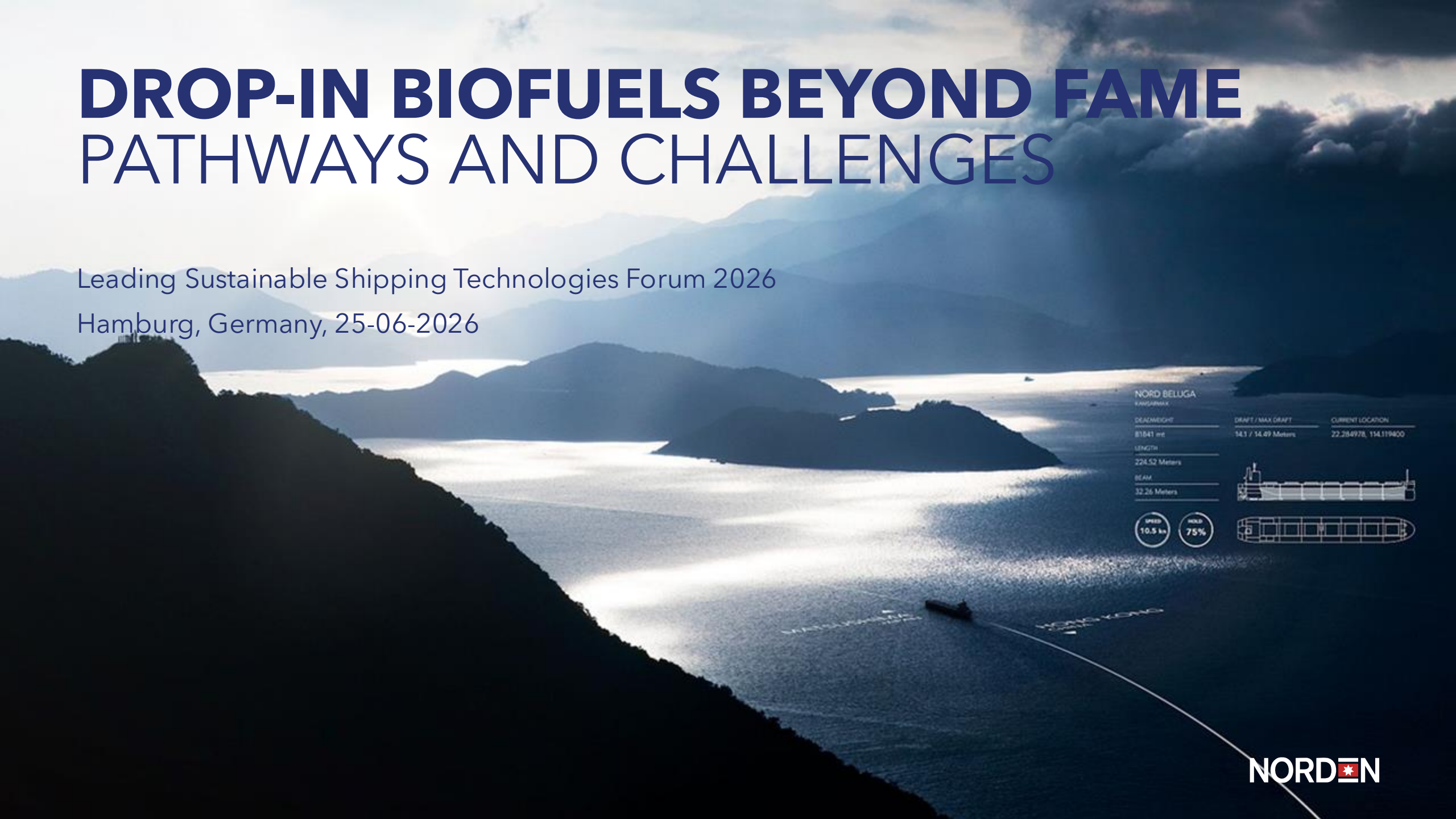
DROP-IN BIOFUELS BEYOND FAME
PATHWAYS AND CHALLENGES

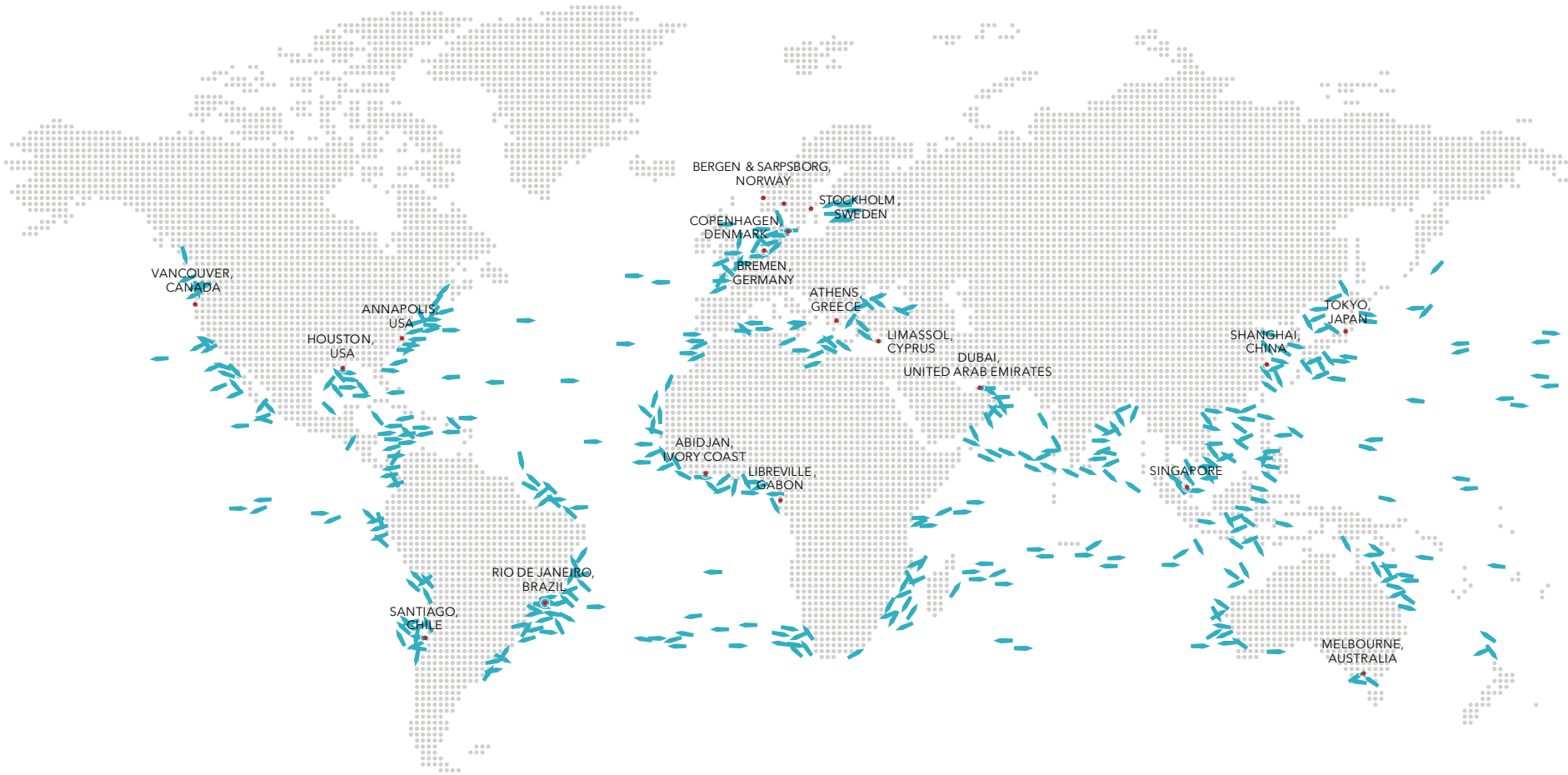
Leading Sustainable Shipping Technologies Forum 2026

Hamburg, Germany, 25-06-2026



NORDEN

We enable smarter global trade



Our values

- **Reliability**
- **Flexibility**
- **Empathy**
- **Ambition**

About
500
global colleagues

About
450
vessels operated

Listed on Nasdaq Copenhagen

Years
155
of rich heritage

We are
52
nationalities across NORDEN

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Agenda
for today

01. Motivation
02. Drop-in fuel pathways
    - FAME and HVO
    - FAME Distillation Residues
    - CNSL
    - Pyrolysis oils & Hydrothermal liquefaction
03. Project examples
04. Summary and outlook

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01. MOTIVATION

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Drivers for decarbonisation in NORDEN
Regulatory pressure and customer demand

- **EU Emission Trading System**
  Cap-and-trade CO2 pricing system aiming to improve ships' energy efficiency
- **FuelEU Maritime**
  Promotes the use of low carbon fuels by setting progressively stricter GHG intensity reduction targets for ships

- **IMO Net Zero Framework**
  Global fuel standard aiming to lower ships' GHG intensity over time, and an emissions pricing system that incentivizes low-carbon fuels and technologies; aims to provide a just and equitable transition.
  Regulation failed adoption in 2025 – ongoing discussions

Regulatory target: net-zero emissions by 2050
→ *NORDEN must reduce emissions to comply with regulations and avoid heavy fines.*

A **low emission solution** allows *Customers* to **reduce environmental regulation costs** while achieving a **meaningful Scope 3 emissions reduction**

NORDEN's Climate Commitments

Carbon emissions transparency

NORDEN provides a carbon **emissions estimate** prior to every journey, and a **post-voyage emissions report**. Transparency over emissions allows our customers to make decisions on freight transport based not just on price and date but on environmental impact too.

Greener shipping solutions

NORDEN is developing a number of **low emissions shipping solutions** for our customers. These range from using advanced analytics for increased vessel efficiency, to low emissions biofuel voyages.

Reduction in CO_2

In the short-term, NORDEN is committed to **reducing emissions** from our operations below the Sea Cargo Charter reduction trajectory *(which is in line with the IMO targets)*.

Zero-emission vessels from 2030

NORDEN commits to only ordering new vessels with the latest **zero-emission technology** from 2030 at the latest, in order to meet our decarbonisation goal.

Net-zero emissions by 2050

Achieving net-zero by 2050 requires a **shift to new low emissions fuels and technologies** in shipping.

Partnerships and certificates

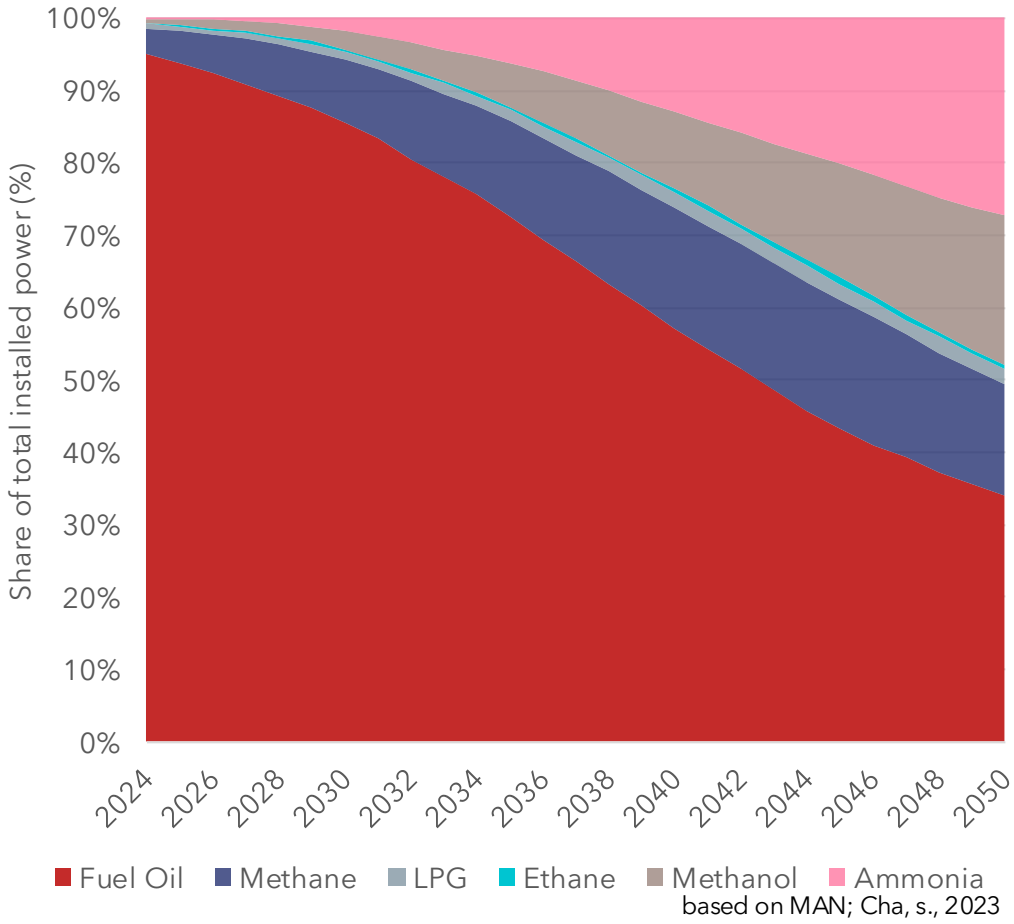
Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping · RSB · Sea Cargo Charter · Smart Freight Centre · Getting to Zero Coalition (Global Maritime Forum) · CDP (Disclosure Insight Action) · ecovadis · United Nations Global Compact

Our support to the UN SDGs

9 Industry, Innovation and Infrastructure · 13 Climate Action

The need for more feedstocks **drop-in biofuels**

- Share of **mono-fuel vessels** in the global fleet remains significant: **> 30%** of installed power **in 2050**
- **Environmental regulations** require reduction of the fuel's emission intensity
- **Cross-sectoral competition** from aviation and land-based transport **for the same** biodiesel **feedstocks**, such as UCO
- Requirement to **provide low-GHG fuels for the existent, mono-fueled fleet**
- **No standards** available **for new fuel-types** → case-by-case assessment to show usability of fuels



based on MAN; Cha, s., 2023

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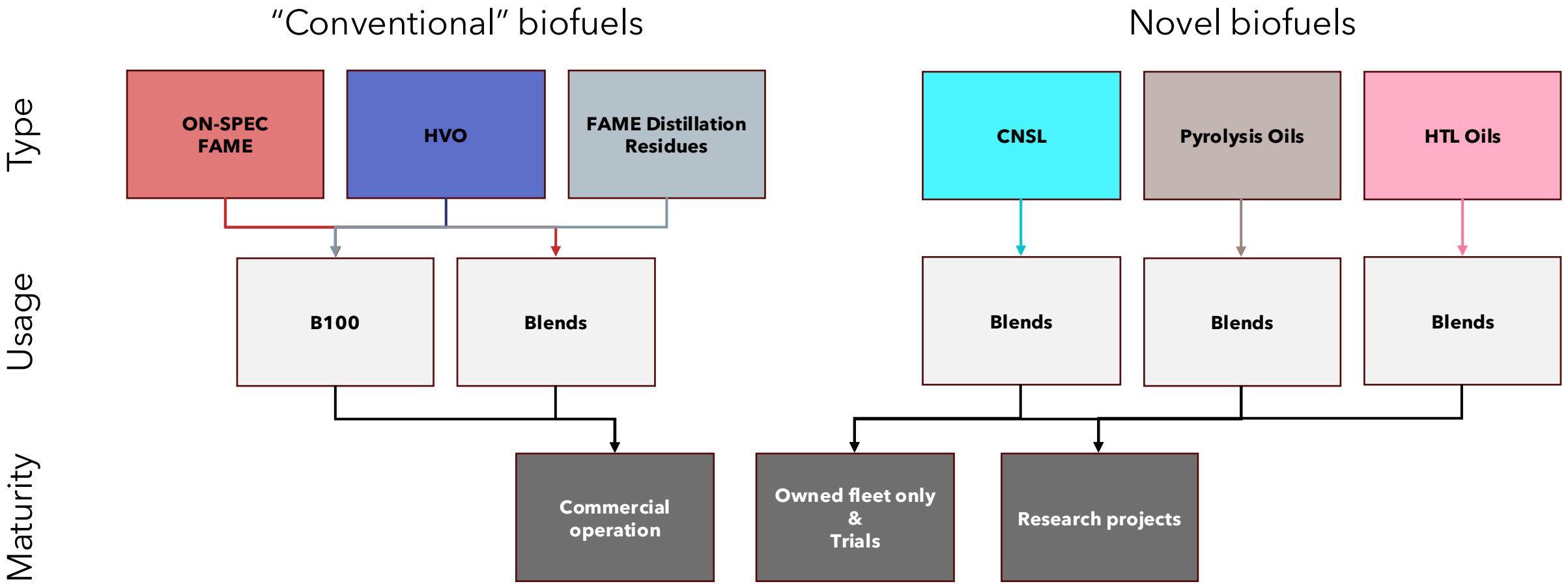
02.
DROP-IN FUEL PATHWAYS

NORDEN biofuel matrix



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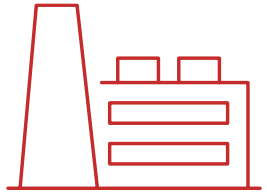
FAME and HVO

Feedstock

Lipids
- Used cooking oil
- Animal fats
- Food waste oils
- Vegetable oils

Process

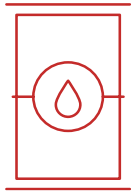
- Transesterification & distillation



- Hydrotreatment

Product

- Fatty Acids Methyl Esters (FAME)
- FAME Distillation residues



- Hydrotreated vegetable oils (HVO)
- Sustainable aviation fuel (SAF)

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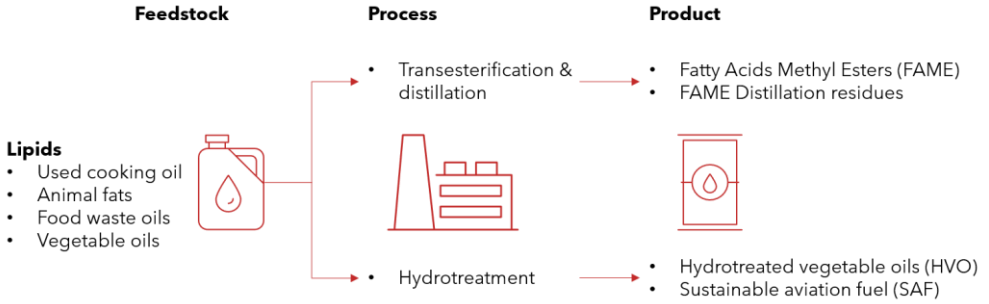
FAME and HVO



Advantages

- Standardized fuels
- FAME → EN 14214 or ASTM D6751
- HVO → EN 15940 or ASTM D975
- Decades of automotive usage → proven technology
- Already available in many ports around the globe → scalable

Challenges

- Feedstock competition
- Aviation (SAF) and road transport compete for UCO → drives price volatility
- FAME stability
- Prone to oxidation → limits storage time; but GCMD proved 6 months w/o degradation in on-board trial
- Operational concerns
- Tank cleaning required?
- Cold flow properties vary

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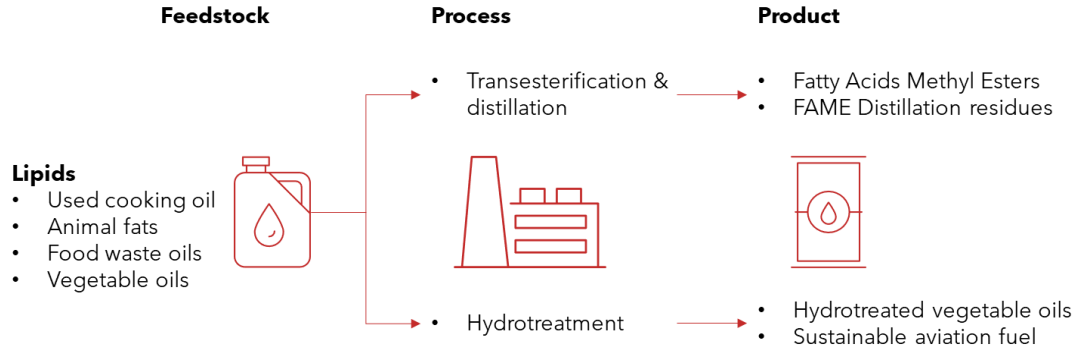
FAME Distillation Residues



Advantages

- Waste stream of FAME production
- ~5% of FAME output
- Lower price
- Higher GHG savings compared to FAME
- Acceptance by Everllence
- "Similar FAME-type"
- Blends with standardized FAME as B100 → operational experience existing

Challenges

- Cold-flow properties
- Pour point higher than with standard FAME
- Wax formation temperature depending on feedstock
- → heating required → balance between shelf-life (oxidation) and handling properties
- Limited acceptance
- Owners → not standardized product
- A/E engine makers → ignition properties
- Flag states → not standardized product

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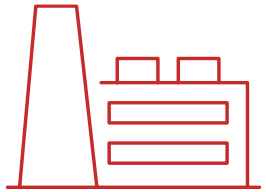
Cashew Nut Shell Liquid

Feedstock

Cashew nut shells

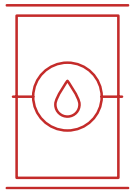
Process

Extraction
- Mechanical
- Thermal
- Chemical

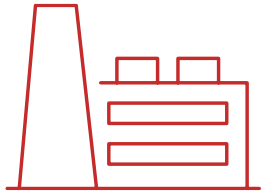


Product

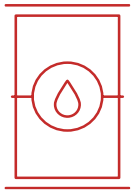
Raw CNSL



Upgrading
- Decarboxylation
- Degumming
- Distillation
- …



Product
- Technical CNSL
- Distilled CNSL
- Cardanol



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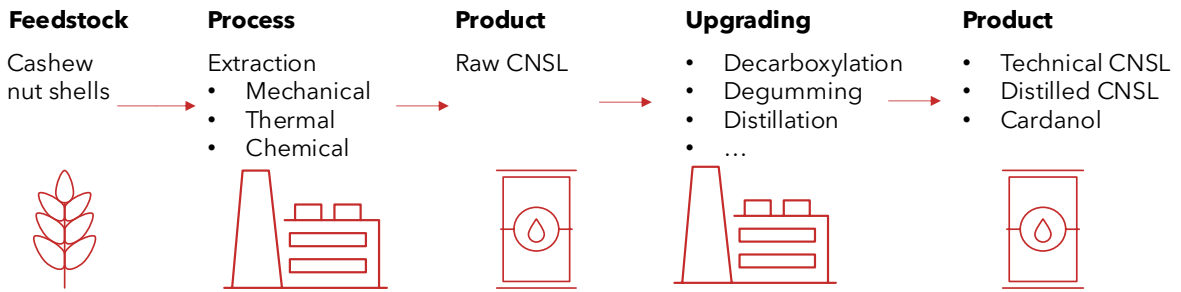
Cashew Nut Shell Liquid



• Advantages

- Previously untapped, waste-based feedstock
  → no competition for food
  → EU RED Annex IX A
- Competitive price point
- Bridge fuel for early adopters
  → Availability for early compliance volumes

Challenges

- Typically high acid number
  → risk of corrosion
- Polymerization of phenolic compounds
  → deposits, injector fouling, lacquer build-up
- Combustion limitations
  → poor ignition quality requires blending
- Miscibility
  → Shown good blendability with LSMGO
  → Risk of phase separation with VLSFO

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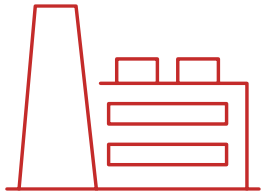
Pyrolysis and HTL oils

Feedstock

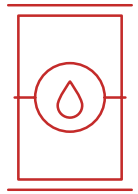
Dry biomass
- Wood
- Straw
- Rice husks
- Nut shells

Process

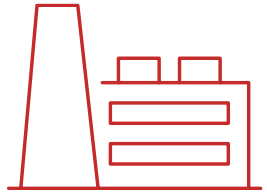
Heating in the absence of oxygen
- Fast
- Slow



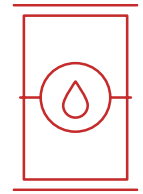
Product
- **Oil**
- Gas
- Char



Upgrading
- Stabilization
- Hydrotreating
- Fractionation
- Distillation



Product
- Bio-oil



Feedstock

Wet biomass
- Sewage sludge
- Manure

Dry biomass
- Straw
- …

Process

High-pressure
High-temperature
Water as solvent

Product
- **Oil**
- Gas
- Char
- Aqueous phase

Upgrading
- Stabilization
- Hydrotreating
- Fractionation
- Distillation

Product
- Bio-oil

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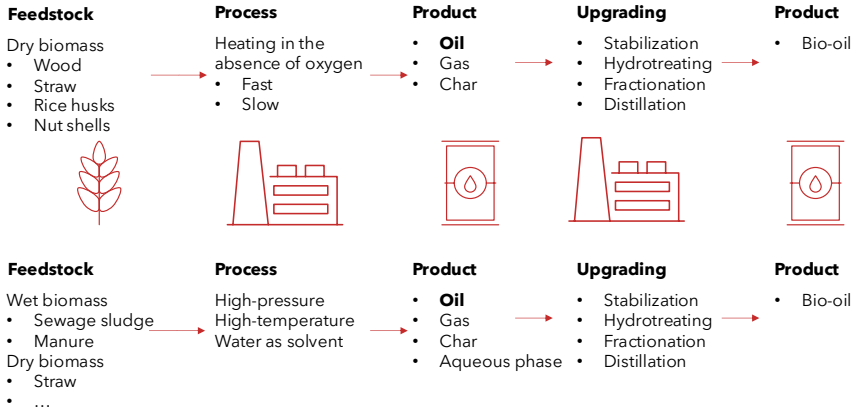
Pyrolysis and HTL oils



Advantages

- Feedstock agnostic
  → global biomass potential ~50 to ~150 EJ/year
- Potential revenue from carbon removal credits
  → supporting price

Challenges

- Fuel variability
  → composition depends on feedstock
  → no consistent fuel quality standard applicable
- Upgrading requirement
  → hydrotreatment needed
  → hydrogen and catalyst demand
  → increases product cost
- Producers lack quality standard guidance
  → collaboration with maritime stakeholders required

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03.
PROJECT EXAMPLES

NORD BISCAY
biofuel trial (2020)

Vessel type: Supramax dry-bulk (62.6k DWT)

Voyage: worldwide

Engine: MAN 6S50ME-B9.5

Biofuel: Goodfuels MR1 (FAME/FAME Bottoms)

NORDEN's role:

Testing for compliance with
MARPOL Annex VI, Regulation 18.3.2
and performance monitoring

Source: MAN

MASH Makes
vessel trial

1st stationary engine trial (Feb 2024)

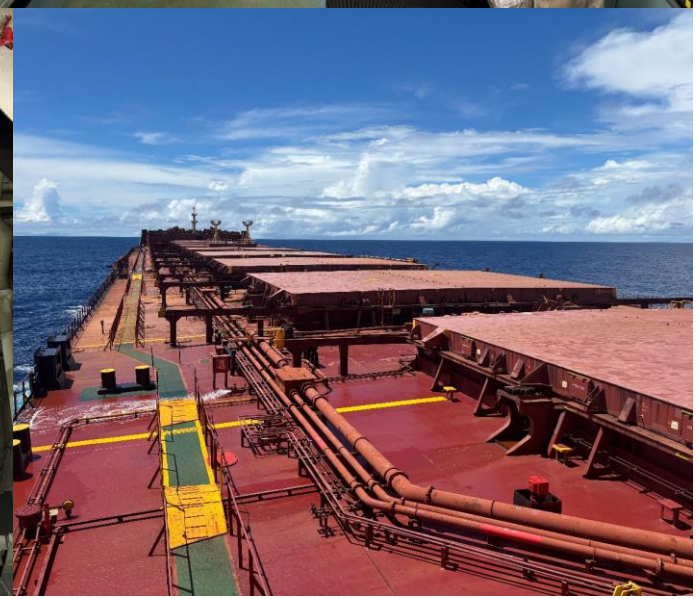
B20 was tested in **stationary engine** at FVTR in Rostock (Germany)

1st vessel trial (Dec 2024 – Feb 2025)

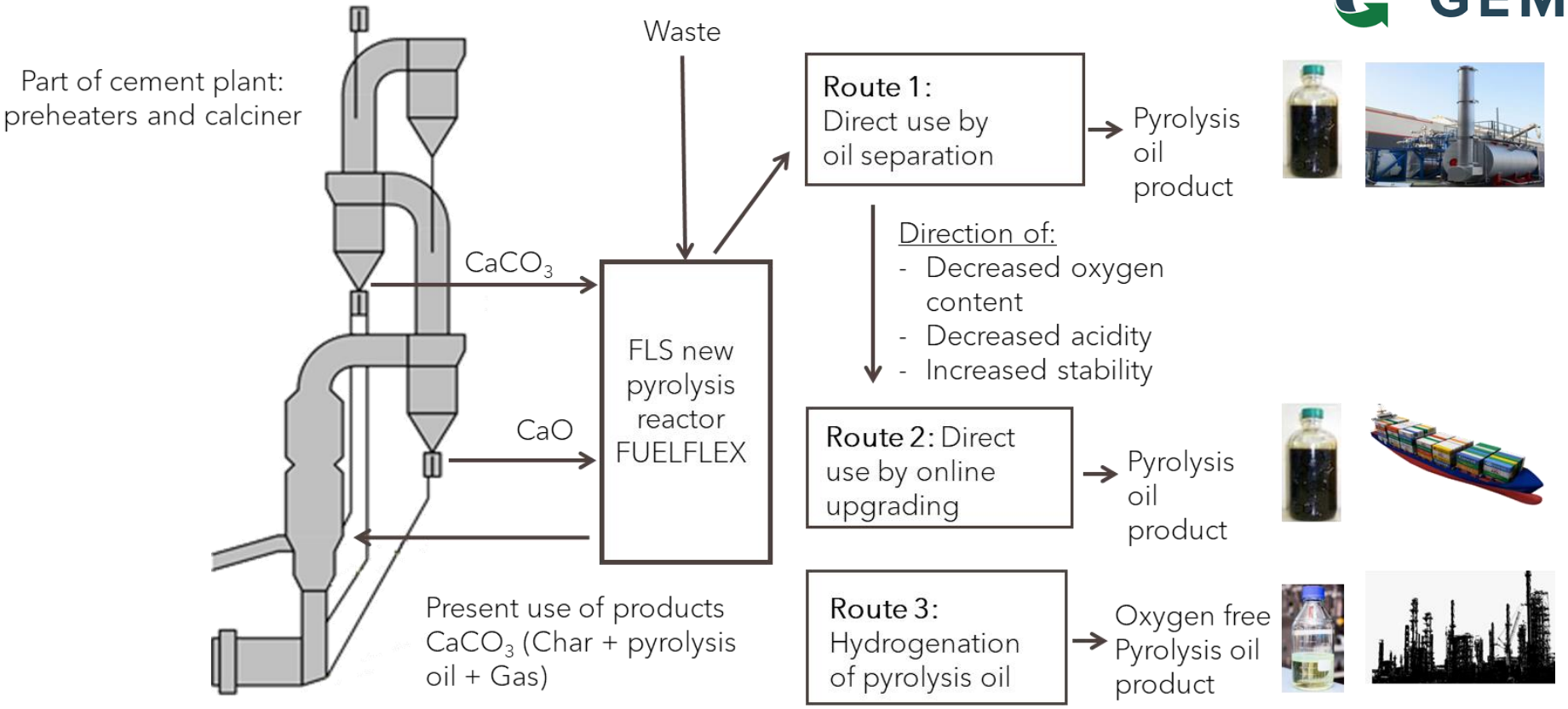
B20 was bunkered to NORD POWER and consumed on **auxiliary engine**. Emission and performance assessment with NORDEN personnel onboard

Status:

- MASH Makes had to file for bankruptcy in H1/2026 resulting from difficulties in upscaling and a changed market for carbon removal credits



CIRCFUEL
research project



NORDEN's role: investigate the quality of the pyrolysis oil for use as marine fuel to support the decarbonisation of the shipping sector.

Straw Fuel Oil
research project

Feedstock agnostic

Whole non-edible biomass or pure lignin

(40% oxygen)

Simple process

Biomass breaks into smaller fragments expelling oxygen

(Heat to 400°C with recycleble alcohol solvent)

Sustainable bio-fuel

The result is stable and upgradeable bio-fuel

(<10% oxygen)

NORDEN´s role: investigate the quality of the biooil produced for use as marine fuel

- Fuel quality investigation and blending
- Combustion tests
- Regulatory assessment
- Identify requirements for using the fuel onboard

04.
SUMMARY AND CONCLUSION

Summary and Conclusions

- Maritime transport will **require drop-in biofuels still in 2050**
- Drop-in biofuels can be **more than just FAME or HVO**
- **FAME and HVO:** Mature and available, but constrained by cross-sectoral competition for feedstock
- **FAME Distillation Residues:** Cost-attractive option with higher operational complexity and limited acceptance
- **CNSL:** Low-cost, waste-based fuel with significant handling and engine challenges
- **Pyrolysis and HTL oils:** Highly scalable future fuel pathway, but not commercially ready for marine yet
- Further effort must be put into **maturing the novel biofuel pathways** to supply consistent qualities at scale
- **Collaboration** between developers, fuel suppliers and ship owners, but also between ship owners is key

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THANK YOU

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