Sustainable Fuels Technology Development for Wärtsilä

Bio4Fuels Days 2024

Helsinki

Kaj Portin, Wärtsilä

13.06.2024

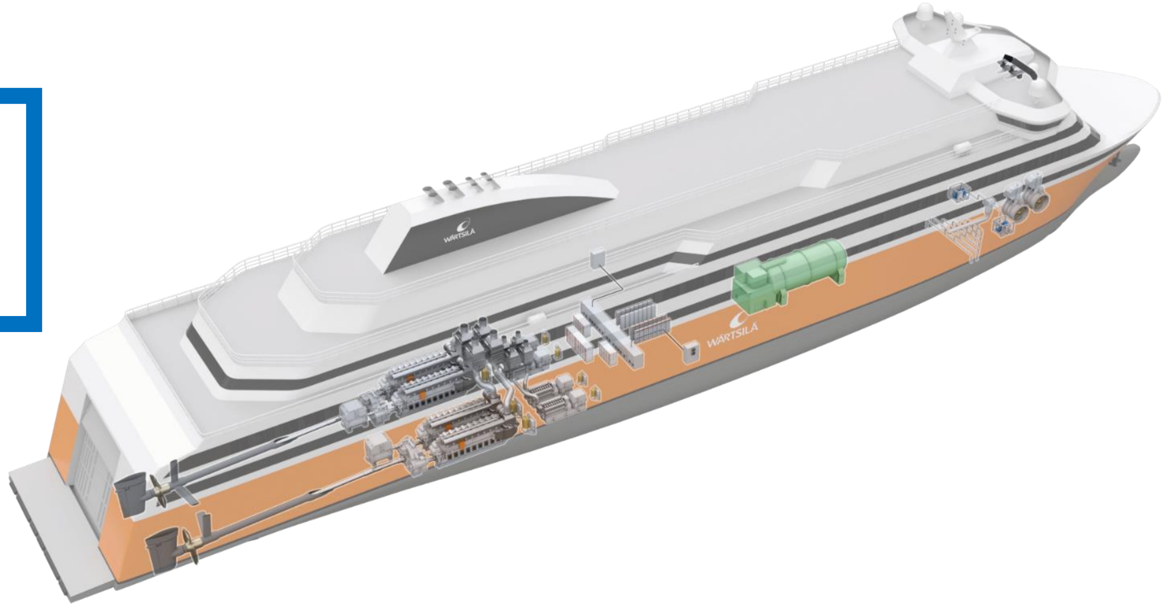
Marine Power product portfolio provides upgradable solutions for a net-zero future

Propulsion equipment

4-stroke medium speed engines

NOx reducers *(SCR)*

Energy & power management systems

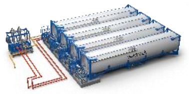


Transactional services

Agreements

Performance-based agreements

Hybrid systems *(including batteries)*



Fuel gas supply systems *(storage)*

Project services

Local versus global Emissions

Category 1: Local emissions: health & environment related

- Contribute to deterioration of human health, loss of wellbeing
- Mainly NO_x, SO_x and particulates
- Also impact the natural environment (flora & fauna) on short term
- Impact depends very much on location of emission. Focus on densely populated areas and sensitive ecosystems

Category 2: GHG emissions: climate related

- Contribute to global warming / climate change
- CO_2 ,CH_4 (methane), and N_2O (laughing gas)
- Low to no impact on human health or the natural environment on short term
- Impact is not dependent on location of emission, as climate change is a global problem

2023 IMO GHG Strategy to reduce GHG emissions to net-zero, by or around 2050

Initial GHG strategy (2018)

2023	2030	2050
EEXI, CII	-40% carbon intensity	70% carbon intensity -50% total GHG emissions

Revised GHG strategy (2023)

	2023	2030	2040	2050
	MEPC 80	-40% carbon intensity; 5% uptake of zero or near-zero GHG emission fuels (striving for 10%);		Net-zero GHG by or around 2050, taking into account different national circumstances
Indicative check points		-20% total GHG emissions (striving for -30%[1)])	-70% total GHG emissions (striving for -80%)	

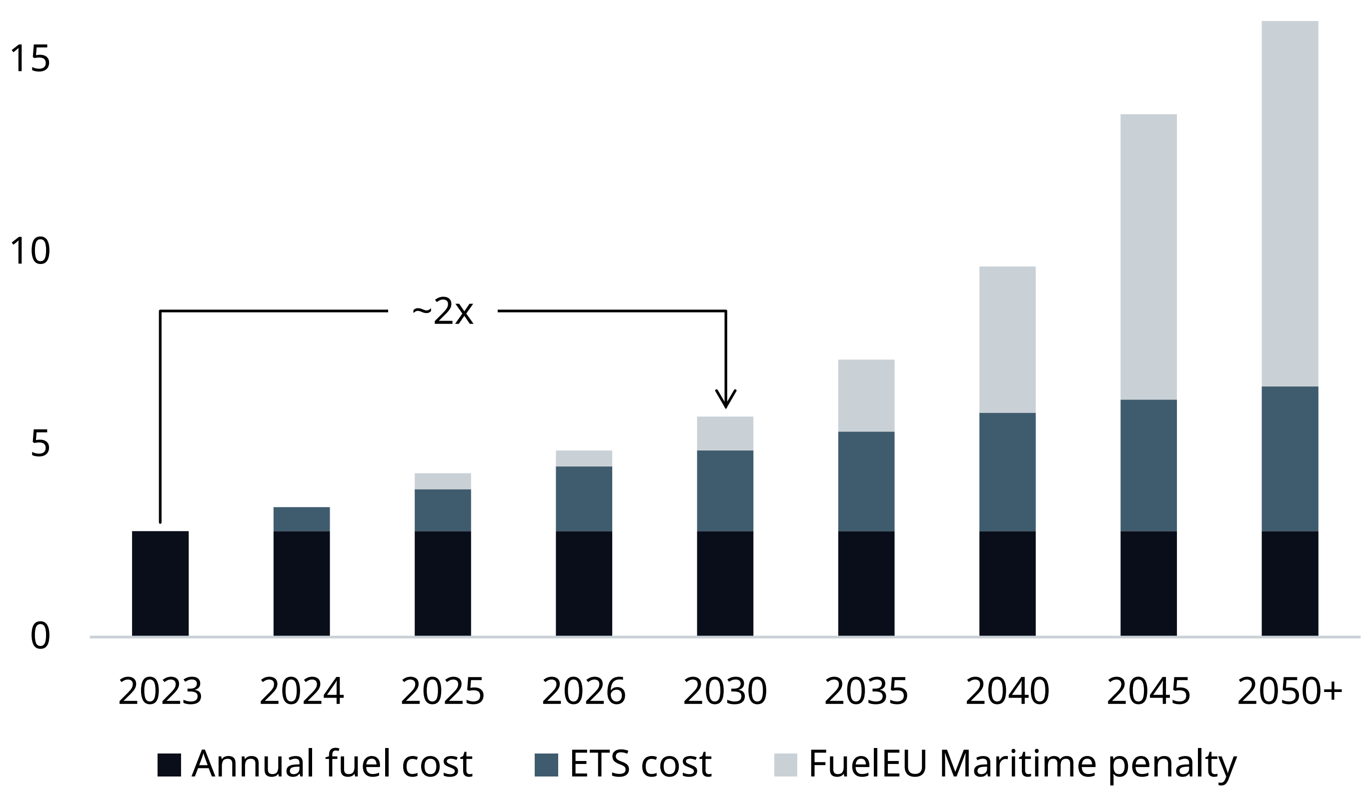
Reduction figures are compared to 2008;

Key takeaways

- IMO MEPC 80 adopted a **revised 2023 IMO GHG Strategy** July 7th 2023.
- Milestones of the new strategy support the Vision to phase out GHG emissions as soon as possible.
- A basket of **mid-term technical and economical measures** should be agreed by 2025 and entry into force 2027. Measures should take into account well-to-wake GHG emissions.
  - Technical element = goal based marine fuel standard regulating the reduction of fuels GHG intensity
  - Economic element = GHG emissions pricing mechanism
- Less ambitious countries have strongly emphasized “a just and equitable transition”, and strategy includes e.g. set of guiding principles to note the different national circumstances, and emphasizes impact assessment and evidence-based decision-making
- The strategy will be subject to a 5-year review period, first due in 2028.
- some still see it as **insufficiently ambitious**: the deal is not aligned with 1.5°C goal, and the “taking into account different national circumstances” linked to the 2050 target leaves room for developing countries to move at slower pace.

Up to 2030, fuel cost will double due to emission fees

Fuel-related costs for Handymax bulker operating in EU waters, EURm[1)]



1) Assuming 5 000 tons/year VLSFO (Very Low Sulphur Fuel Oil) consumption subject to EU Fit-for-55, VLSFO at EUR 550/ton; EU allowances from EUR 100/ton today to EUR 230/ton in 2050 (source: Transport & Environment NGO); 2) E.g., local regulations and emission fees (EU Fit-for-55), green financing (Poseidon Principles), climate-linked chartering (Sea Cargo Charter), companies' ESG targets

Multiple business drivers will add further pressure to decarbonise shipping[2)]

↓

The transition will happen under the lifetime of a vessel

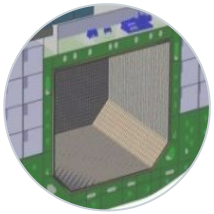
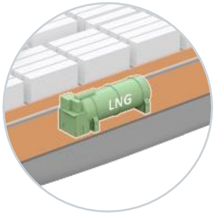
↓

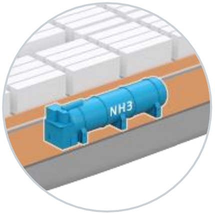
Upgradability is critical for new vessel orders

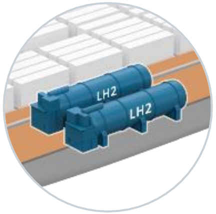
↓

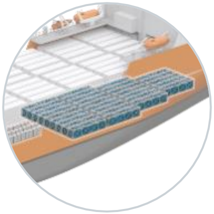
Being perceived as front-runners in technology and services strengthens the positioning already today

Cost of emissions will close the price gap between fossil and sustainable fuels; fuel selection impacts the vessel structure





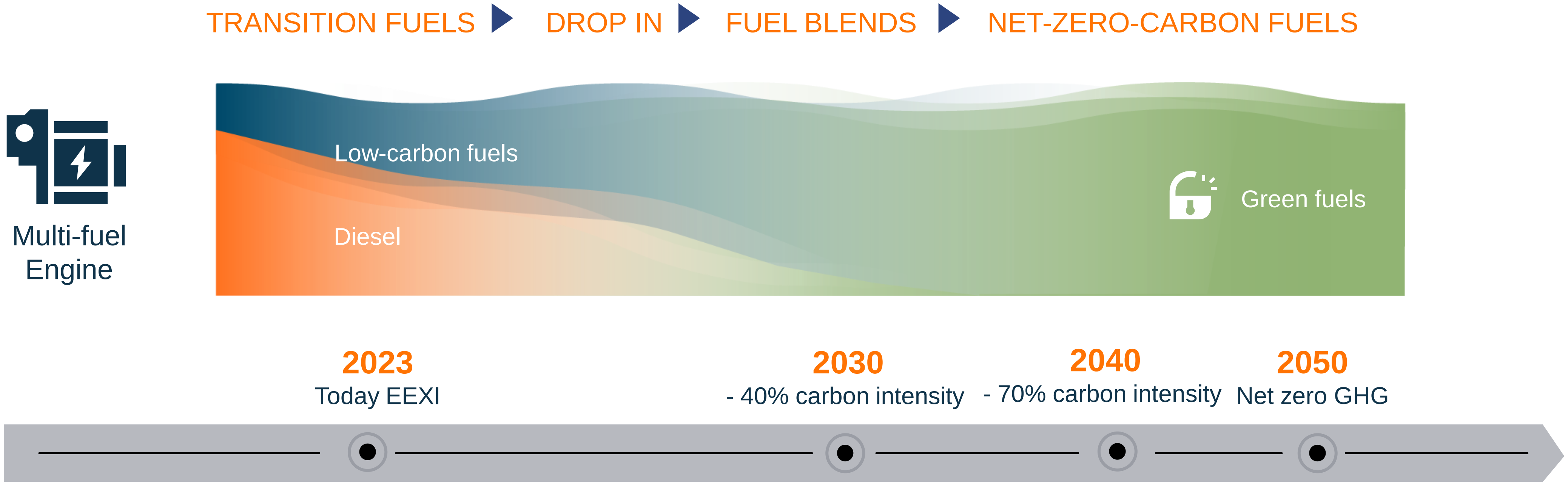



Fuel type	**Low Sulphur Fuel Oil** @ 20°C	**Liquified Natural Gas** @ -162°C	**Methanol** @ 20°C	**Ammonia** @ -33°C	**Liquid Hydrogen** @ -253°C	**Compressed Hydrogen** @ 350bar	**Marine Battery Rack**
Fuel price factor (per GJ)[1]	1x	1.1x – 4.6x[2]	2.6x – 5.5x[3]	2.4x – 4.3x[4]	3.6x – 4.6x[4]	2.1x – 3.1x[4]	2.0x – 5.3x[8]
Fuel price factor in 2035, incl. carbon tax[1] [5]	1x	0.8x – 1.4[2]	0.8x – 1.6x[3]	0.7x –1.2x[4]	1.2x – 1.5x[4]	0.6x – 1.0x[4]	0.8x – 2.0x[8]
Gross tank size factor[6]	1x	1.7x – 2.4x[7]	1.7x	3.9x	7.3x	19.5x	~40x (~20x potential)

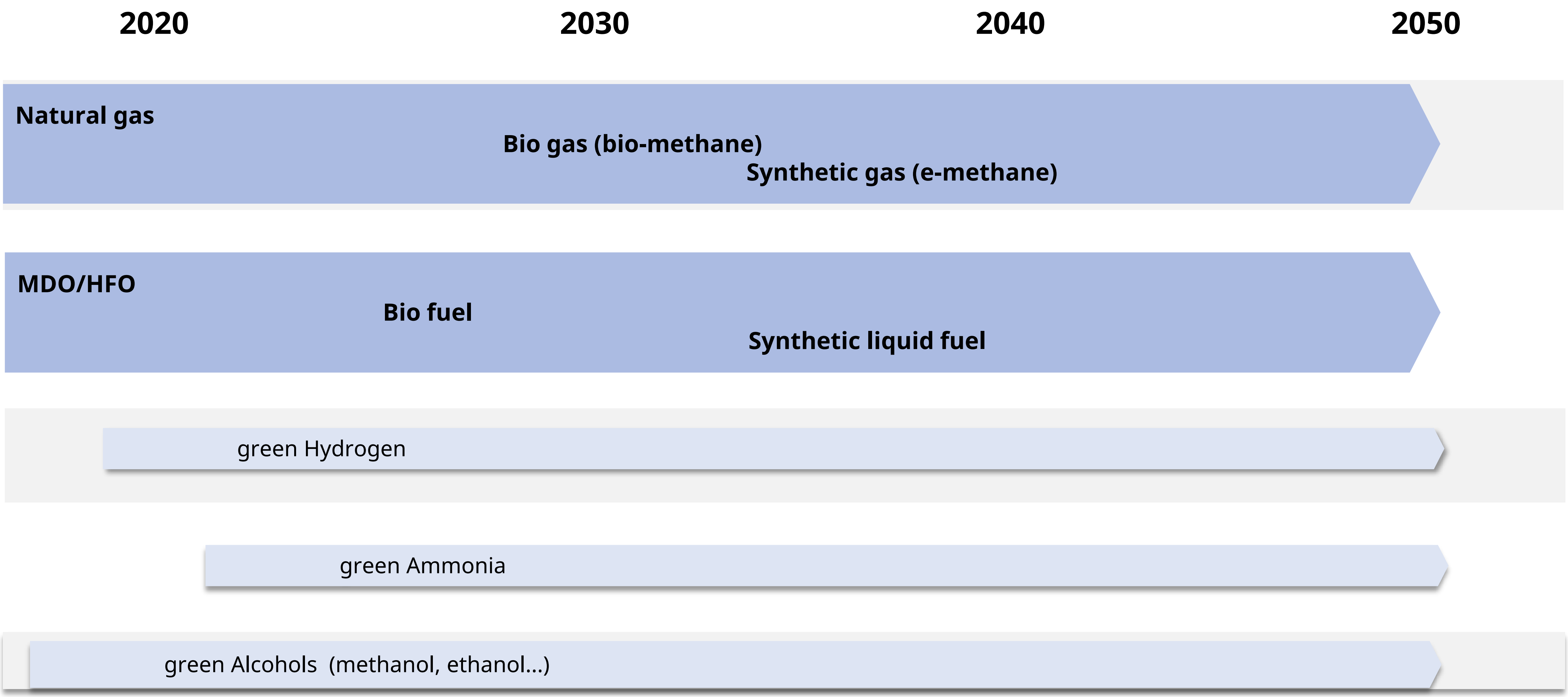
1) Fuel production cost estimate for 2025 and 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023; 2) Price range spans between fossil & electro- methane; 3) Price range spans between bio- & electro- methanol; 4) Price range spans between blue- & electro- ammonia/hydrogen; 5) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 6) Gross tank estimations based on Wärtsilä experience; 7) 1.7x membrane tanks, 2.4x type C tanks; 8) Shore energy price EUR 10-27/kWh

Certainty in transition

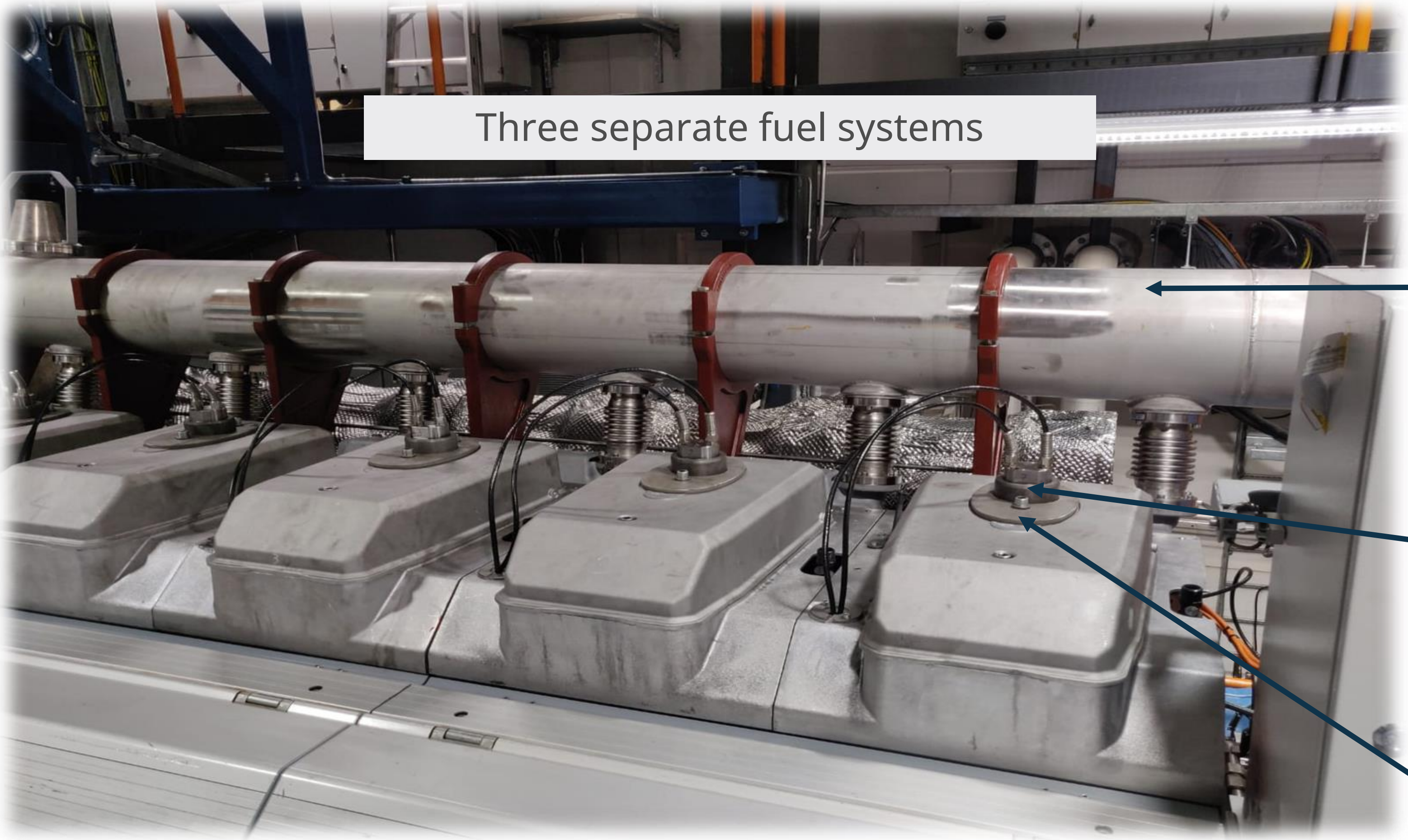
Infrastructure and availability of green fuels need time to mature - current Wärtsilä multi-fuel Wärtsilä multi-fuel technology offer a viable upgrade path



Fuel Roadmap – Focus on Renewable Fuels



The multifuel engine



Gaseous fuels*
- LNG
- LPG
- Ammonia
- Hydrogen

Liquid fuels*
- HFO
- MDO
- LPG
- Ammonia
- Methanol
- Ethanol

Pilot fuel*
- MDO

* Including corresponding bio and synthetic fuel

Development for Future Fuels continues

Bio and e- diesel

Bio and e- methane

Can readily be used with equipment made for LNG or diesel and blended in all ratios

OK

MeOH

Green Methanol

Stena Germanica started operation on Methanol in March 2015

Verified: 2015
Volume ramp-up: 2023

NH_3

Green Ammonia

Combustion concepts to maximise engine performance and related safety technologies are being verified and demonstrated

Tech ready: 2023
Volume ramp-up: 2025

H_2

Green Hydrogen

Our gas engines are already able to blend up to 25% hydrogen in LNG, and combustion concepts under work for 100% hydrogen.

Pilots with blends: 2021
Tech for pure H2 ready 2025
Volume ramp-up: 2027

Areas for cooperation and development

- **Legislation**
- **Systems**
  - Tank system, fuel handling, engine, exhaust and after treatment, etc.
- **Training and PPE**
- **Robust and safe operation on vessels and power plants**
- **Fuel availability and cost operation**

Natural gas
LNG
LBG

Natural gas: Composition

Example of natural gas composition (Spain)

- Methane 91,44 % mole
- Ethane 5,35 % mole
- Propane 1,22 % mole
- Butane 0,41 % mole
- Pentane 0,03 % mole
- Hexane and heavier HC’s 0,02 % mass
- Carbon dioxide 0,54 % mole
- Water 0,00 % mole
- Nitrogen 0,99 % mole
- Trace amounts of chlorine, fluorine, ammonia, hydrogen sulphide, particles.

- Composition of natural gas can vary significantly depending on natural gas origin and treatment process.

Biogas upgrading

Raw biogas is produced through the breakdown of organic matter in the absence of oxygen, which is referred to as Anaerobic Digestion. (AD)

TYPICAL COMPOSITION:

- 50-70% Methane
- 30-50% Carbon dioxide
- < 0.1% Oxygen
- < 0.1% Nitrogen
- Hydrogen sulphide, water and small amounts / traces of harmful and aggressive elements depending on feedstock.
- NOT a suitable fuel quality for the engines!

Biomethane is produced by separating and cleaning the raw biogas.

TYPICAL COMPOSITION:

- 99,9% Methane
- 0.1% Carbon dioxide
- < 0.1% Oxygen
- < 0.2% Nitrogen
- < 5mg/m^3 Hydrogen sulphide

- Methane slip during manufacturing process is < 0.1%
- Activated carbon removes H_2S, also other impurities like siloxanes are removed.
- Good gas quality for the engines!

Liquid biofuels

Liquid bio fuels: General

- Categorization within Wärtsilä
  - Straight (SVO) / pure (PVO) vegetable oils (palm, soya, etc.)
  - Biodiesel (FAME) and its blends with fossil fuels
  - Paraffinic renewable diesel fuel from synthesis / hydrotreatment (HVO) and blends with fossil fuels
  - Processed fuels belonging to HFO substitutes, like VLSFO/FAME or VLSFO/HVO blends.

Liquid bio fuels: Specifications

Doc. Name: Fuel characteristics - LBF   Doc. ID: DMTA00067349   Revision: -   2 (9)

FUEL CHARACTERISTICS

1. Liquid biofuel characteristics and specifications

The Wärtsilä® diesel and Dual Fuel (DF) engine types specified in the table hereafter are designed and developed for continuous operation on liquid biofuel (LBF) qualities with the properties included in the Tables 1, 2.1 - 2.4 and 3. For the Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) operation included in Table 1 dedicated kits are required.

Engine type	Liquid biofuel category		
	Straight and pure vegetable oils, Table 1 1,6)	FAME / Biodiesel, Table 2.1 1,6)	Paraffinic diesel fuels, Table 3 2)
Wärtsilä 20	Yes 3)	Yes	Yes
Wärtsilä 25	No	Yes 7)	Yes 7)
Wärtsilä 26 3)	Yes	Yes	Yes
Wärtsilä 31	No	Yes	Yes
Wärtsilä 32	Yes	Yes	Yes
Wärtsilä 38	No	Yes	Yes
Wärtsilä 46	Yes 3)	Yes	Yes
Wärtsilä 46F 4)	No	Yes	Yes
Wärtsilä 50	Yes 3)	Yes	Yes
Wärtsilä 64	No	Yes	Yes
Wärtsilä 20DF 5)	Yes 3)	Yes	Yes
Wärtsilä 25DF	No	Yes 7)	Yes 7)
Wärtsilä 31DF 5)	No	Yes	Yes
Wärtsilä 34DF 5)	Yes 3)	Yes	Yes
Wärtsilä 46DF 5)	No	Yes	Yes
Wärtsilä 46TSDF 5)	No	Yes	Yes
Wärtsilä 50DF 5)	Yes 3)	Yes	Yes

Note 1: Liquid biofuels included in the Table 1 and 2.1 have typically lower heating value (LHV) than fossil fuels, why the capacity of fuel injection system influencing on guaranteed engine output must be checked case by case. Concerning biodiesel blends included in tables 2.2, 2.3 and 2.4 the influence of LHV is however not significant.

Note 2: Liquid biofuels included in the Table 3 have a low density, why the capacity of fuel injection system influencing on guaranteed engine output must be checked case by case. Their flash point can based on specifications be also lower than 60 °C required for marine applications by SOLAS and Classification societies, which may prevent the use.

Note 3: Fuel injection system is not validated for Straight and Pure Vegetable oils (SVO and PVO) qualities. Wärtsilä have to cover possible FIE warranty cost. Depending on FIE equipment, field follow up / validation may be required.

Note 4: Valid for the engines equipped with Twin Pump.

Note 5: If a liquid biofuel is used as a pilot fuel in the DF engine types, only the products fulfilling the specification included in the Table 2.1 and 3 are allowed to use.

Note 6: The use of liquid bio fuels qualities included in the Table 1, 2.1, 2.2, 2.3 or 2.4 always require a NSR to be made.

WÄRTSILÄ

DATA & SPECIFICATIONS

4-Stroke Engines
Technical Services

WS02N203
Issue 4, 29 December 2022

Fuel oil specification for liquid biofuel

Distribution to operators and owners of installations concerned

For your information

Engines concerned
The following WÄRTSILÄ® diesel and dual fuel engines:

- WÄRTSILÄ® 20
- WÄRTSILÄ® 26
- WÄRTSILÄ® 31
- WÄRTSILÄ® 32
- WÄRTSILÄ® 38
- WÄRTSILÄ® 46
- WÄRTSILÄ® 46F
- WÄRTSILÄ® 50
- WÄRTSILÄ® 64

- WÄRTSILÄ® 20DF
- WÄRTSILÄ® 31DF
- WÄRTSILÄ® 34DF
- WÄRTSILÄ® 46FDF
- WÄRTSILÄ® 50DF

See Note 3 on next page regarding:

- WÄRTSILÄ® Vasa 32, 32GD
- WÄRTSILÄ® Vasa 32LN, 32LNGD
- WÄRTSILÄ® 32DF

Reference
Fuel, lubricating oil, cooling water

Introduction
The document *"Fuel characteristics - LBF"* has been revised.

Validity
Until further notice. Replacing issue 3, dated 23 November 2020.

Before taking any action, always check the available online systems for the latest revision of this document. Any locally stored or printed version is considered to be an uncontrolled document.

Wärtsilä Finland Oy
P.O. Box 244 (Järvikatu 2-4)
FIN-65101 Vaasa
Tel: +358 010 709 0000
www.wartsila.com

Renewable diesel (HVO): Pros and Cons

Pros	Cons
+ Sulphur oxide emissions closed to zero	- Flash point limit in the standard min. 55 ºC while SOLAS and Class require min. 60 ºC. Fuel purchaser shall require that flash point of delivered batches is > 60 ºC.
+ Low particulate emissions	- Price about triple or even higher compared to fossil diesel
+ Reduction in CO_2 emissions (from well to tank)	- Production volumes still low and competition with other segments exists
+ HVO mixes well with fossil fuels (HFO & MGO)	
+ Can be used in the existing engines w/o modifications	
+ The EN 15940:2016 standard is available	

Biodiesel (FAME): Pros and Cons

Pros	Cons
+ Sulphur oxide emissions closed to zero	- Contains ~ 13% less energy than fossil diesel
+ Low particulate emissions	- Water separation from biodiesel is more challenging
+ Reduction in CO_2 emissions (from well to tank)	- Solvent characteristics may degrade rubber and attack certain metals - Solvent characteristics can lead to loosening of old deposits from fuel system causing e.g. filter clogging. Tank cleaning prior to use to be considered.
+ Biodiesel mixes well with petroleum diesel	- Can foster the risk of microbial activity
+ Good lubrication properties	- Long term storage period limited (Acid number increases, oxidation takes place)
+ Can be used in the existing engines w/o modifications	- Cold flow properties may be a problem (mainly a quality issue)
+ The EN 14214:2012 standard is available	- Price about double compared to fossil diesel
	- Production volumes still low and competition with other segments exists

Liquid biofuels: Experience

Renewable diesel (HVO)

- Neste My tested in a Laboratory engines
- BioVerno tested in a Laboratory engine.
- Documented long-term field experience does not exist.
- Gas-to-Liquid (GTL) synthetic diesel manufactured with Fischer-Tropsch process is from quality point of view similar compared to Neste My & BioVerno but not a renewable fuel if fossil natural gas is used as a feedstock.

Biodiesel (FAME)

- Biodiesel B100 tested in a Laboratory engine
- Documented long-term field experience for 100% FAME does not exist.
- 2 – 10% biodiesel / fossil diesel blend used in various countries. No big drawbacks recorded. Blending ratios have increased up to 20 – 30%.

Hydrogen

Press release Hydrogen

Wärtsilä gas engines to burn 100% hydrogen

Wärtsilä Corporation, Press release, 5 May 2020 at 11:00 AM E. Europe Standard Time

Press release Hydrogen

Wärtsilä & US partners succeed with world's first-of-its-kind power plant fuel tests using blended hydrogen

Wärtsilä Corporation, News 8 November 2022 at 13:00 UTC+2

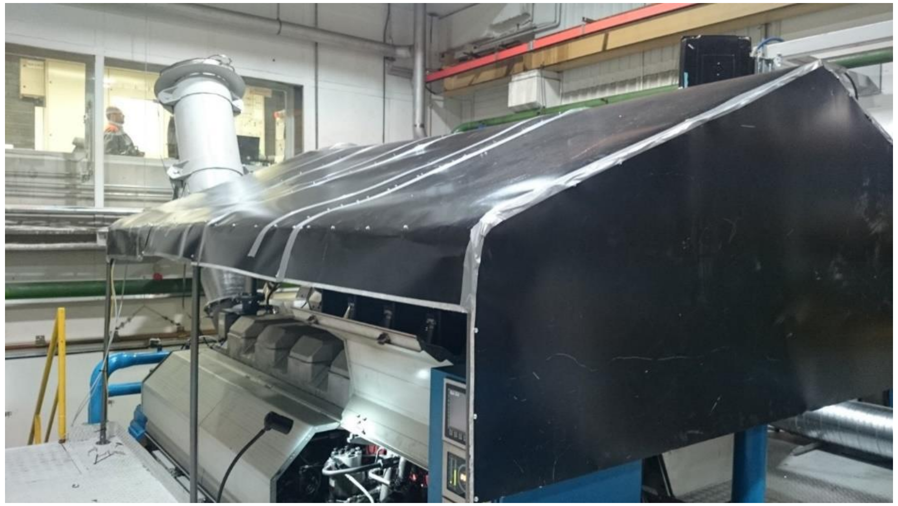
The testing of hydrogen blended fuel carried out by the technology group Wärtsilä in collaboration with WEC Energy Group, EPRI and Burns & McDonnell has been concluded. The tests were made at WEC Energy Group's 55 MW A.J. Mihm power plant in Michigan, USA using an unmodified 18 MW Wärtsilä 50SG engine. The hydrogen and hydrogen blending skid was provided by Certarus Ltd. The tests were completed in October 2022.

Hydrogen mixed in natural gas

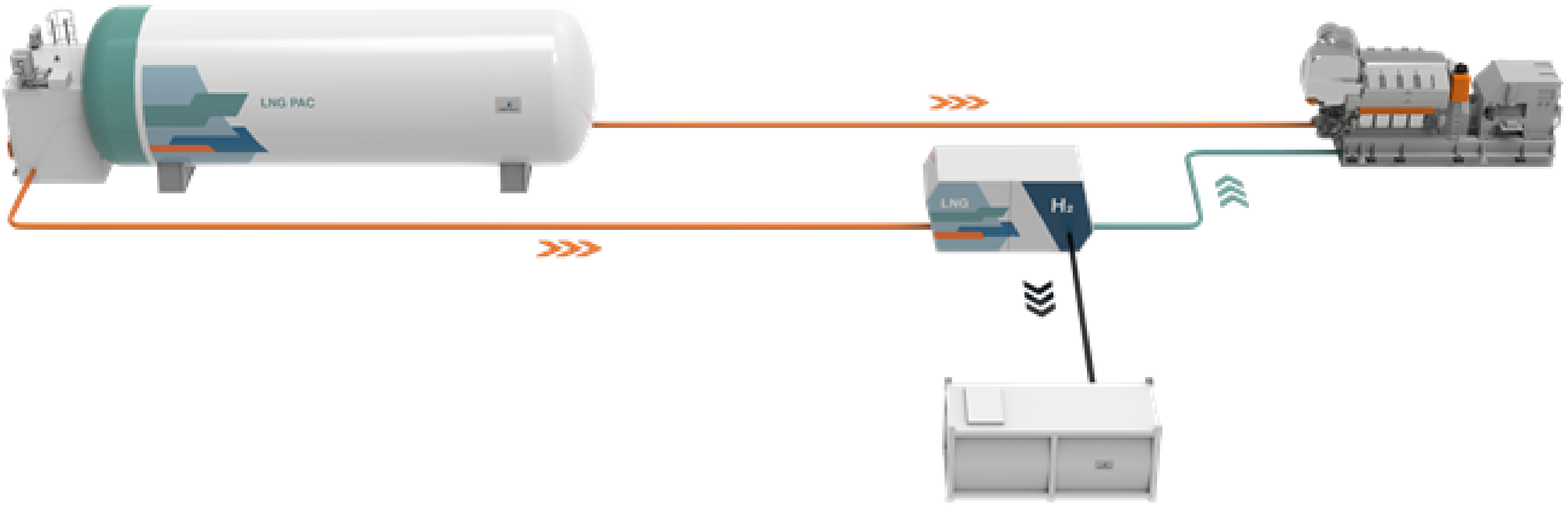
- Target to study the effect of hydrogen mixed in NG in lean-burn DF and SG engines

- Specific caution on safety
  - Hydrogen sniffers for gas pipes
  - Protective hood above the engine
  - Improved gas ventilation

- Up to 30% of hydrogen in NG could be used as fuel in Wärtsilä gas engine after optimized controls

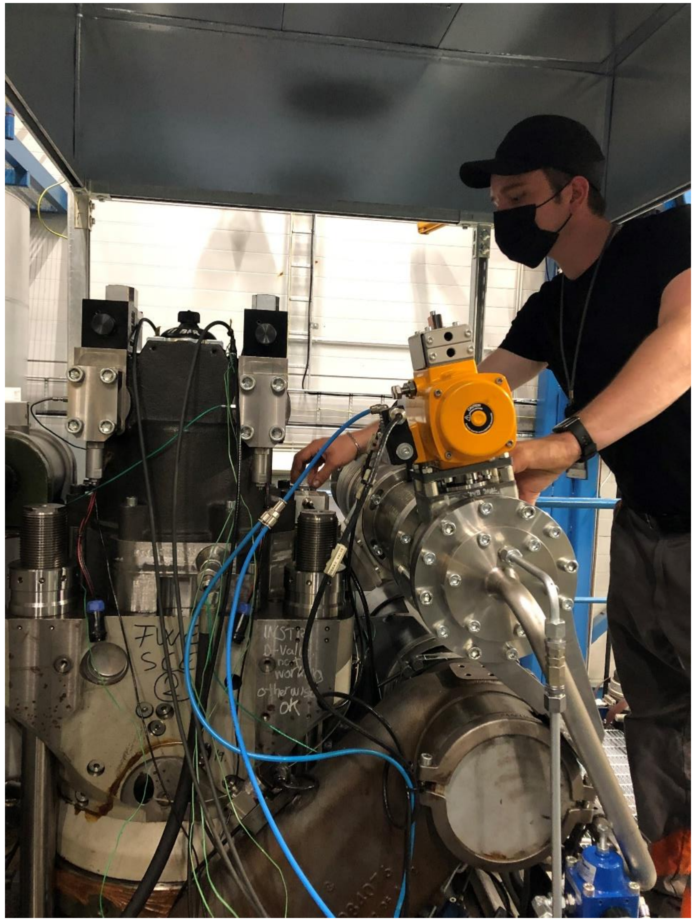


Carbon capture + H2 production from LNG



Wärtsilä partners with cleantech start-up Hycamite to jointly develop technology for onboard production of hydrogen from LNG (wartsila.com)

Pure hydrogen engine tests 1st July 2021



Ammonia: advancing from industrial chemical to zero-carbon ship fuel through R&D and collaboration

2021

First engine tests with ammonia blends

2022

Industry collaboration for solution validation

2023

Technical concept ready

2024

First ammonia engine deliveries

Demo 2000 – NH3 Demonstration project at Stord

2020 - 2023

Partners

SUSTAINABLE ENERGY | NORWEGIAN CATAPULT CENTRE

Forskningsrådet

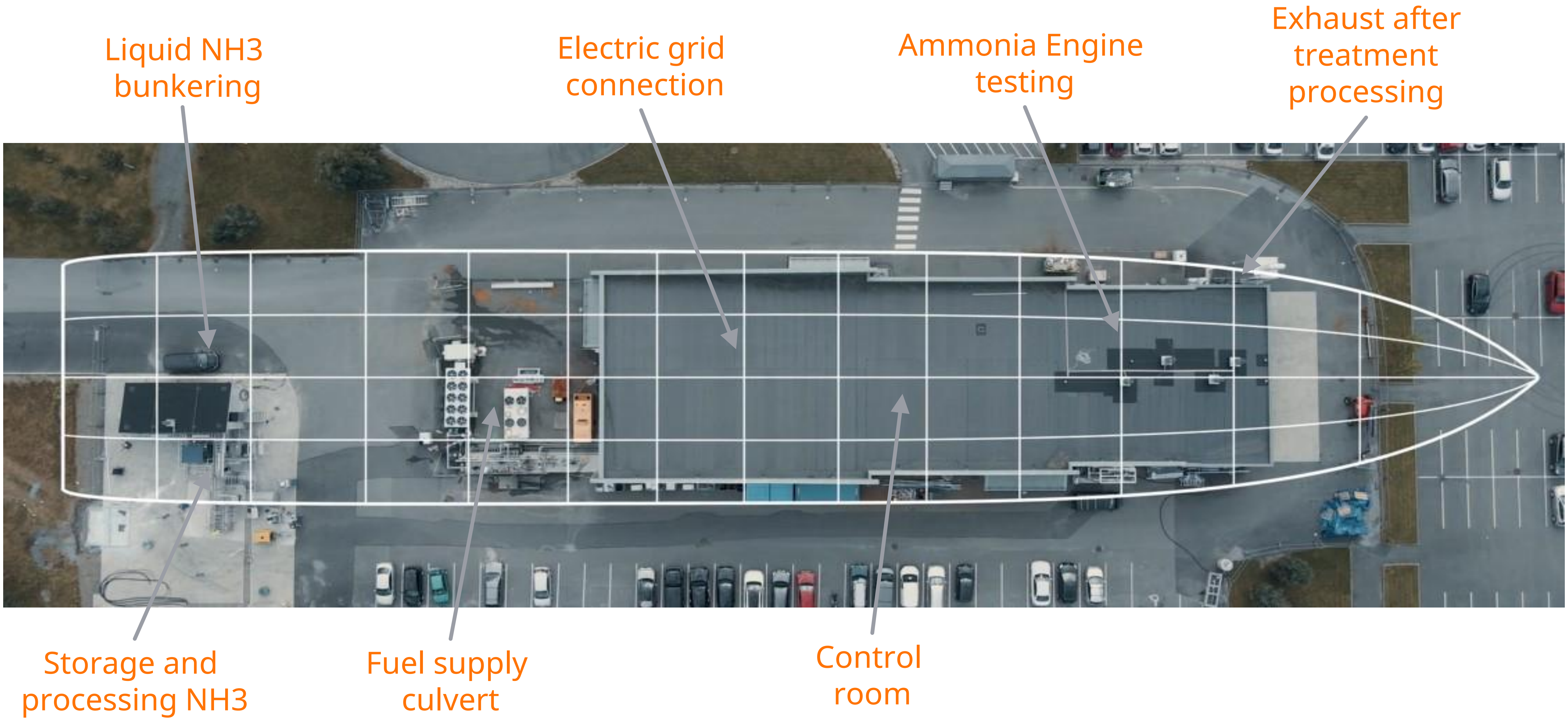
REPSOL

Knutsen OAS Shipping

equinor

WÄRTSILÄ

The ship view of the Demo 2000 ammonia engine testing



DEMO 2000 UPDATE MAY 2023

ACHIEVEMENTS FROM TEST PROGRAM:

26 ton Ammonia consumed in Stord tests

90% + Ammonia share

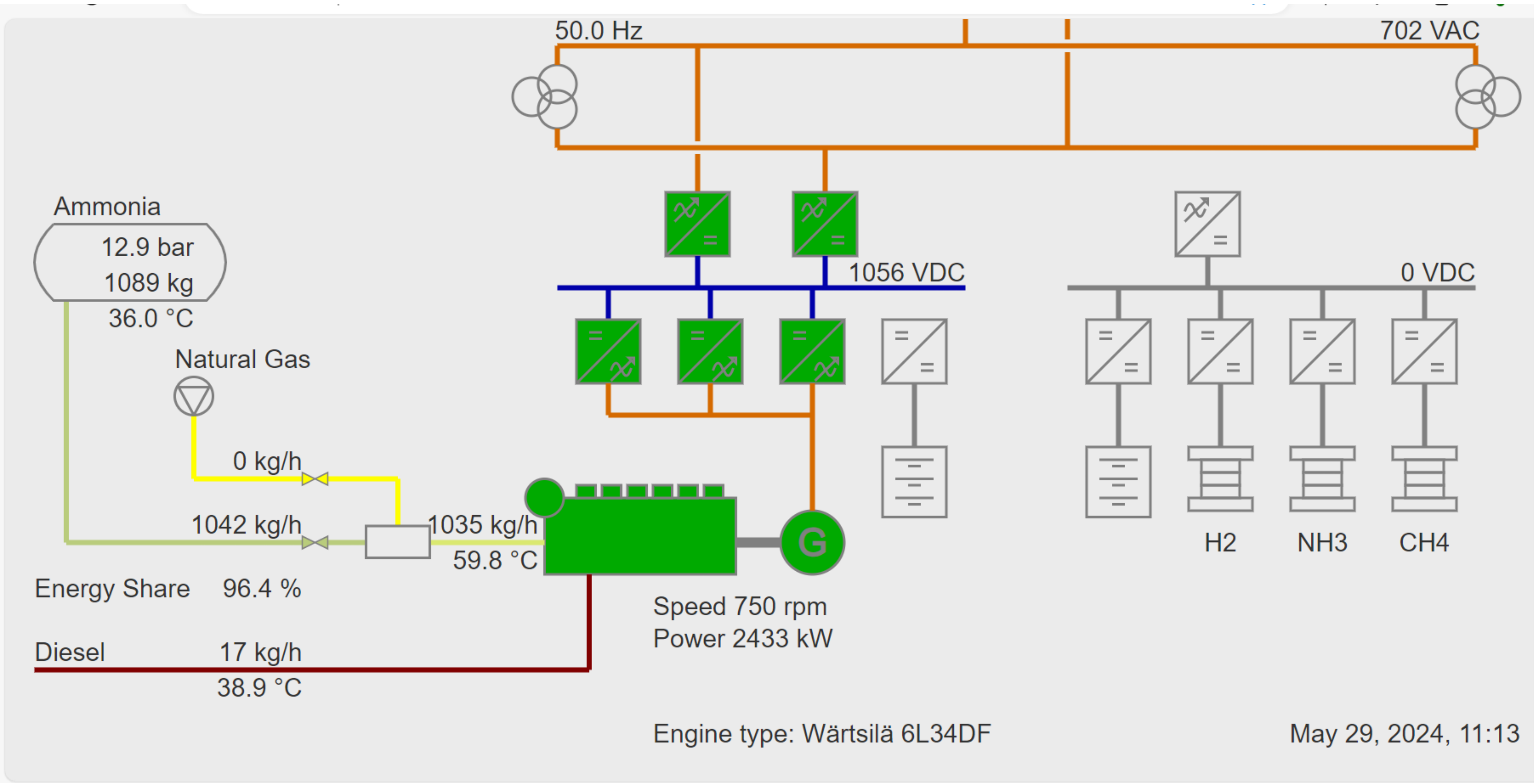
Natural Gas mixing

89% GHG reduction potential

N_2O < 5ppm after Catalyst

NOx = Most promising (<< Tier III)

Ammonia operation at Stord



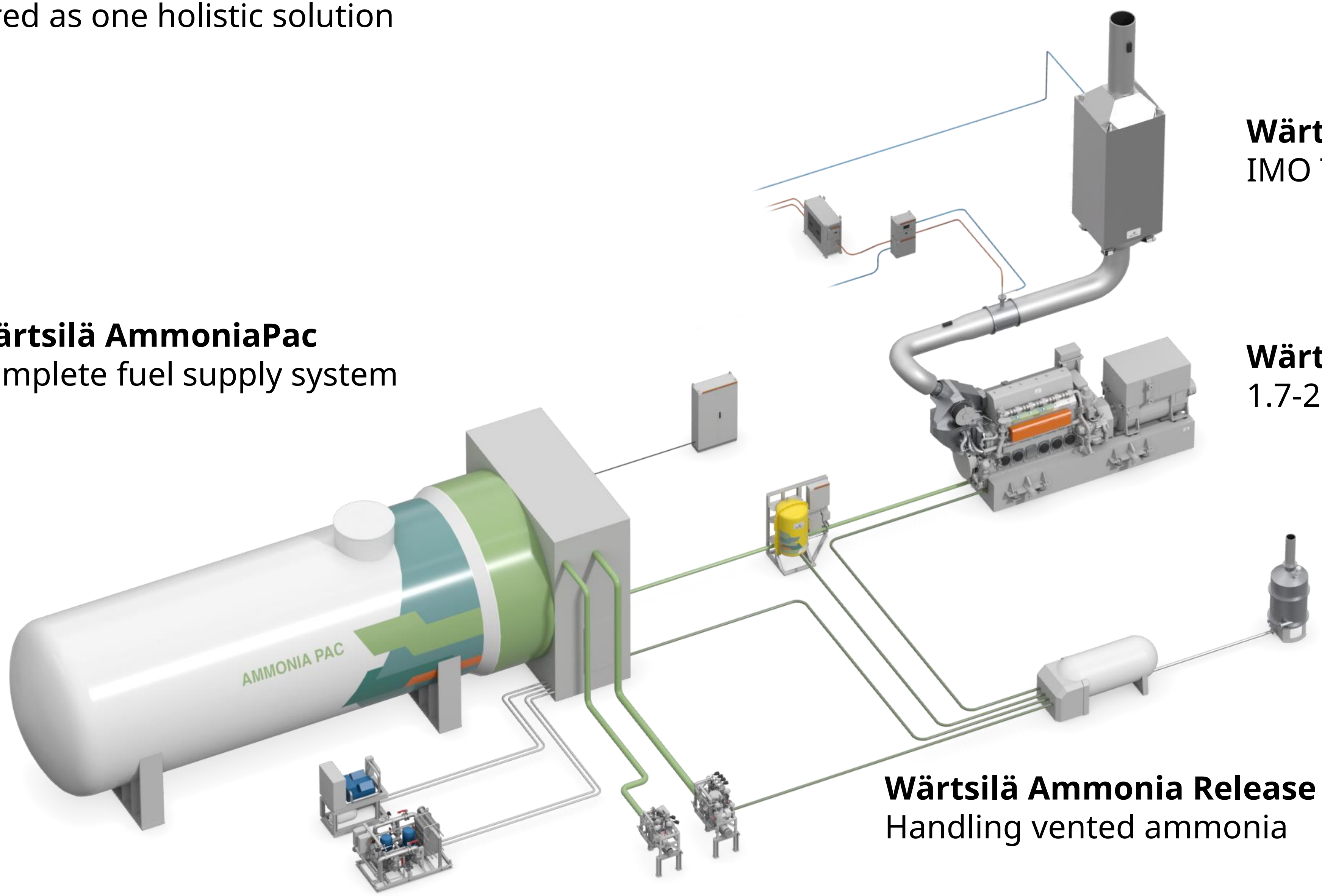
AmmoniaPac - System overview

Engineered as one holistic solution

Wärtsilä AmmoniaPac
Complete fuel supply system

Wärtsilä NOx Reducer
IMO Tier II / Tier III

Wärtsilä 25 Ammonia
1.7-2.7MW



Wärtsilä Ammonia Release Mitigation System
Handling vented ammonia

Approval in principle by Classification Societies

WÄRTSILÄ

DNV

APPROVAL IN PRINCIPLE

Particulars of Product

Designer:	**Wärtsilä Finland Oy**
Product:	**Wärtsilä 25DF Ammonia**

This is to verify:

That the plan for development and principle of engine design has been assessed by DNV and found to comply with current Rules of the Society, as specified below.

- DNV Rules for classification, Ship, DNV-RU-SHIP-Pt.6 Ch.2 Sec.8 – FUEL READY Ammonia (MEc/AEc), July 2023

中国船级社

CHINA CLASSIFICATION SOCIETY

证书编号/Certificate No.
JS23PPR00003_05

船用产品原理认可证书

APPROVAL IN PRINCIPLE FOR MARINE PRODUCT

概念认可证书

CERTIFICATE OF CONCEPT APPROVAL

兹证明本证书所述设计方设计的下列产品的技术原理具有可行性，能够原则上满足列明标准的要求。
This is to certify that the innovative design principles in the following products designed by the designer stated in the certificate are feasible, and can meet the requirements of the standards listed below in principle.

设计方/ Designed by

Wärtsilä Finland Oy

认可产品/ Product Approved

氨/燃油双燃料发动机

Ammonia/Fuel Oil Dual Fuel Engine

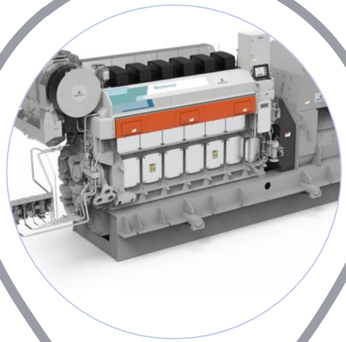
Methanol: delivering capability to power marine engines and achieving carbon neutrality

2015

Conversion of Stena Germanica ZA40 engines

2020

Development & demonstration of methanol technology



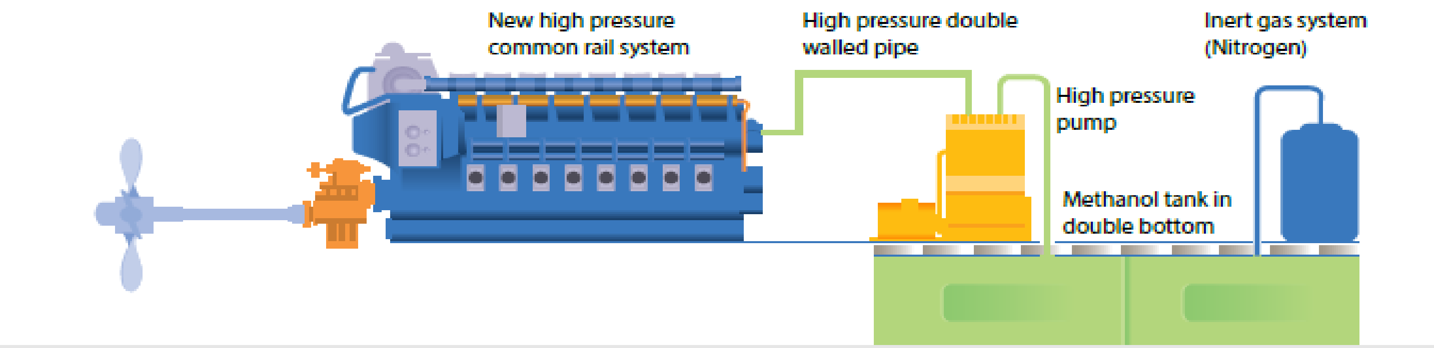
2022

W32 Methanol engine launch & MethanolPac

2023

Launch additional methanol engine types & retrofit options

Methanol adaptation of Stena Germanica



Engine before and after conversion

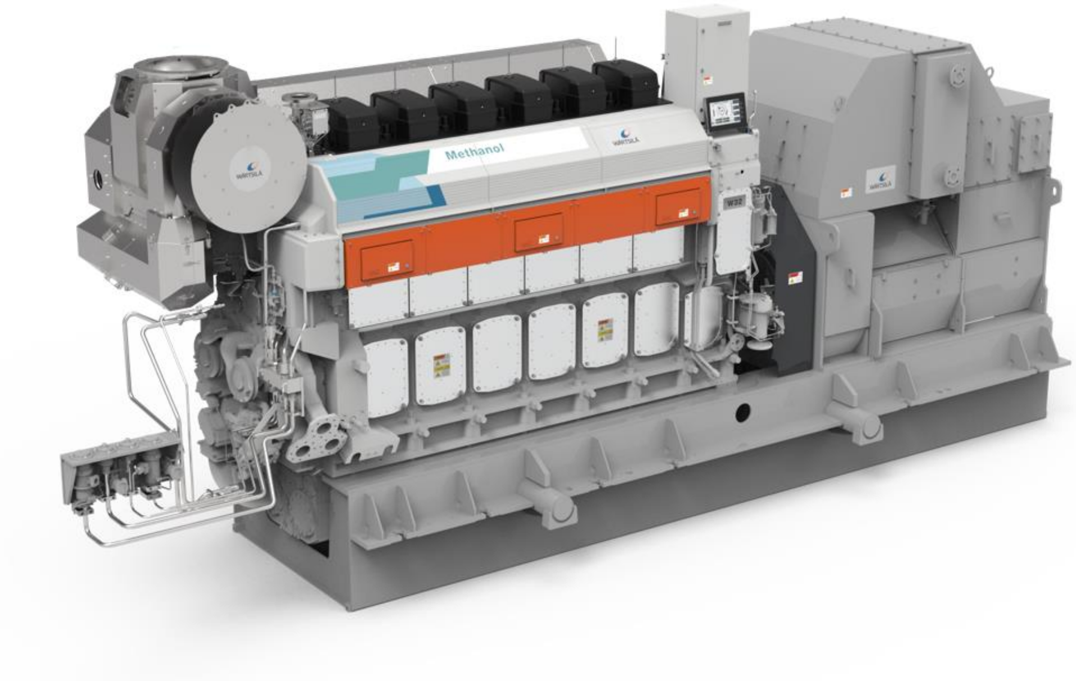
First Wärtsilä 32 Methanol order

- Owner: Van Oord
- Yard: Yantai Raffles
- Scope of delivery:
  - 5 x W32 Methanol main gensets
  - SCRs
  - MethanolPac
  - Retractable and tunnel thrusters
- Delivery of equipment Q2 2023

Wärtsilä 32 Methanol - the power to reach carbon-neutral

W32 Methanol available in March 2023 ExW

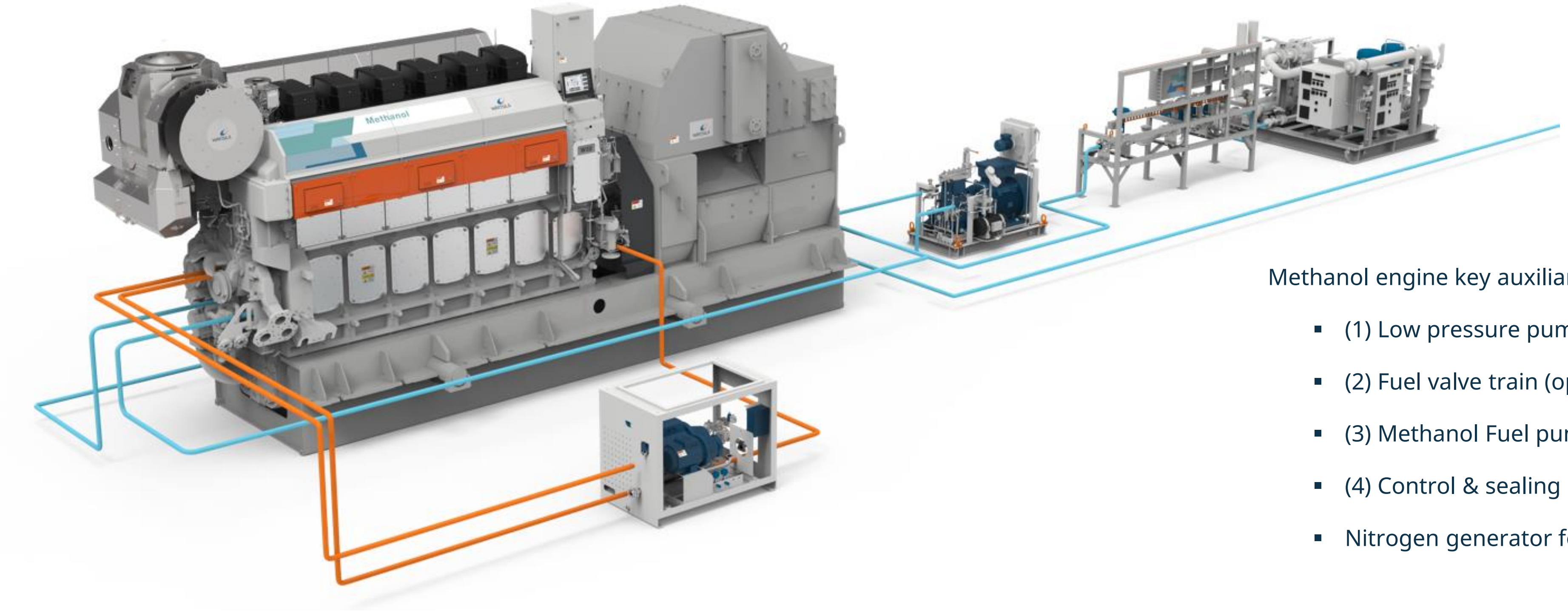
- Based on proven and reliable W32 engine concept
    - Experience from earlier W32GD engine design, and Sulzer ZA40 methanol
- Back up fuel operation possible (LFO + LBF, HFO)
    - Fuel switch (Methanol ⇔ Liquid) can be made without loss of power
- Auxiliary engine (AE), Diesel electric engine (DE) and Variable speed Main Engine
- Variable speed Main Engine October 2023 Exw



System overview

Methanol engine key components:

- Multifuel injection system
- Cylinder heads - optimised for methanol combustion with pilot and main fuel
- Common rail for methanol fuel



Methanol engine key auxiliary components:

- (1) Low pressure pump with cooler (optional scope)
- (2) Fuel valve train (optional scope)
- (3) Methanol Fuel pump unit
- (4) Control & sealing oil unit for injector sealing and injection cont
- Nitrogen generator for system purge (optional scope)

Summary

- Decarbonising of the marine sector is urgent and requires a wide range of measures
- A successful development requires expertise and actions from many contributors
- Wärtsilä’s portfolio provides several solutions towards a net-zero future
- Fuel flexibility secures a future proofed solution
- Concepts for ICE operation on the future fuels like Biofuels, Ammonia, Hydrogen, and Methanol are already being developed and demonstrated.