INNOVATIVE MARINE FUEL SOLUTIONS TO RAPIDLY TRANSITION TO NET ZERO

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AGENDA

1. THE ROLE OF FUEL TECHNOLOGY TO DECARBONISE SHIPS
2. BIOFUELS - THEIR USE IN THE MARINE SECTOR
3. ALTERNATIVE BIOFUEL SOLUTIONS

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THE RACE TO NET-ZERO

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Options today? there are many!  
Is the rate of change fast enough?

What can be done today to help transition quickly, without incurring significant costs or fleet changes?

We are focusing today on:
1. Improving energy efficiency
2. Lowering emissions
Using disruptive technology...
A CRASH COURSE IN EMULSIONS!

THE RACE TO NET-ZERO

Water-in-oil Emulsions

Oil-in-water Emulsions

For engines: Water helps combustion & emissions

Water power that leaves turbochargers in its wake

Water, not gasoline – Water injection is based on a simple principle: the engine cannot be allowed to overheat. So before the fuel is ignited, a fine water mist is injected into the intake manifold to cool things down.

up to

13%

lower fuel consumption even with rapid acceleration or on long highway journeys

5 LITRES OF WATER FOR 500 HORSES.
8% greater performance. 8% less consumption.
**Water-In-Oil Emulsion Fuel Technology**

- Conventional emulsion systems add water to marine fuels to produce Water-in-Oil emulsions.
- This reduces NOx (each % of water added reduces NOx by a % typically).
- Also improves combustion and reduces Black Carbon due to secondary fuel atomisation.
- Potential for higher engine efficiency in some cases.
- Implemented by installing an emulsion system on the vessel.

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**WIO technology is deployed at the point of use, to improve the combustion of conventional fuels**
Oil-In-Water Emulsion Fuel Technology

- Uses lowest value fuel components at the refinery or fuel terminal for blending
- Improves blending stability, and water lowers viscosity and NOx by 20-30% typically
- Complete combustion from micron-sized fuel droplets, reducing Black Carbon substantially
- Improves engine efficiency, lowering energy consumption to achieve CO2 savings of up to 6-9%
- New fuel flexibility is provided by installing a separate emulsion fuel booster unit on the vessel

30-70% Oil/biofuel
<1% Additives

OIW technology is deployed at fuel production, to reduce fuel costs and emissions

30-70% Water/biofuel

Each water droplet contains tiny (5-10 microns) oil droplets
Water evaporates dispersing tiny oil droplets

Increasing temperature
Microscopic oil droplets combust in a flame, producing energy with complete combustion

Feedstock → Production → Transport → Port → Bunkering → Fuel System → Engine → Emissions
Diesel & Marine Experience

- Quadrise have >60 million tons of emulsion experience
- 150,000 reliable running hours on 4-stroke Wartsila engines for base-load power generation
- Comprehensive 2-stroke marine MSAR® programme with Maersk, on MAN and Wärtsilä engines, resulting in:
  - Trials on MAN D&T, Mitsui & Wärtsilä test engines
  - Proof of concept tests at sea on Maersk Bogor and Seago Istanbul vessels
  - Operational trial on Seago Istanbul (~1500 hours)
  - Interim LONO obtained on Wärtsilä Flex 96
- Further operational experience and full LONO in planning phase under JDA with MSC Shipmanagement
Energy efficiency benefits of up to 6-9% (4S/2S)... Result in 5-9% lower CO₂ & GHG emissions well-to-wake.

Plus... reduced smoke (black carbon) & NOx emissions.
## Marine biofuel options

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Supply</th>
<th>Compatibility</th>
<th>Cost</th>
<th>Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAME biodiesel</td>
<td>Veg oils, UCO, tallow</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>Hydrotreated renewable diesel</td>
<td>Veg oils, UCO, tallow</td>
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<tr>
<td>FT diesel</td>
<td>Lignocellulosic biomass, natural gas</td>
<td>-</td>
<td>✗</td>
<td>✓</td>
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<tr>
<td>DME</td>
<td>Lignocellulosic biomass, natural gas</td>
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<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Methanol</td>
<td>Lignocellulosic biomass, natural gas</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
</tbody>
</table>

Is there also a role for disruptive biofuel solutions tailored for shipping?

| BIO MSAR              | Biodiesel, fatty acids, ??                 | ✓             | ✓    | MSC      |

Data summarised from ICCT Working Paper Sep 2020

Legend: ✓ Good; - Average; ✗ Poor
Commercialising a new biofuel for marine users

Launched at the end of last year, bioMSAR™ combines the benefits of MSAR® fuel & technology to blend renewable fuels (both oil and water based).

>4m tpa of glycerine today, mostly as a by-product of biofuel & fatty acid & alcohol production

e.g. 1 barrel of crude Glycerine is produced for every 10 barrels of biodiesel...
This can be refined for fuel applications!
Glycerine experience in diesel engines

- Glycerine has already been utilised in diesel generators to power Formula-E race cars and VW’s record-breaking Pike’s Peak ID R.

- Good potential as a marine transition fuel as not an obvious option for aviation or road transportation:
  - Based on 40% glycerine, CO₂ emission reductions are 25% well-to-wake or tank-to-wake.
  - Glycerine content can be tailored to user requirements.
  - In bioMSAR™ it can be used in existing marine diesel engines, with only minor modifications to the fuel handling system (same tanks, but separate fuel booster).

Glycerine benefits:
- Non-toxic
- Non-flammable
- Good lubricity
- Bio-degradable
- Low g/MJ CO₂
- No methane slip
Energy efficiency benefits of up to 7%

Over 20% lower CO₂ & GHG emissions well-to-wake

Low NOx and smoke emissions, reducing black carbon
for each ship converted to **bioMSAR** we reduce CO₂ emissions by the equivalent of **11,000 PETROL CARS**
bioMSAR™ successfully tested on 4S Wärtsilä & high-speed diesels

Recent bioMSAR™ testing confirmed;

✓ Engine performance was very similar to MSAR® & other fuels
✓ High engine efficiency of up to 7%, as seen with MSAR®
✓ Lower CO₂ emissions per kWh calculated (WTW or TTW)
✓ Overall NOx emissions were similar to MSAR®
✓ Low smoke, THC and CO with bioMSAR™

As with MSAR®, which was successfully tested on ME and Flex engines, bioMSAR™ also needs to be tested on a 2S engine

Further options to expand global supply of glycerine being studied

New opportunities to incorporate other renewable fuels into the oil or water phases of the fuel using MSAR® blending technology to enhance the stability of marine transition fuels
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Making Waves
The Future of Shipping
ANY QUESTIONS?

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Q&A