Investment in developing new CC systems
- Best IP rights to protect the investment and opportunities?
- If patents, can be any aspect of CC systems provided the invention is new and an improvement

An Opportunity and a Threat!

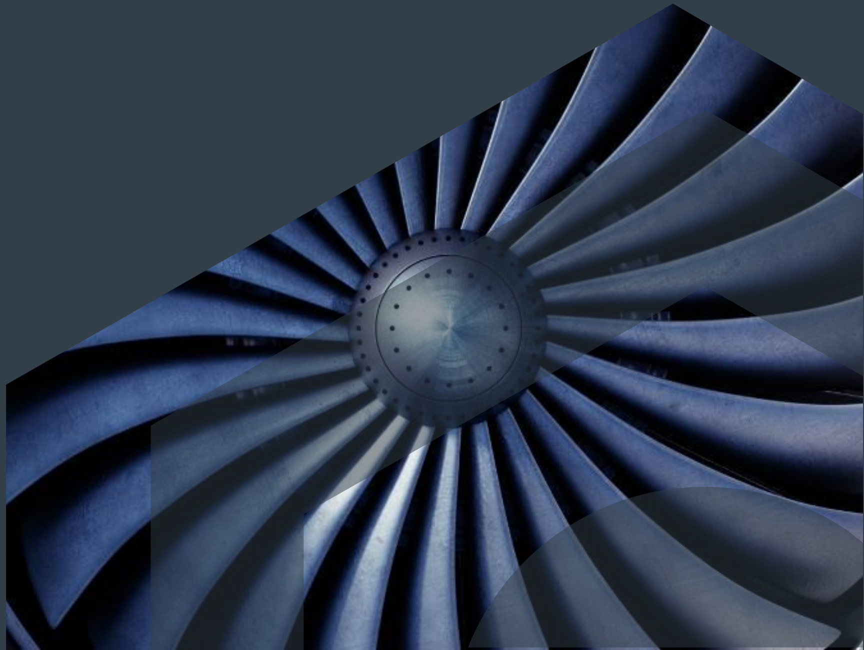
A Threat:

- Legal Issues!
    - ➢ Patent Infringement
        - Manufacturers and Suppliers
        - Ship Owners/Fleets
    - ➢ Trade Secret issues



What would I suggest?

- Be IP aware and prepared to do your IP homework.



Thank You

Colin Baker, Partner & Head of Cleantech
E: colin.baker@potterclarkson.com

Potter Clarkson
UK, Sweden, Denmark, Germany
W potterclarkson.com | E info@potterclarkson.com

DIN VEJ TIL INNOVATION, VIDEN OG SAMARBEJDE

MARLOG ER DANMARKS OFFICIELLE KLYNGEORGANISATION FOR DET MARITIME ERHVERV & LOGISTIK, OG VI ARBEJDER FOR DANMARK SOM ET BÆREDYGTIGT OG INNOVATIVT FØRENDE KRAFTCENTER.

The Quick Fix

Mangler du oplysninger, sparring eller en kontakt?
Vi stiller vores viden og netværk til rådighed for dig, så du hurtigt kan komme videre.

Viden & Visitkort

Viden er alt. Du går altid fra vores netværksmøder, sociale events og webinarer med nye idéer og kontakter. Vi sætter en ære i, at der altid er tid til at bytte visitkort.

Det Lange Seje Træk

Går du "all in" i et af vores projekter, garanterer vi, at både din virksomhed og branchen nyder godt af anstrengelserne.

World Careers

En målrettet kampagne mod unge mennesker for at udbrede kendskabet til det maritime erhverv, og mulighederne for job og uddannelse.

Læs mere og find vores medarbejdere på:

www.marlog.dk

Eller kig forbi en af vores lokationer i Danmark:

København, Frederikshavn, Svendborg, Bornholm, Esbjerg og Fredericia

info@marlog.dk

DEN NYE SUPER KLYNGE

Maritime & Logistics Innovation Denmark

MARLOG