




# Wärtsilä Ammonia-Platform

The comprehensive solution for targeting net zero

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# Decarbonisation transformation

Decarbonisation will transform the marine industry at an unprecedented pace


Fuel flexible engine technology allows for an opportunity balancing decarbonisation targets with financial viability

Collaboration and partnership are essential in resolving the challenges we will face in upcoming decades

2050: -50% GHG emissions from shipping
EEXI, CII, ETS, RED II, FuelEU Maritime etc.
Green financing, Green cargo, ESG policies

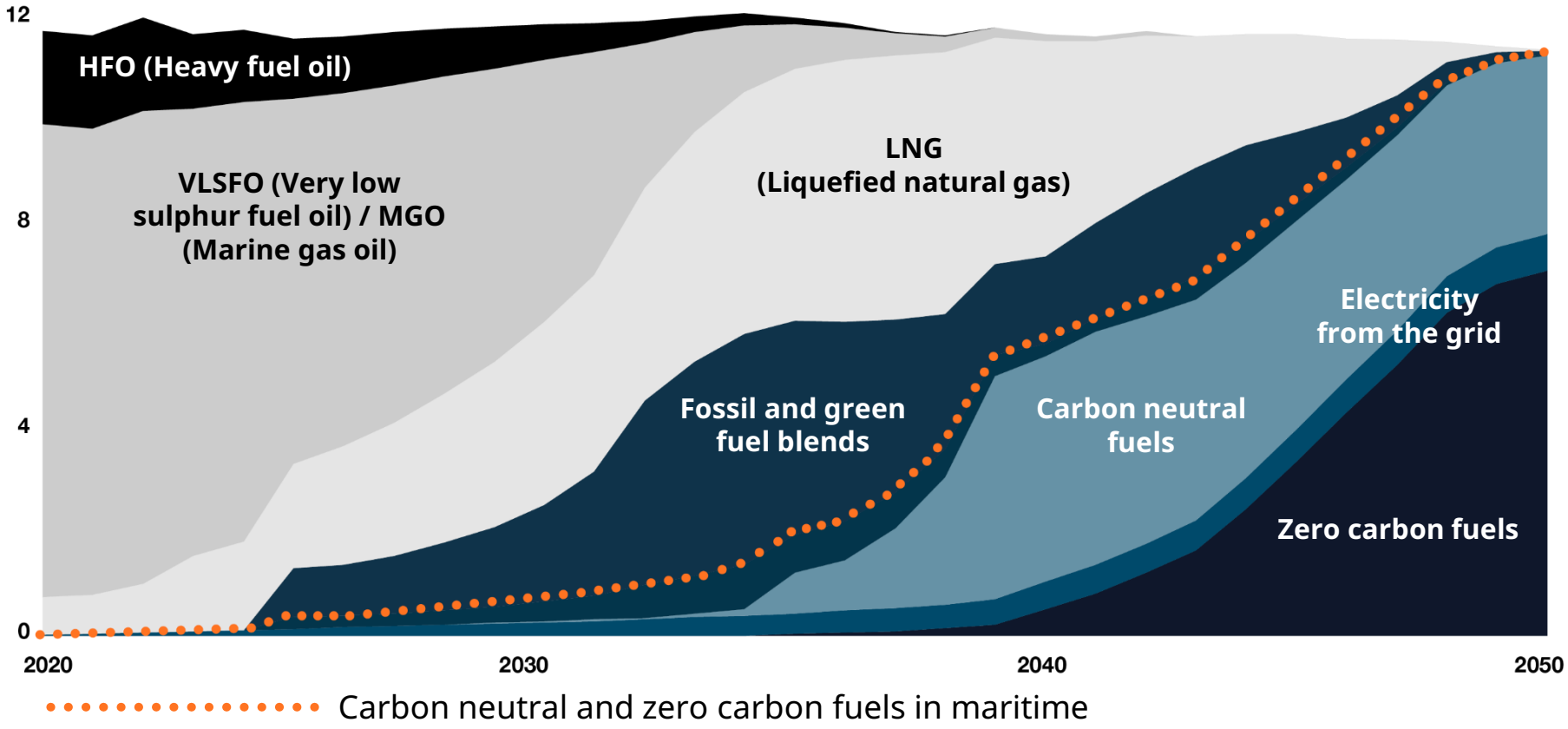
# Moving from single-fuel industry to multi-fuel

Investment in fuel flexibility secures customers' asset lifetime

**Owners will decide on technology partners now:**

- Vessel life is 25-30 years
- Critical decision criteria:
  - Multifuel capabilities for blending with green fuels
  - Conversion capabilities for future fuels

**Distribution of fuel types for Decarbonisation 2050 (1.5°C scenario), exajoule**




Source: DNV Maritime Forecast 2050 model, Wärtsilä internal estimates

# We develop sustainable and future proof technologies

We continuously invest in innovation and product development to deliver sustainable technologies and solutions.

By joining forces with other ecosystem players, we can ensure an even broader solution offering for our customers.

**~2,850** patents and patent applications in January 2023

**241** MEUR invested in R&D in 2022 (~4% of net sales)

# Main solutions

## Propulsion

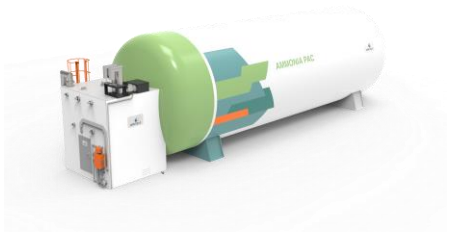
- Hydrodynamic studies through OPTI DP.
- Multiple thruster types: steerable, retractable, combi and transverse.
- All thrusters are e-driven ensure energy efficiency. Tilted units providing best performance to the asset.
- Propulsion control system in combination with the DP system

## Power Conversion

- Diesel Electric propulsion systems.
- Hybrid and full electric systems.
- Optimized Energy Mgmt Systems.
- More than 100 hybrid installations.

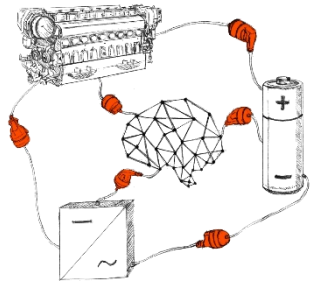
## Engines / Generators

- Ability to run on alternative fuels providing fuel flexibility.
- Newly developed engines with modular structure for easier maintenance and retrofitting.
- Longer time between overhauls.
- Catalysts for exhaust cleaning.



## Fuel Storage & Supply

- Fuel storage and supply can be adapted to multiple fuels, ranging from conventional liquid fuels and natural gas to alternative fuels.
- More than 146 vessels equipped with the Wartsila LNG Pac



## Integration

- De-risk Alternative Fuels
- System integration ensuring optimal vessel functionality based on vessel operational modes and multiple energy sources.

## Lifecycle

- Alternative fuels experience and developing safety procedures.
- Guaranteed asset performance.
- Remote operational support.
- AI-based anomaly detection through sensors.
- Improved engine efficiency.

# Multifuel combustion engines let you adopt green fuels at your own pace

## Technical feasibility enables progressive adoption of green fuels

**Drop-in**

Drop in the tank compatible biofuels e.g. LNG and liquid bio-methane

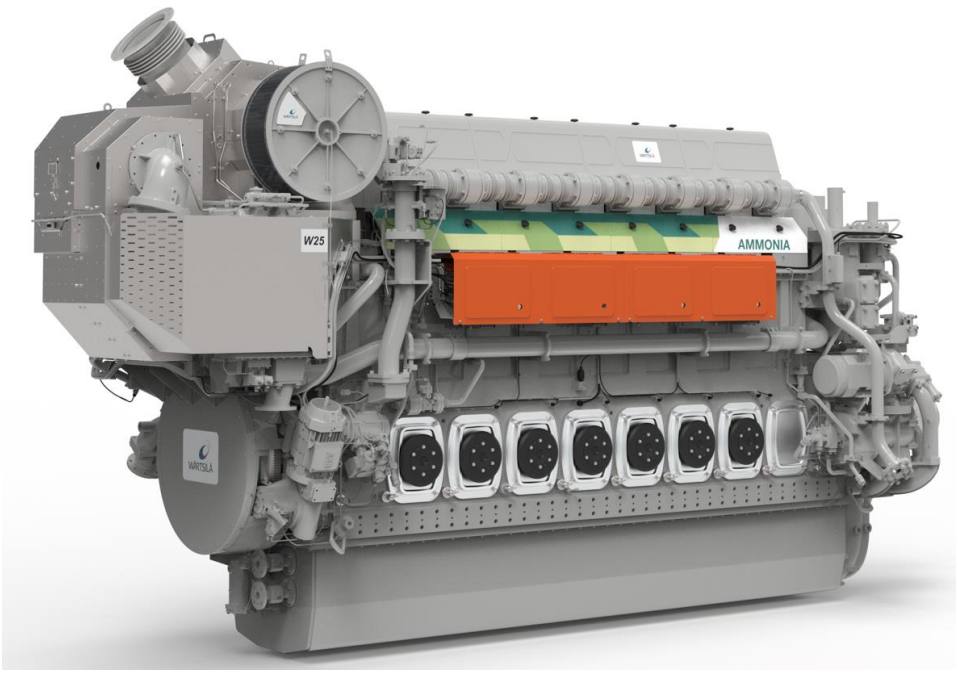
▼

**Blending**

Injecting different fuels e.g. fuel oil and green ammonia into the engine

▼

**100% Pure**

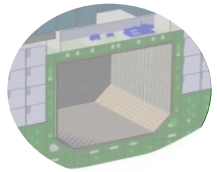
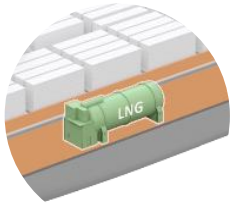
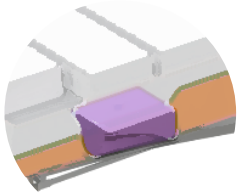
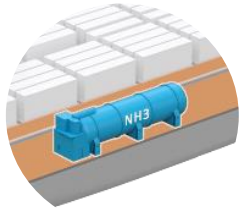
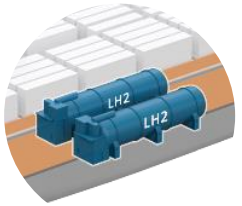
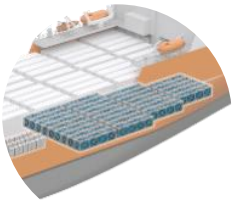



## Best Total Cost of Ownership makes transition financially viable [1)]

- Low CAPEX and vessel-long lifespan
- Predictable operational and maintenance costs
- Upgradeable, modular structures mean faster conversions

Source: 1) DNVGL Maritime Forecast ed. 2020 and Lloyd's Register Techno-Economic Assessment of Zero Carbon Fuels ed. 2020

# Marine Fuels Today and in the Future

| Fuel type |  **Low Sulphur Fuel Oil** @ 20°C |   **Liquified Natural Gas** @ -162°C |  **Ethanol** @ 20°C |   **Methanol** @ 20°C |   **Ammonia** @ -33°C |   **Liquid Hydrogen** @ -253°C |  **Compressed Hydrogen** @350bar |
|---|---|---|---|---|---|---|---|
| **Key considerations** | ▪ Standard tank arrangement | ▪ Cryogenic system | ▪ Lower toxicity compared to methanol<br>▪ Flexible tank arrangement | ▪ Mildly toxic<br>▪ Flexible tank arrangement | ▪ Toxic<br>▪ Corrosive | ▪ Highly flammable<br>▪ Cryogenic system | ▪ High pressure<br>▪ Multiple tanks arrangement<br>▪ Highly flammable |
| **Regulation readiness** | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| **Volumetric energy equivalent** | 1x | 1,6x | 1.7x | 2.3x | 2,9x | 4.3x | 11.7x |
| **Tank hold space compartment volume** | 1x | 1.7x – 2.4x *) | 1.3x | 1.7x | 3.9x | 7.3x | 19.5X |

Gross tank estimations based on Wärtsilä experience considering inspection spaces needed around the tanks. Cylindrical tanks only considered for LNG, if stored in prismatic tank then LNG gross tank size factor is better for LNG than for methanol.
*) 1.7x membrane tanks, 2.4x type C tanks

## Bio LNG

**or Synthetic methane**

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

Verified: 2003
Cryogenic LNG operations are well-known (IGF code of safety for ships since 2016)

## MeOH

**Green Methanol**

Stena Germanica started operation on Methanol in 2015

Verified: 2015
Volume ramp-up: 2023
Non-pressurised tanks.
Toxic, Local (NOx) and GHG emissions

## EtOH

**Green Ethanol**

An Ethanol engine is being investigated. Ethanol testd in March 2024.

Verified: 2024
Volume ramp-up:
Non-pressurised tanks.
Toxic, Local (NOx) and GHG emissions

## $NH_3$

**Green Ammonia**

Combustion concepts to maximise engine performance and related safety technologies are currently being investigated

Tech ready: 2023
Volume ramp-up: 2025
Non-cryogenic but toxic.
No rules & regulations
Local (NOx) and GHG emissions

## $H_2$

**Green Hydrogen**

Our gas engines are already able to blend up to 25% hydrogen in LNG, and combustion concepts under work for 100% hydrogen. Pure Hydrogen on 70% of typical marine engine load achieved already

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

Storage of LH2 at -253 C
Local emissions (NOx)

# Ammonia as marine fuel

At atmospheric temperature and pressure ammonia is a gas, that is lighter than air

Ammonia is colourless, toxic and has a strong smell which can be noticed at 5-50 ppm (severe irritation and/or burns to the eyes, nose, throat and skin occurs at 400-700 ppm)

Ammonia is corrosive - careful material selection is required

Ammonia is flammable, but hard to ignite

Lower heating value 18.6 MJ/kg

Ammonia is a carbon free fuel and when produced with renewable energy total GHG emissions are significantly reduced

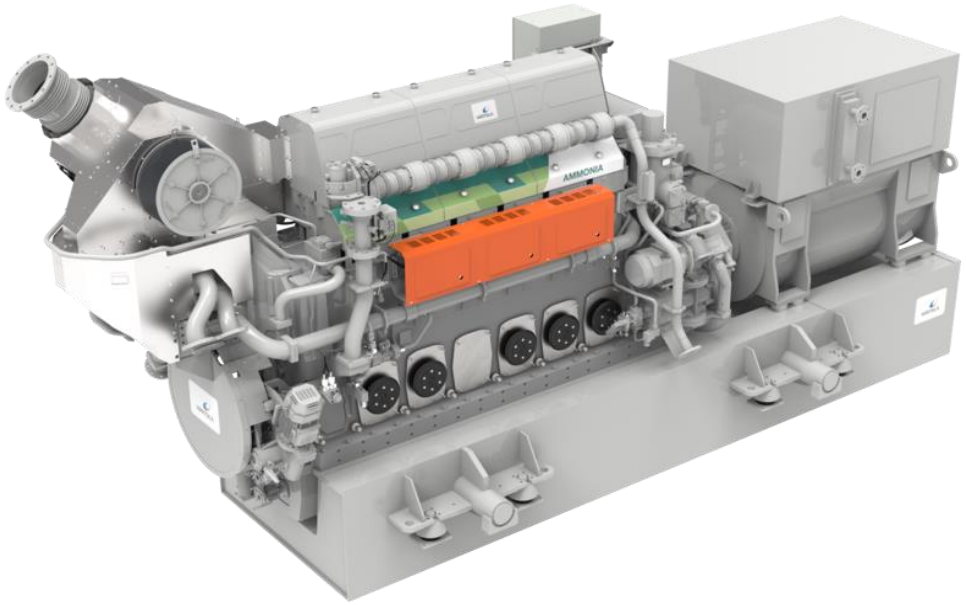
Higher heating power needed to evaporate ammonia, compared to LNG

# Ammonia bunkering availability


Source: DNV Energy Transition Outlook 2023, Maritime Forecast to 2050

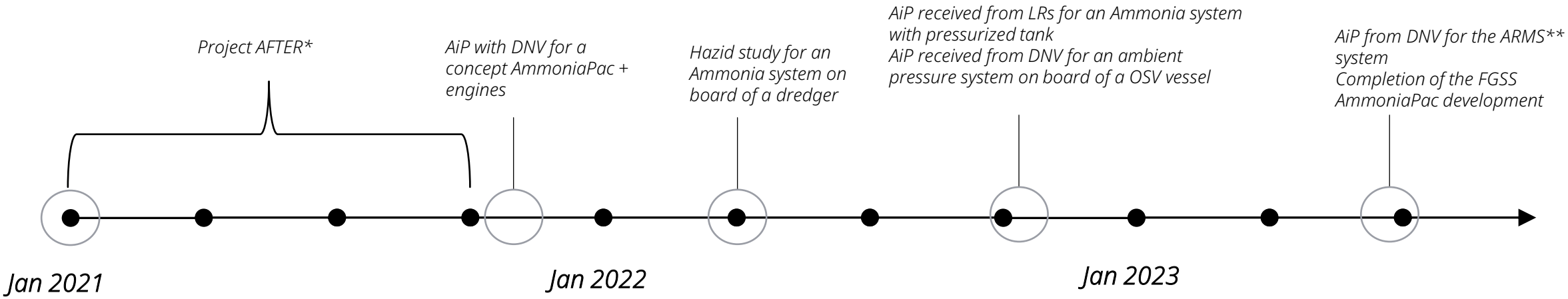
# Wärtsilä 25 on Ammonia

The marine sector's first 4-stroke solution for ammonia fuel





- Ammonia engine technology based on LNG fuelled Wärtsilä 25DF engine ranging from 1.7 MW to 2.7 MW.
- ≥ 70% less greenhouse gas emissions with sustainable ammonia compared to diesel → meeting current EU targets until 2050 and exceeding the IMO target for 2040
- The Wärtsilä 25 Ammonia solution delivered together with Wärtsilä's fuel supply system, AmmoniaPac and aftertreatment, Wärtsilä NOx Reducer



# Wärtsilä 25 – the engine with true flexibility

| | Wärtsilä 25 | | Wärtsilä 25DF | | Wärtsilä 25 Ammonia | |
|---|---|---|---|---|---|---|
| Cylinder bore (mm) | 250 | | 250 | | 250 | |
| Piston stroke (mm) | 340 | | 340 | | 340 | |
| Nom speed (rpm) | 900 | 1 000 | 900 | 1 000 | 900 | 1 000 |
| Power / cyl. (kW) | 345 | 375 | 315 | 345 | 280 | 305 |
| BMEP (MPa) | 2.72 | 2.70 | 2.52 | 2.48 | 2.24 | 2.19 |
| 6L power (kWm) | 2 070 | 2 250 | 1 890 | 2 070 | 1 680 | 1 830 |
| 7L power (kWm) | 2 415 | 2 625 | 2 205 | 2 415 | 1 960 | 2 135 |
| 8L power (kWm) | 2 760 | 3 000 | 2 520 | 2 760 | 2 240 | 2 440 |
| 9L power (kWm) | 3 105 | 3 375 | 2 835 | 3 105 | 2 520 | 2 745 |
| Application | DM, DE, AUX | | DE, AUX | DM, DE, AUX | DE, AUX | |

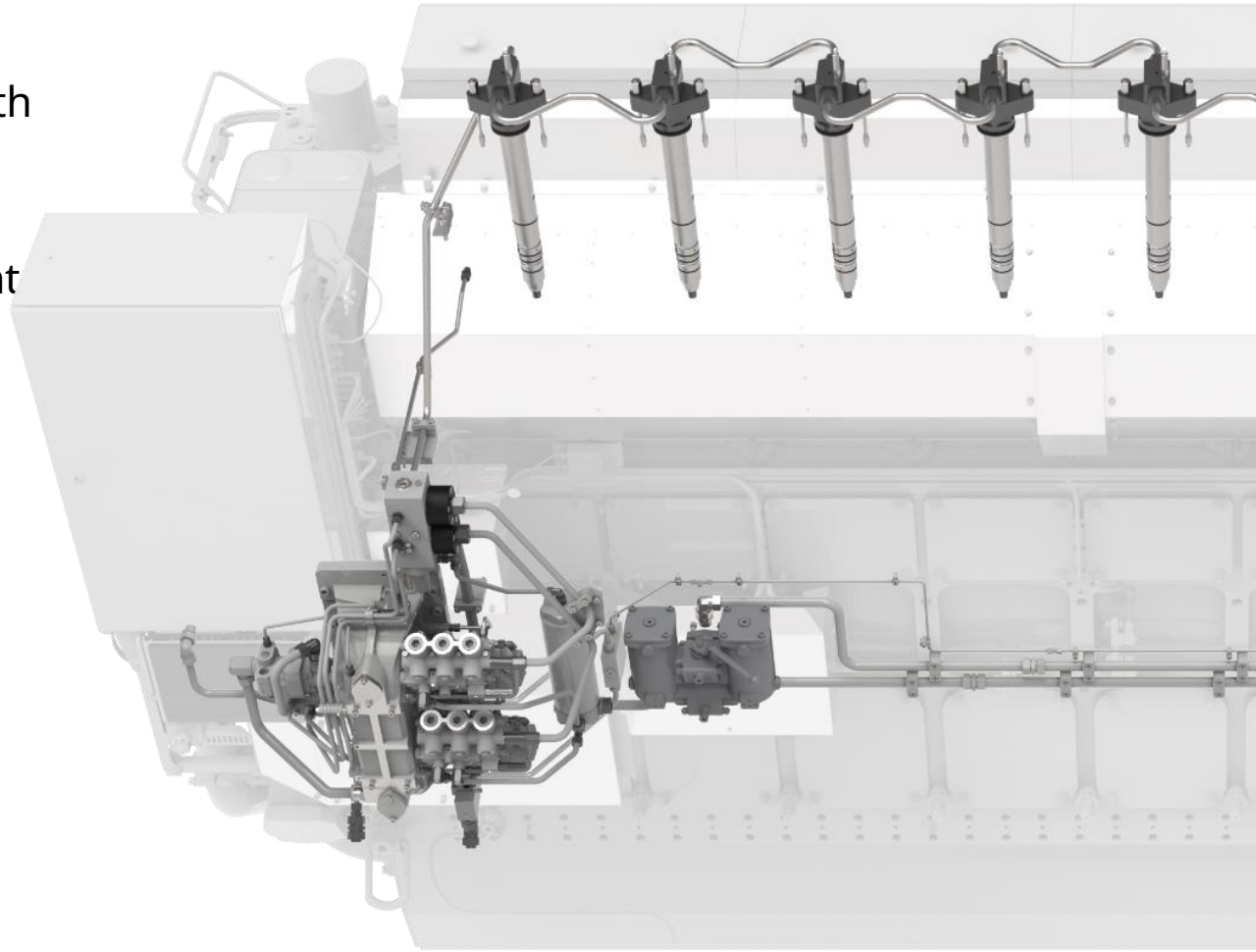
# Modular engine platform with latest technologies

Fuel systems

- New generation common rail fuel injection technology with high pressures for ideal combustion
- No separate pilot injector
- Optimized gas admission settings for each operating point with cylinder wise combustion control
- Smokeless operation in all conditions

Valve train

- Variable valve timing providing flexibility is an enabler for combustion of future fuels and low emission optimization



# Look to flexibility and future proofing with modular structure

WÄRTSILÄ

**Exhaust gas & charge air system**

M0001 M0002
M0003 M0004
M0005 M0006
M0007 M0008
M009 M0010
M0011 M0013
M0014 M0015
M0016 M0017
M0018 M0021
M0051 M0052
M0103 M0104
M0116 M0133
M0139 M0140
M0142 M0143
M0144 M0145
M0147 M0160
M0162 M0179
M0195 M0226
M0396

**Control system**

M0112 M0123
M0154

**Cooling water system**

M0089 M0096
M0097 M0105
M0106 M0115
M0150 M0156

**Installation dependent equipment**

M0029 M0039
M0134 M0135
M0174 M0188

**Starting air system**

M0086 M0087
M0102 M0153
M0158

**Lubricating oil equipment**

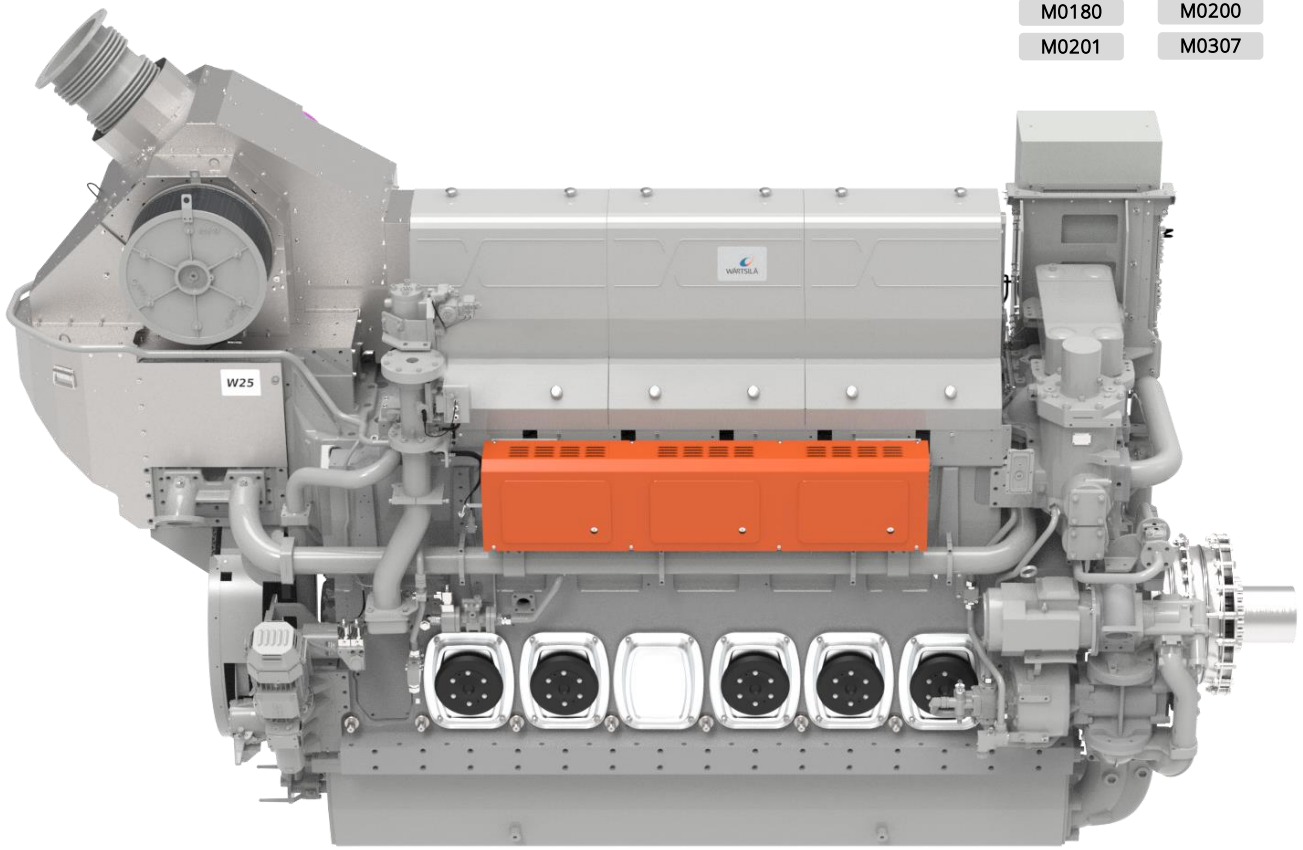
M0012 M0043
M0090 M0091
M0092 M0093
M0094 M0095
M0098 M0101
M0157 M0159
M0167 M0168
M0170 M0171
M0180 M0200
M0201 M0307

**Fuel system**

M0053 M0056
M0065 M0066
M0067 M0068
M0069 M0070
M0071 M0072
M0074 M0076
M0077 M0078
M0079 M0081
M0137 M0146
M0148 M0161
M0163 M0165
M0169 M0175
M0193 M0408

**Main components**

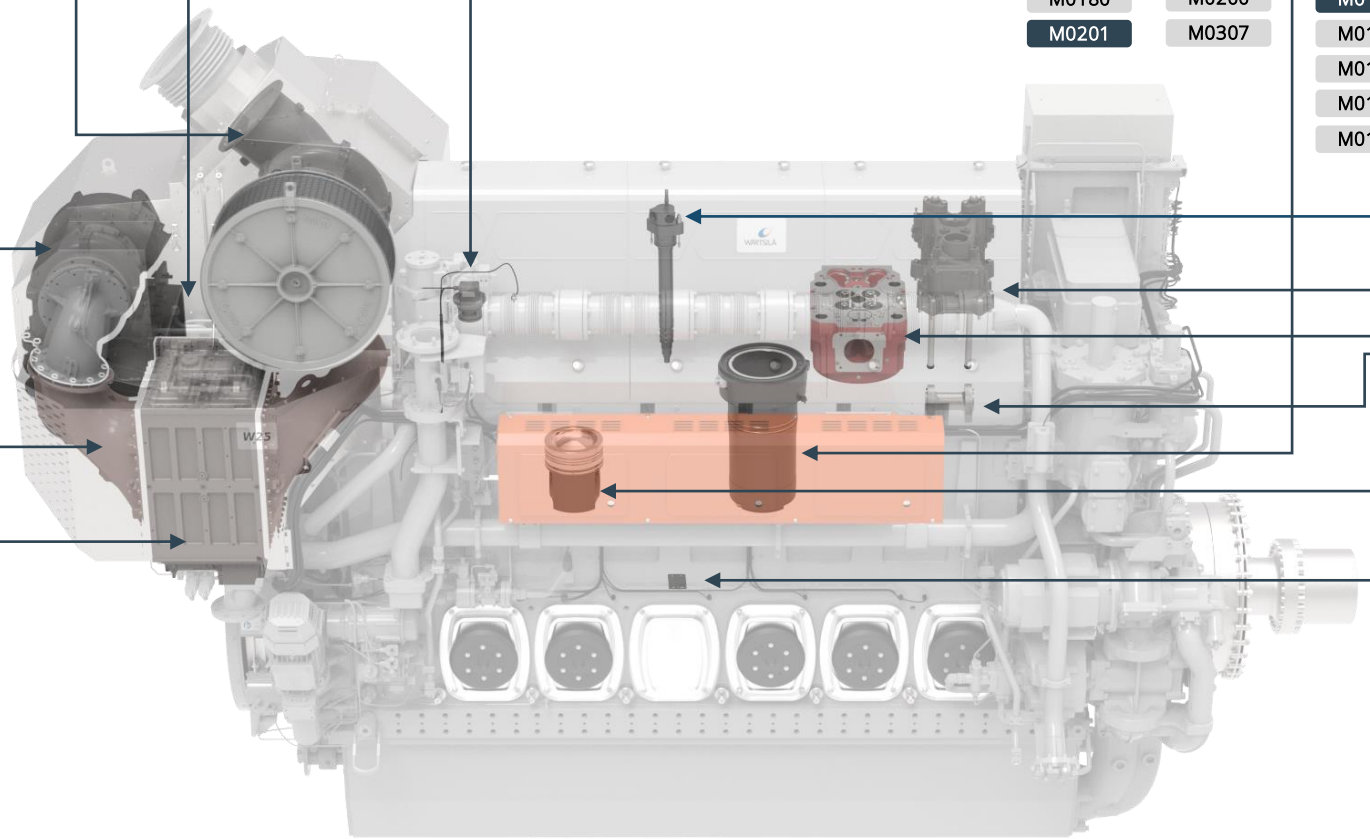
M0022 M0023
M0024 M0025
M0026 M0027
M0028 M0030
M0031 M0032
M0033 M0034
M0035 M0036
M0037 M0038
M0040 M0041
M0042 M0044
M0045 M0046
M0047 M0048
M0049 M0050
M0054 M0055
M0057 M0058
M0059 M0060
M0061 M0062
M0063 M0064
M0073 M0080
M0082 M0083
M0084 M0085
M0088 M0099
M0100 M0121
M0126 M0136
M0138 M0141
M0149 M0151
M0152 M0155
M0164 M0172
M0178 M0190
M0222 M0402
M0404 M0405
M0406 M0407




**Automation system**

M0019 M0020
M0075 M0107
M0108 M0109
M0110 M0111
M0113 M0114
M0117 M0118
M0119 M0120
M0122 M0124
M0125 M0127
M0128 M0129
M0130 M0131
M0132 M0166
M0173 M0176
M0177 M0181
M0182 M0183
M0184 M0185
M0186 M0187
M0189 M0194
M0196 M0197
M0198 M0199
M0213 M0214
M0215 M0216
M0397 M0398
M0399 M0400
M0401 M0410
M0645

# Modular structure – Diesel to DF conversion



## Exhaust gas & charge air system

M0001 M0003 M0005 M0007 M009 M0011 M0014 M0016 M0018 M0051 M0103 M0116 M0139 M0142 M0144 M0147 M0162 M0195 M0396

M0002 M0004 M0006 M0008 M0010 M0013 M0015 M0017 M0021 M0052 M0104 M0133 M0140 M0143 M0145 M0160 M0179 M0226

## Control system

M0112 M0154

M0123

## Cooling water system

M0089 M0097 M0106 M0150

M0096 M0105 M0115 M0156

## Installation dependent equipment

M0029 M0134 M0174

M0039 M0135 M0188

## Starting air system

M0086 M0102 M0158

M0087 M0153

## Lubricating oil equipment

M0012 M0090 M0092 M0094 M0098 M0157 M0167 M0170 M0180 M0201

M0043 M0091 M0093 M0095 M0101 M0159 M0168 M0171 M0200 M0307

## Fuel system

M0053 M0065 M0067 M0069 M0071 M0074 M0077 M0079 M0137 M0148 M0163 M0169 M0193

M0056 M0066 M0068 M0070 M0072 M0076 M0078 M0081 M0146 M0161 M0165 M0175 M0408

## Main components

M0022 M0024 M0026 M0028 M0031 M0033 M0035 M0037 M0040 M0042 M0045 M0047 M0049 M0054 M0057 M0059 M0061 M0063 M0073 M0082 M0084 M0088 M0100 M0126 M0138 M0149 M0152 M0164 M0178 M0222 M0404 M0406

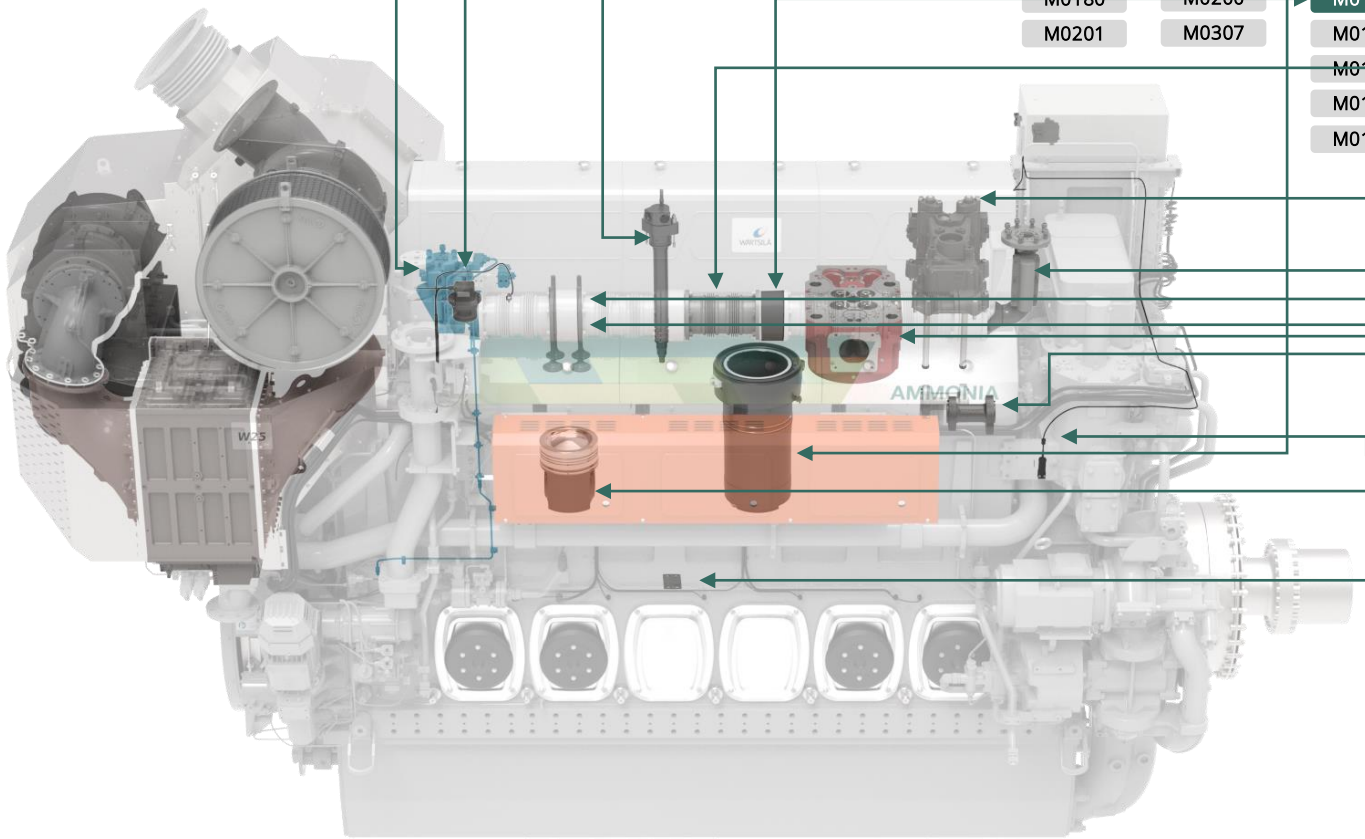
M0023 M0025 M0027 M0030 M0032 M0034 M0036 M0038 M0041 M0044 M0046 M0048 M0050 M0055 M0058 M0060 M0062 M0064 M0080 M0083 M0085 M0099 M0121 M0136 M0141 M0151 M0155 M0172 M0190 M0402 M0405 M0407

## Automation system

M0019 M0075 M0108 M0110 M0113 M0117 M0119 M0122 M0125 M0128 M0130 M0132 M0173 M0177 M0182 M0184 M0186 M0189 M0196 M0198 M0213 M0215 M0397 M0399 M0401 M0645

M0020 M0107 M0109 M0111 M0114 M0118 M0120 M0124 M0127 M0129 M0131 M0166 M0176 M0181 M0183 M0185 M0187 M0194 M0197 M0199 M0214 M0216 M0398 M0400 M0410

# Modular structure – DF to Ammonia conversion




**Exhaust gas & charge air system**

M0001 M0002 M0003 M0004 M0005 M0006 M0007 M0008 M009 M0010 M0011 M0013 M0014 M0015 M0016 M0017 M0018 M0021 M0051 M0052 M0103 M0104 M0116 M0133 M0139 M0140 M0142 M0143 M0144 M0145 M0147 M0160 M0162 M0179 M0195 M0226 M0396

**Control system**

M0112 M0123 M0154

**Cooling water system**

M0089 M0096 M0097 M0105 M0106 M0115 M0150 M0156

**Installation dependent equipment**

M0029 M0039 M0134 M0135 M0174 M0188

**Starting air system**

M0086 M0087 M0102 M0153 M0158

**Lubricating oil equipment**

M0012 M0043 M0090 M0091 M0092 M0093 M0094 M0095 M0098 M0101 M0157 M0159 M0167 M0168 M0170 M0171 M0180 M0200 M0201 M0307

**Fuel system**

M0053 M0056 M0065 M0066 M0067 M0068 M0069 M0070 M0071 M0072 M0074 M0076 M0077 M0078 M0079 M0081 M0137 M0146 M0148 M0161 M0163 M0165 M0169 M0175 M0193 M0408

**Main components**

M0022 M0023 M0024 M0025 M0026 M0027 M0028 M0030 M0031 M0032 M0033 M0034 M0035 M0036 M0037 M0038 M0040 M0041 M0042 M0044 M0045 M0046 M0047 M0048 M0049 M0050 M0054 M0055 M0057 M0058 M0059 M0060 M0061 M0062 M0063 M0064 M0073 M0080 M0082 M0083 M0084 M0085 M0088 M0099 M0100 M0121 M0126 M0136 M0138 M0141 M0149 M0151 M0152 M0155 M0164 M0172 M0178 M0190 M0222 M0402 M0404 M0405 M0406 M0407

**Automation system**

M0019 M0020 M0075 M0107 M0108 M0109 M0110 M0111 M0113 M0114 M0117 M0118 M0119 M0120 M0122 M0124 M0125 M0127 M0128 M0129 M0130 M0131 M0132 M0166 M0173 M0176 M0177 M0181 M0182 M0183 M0184 M0185 M0186 M0187 M0189 M0194 M0196 M0197 M0198 M0199 M0213 M0214 M0215 M0216 M0397 M0398 M0399 M0400 M0401 M0410 M0645

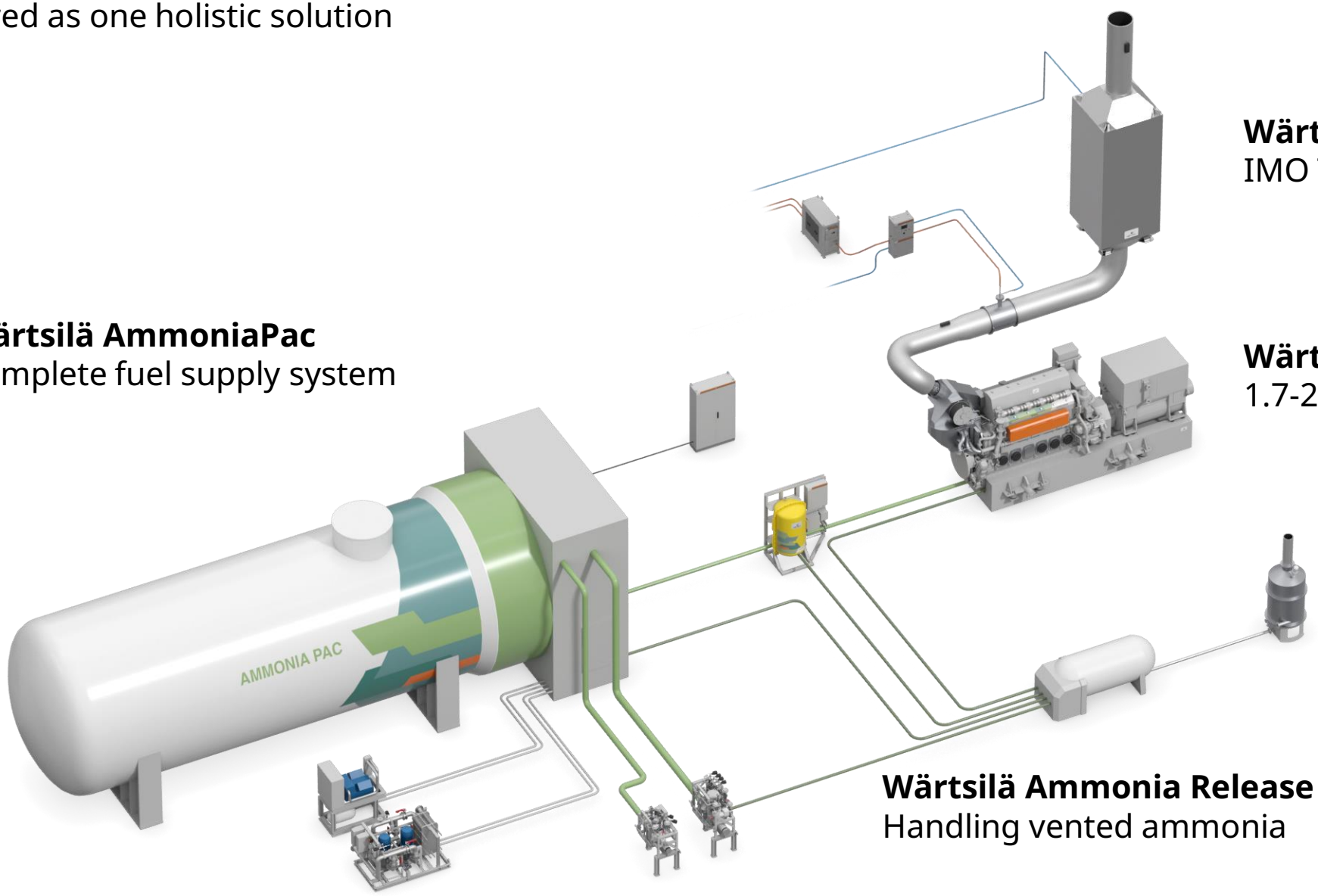
# System overview

Engineered as one holistic solution

**Wärtsilä NOx Reducer**
IMO Tier II / Tier III

**Wärtsilä 25 Ammonia**
1.7-2.7MW

**Wärtsilä AmmoniaPac**
Complete fuel supply system




**Wärtsilä Ammonia Release Mitigation System**
Handling vented ammonia

# AmmoniaPac – fuel supply system

Based on the well proven LNGPac design - a safe and user-friendly system for both operators and service personnel

Type-C Ammonia fuel storage tank(s)

- Single shell in carbon steel or stainless steel
- 20 bar(g) design pressure
  - Bunker Ammonia at any temperature
  - Unlimited holding time without auxiliary systems
- 9 bar(g) design pressure
  - Bunker mainly refrigerated Ammonia
  - Limited holding time (15/21 days) without auxiliary systems

Tank connection space

- Contains pump based fuel processing system
- Delivers gasous ammonia at ~9 bar(g) to GVU
- Double manhole enclosure and integrated airlock enables safe installation below deck

# AmmoniaPac – fuel supply system (cont.)

Bunkering and vapor return skids

- Sizes up to DN100 available, larger upon request
- Based on standard skid design from LNGPac

Subcooling unit

- Provides cooling of Ammonia in the storage tank
- Enables unlimited holding time for 9 barg tank system

Heating media system

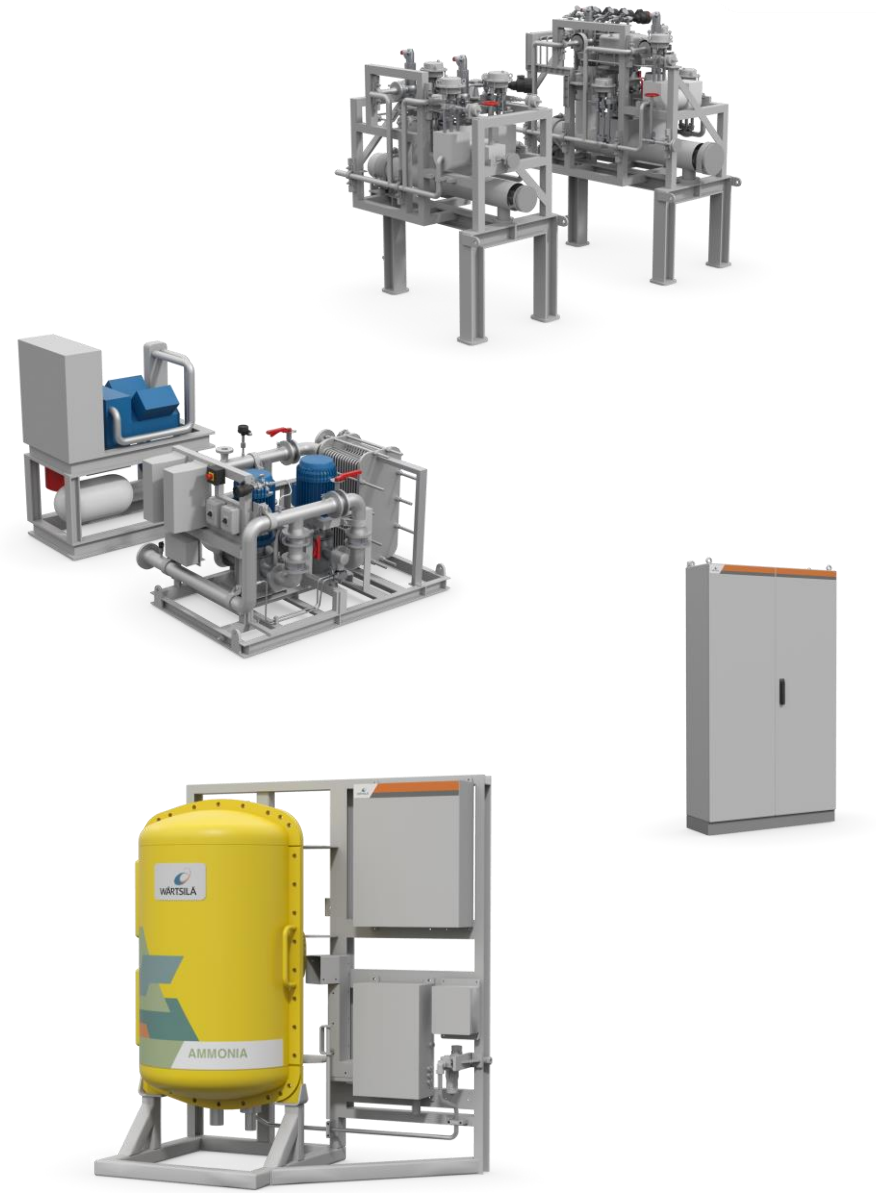
- Provides heat for vaporization and heating of the Ammonia fuel

AmmoniaPac Control and Automation System

- PLC-based control system with independent safety system
- Same platform as LNGPac with fully remote operation

Gas Valve Unit (GVU-ED)

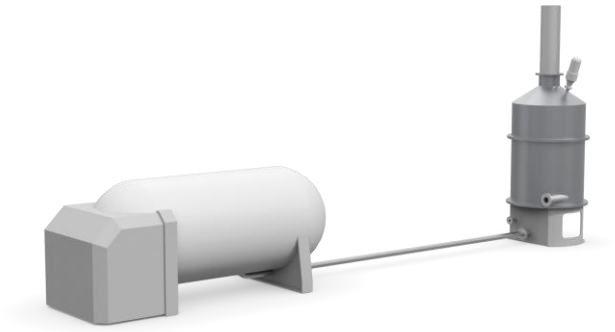
- Filters and regulates the gas pressure to each engine according to load requirement
- Can also be integrated into the TCS



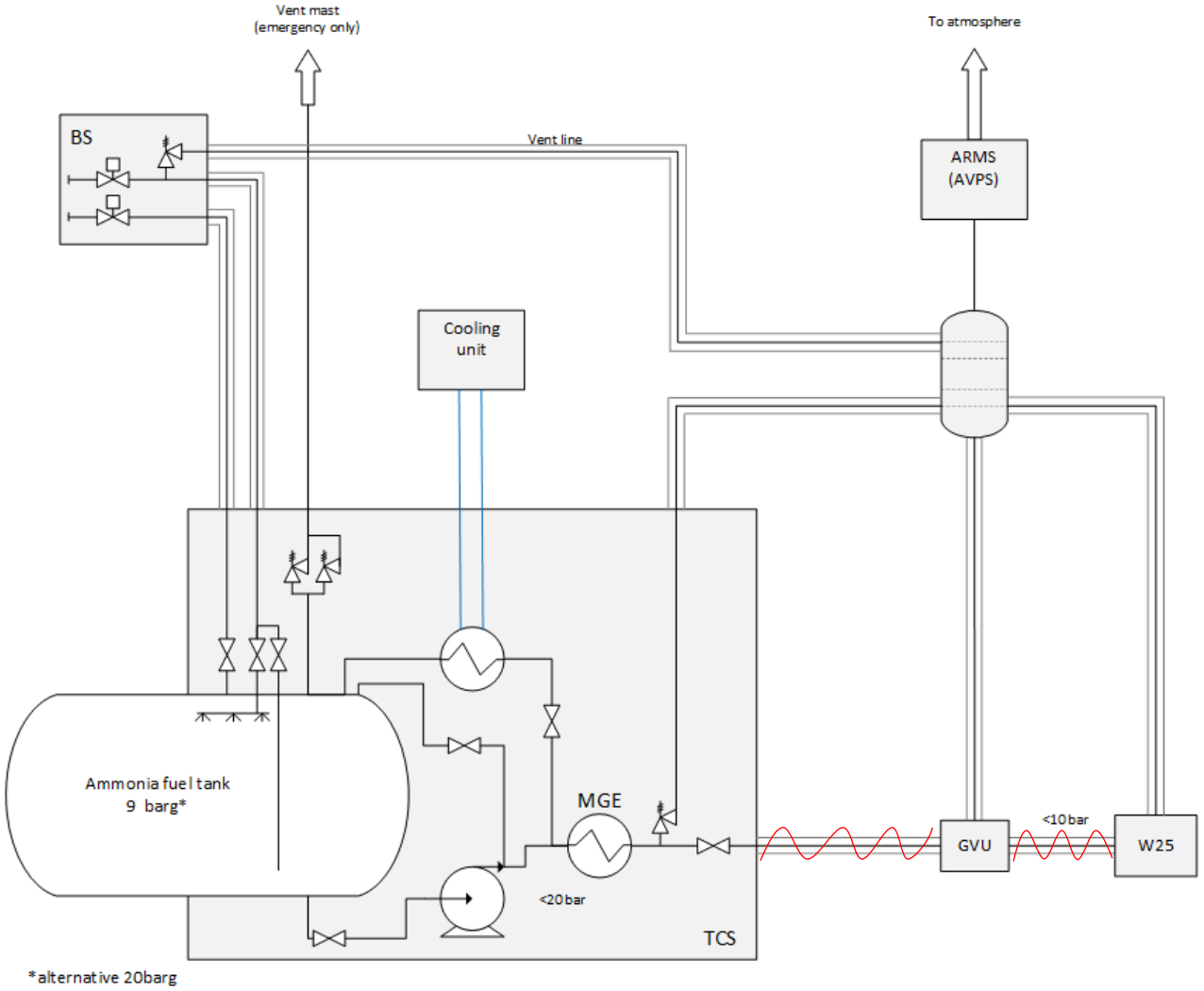
# AmmoniaPac – fuel gas supply system (cont.)

Wärtsilä Ammonia Release Mitigation System (WARMS)

- All vented Ammonia from the system is led to the ARMS collection tank (except tank PRVs)
- The collected gas is burned off in the burner, resulting in practically zero emissions
- Uses ammonia as pilot fuel to avoid additional CO2 emissions



Heating added on fuel piping to GVU and engine to keep Ammonia from condensing



# NOR - Aftertreatment System

Optimized for both ammonia mode and diesel mode

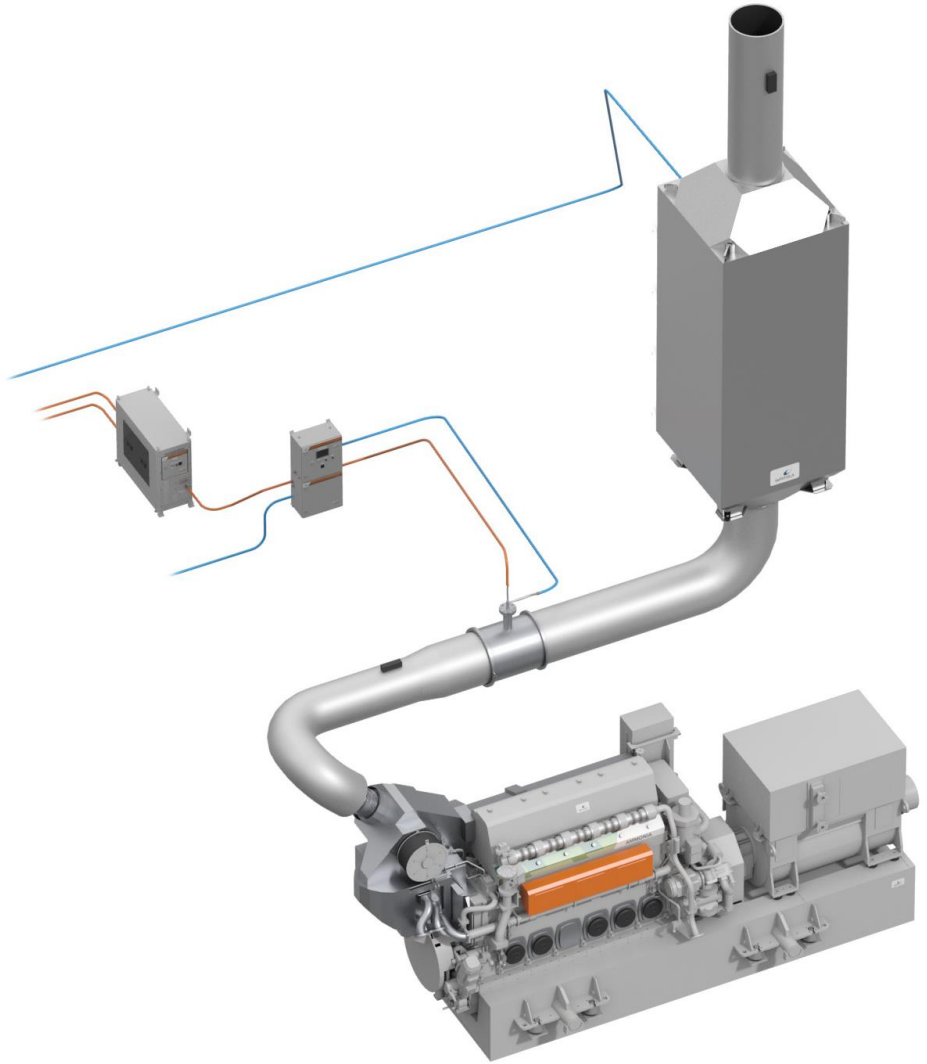
The NOR system consist of a mixing unit, reactor with catalyst elements and auxiliary system for dosing and control

Common automation platform for engine and NOR system

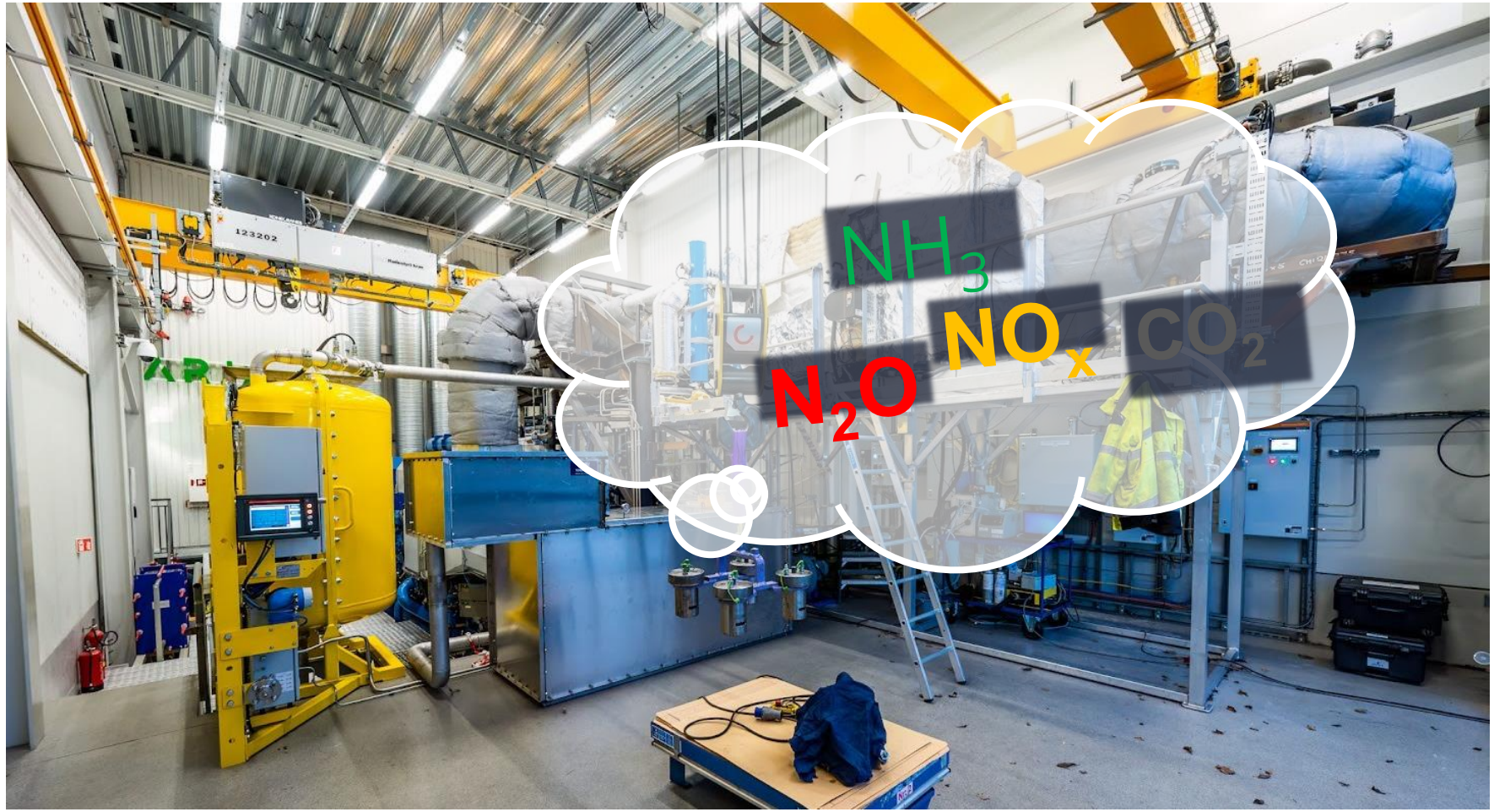
Continuous emission measurements for control purpouses

Reactor equipped with automatic soot blowing

For engine conversion cases, evaluation of possible installed NOx Reducer evaluated on case by case basis



# Ongoing Testing – Ammonia Technology




**ACHIEVEMENTS**

70-95% Ammonia share

70-94% GHG reduction

$N_2O$ < 5ppm (after SCR)

NOx = (**Tier III**)

# Ammonia safety - accumulated knowledge

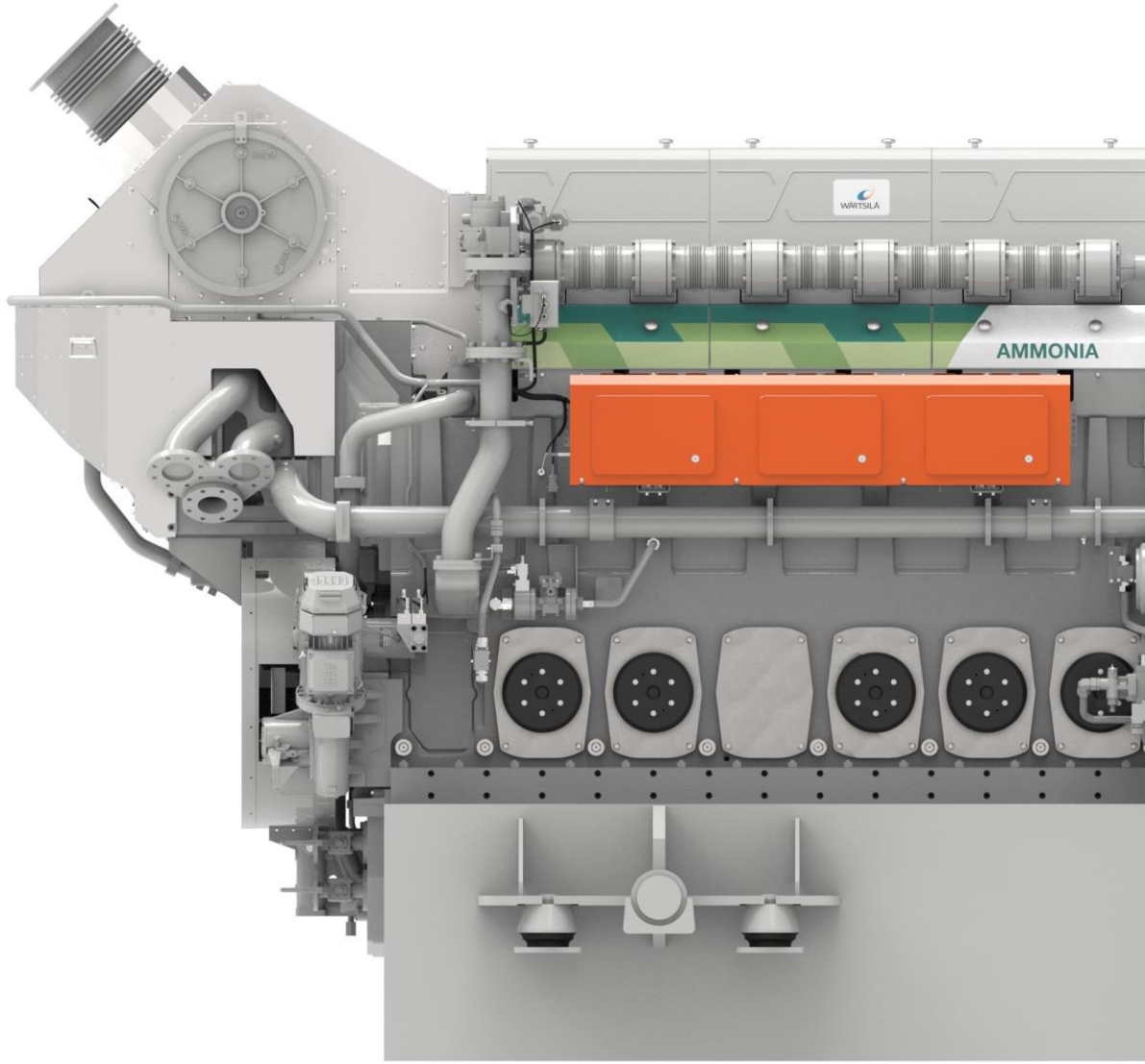


# Safe and reliable operations ensured

- Foundation for the ammonia solution is well proven LNG safety principles
- Safety concept developed together with classification societies
- Due to the toxicity of ammonia the main difference to LNG DF are the maintenance procedures and additional isolation valves for the fuel gas supply system
- PPE to be easily available, including gas detection
- In normal operation personnel can enter engine room when engine is running. Engine start and stop in diesel mode
- Integrated automation system ensuring safe operations
- Wärtsilä offers training services and a global service network available 24/7

# Key takeaways

- ✓ Total greenhouse gas emissions reduced at minimum 70%
- ✓ Dual-fuel technology with full flexibility to run in ammonia mode or diesel mode
- ✓ Complete solution - fuel gas supply system, engine and aftertreatment system
- ✓ Integrated automation system ensuring safe operations
- ✓ Wärtsilä offers training services and a global service network available 24/7

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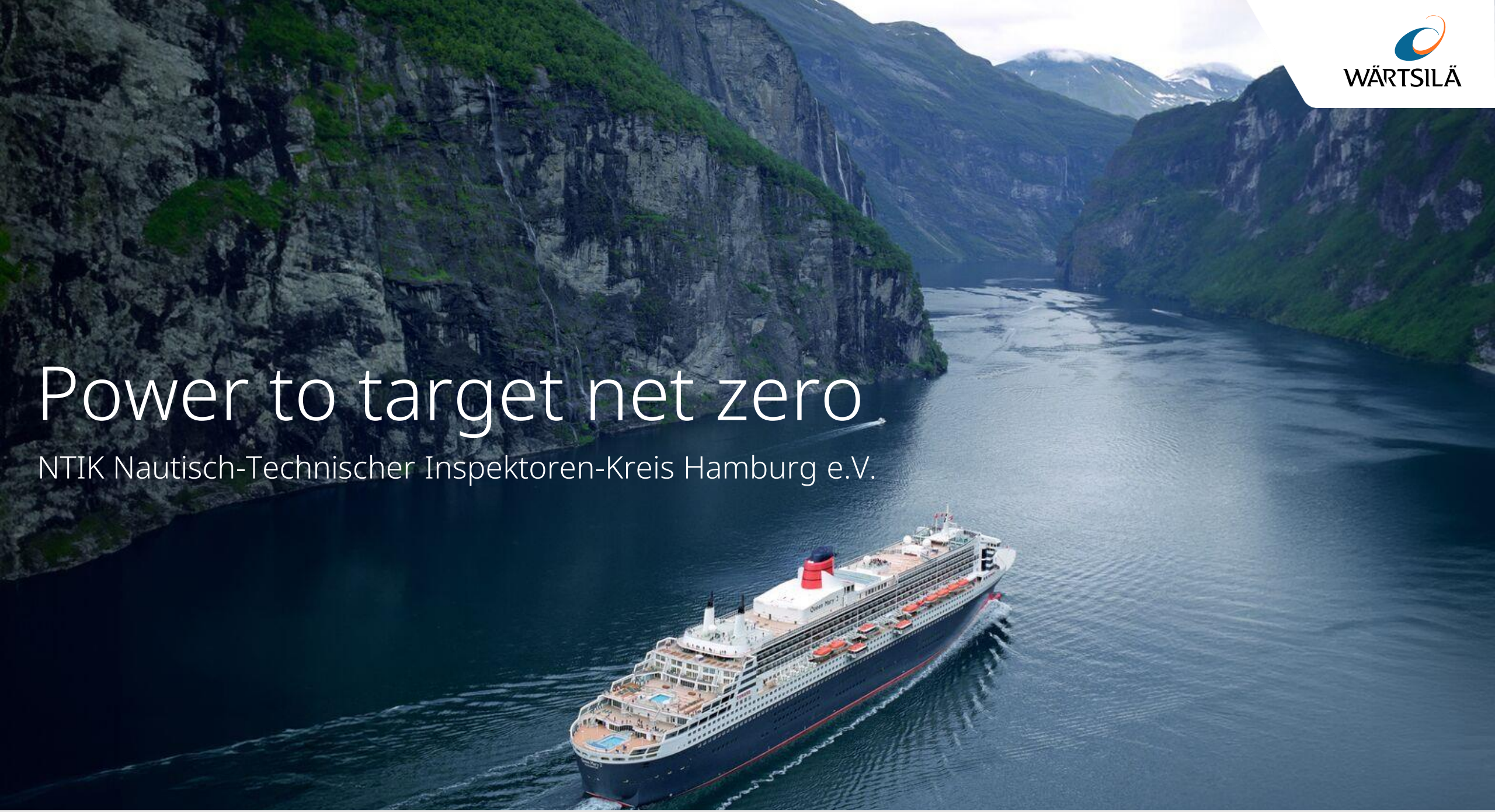

# Power to target net zero

NTIK Nautisch-Technischer Inspektoren-Kreis Hamburg e.V.