
SVENSK
SJÖFART
SWEDISH SHIPOWNERS´ ASSOCIATION

Välkomna till sjöfartslunch om framtida framdrivningsmedel!

Program

12.00

- **Statusuppdatering om sjöfartens bränslepalett** – Julia Hansson, forskare, IVL & Chalmers
- **Hur ser utvecklingen ut gällande elektrobränslen?** – Claes Fredriksson, VD Liquid Wind, Thomas Stenhede, Liquid Wind
- **Senaste nytt om projektet Zeed och Ammoniak – vad, varför, hur och när?**

  – Cato Espero, Wärtsilä

13.30 Slut

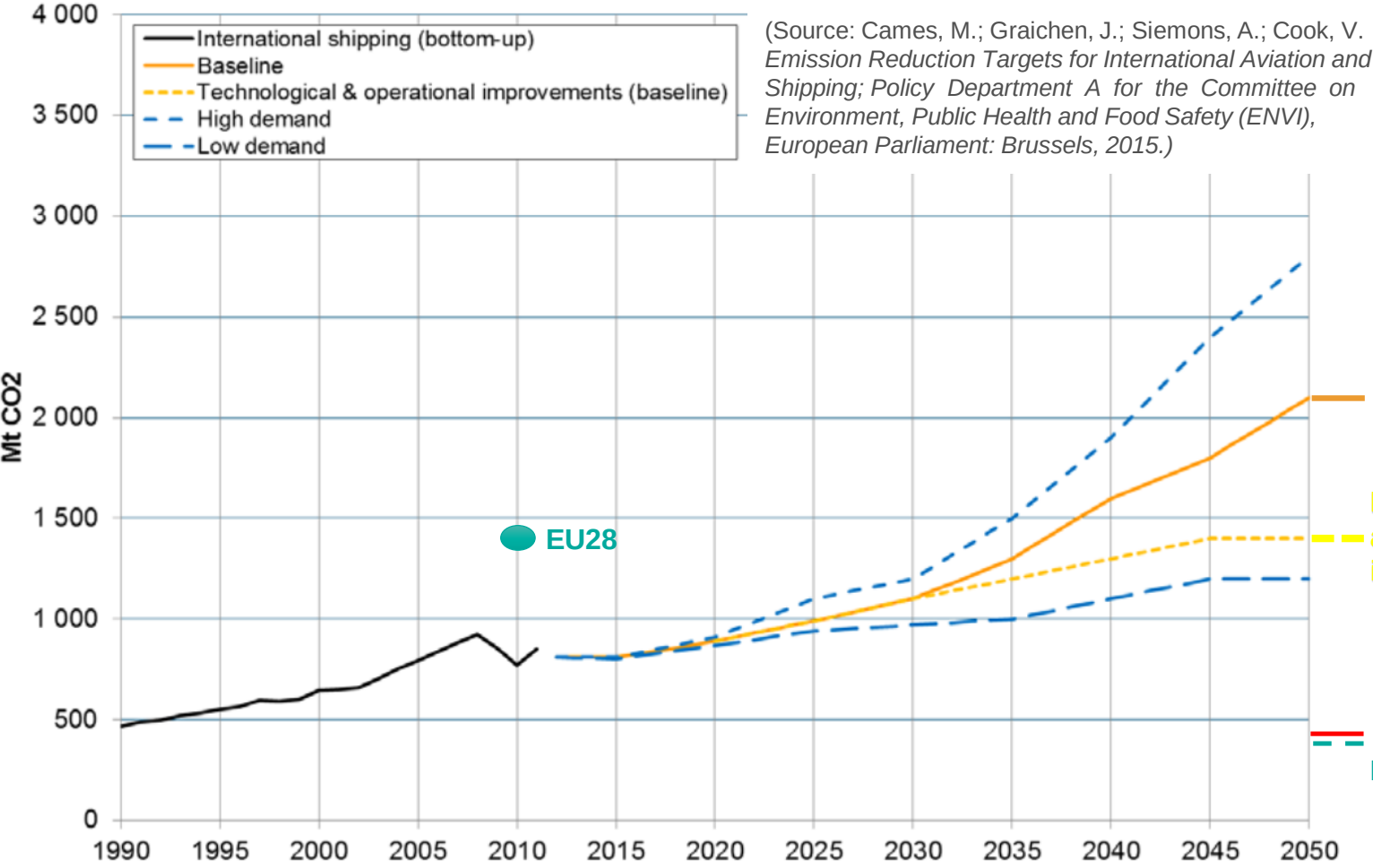
Statusuppdatering om sjöfartens bränslepalett

Julia Hansson, forskare, IVL & Chalmers

Statusuppdatering om sjöfartens bränslepalett

Julia Hansson och Selma Brynolf, Svensk Sjöfarts sjöfartslunch om framtida framdrivningsmedel, 2020-01-23

Why alternative fuels in shipping?



(Source: Cames, M.; Graichen, J.; Siemons, A.; Cook, V. *Emission Reduction Targets for International Aviation and Shipping; Policy Department A for the Committee on Environment, Public Health and Food Safety (ENVI), European Parliament: Brussels, 2015.)*

Reducing energy need important!

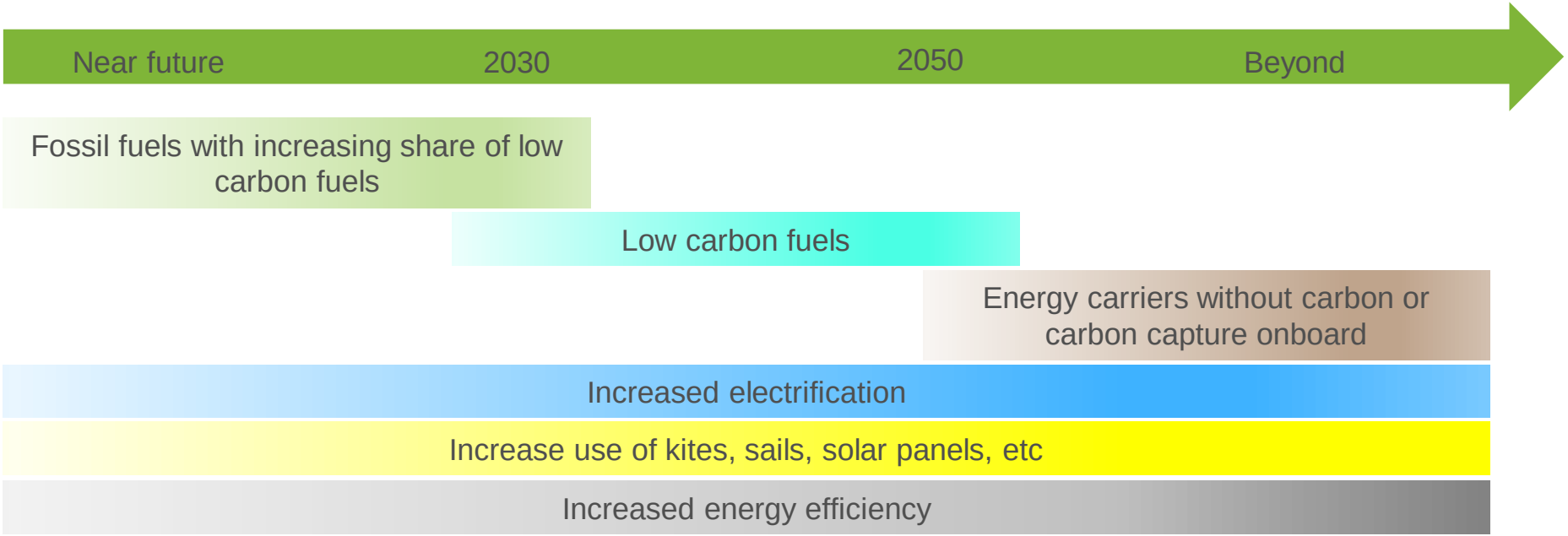
Corresponds to 17% of global CO_2 emissions in 2050

Including technological and operational improvments

IMO target for 2050

EU28 target for 2050

WHAT FUTURE FUELS ARE AVAILABLE?



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LOW CARBON FUELS

lower emissions of GHGs during the fuel life cycle than fossil fuels

- (Liquefied natural gas (LNG))
- (Fossil methanol)
- Biofuels
  - Hydrotreated vegetable oil (HVO) and FAME
  - Bio-methanol
  - Liquified biogas (LBG)
  - Bio-oils (e.g., pyrolysis oil, hydrothermal liquefaction) and synthetic diesel (under dev.)
  - Ethanol/lignin and other lignin based fuels (under development)
- Electrofuels (produced from water and CO_2 using electricity)

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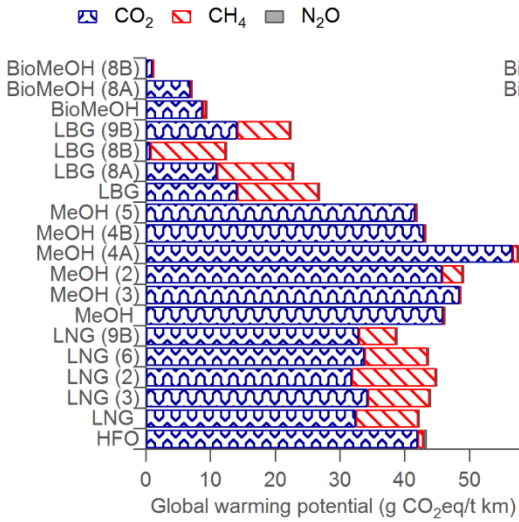
Liquified natural gas (LNG)

- Number of ships, LNG terminals and LNG infrastructure are increasing
    - LNG terminal in Gothenburg
- + Almost no SO_2 and PMs, much lower NO_x
- Impact on climate change? The global warming potential depend on time perspective and extent of methane slip

Methanol

- Some dual fuel vessels operating or under order
- Easier conversion of existing engines
- No need for cryogenic tanks
- Well developed global logistical systems intended for distribution to chemical industry
- Today mainly produced from natural gas and coal, but could be produced in many different ways (biomass, electrofuel)
- Not as low emissions of NO_x as with LNG
- What about climate impact? -> Depend on raw material and production pathway, low bio and e-fue



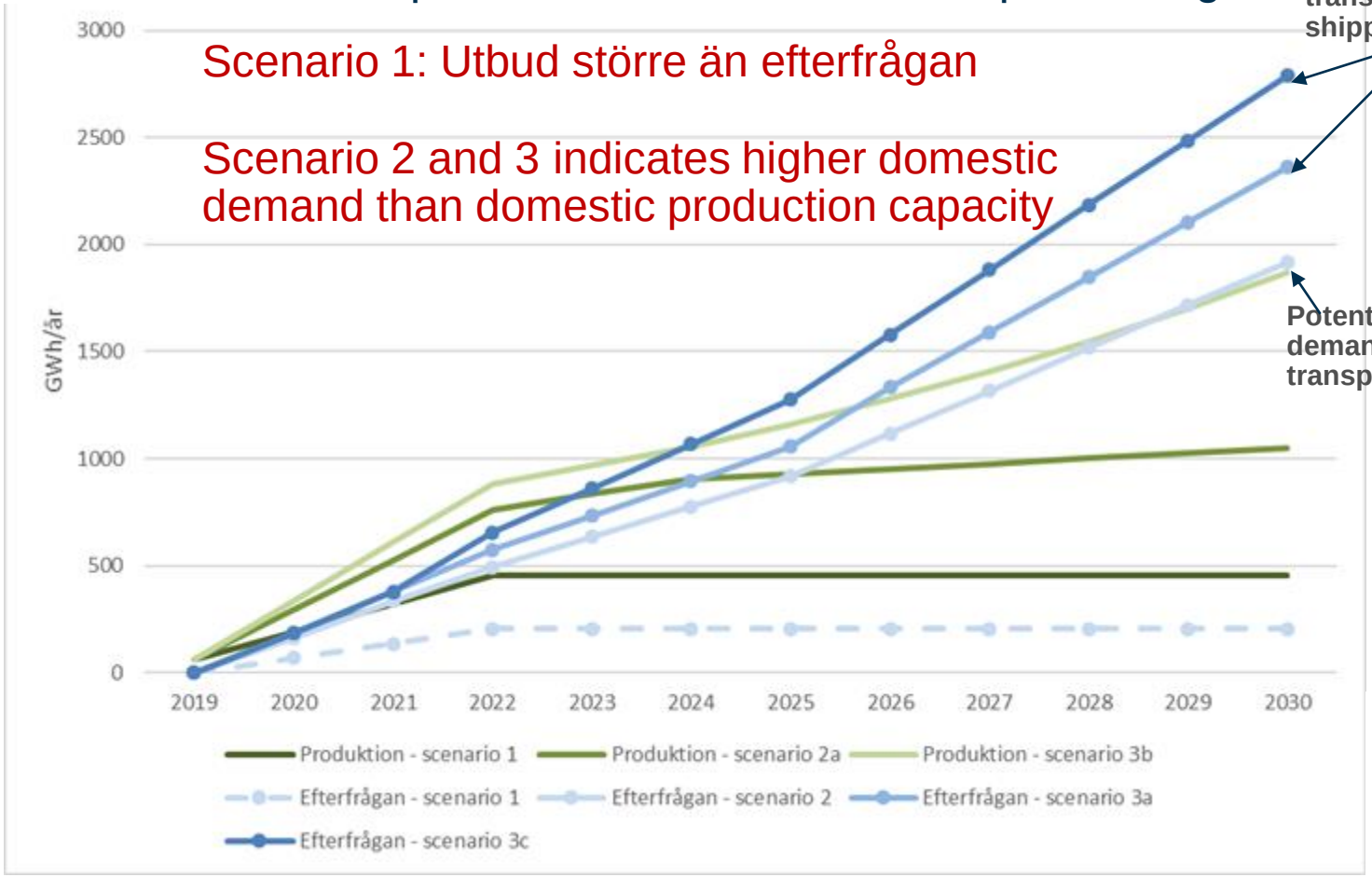
Biofuels

- Discussed a lot, some trials in ships (e.g. biodiesel, LBG…)
- Several possible pathways to biofuels in shipping e.g.,
  - Diesel fuels → biodiesel (FAME, HVO), vegetable oils
  - LNG → liquefied biogas (LBG)
  - Fossil methanol → bio-methanol
- Questions
  - Are there enough sustainable produced biomass for all sectors?
  - Where are biomass used most cost-effectively? Road and aviation will also increase demand
  - Successful development of more variants/options

LBG (liquified biogas)

- LBG tested on ships bunkering in Sweden
- Study on the prospects for LBG in Sweden to 2030
- I scenarier fokus på sjöfart som omfattas av 70%-målet till 2030, Gotlandsrederiet, statliga fartyg som vägfärjor, isbrytare, lotsbåtar Kvarkenfärjan
- Gotlandsrederiet anger att 5–10 % av bränsleanvändningen till fartyget Visborg kan utgöras av biogas på kort sikt
- För övriga fartyg (70%-mål) just nu större fokus på andra alternativ

Swedish scenarios for production and demand of liquified biogas



Potential increased demand from road transport + shipping

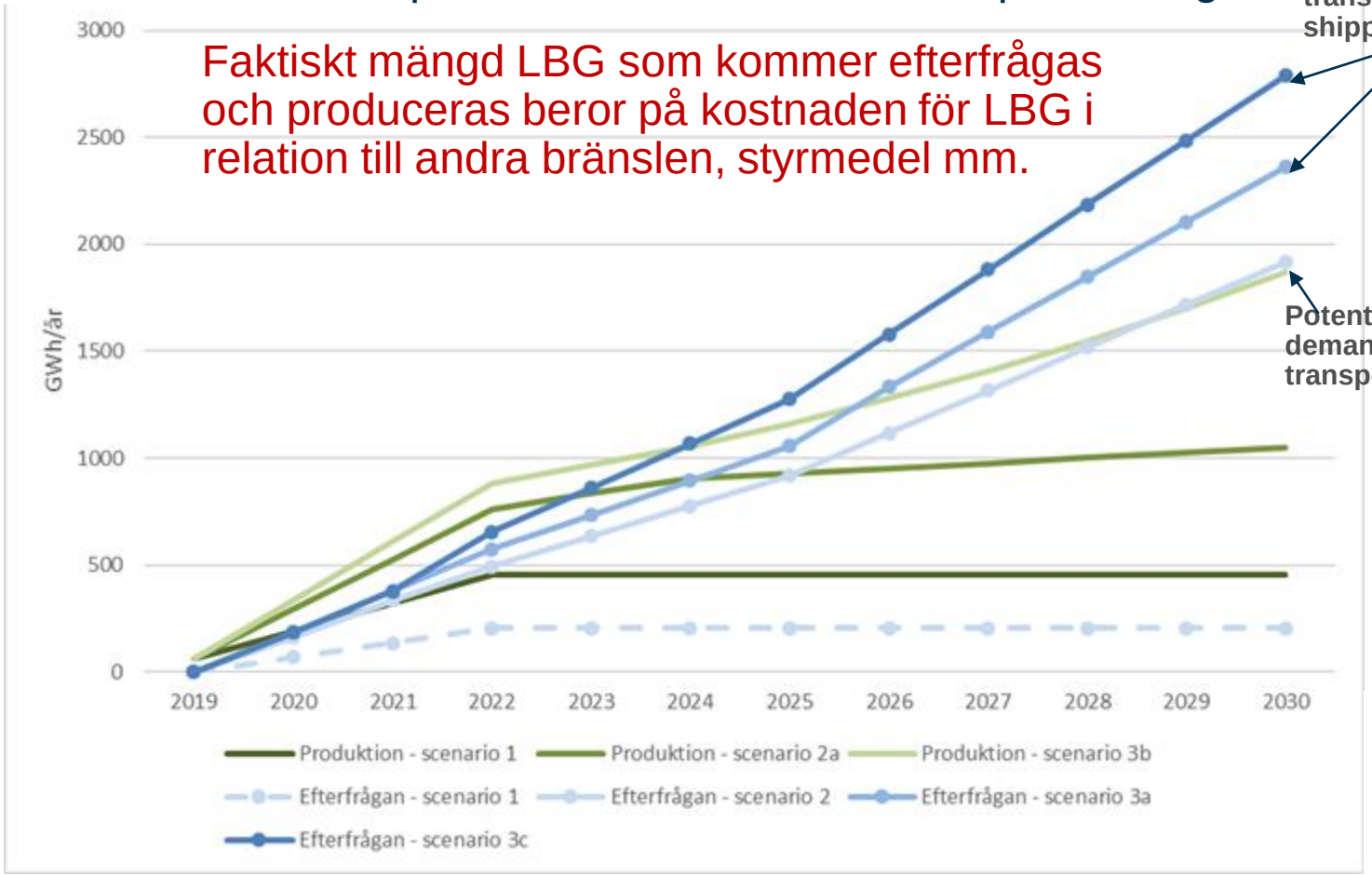
3a: 1 fartyg 5% LBG fr 2022, 2 fartyg 5% fr 2026
3c: 2 fartyg 10% LBG fr 2022, ökning till 10 fartyg 10% 2030

Potential increased demand from road transport

Source: Hjort et al., 2019. Utsikt för förnybar flytande metan i Sverige till år 2030. Report, f3

Swedish scenarios for production and demand of liquified biogas

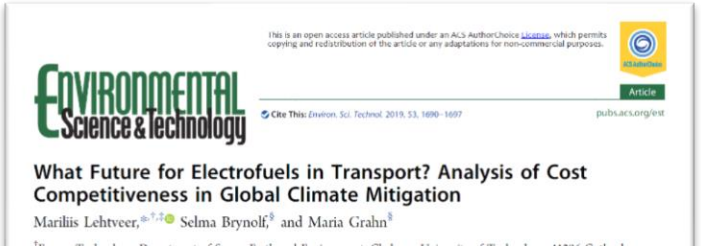
Faktiskt mängd LBG som kommer efterfrågas och produceras beror på kostnaden för LBG i relation till andra bränslen, styrmedel mm.



Source: Hjort et al., 2019. Utsikt för förnybar flytande metan i Sverige till år 2030. Report, f3

Electrofuels

- Can be a complement to biofuels
- Utilizing renewable electricity to produce fuels (various), possibility to use electricity also for long distances
- Possibility to produce the desired fuel (e-methanol, e-diesel etc.)
  - Comes at an energy cost...
- Can they be cost-competitive? Future cost of electrofuels expected to be in the same range as advanced biofuels.
- Cost-effectiveness of electrofuels in global climate mitigation will likely depend on the amount of CO_2 that is possible to store, which is generally more cost-effective.
- What about impact on climate?



ZERO CARBON FUELS AND ABATEMENT TECHNOLOGIES

without direct carbon emissions and potential for zero carbon emissions during the fuel life cycle

- Hydrogen
- Ammonia
- Electricity
- Carbon capture (not covered in this presentation)

Hydrogen

- It does not contain carbon!
- Problem to store large amounts of cryogenic hydrogen onboard ships
    - Not tested for marine applications
- Mainly produced by steam reforming of natural gas, but electricity and electrolyser goes down
- A more energy efficient fuel to produce (compared to electrofuels)

Ammonia (NH_3)

Rapport på g – håll koll via Lighthouse

- Carbon-free fuel that can be produced from renewable energy sources
- Fuel option discussed internationally but not yet used.
- Higher volumetric energy density than liquid hydrogen, but require larger space onboard than other fuels (less than H2)
- Infrastructure exists today NH_3 mainly for fertilizer - working fuel infrastructure and bunkering systems needed
- Mainly produced from steam reforming of natural gas, but can be produced from renewable energy sources – however need to be expanded substantially!
- Can be used in fuel cells or in combustion engines
  - But limited amount of trials done
  - Pilot fuels needed, low efficiency - demonstrations of emissions and efficiencies called for
- Safety is a major concern!

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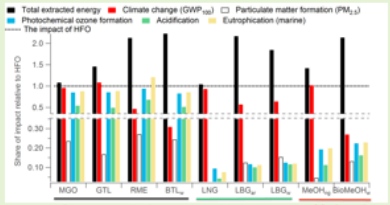
Battery electric propuslion

- An very efficient way to use energy onboard ships
- Large interest for smaller batteri-electric vessels such as ferries and the number of hybrid vessels are increasing
- Challenges with cost, weight, safety, sustainability and availability of batteries etc.

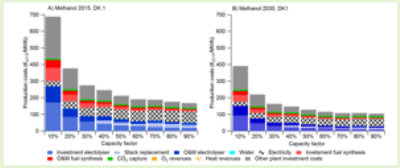
Examples of hybrid and fully battery electic vessels
1. Norway: Future of the Fjords, an all-electric tourist ferry,
2. Norway: Vision of the Fjords, a hybrid electric tourist ferry,
3. Norway: Ampere, all electric first passenger ferry (120 cars and 360 pax),
4. Norway: YARA Birkeland, all electric autonomous chemical tanker, 9 MWh battery,
5. Norway: Karoline, battery electric fishing cutter,
6. Denmark: e-Ferry, EU Commission funding an all-electric passenger ferry,
7. Finland: Aranda, ship being retrofitted into a battery-hybrid propulsion system
8. Belgium-Netherlands: Port-Liner, EU subsidised battery barges,
9. Norway: Hurtigruten, battery-hybrid cruise ship,
10. Norway: Fjord 1, orders new battery-electric ferries
11. Denmark-Sweden: Tycho Brahe, 4.2MWh battery pack with automated shore-side charging,
12. Denmark-Sweden: Aurora, 4.16MWh battery pack with automated shore-side charging,
13. Denmark: Maersk: batteries could be deployed on container ships by 2020
14. Italy: Grimaldi shipyard building 6 battery-hybrid RoRo ships,
15. Turkey: Zero Emissions Electric Tugboat with a huge 1.5MWh battery pack (in development),
16. China: all electric ferry with massive 2.4MWh battery pack,
17. China: HYTug, a battery-hybrid tugboat,
18. Canada: RAlly 1600-E, a battery-electric pilot boat (at design stage),
19. Canada: BC Ferries, looking for battery-hybridisation,
20. US: Puyallup, Wenatchee & Tacoma, ferries carrying 2500 pax & 202 cars in Washington state,
21. US: Bend Ferry, to be retrofitted into battery electric propulsion,
22. Germany: Damen shipyard developing battery-electric and battery-hybrid propulsion solutions.

HOW TO ASSESS ALTERNATIVE FUELS?

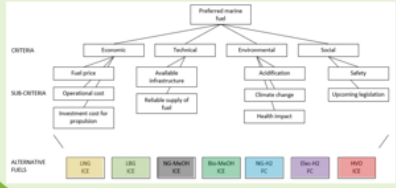
Life cycle assessment (LCA)



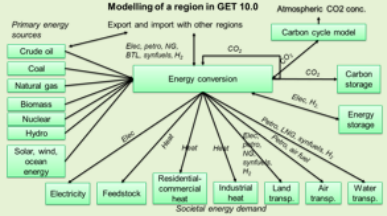
Techno-economic assessment (TEA)



Multi-criteria decision analysis (MCDA)



Global energy system modelling



Scenario development and analysis

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Biomass and Bioenergy 126 (2019) 159–173

Ammonia added later

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: www.elsevier.com/locate/biombioe

Research paper

Alternative marine fuels: Prospects based on multi-criteria decision analysis involving Swedish stakeholders

Julia Hansson[a,b,*], Stina Månsson[c], Selma Brynolf[a], Maria Grahn[a]

AIM: assess the prospects for seven selected alternative fuels—for **deep-sea shipping in 2030** by applying a **multi-criteria decision analysis approach** and specifically considering the influence of **various stakeholder preferences**.

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Inclued Marine fuels

- Liquefied natural gas (**LNG**),
- Liquefied biogas (**LBG**),
- Biomass and Natural gas based **Methanol** (Bio-MeOH + NG-MeOH)
- **Hydrogen** for fuel cells produced from (i) natural gas (NG-H2)or (ii) electrolysis based on renewable electricity (Elec-H2)
- Hydrotreated vegetable oil (**HVO**)

Added later:

- Renewable **Ammonia** in fuel cells (FC) and internal combustion engines (ICE) (Elec-NH3)
- Natural gas based **Ammonia** in FCs and ICEs (NG-NH3)

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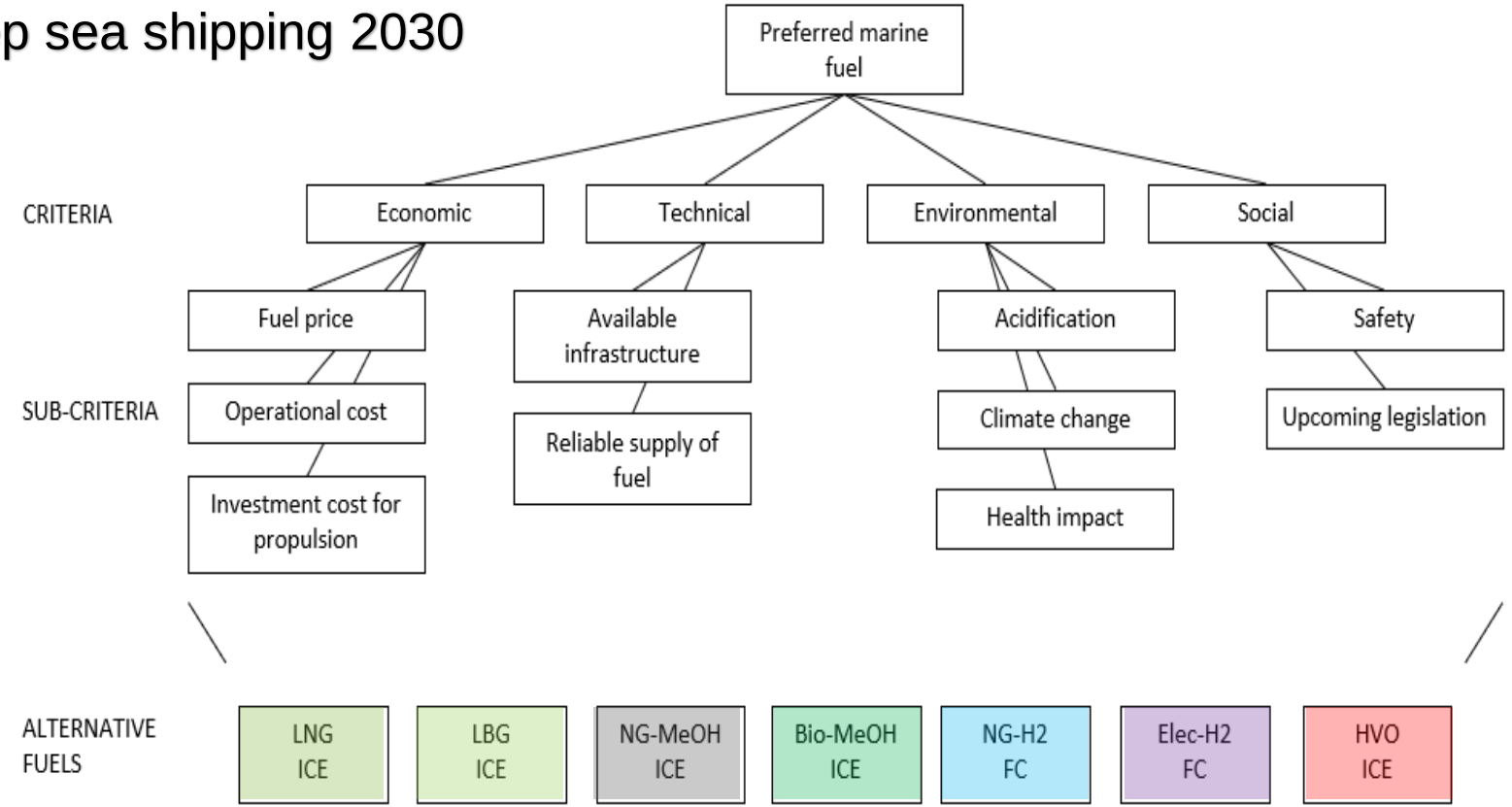
Multi-criteria decision analysis

Deep sea shipping 2030



MULTI-CRITERIA ASSESSMENT

Fuel options scored based on how they perform for each sub-criteria based on available info (e.g., climate change impact, operational cost)

Criteria/Sub-critera given weights based on how important they are, relative importance (based on individual (joint) and stakeholder group preferences: *Authority, Ship-owner, Fuel producer and Engine manufacturer*)

Ranking: What alternative marine fuel is most preferable considering the stakeholders' preferences?

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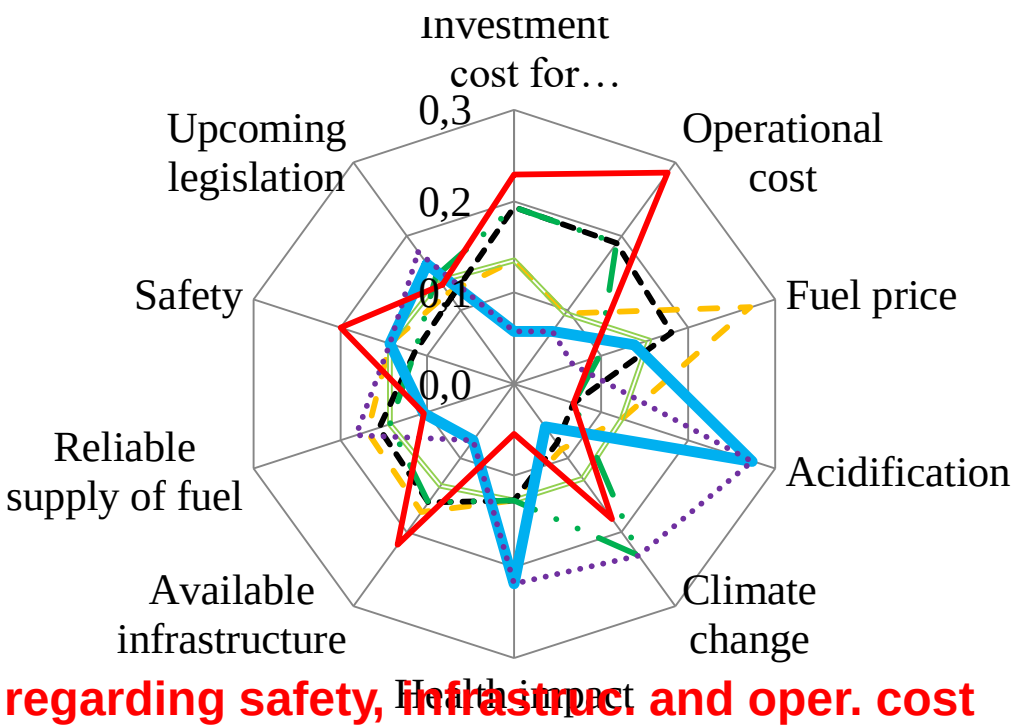
Fuel scoring



Best regarding safety, infrastruct and oper. cost

Liquefied natural gas (LNG)

Liquefied biogas (LBG)

Natural gas based methanol

Biomass based methanol

Natural gas based hydrogen in fuel cells

Wind power based hydrogen in fuel cells

Hydrotreated vegetable oil (HVO) produced from tall oil

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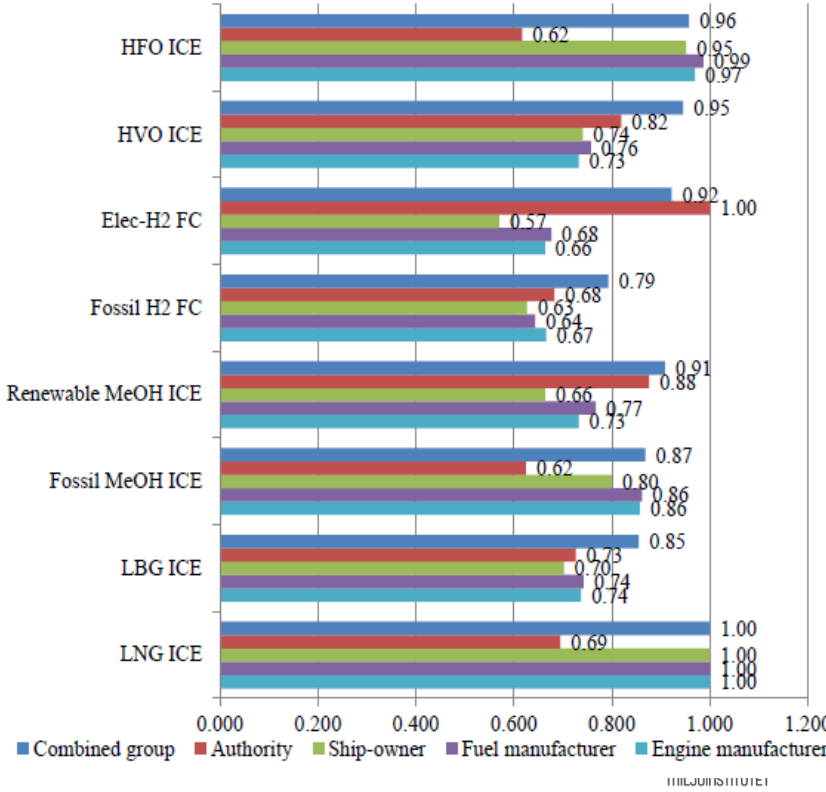
Ranking of marine fuels influenced by stakeholder group preferences

- For ship owners, fuel producers, and engine manufacturers, economic criteria, in particular fuel price, most important…
- …this results in that **LNG** and **HFO** ends up in the top, followed by **fossil methanol**, and then **various biofuels** (LBG, renewable methanol, and HVO).
- Representatives from Swedish government authorities prioritize environmental criteria, specifically GHG emissions, and social criteria (potential to meet regulations)…
- …this results in **renewable hydrogen** in the top, followed by **renewable methanol**, and then **HVO**.



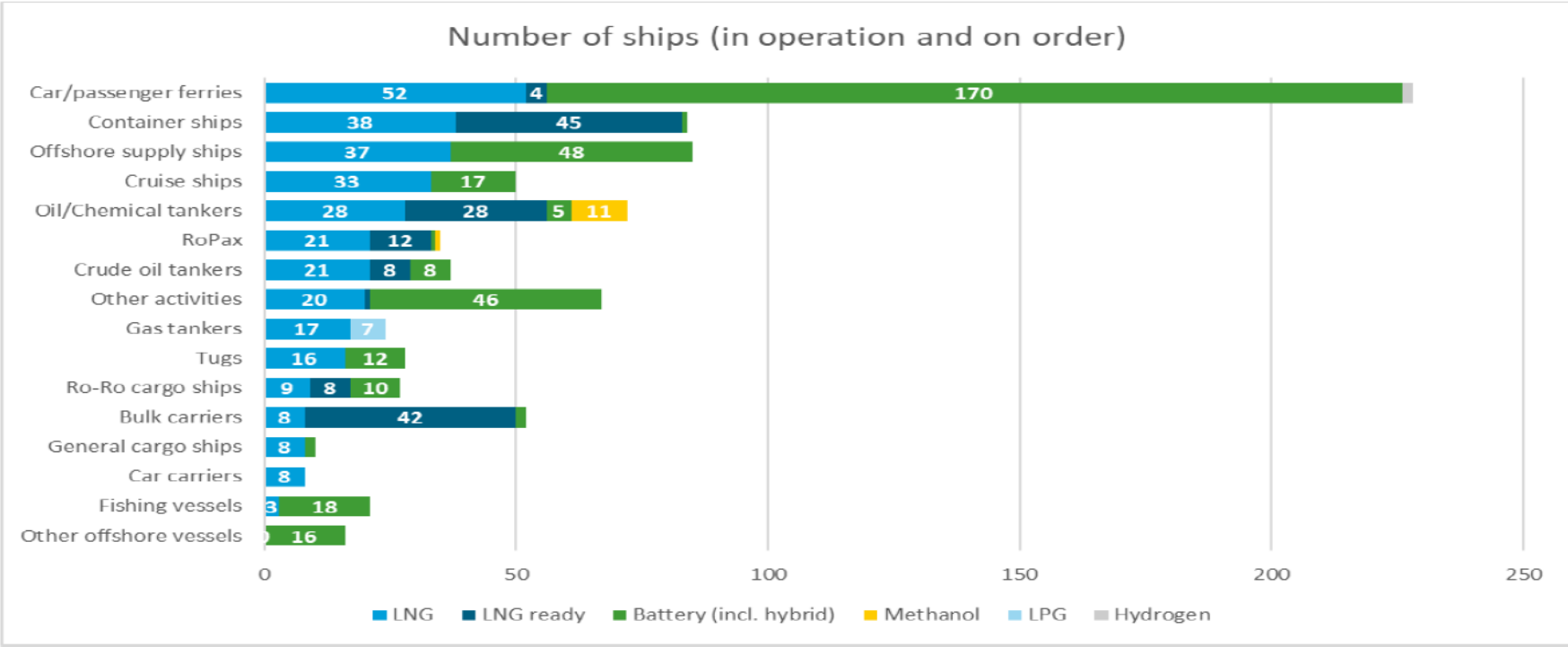


Figure 3-1: Uptake of alternative fuels in the world fleet, July 2019 (ships in operation and on order) (/24/)

Source: DNV GL (2019)

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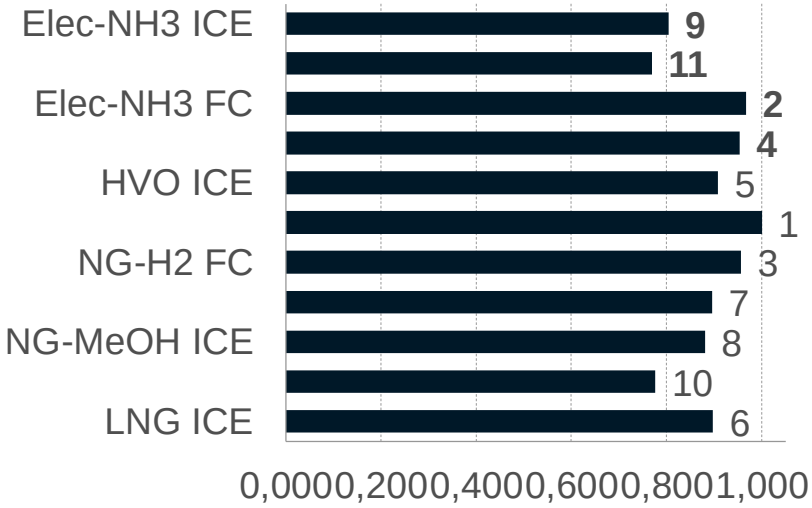
What about ammonia?

Preliminary base case joint ranking

- Ammonia in fuel cells turns out better than ammonia in internal combustion engines
- Initial assessment indicates that ammonia might be as interesting as hydrogen and biomass-based marine fuels (also the case for other stakeholder groups)



Source: Lövdahl, J., Magnusson, M., 2019. Evaluation of Ammonia as a Potential Marine Fuel - Modelling and assessment of alternative marine fuels … Master thesis. Chalmers University of technology.

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SUMMARY

Fuel	Relative cost	Technology maturity	Enabler	Challenges
Biofuels	Middle	Known	Can be used as blends in existing ships	Sustainability and availability of biofuels
Electrofuels	High	Known	Can be used as blends in existing ships, flexible	Electricity intense production
Hydrogen and ammonia	Middle/High	Not tested in marine application	Availability of cheap natural gas	Renewable production need to increase substantially, Limited amounts of NG with CCS can be used in a 1.5 C scenario Safety issues ammonia! H2 space requirement
Battery-electric	High	Known and tested for ferries	Low cost electricity and changing infrastructure for ships	Battery cost, weight, sustainability and availability of batteries, available short-distance

Our reports and papers (1/2)

Hansson, J., Brynolf., S, Fridell, E., 2020. On the potential of ammonia as fuel for shipping - A synthesis of knowledge. Lighthouse report.

Hansson, J., Månsson, S., Brynolf, S., Grahn, M., (2019). Alternative Marine Fuels: Prospects Based on Multi-Criteria Decision Analysis Involving Swedish Stakeholders. Biomass and Bioenergy 126. https://doi.org/10.1016/j.biombioe.2019.05.008.

Winnes, H., Fridell E., Hansson, J., Jivén, K., 2019. Biofuels for low carbon shipping. Tripple F Reportnumber 2019.1.21c

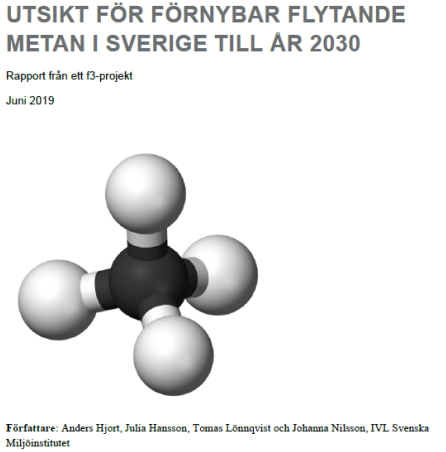
Hansson, J., Brynolf, S., Andersson, K., Månsson, S., Grahn, M., Fridell, M., (2018). Prospects for alternative marine fuels. f3 2018:11. https://f3centre.se/app/uploads/2018-11_42403-1_Hansson-et-al_FINAL_180530.pdf.

Our reports and papers (2/2)

Brynolf, S., Taljegård, M., Grahn, M., Hansson, J., (2018). Electrofuels for the transport sector: A review of production costs. Renewable and Sustainable Energy Reviews 81 (2). https://doi.org/10.1016/j.rser.2017.05.288

Hjort, A., Hansson, J., Lönnqvist, T., Nilsson, J., (2019). Utsikt för förnybar flytande metan i Sverige till år 2030. f3 2019:05. www.f3centre.se.

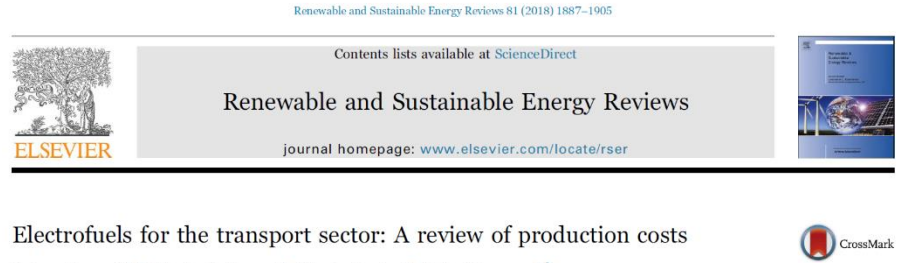
Lehtveer, M., Brynolf, S., Grahn, M. (2019). What future for electrofuels in transport? – analysis of cost-competitiveness in global climate mitigation. Environmental Science and Technology 53 (3).


UTSIKT FÖR FÖRNYBAR FLYTANDE METAN I SVERIGE TILL ÅR 2030

Rapport från ett f3-projekt

Juni 2019

Författare: Anders Hjort, Julia Hansson, Tomas Lönnqvist och Johanna Nilsson, IVL Svenska Miljöinstitutet


Renewable and Sustainable Energy Reviews 81 (2018) 1887–1905

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Electrofuels for the transport sector: A review of production costs

Selma Brynolf[a,*], Maria Taljegard[a], Maria Grahn[a], Julia Hansson[a,b]

Tack för att ni lyssnat!

julia.hansson@ivl.se

Pågående projekt bl a:
Vägen mot 50% minskning av GHG-utsläpp från sjöfart till 2050

Mål: utvärdera ett par tekniska lösningar och styrmedel med stor potential att bidra till IMO:s mål för växthusgasutsläpp till 2050

Framtida bränsleval för flyg, sjöfart och vägtransporter ur ett energisystemperspektiv

Syfte: analysera framtida kostnadseffektiva bränsleval för framför allt flyg och sjöfart i framtiden

Energimyndigheten

SVENSKT KUNSKAPSCENTRUM FÖR FÖRNYBARA DRIVMEDEL

LIGHTHOUSE
SWEDISH MARITIME COMPETENCE CENTRE

FORMAS

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Hur ser utvecklingen ut gällande elektrobränslen?

Claes Fredriksson, VD Liquid Wind
Thomas Stenhede, Senior Technical Advisor, Liquid Wind

Powering Carbon Neutral Shipping

Liquid Wind

Claes Fredriksson
Founder & CEO
Claes@LiquidWind.se

Thomas Stenhede
Senior Technical Advisor
Thomas@LiquidWind.se

What is electro-fuel?

Renewable Electricity

Upcycled Carbon Dioxide

E-methanol

- ✓ Carbon-neutral Fuel
- ✓ ~90% reduction in CO_2 emissions
- ✓ IMO Compliant
- ✓ Proven performance for Shipping
- ✓ +50% engine efficiency
- ✓ Improved Ocean Stewardship

Liquid Wind | Circular Carbon Energy for a cooler world

Key part of Future Fuel mix

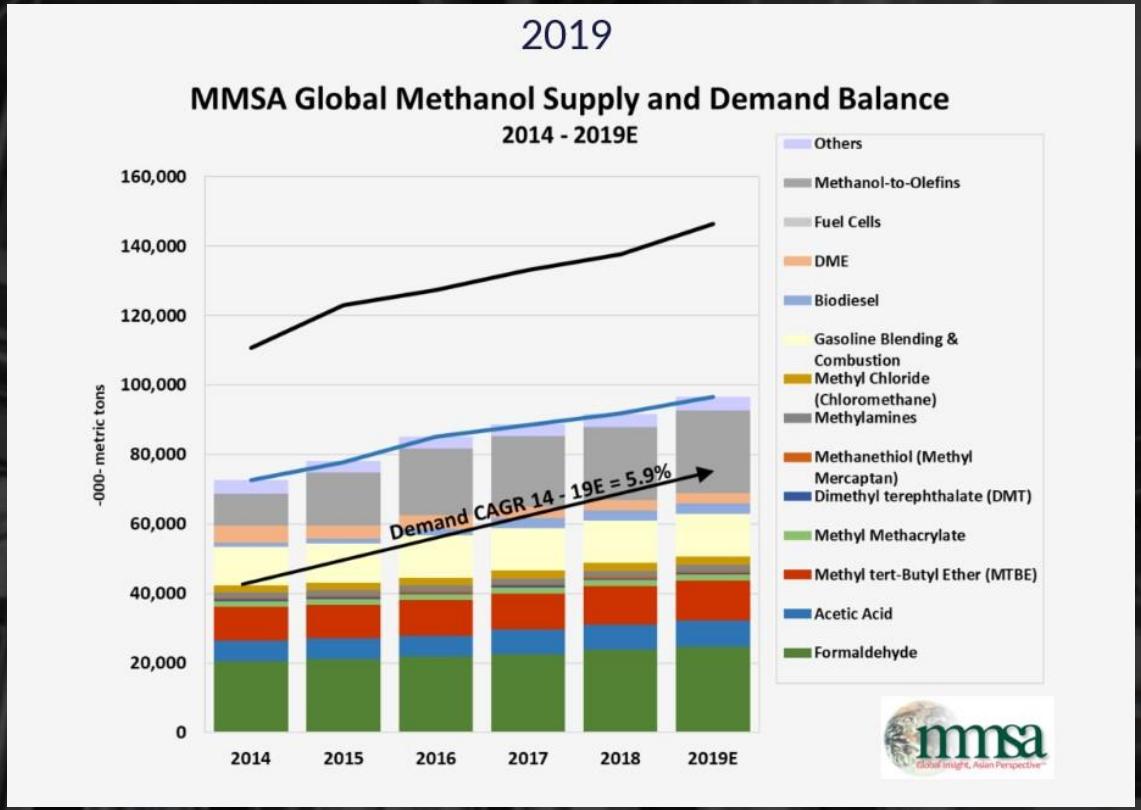
- Proven performance
- First vessel, Stena Germanica, retrofitted 2015
- Growing interest and investment

Dual Fuel – Methanol / Fuel Oil Vessels

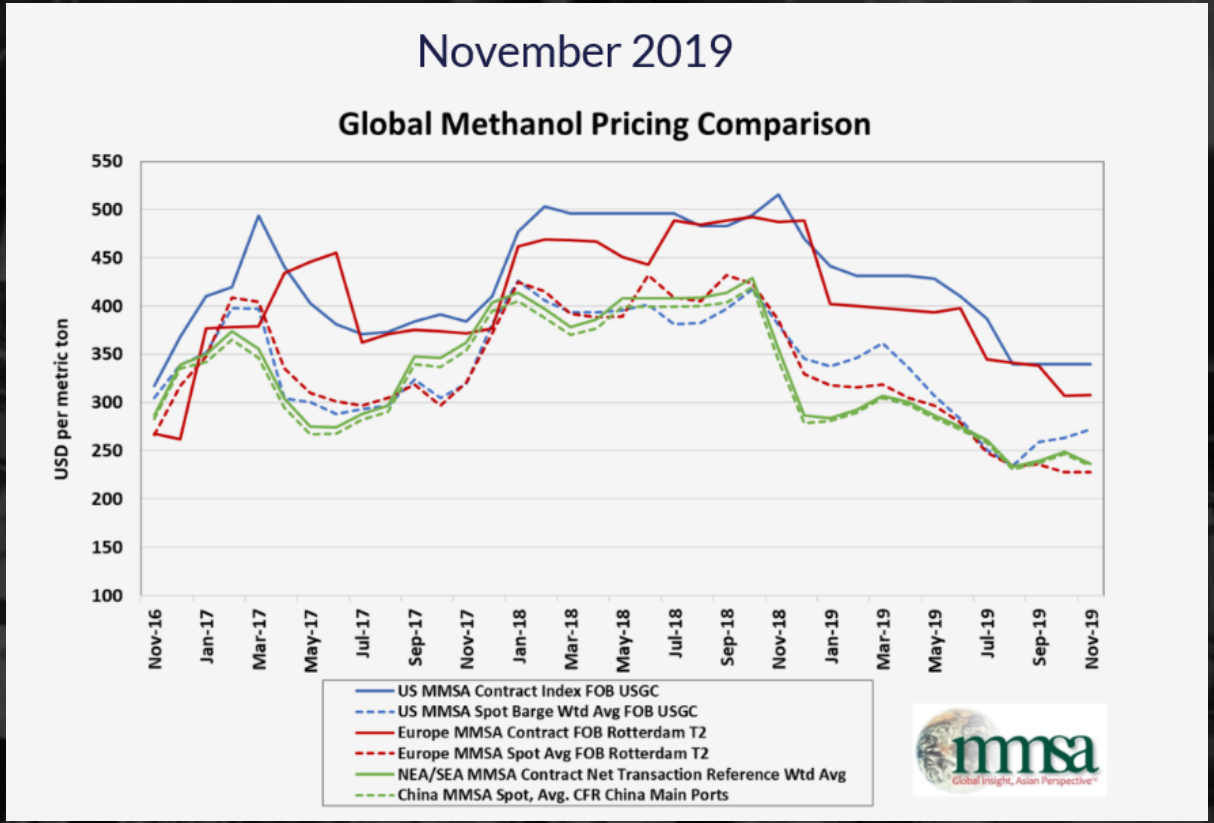
Duel Fuel vessels currently operating or under order;

- One Ropax
- Thirteen Tankers
- Two Pilot Vessels
- One Tugboat (under construction)

Global demand for Methanol is increasing significantly

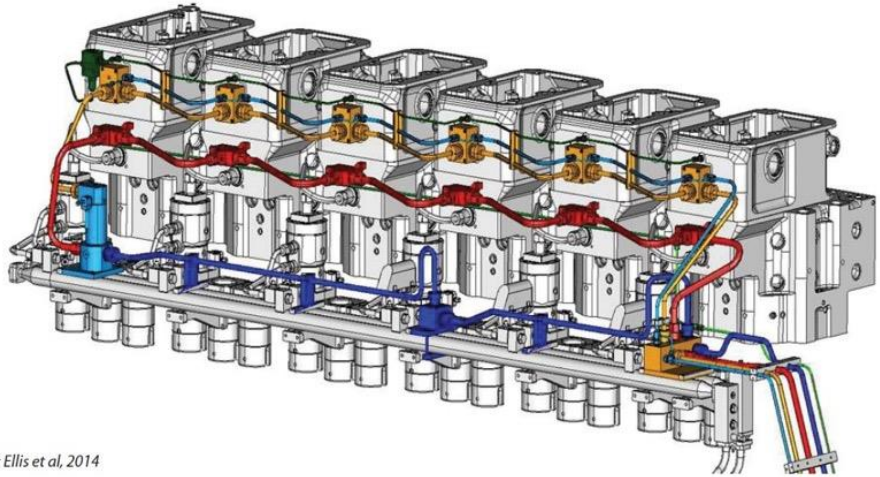


Methanol price is declining, now comparable with MGO



High-performing Methanol engines available

Figure 13: Wärtsilä engine with additional piping for methanol



Source: Ellis et al, 2014

Figure 14: MAN engine adapted for methanol

Source: Sejer Laursen, 2015b

Methanol & E-methanol?

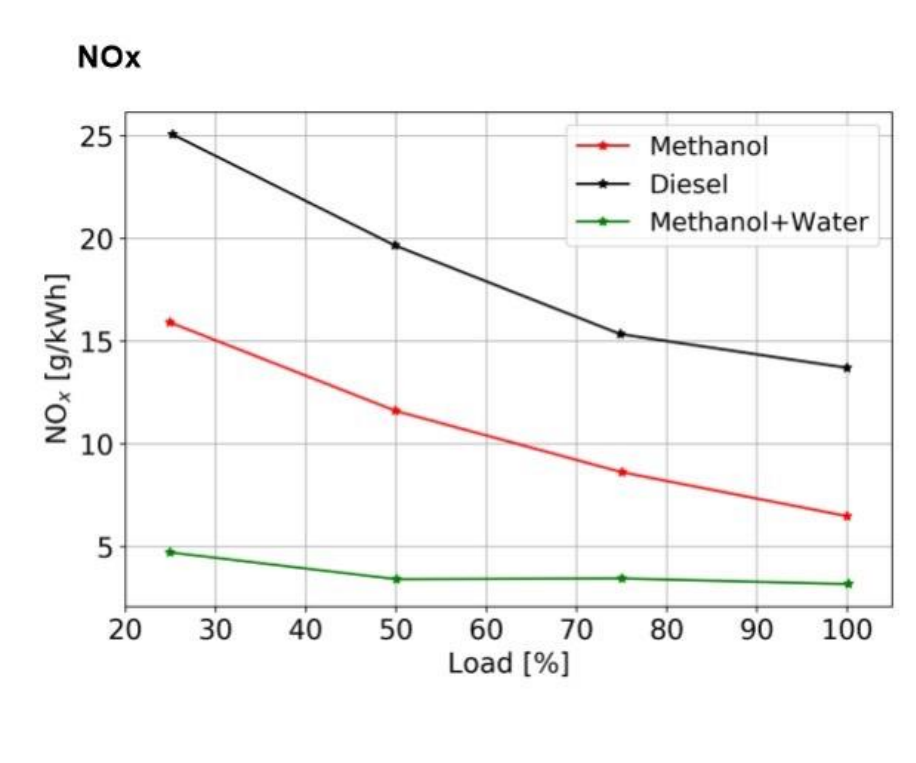
Transitioning to carbon neutral shipping

- Derived from fossil-fuels
- Highly-used commercial chemical
- Widely available, in every port
- Improved environmental profile vs MGO and HFO

- Derived from renewable sources
- Carbon neutral
- 90+% CO_2 emission reduction

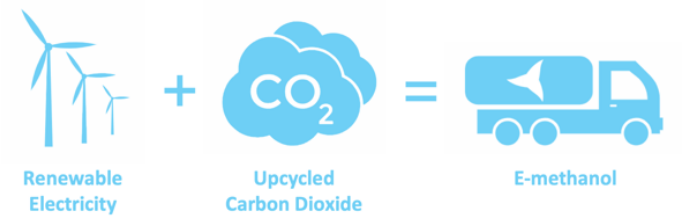
- E-methanol and methanol are blendable
- Liquid – easy to store and transport
- Compatible with existing infrastructure
- Better Ocean stewardship

No SOx. Reduced NOx. Reduced Particulates.



E-methanol Production

Liquid Wind is currently developing the first **commercial-scale** facility in Scandinavia

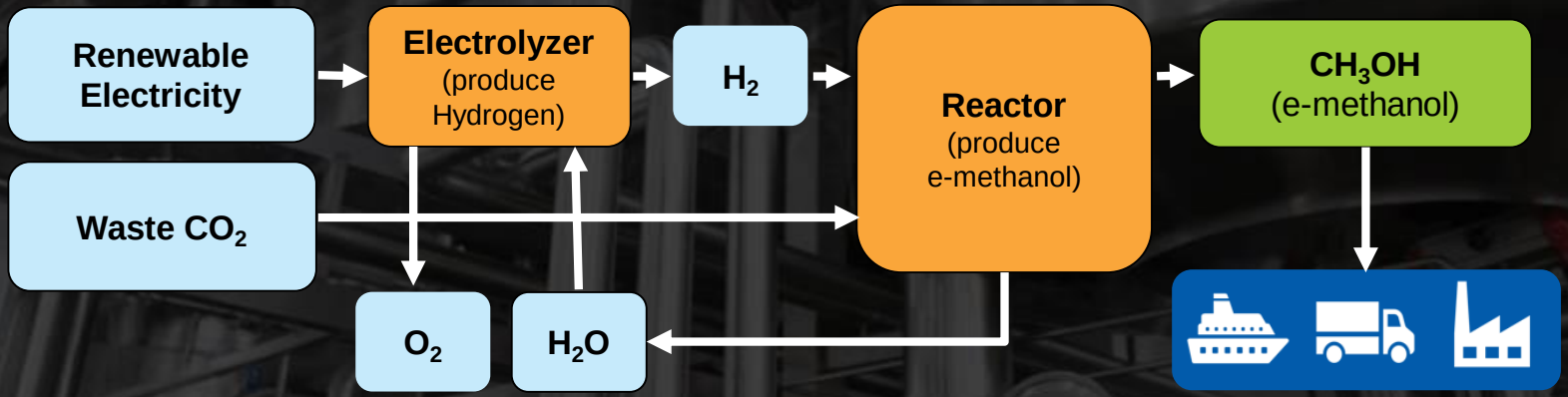


- **45 000 Tons fuel** / year
- **90 000 Tons CO_2 reduction** / year

First facility operational in 2023
6 facilities planned until 2030
To be followed by international expansion

Liquid Wind | Circular Carbon Energy for a cooler world

Converting Carbon Emissions to Electro-Fuel

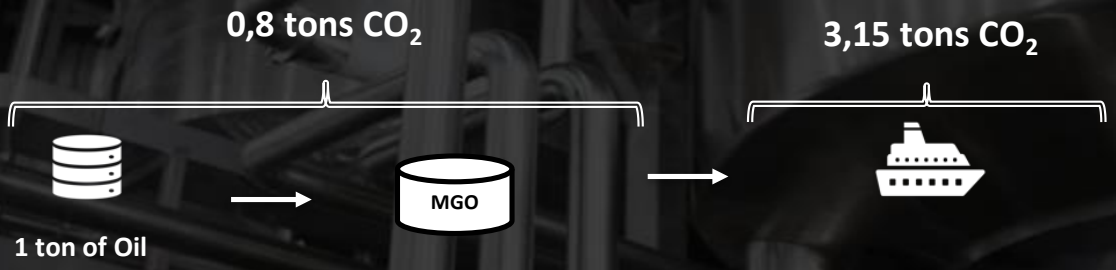


- ✓ Renewable fuel
- ✓ Proven Technology
- ✓ Easy to adopt and store

- ✓ Prevents new carbon emissions
- ✓ Enables decarbonization of industry

Every 2 tons of e-Methanol used prevents emission of 4 tons of CO_2

Classic Fossil case



~ 4 tons CO_2

Liquid Wind case

~ 0 tons CO_2

½ energy content

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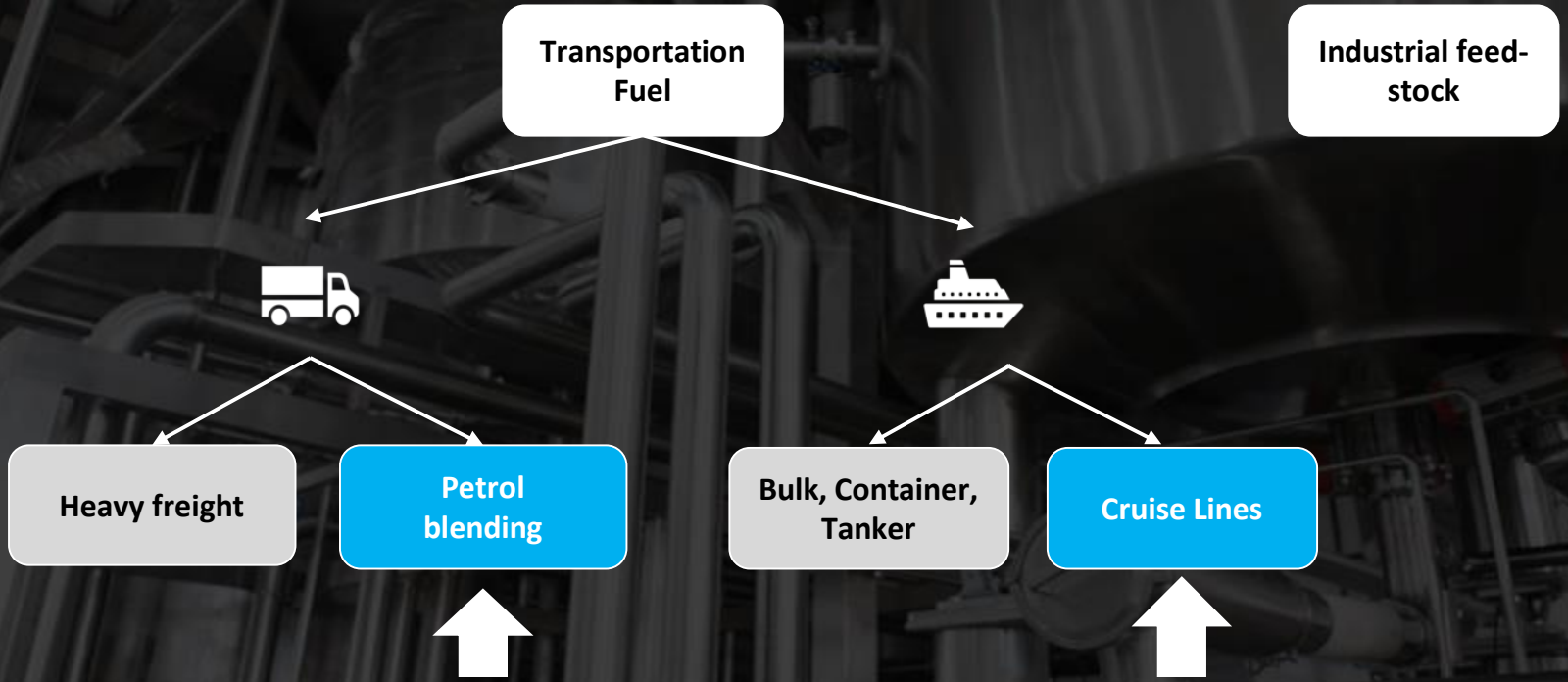
Target Markets for e-methanol



Project Financing: Following the Wind

- New wind farm

PPA Renewable electricity (10 years)

CO_2 and land agreements (10 years)

- Rottneros
- Södra
- SCA

Equity providers

- Pension Funds
- Industrial Comp
- Siemens FS
- Swedish EPA

Project SPV FlagshipONE

Debt Providers

- EIB
- EKF, KfW
- Commercial banks

Long-term (10 years) e-methanol purchase agreements eMPA

- Royal Caribbean
- Maersk
- Stena Line

”We see a Liquid Wind facility as a very interesting investment object to complement KGAL’s Nordic wind portfolio”

Jonas Metzger, Head of Transaction Management, KGAL Investment Management

“Presently we are really looking deeper into new combustion technologies and the suggested e-methanol seems to be really interesting”

Ulrich Voss, Director Shipmanagement & MRO, TUI Cruises GmbH

Liquid Wind | Circular Carbon Energy for a cooler world

Liquid Wind Team & Consortium

Passionate & Experienced Team Members

Claes Fredriksson

CEO & Founder

Thomas Nilsson

Sales & Financing Director

Roy Svantesson

Project & Construction Director

Tuya Bold

Head of Finance

Christina Thulin

Community Ambassador

Allie Downes

Marketing Manager

Thomas Stenhede

Senior Technical Advisor

Carl-Magnus Olesen

Procurement & System Operation Director

Magnus Nydén

CTO & Public Policy Director

World–class Consortium Partners

HALDOR TOPSOE · SIEMENS · COWI · CCS Carbon Clean Solutions · nel · Nouryon · aspo

Liquid Wind | Circular Carbon Energy for a cooler world

Bridging the gap to a Carbon Neutral Fleet

Liquid Wind in partnership with SSPA

Support shipowner's with converting installed engines

Develop vessel conversion methods for auxiliary engines, including engine testing.

Staged approach, start with one auxiliary engine.

A Marinvest tanker running on methanol

Are you interested in accelerating the transition to Carbon Neutral Shipping?

Powering Carbon Neutral Shipping, for a cooler world

- ✓ Methanol is an excellent marine fuel
- ✓ Methanol pricing is competitive with MGO
- ✓ Carbon laws demand a low carbon approach
- ✓ Production costs for electro fuel are falling
- ✓ The Göteborg methanol cluster is growing
- ✓ Liquid Wind offers locally produced green methanol

Liquid Wind

Claes Fredriksson
CEO & Founder
Claes@LiquidWind.se
0768 616161

Thomas Stenhede
Senior Technical Advisor
Thomas@LiquidWind.se
0705 915079

Senaste nytt om projektet Zeed och Ammoniak – vad, varför, hur och när?

Cato Espero, Wärtsilä


ZEEDS
Zero
Emission
Energy
Distribution
at Sea


FUTURE
INNOVATION
DAY//18
INNOVATION
26 April 2018


PBL: performance based partnership
Performance-based partnership agreement with Carnival Corporation provides both mutual incentives and shared risks.
Condition Based Maintenance and Dynamic Maintenance Planning allow to optimize operations and extend overhaul intervals, enabling savings of tens of millions of dollars.
FUTURE
DAY//18


FUTURE
FUTURE
INNOVATION
DAY//18


FUTURE
INNOVATION
DAY//18

ZEEDS

SHIPPING

1 BILLON TONS CO_2


AkerSolutions™


DFDS


equinor


GRIEG STAR


KVÆRNER™


WÄRTSILÄ

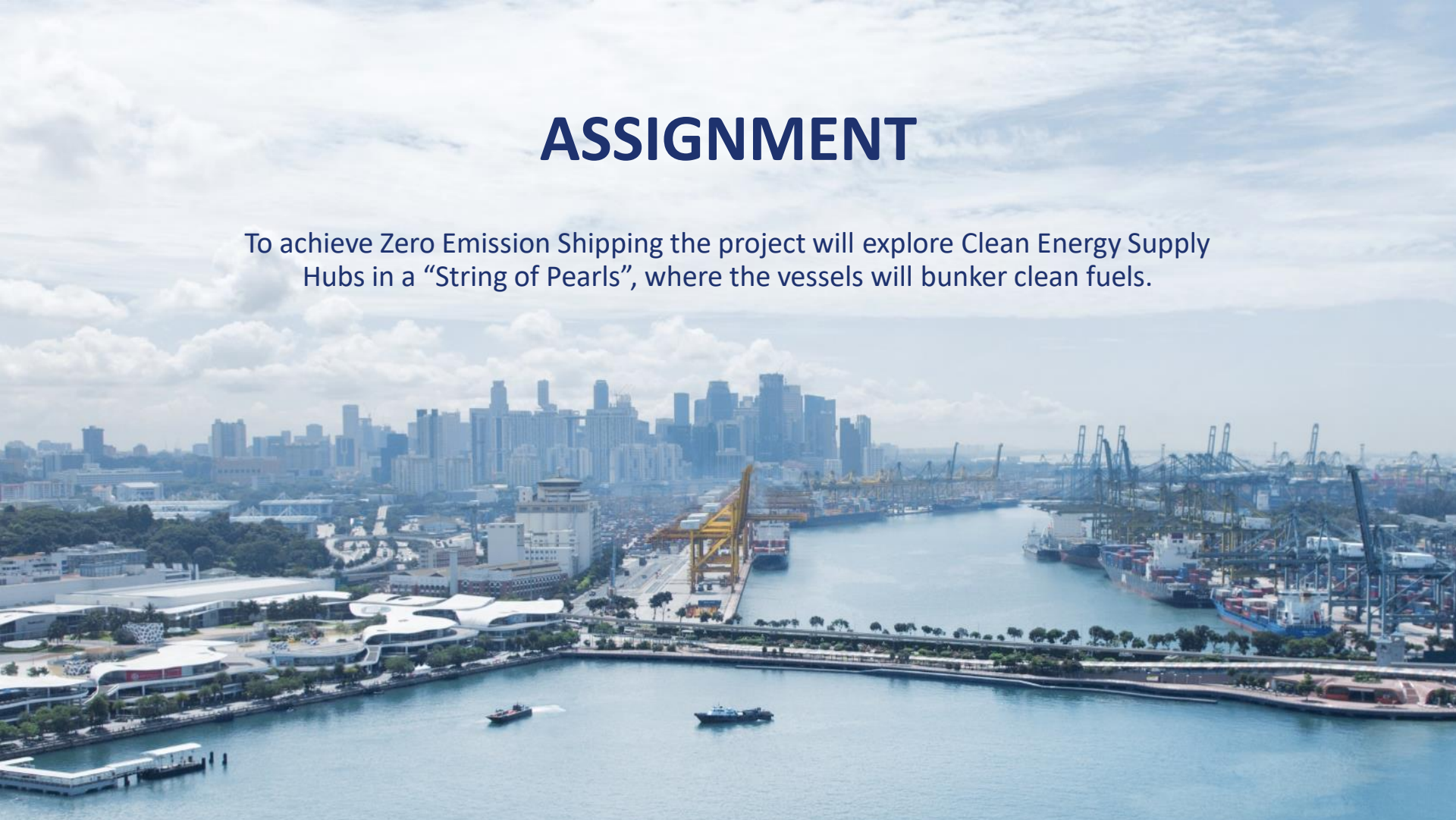
17 Goals to Transform Our World

The Sustainable Development Goals are a call for action by all countries – poor, rich and middle-income – to promote prosperity while protection the planet. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and adress a range og social needs including education, health, social protection, and job opportunities, while tackling climate and environmental protection.


HEADING FOR
THE CENTURY OF
THE
l Hem
ctor, Aviation
sport and

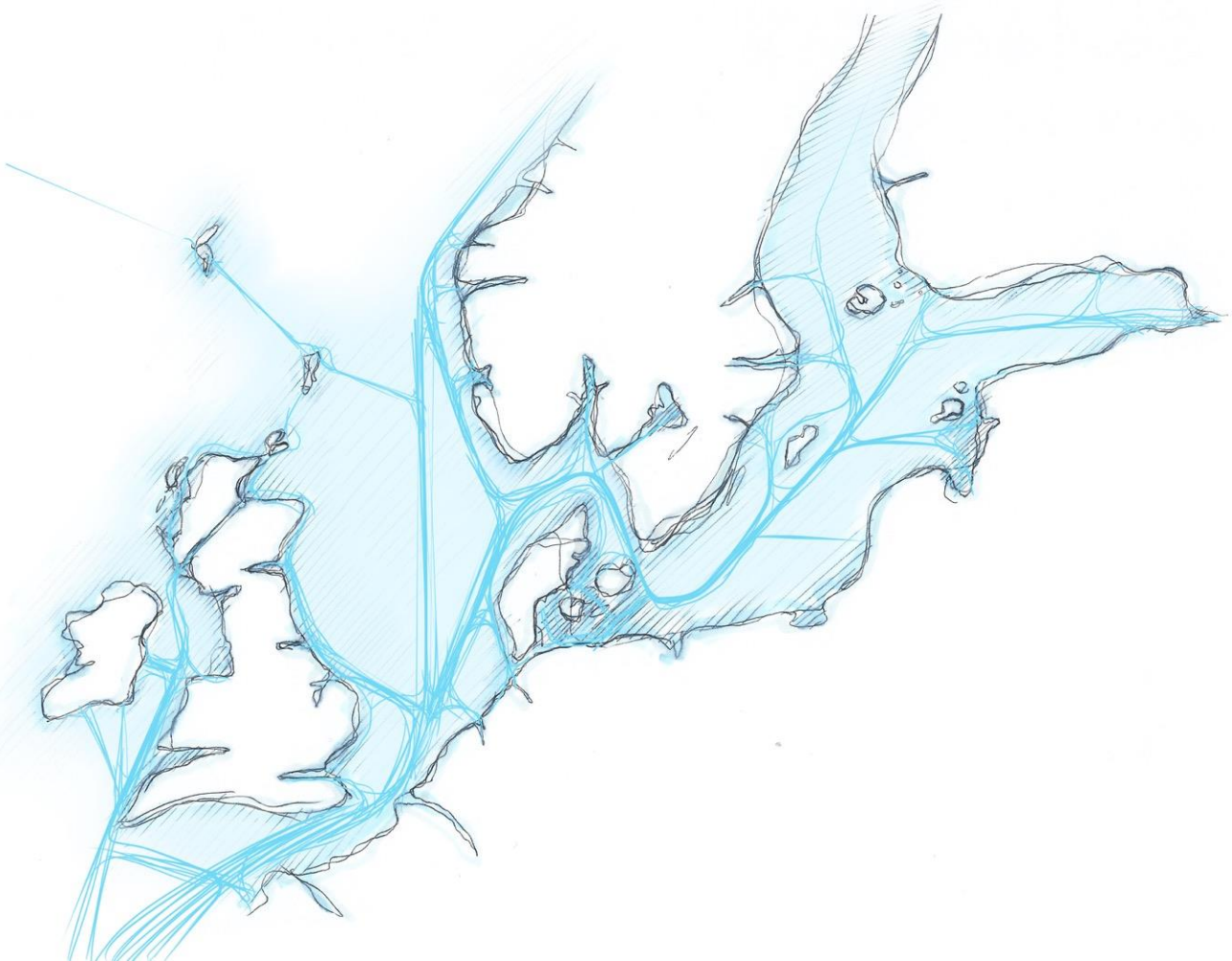
ASSIGNMENT

To achieve Zero Emission Shipping the project will explore Clean Energy Supply Hubs in a “String of Pearls”, where the vessels will bunker clean fuels.



ZEEDS

ZEEDS



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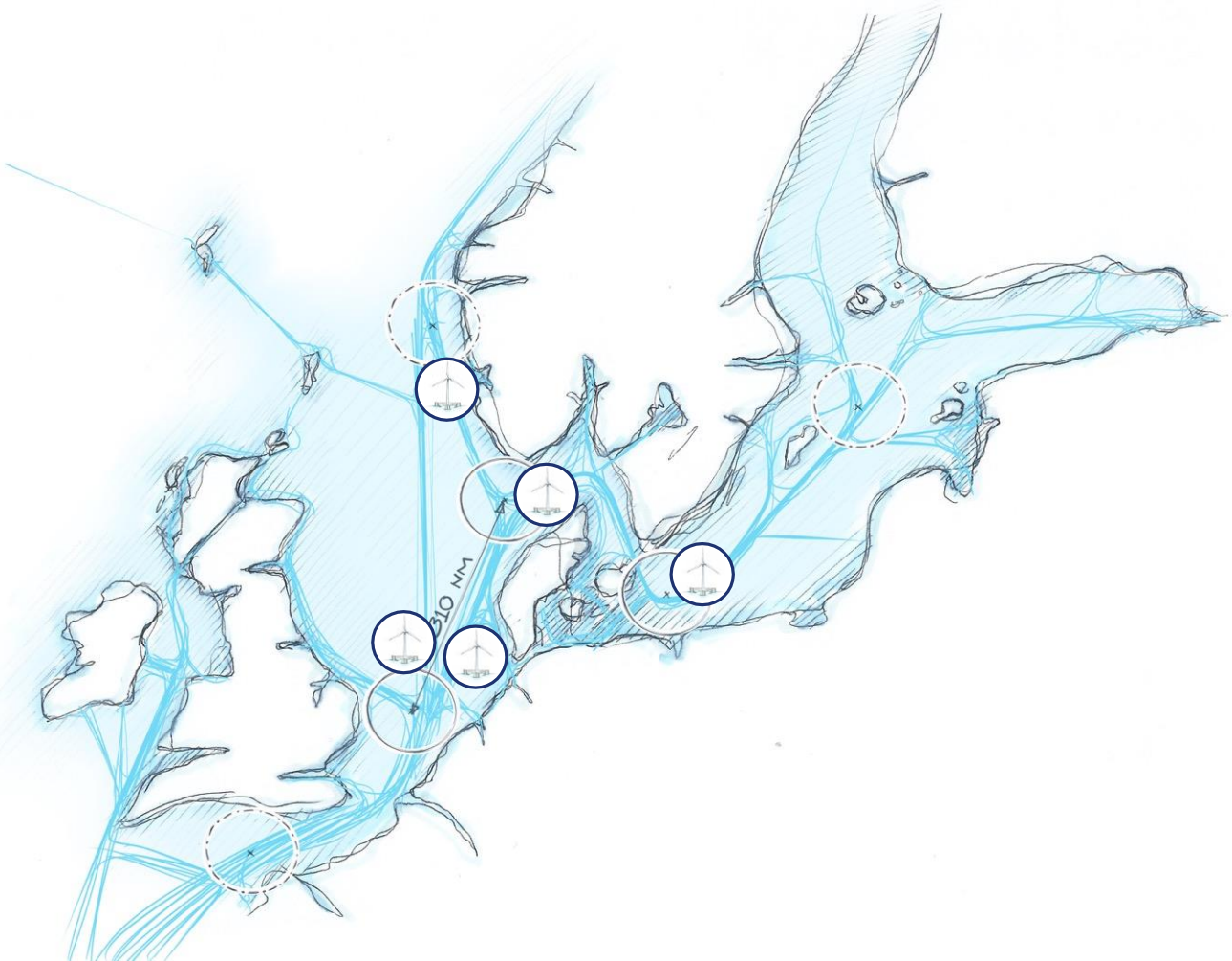

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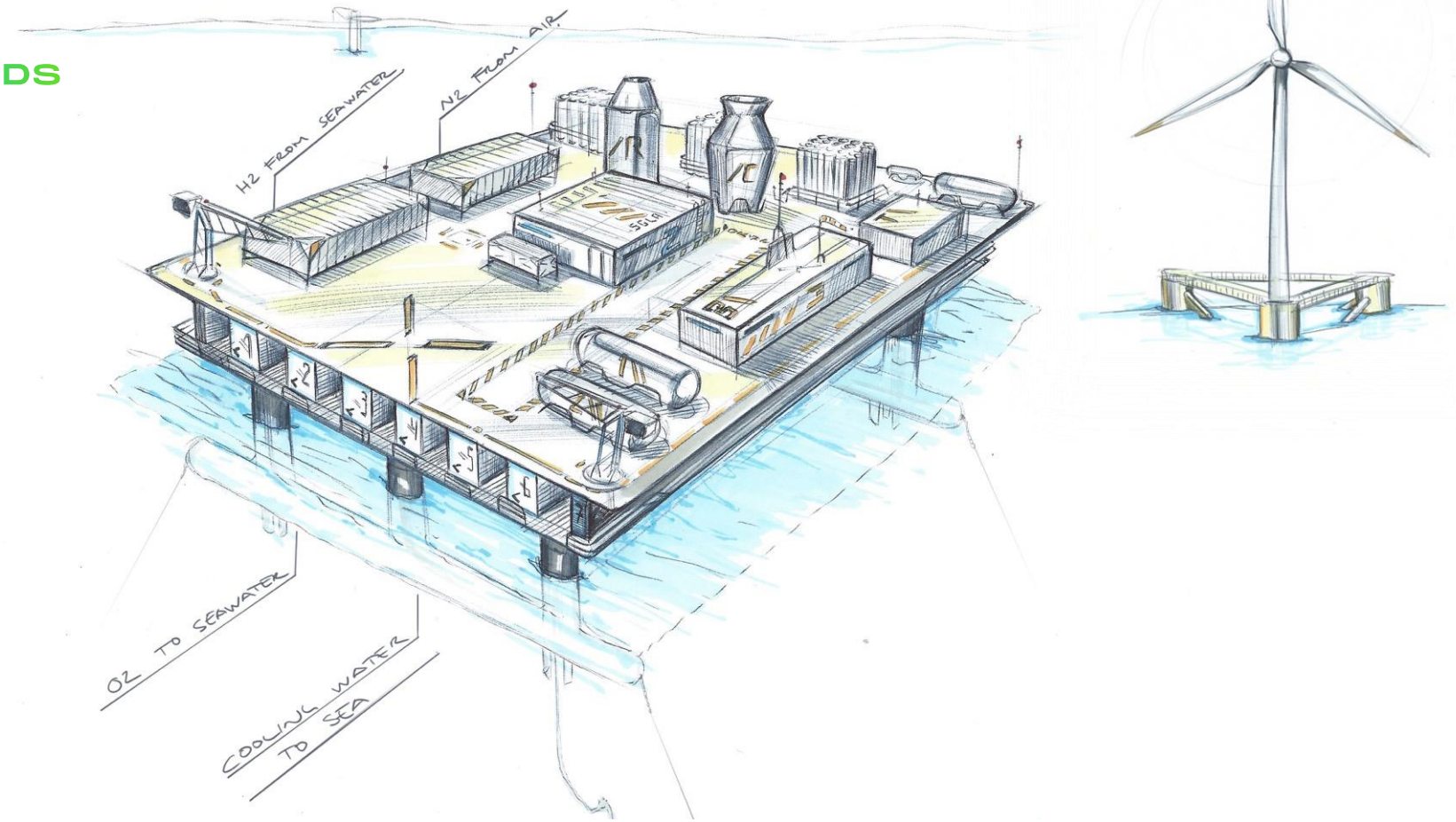
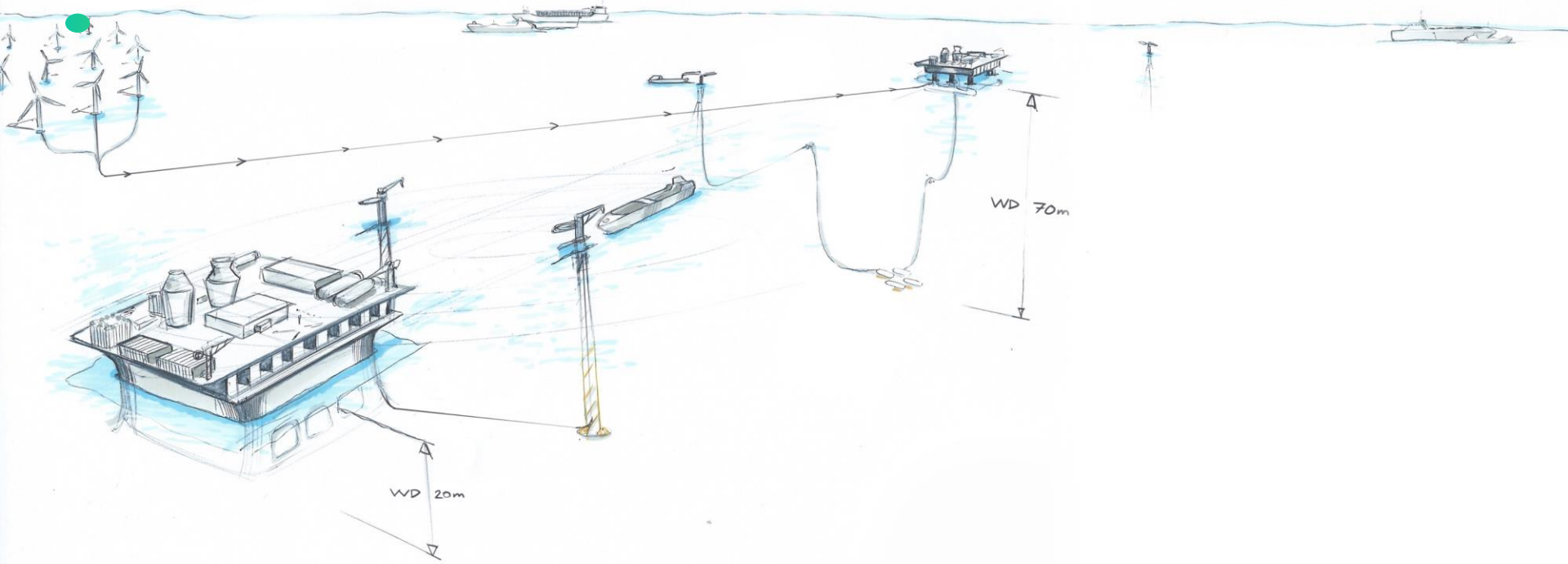

H2 FROM SEAWATER
N2 FROM AIR
O2 TO SEAWATER
COOLING WATER
TO SEA

ZEEDS



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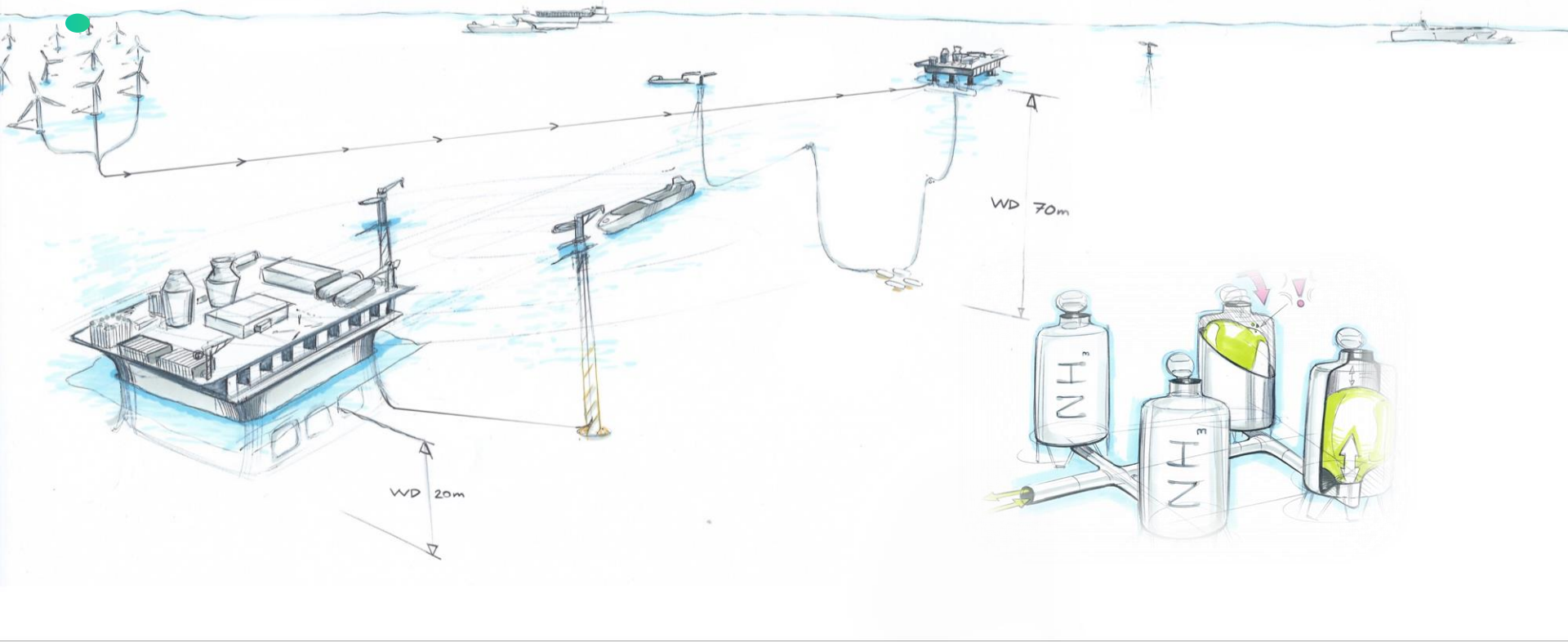

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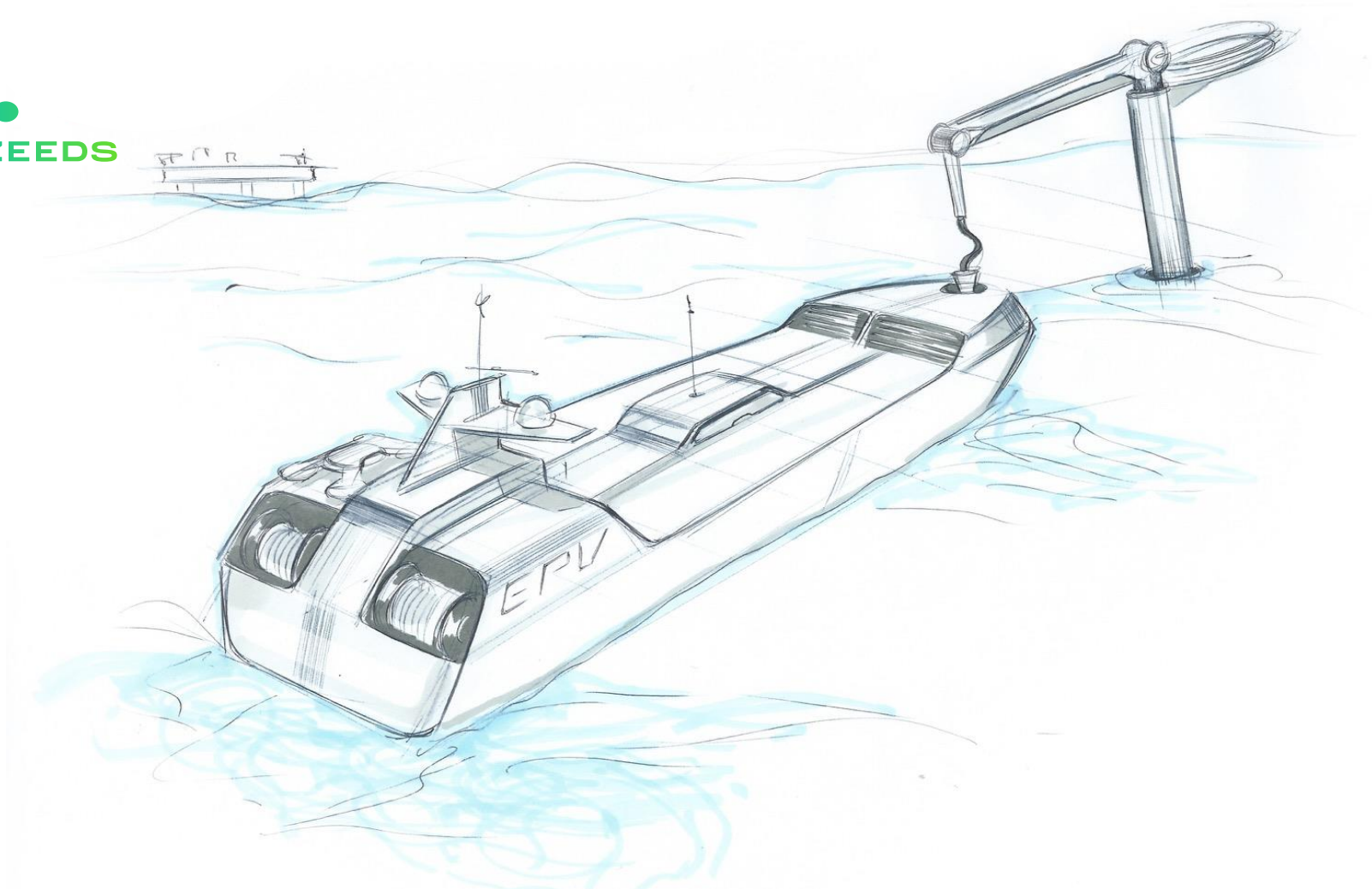

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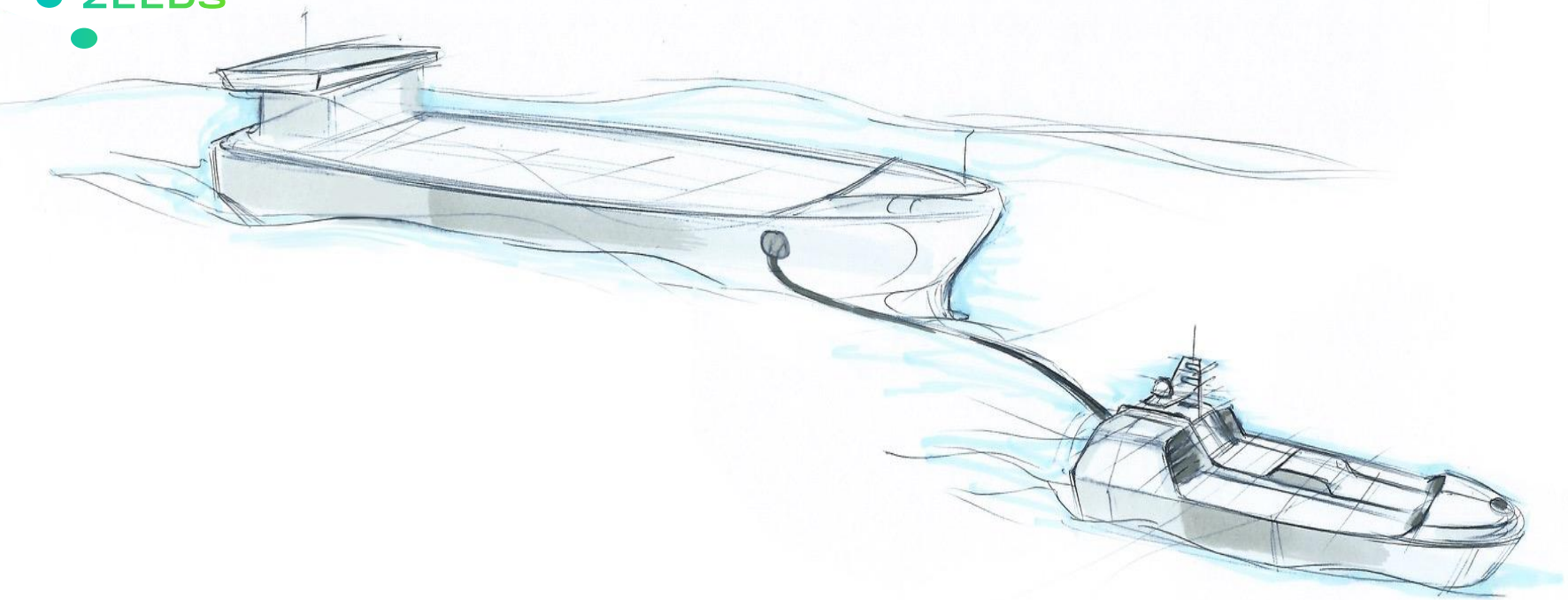

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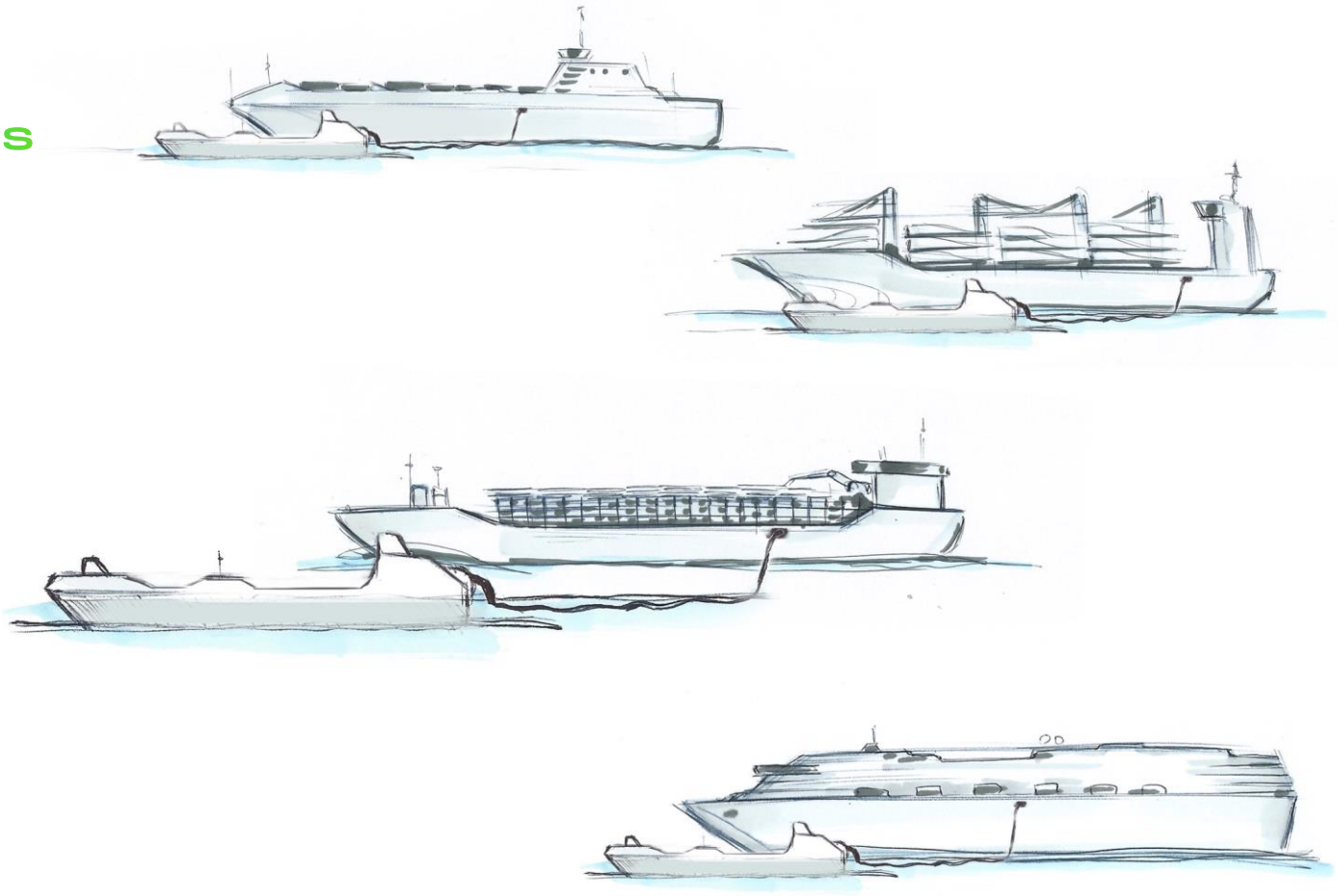
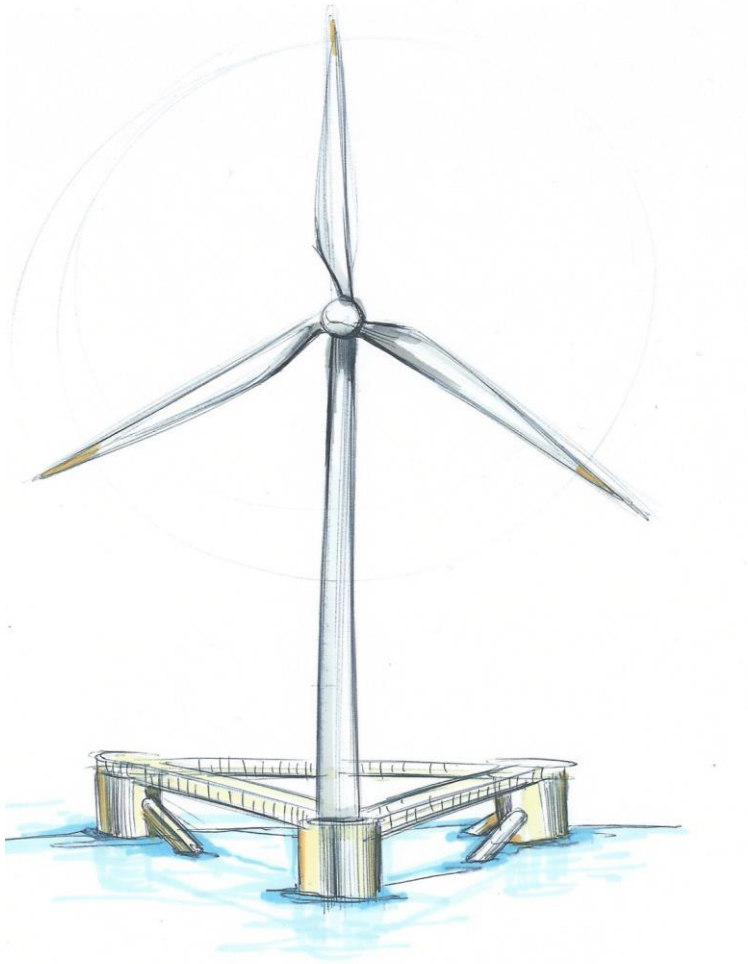


ZEEDS

74
Windturbines

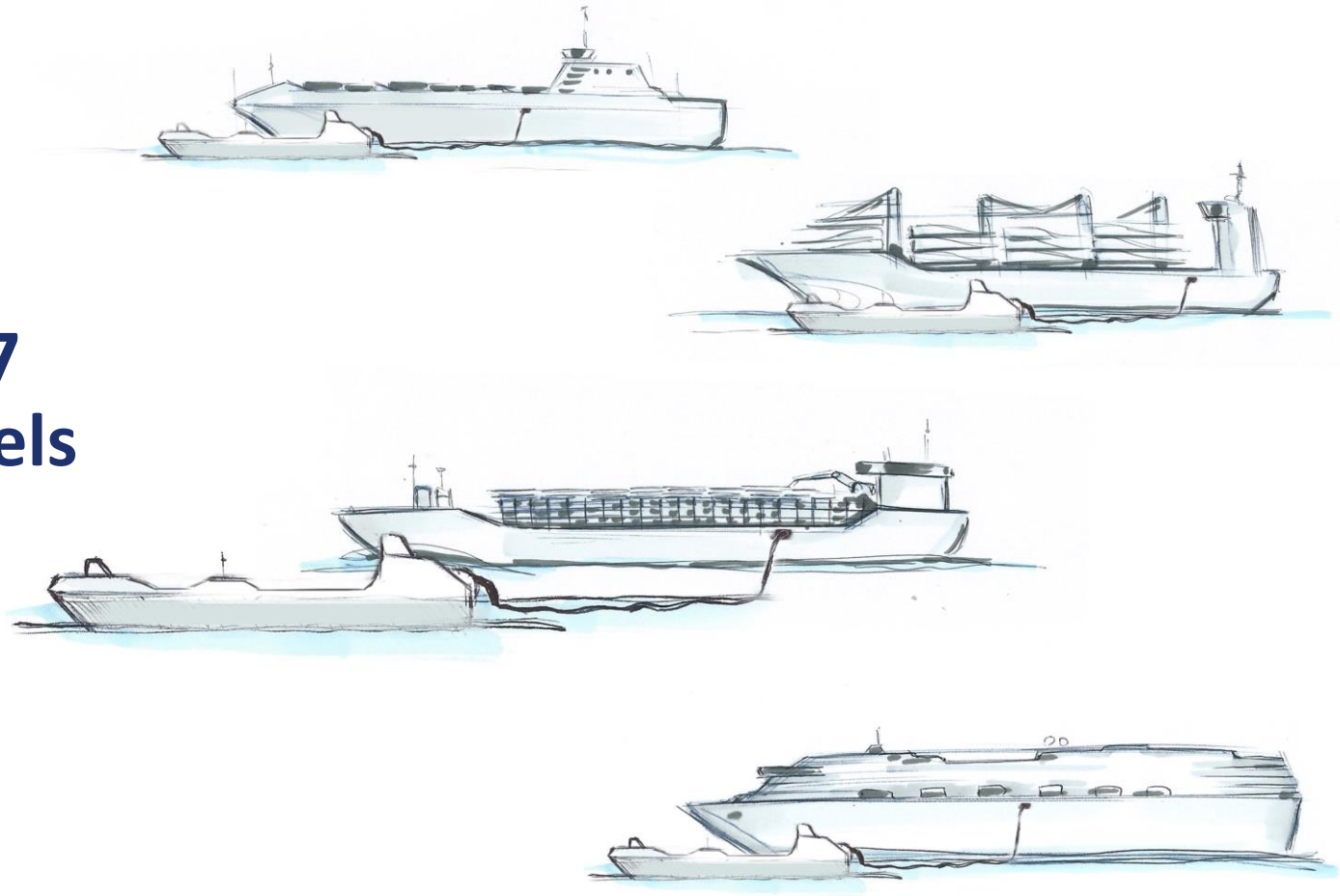


ZEEDS

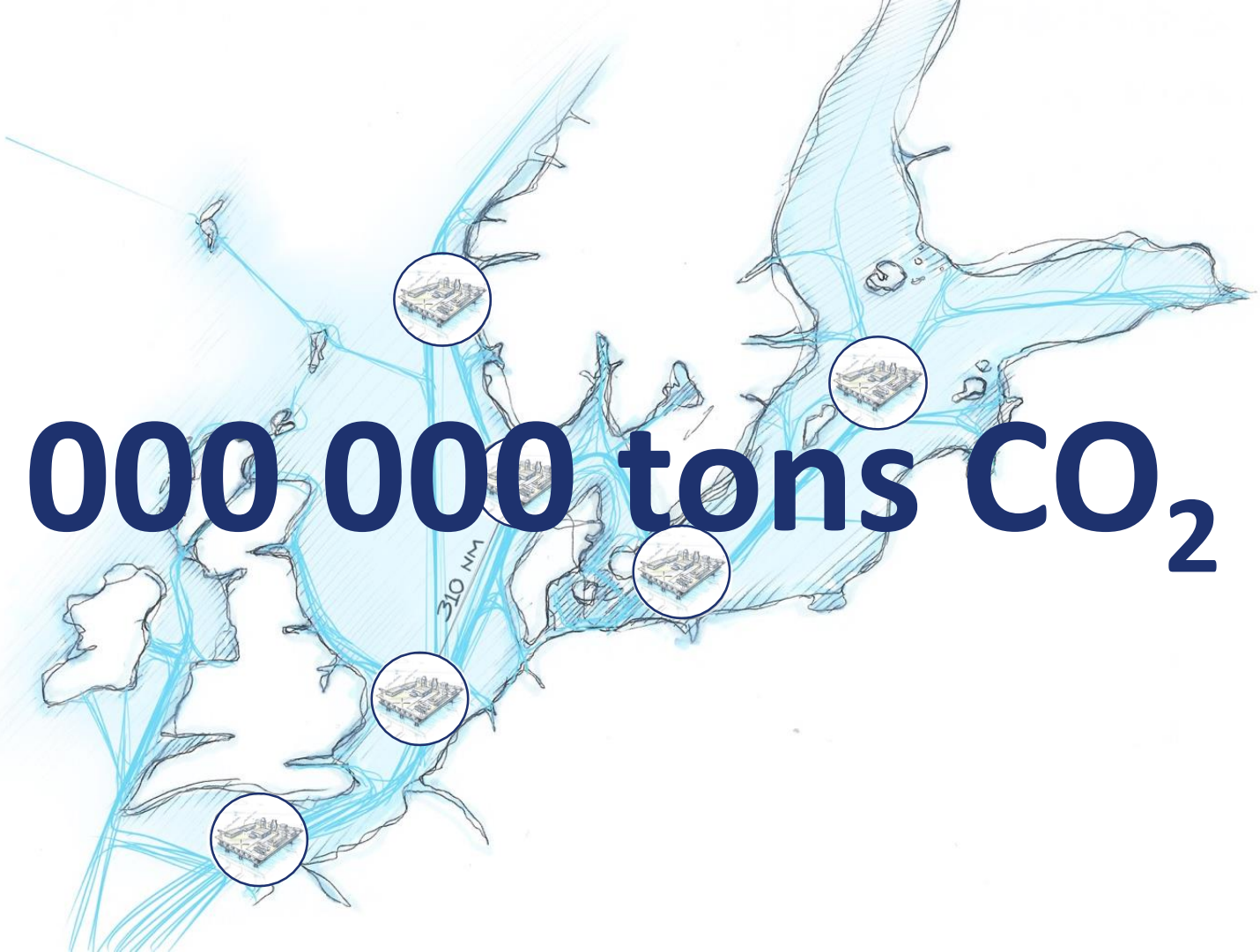
2500m³ Ammonia

ZEEDS

147 Vessels

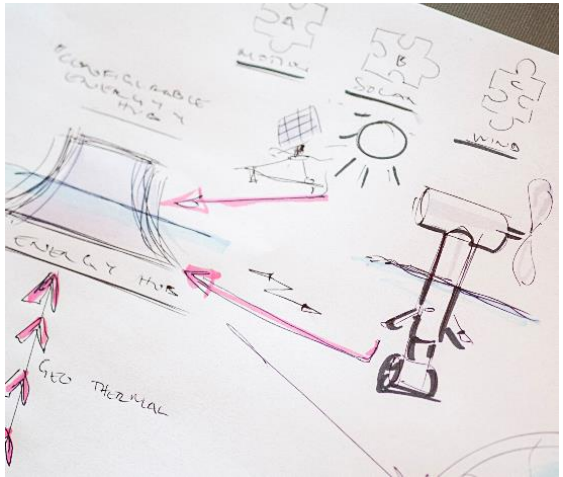


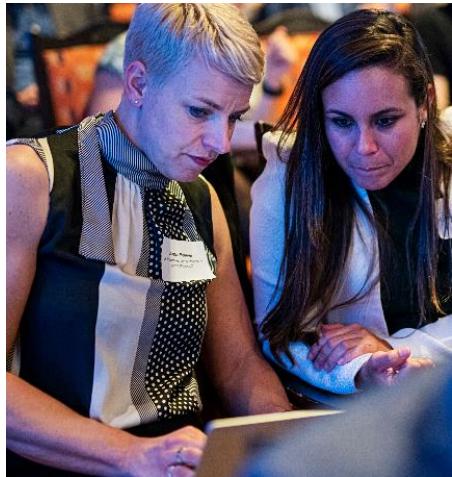
ZEEDS



1 000 000 tons CO_2

JOIN US!





ShipFC – convert offshore vessel to run on ammonia fuel cell

ZEEDS

- *ShipFC consortium gets €10m EU fund injection*
- *2MW ammonia fuel cell retrofitted, allowing it to sail solely on the clean fuel for up to 3,000 hours annually*
- *The latest stage in the long running collaboration between Equinor, Eidesvik and Wärtsilä (FellowShip)*
- *Fuel cell delivered by Prototech*
- *The sip-side ammonia system will be supplied by Wärtsilä*

Zero
Emission
Energy
Distribution
at Sea

Tack!

SVENSK SJÖFART
SWEDISH SHIPOWNERS' ASSOCIATION

Missa inte nästa sjöfartslunch!

Tema: Cyber Risk Management

3 mars kl.11.30-13.30