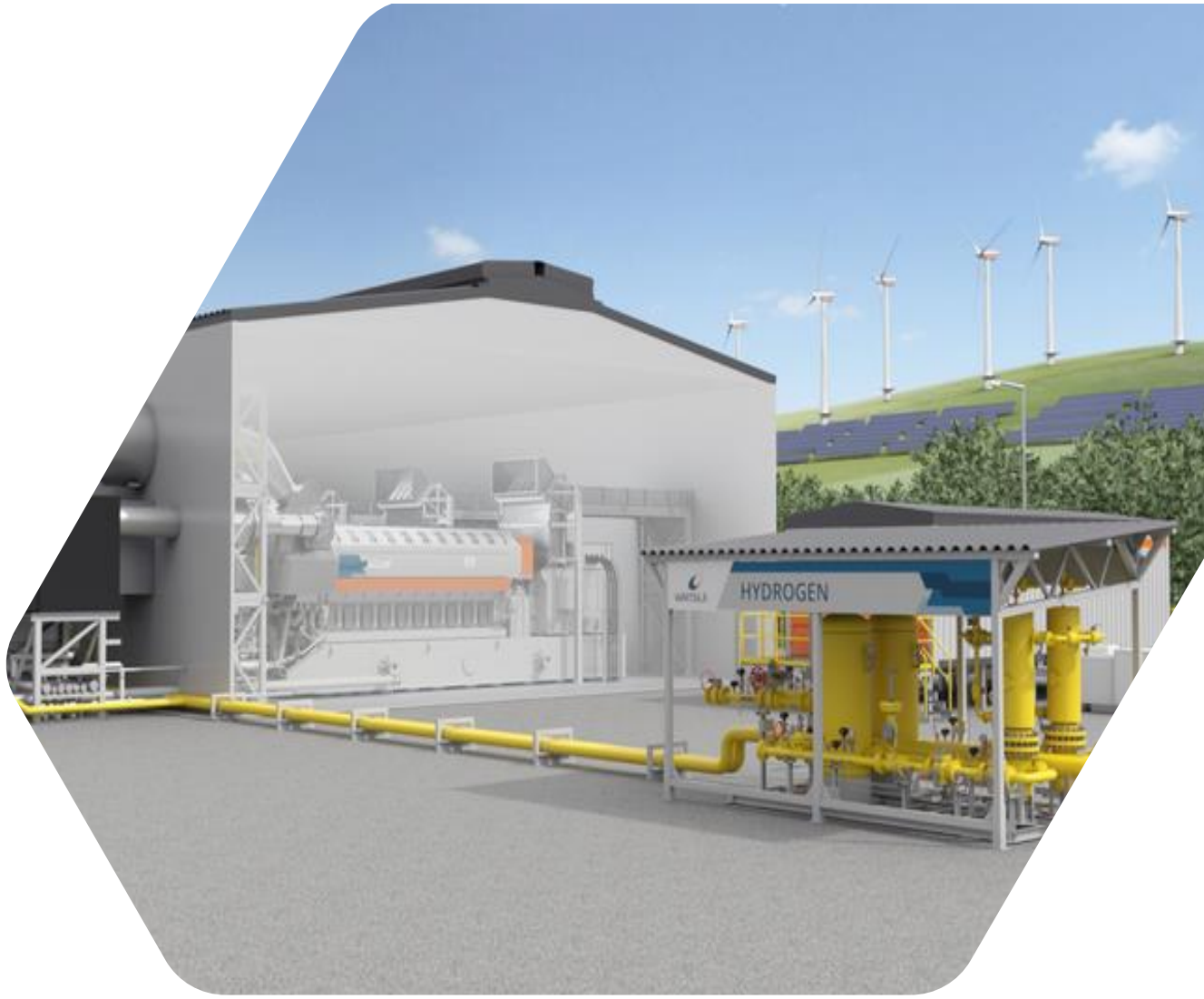
Decarbonisation with sustainable fuels



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Decarbonisation is feasible with current technologies

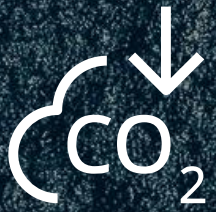
We already have the technologies needed for net zero power systems

- Wind and solar
- Energy storage
- Flexible power plants
- Sustainable fuels

25%
hydrogen blending is possible

Emission limits met

No modification on the engine



~10% CO_2 reduction is a reasonable first target

150+ methanol engines sold

Fuel flexibility is the key to deal with uncertainities

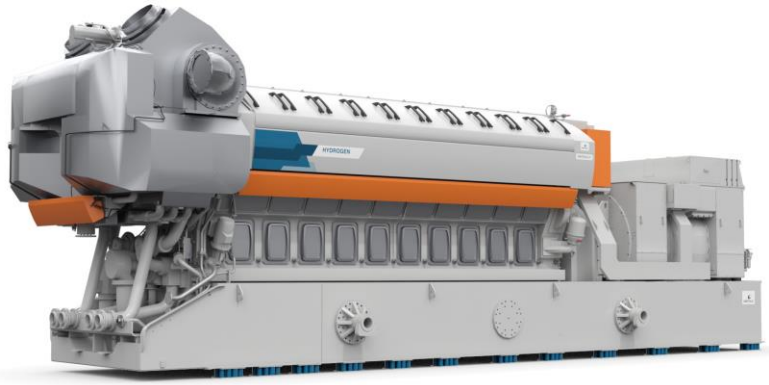
World’s first large scale hydrogen engine power plant

We have **launched world’s first large scale hydrogen engine power plant** to the market to address the need to decarbonise the energy sector.

Introducing two hydrogen engines

Wärtsilä 31SG-H_2 hydrogen-ready engine

Wärtsilä 31H_2 pure hydrogen engine



Natural gas + Hydrogen ready	Hydrogen + Natural gas
0-25 vol-% hydrogen in natural gas	0-100 vol-% natural gas in hydrogen
Conversion option to run on 100% hydrogen	

- Engines are expected to be available for orders in 2025, and available for delivery from 2026.
- Switching fuel from natural gas to pure hydrogen will impact the engine performance such as output and efficiency, the exact impact will be communicated in conjunction with the sales release

Wärtsilä 31 installations

The pure hydrogen power plant concept is 3rd party certified by TÜV-SÜD

For plant owners and financiers, certification **improves investment security**

TÜV SÜD has established a guideline for H2-readiness of power plants and provides independent certification to original equipment manufacturers (OEMs) and plant builders (EPCs).

The certification covers the entire power plant, including:

- Fuel gas supply
- Gas engine (natural gas and H2)
- Exhaust gas system
- Combined heat and power
- Auxiliaries
- Building
- HVAC
- Instrumentation & Control
- Plant Performance
- Explosion protection
- Fire protection
- Hazard and risk analysis
- Conformity
- Permits

ZERTIFIKAT ◆ CERTIFICATE ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

TÜV SÜD

H_2-READINESS CONCEPT CERTIFICATE

The Certification Body of
TÜV SÜD Industrie Service GmbH
Energy and Systems

certifies, that the hydrogen readiness concept for the bidding phase of newly built and retrofitted power plants using the 31SG engine of the company

WÄRTSILÄ

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Hiilitaiturinkuja 2
00180 Helsinki, Finland

complies with the requirements
as defined in the TÜV SÜD guideline:

Certification Guideline H_2-Readiness of Gas Engine Power Plants,

Edition 2023 Rev.1.

The hydrogen readiness concept meets the requirements for the certification of hydrogen readiness for 100 vol.-% hydrogen.

This Certificate is based on the Audit Report 500604631 Rev.2 dated 07.06.2024.

This Certificate is valid till 10.06.2027.

Certificate – Register-No.: KC/500604631/32/24

Munich, 11.06.2024

Dr. Thomas Gallinger
Technical Certifier
Certification Body Energy and Systems

Katrin Hausmann
Certification Body
Energy and Systems

TÜV SÜD Industrie Service GmbH · Certification Body Energy and Systems · Westendstraße 199 · D-80686 Munich
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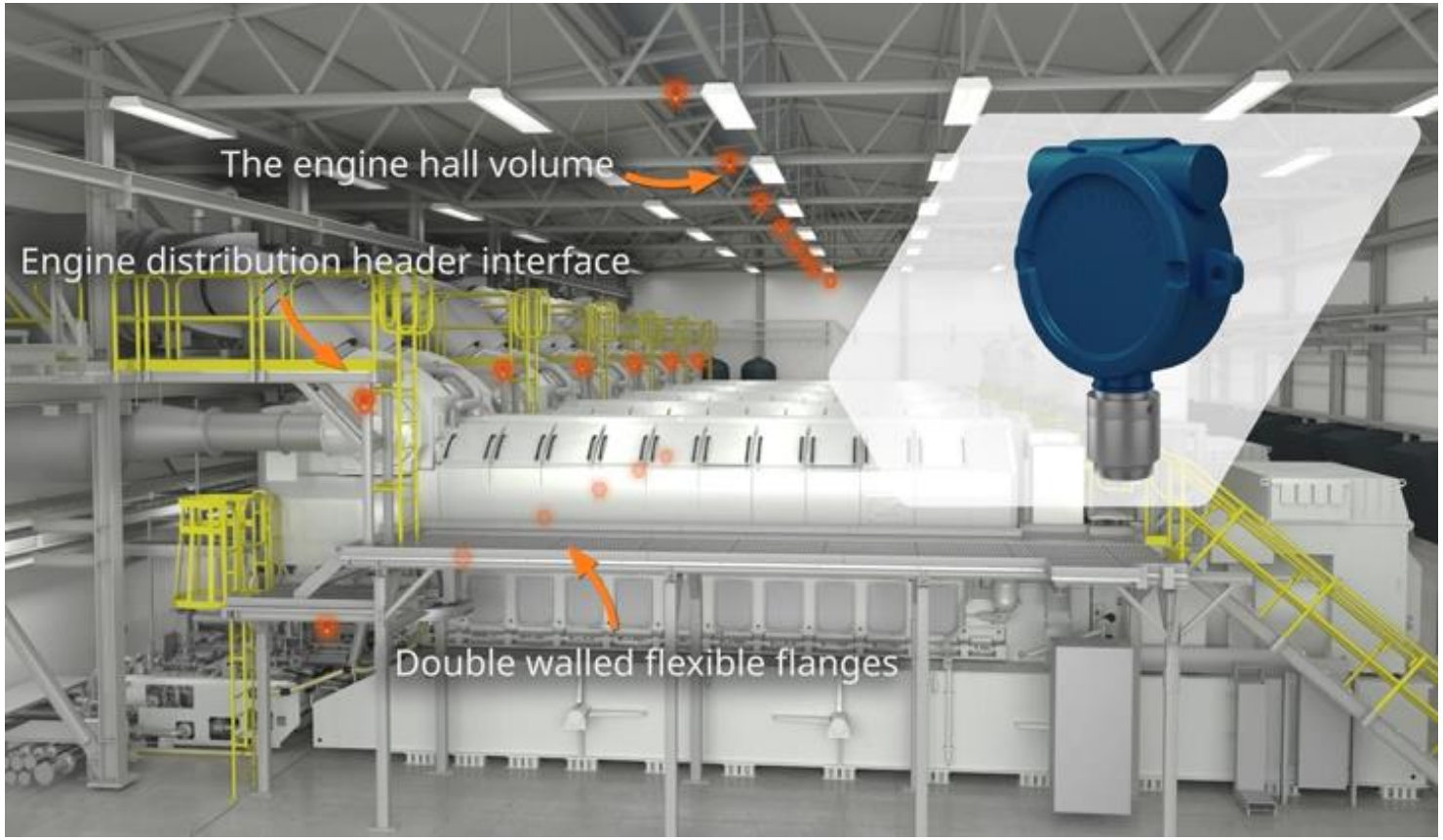
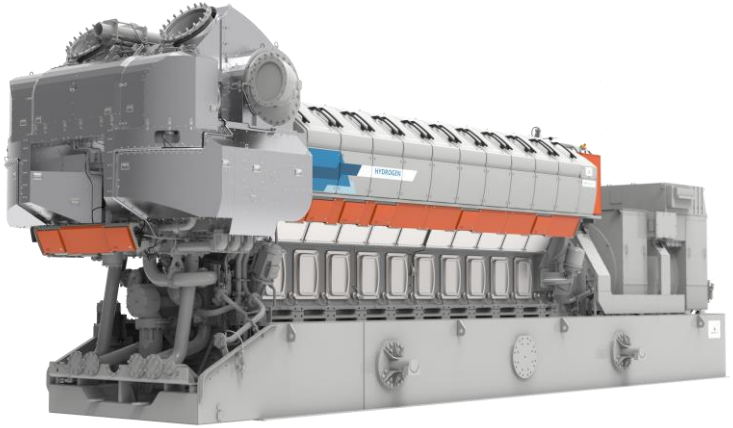
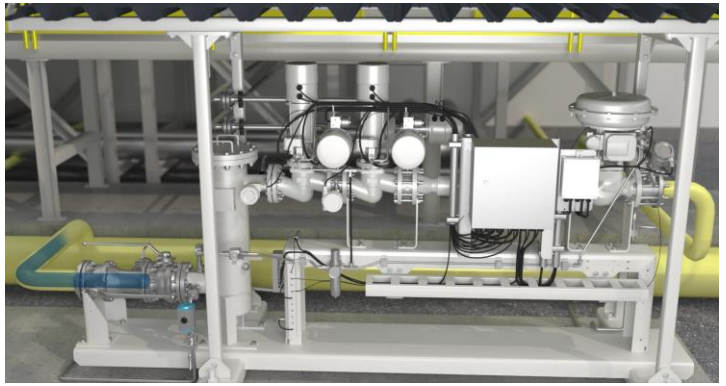
The main changes on the hydrogen power plant compared to natural gas

Are limited to the engine itself, fuel system as well changes to the safety monitoring/detection.







Systems affected when introducing pure hydrogen

Fuel gas supply system

- Materials (avoid H_2 embrittlement, explosion risk)
- Pressurisation

Engine top part

- Fuel-injection
- Cylinder heads
- Piston tops

Exhaust gas abatement

- Catalysts according to local requirements:
- SCR for NOx
- OXI for CO and VOC (only for natural gas)

Safety systems

- Explosion risks
- Outdoors
- Ventilation
- Double wall piping inside the engine hall
- H_2 sensoring

Balance of plant and fuel distribution

- H_2 gasgrid connection or
- H_2 onsite production with storage (not in Wärtsilä scope)

Sustainable fuels for existing plants

Decarbonisation has increased the uncertainty and business risk

Business risk driven by uncertainties related to politics, technology and infrastructure

Fuel flexibility key to deal with uncertainties

Hydrogen| Ammonia| Methanol | Ethanol

Fuel flexibility through multi-fuel capability as well as conversions

The journey towards zero carbon emissions has already started

CH_4

Bio- or Synthetic methane

Contains about 99% methane and can readily be used in liquid form with equipment made for LNG.

MeOH

Methanol / Ethanol

Released products: W9L32 (Marine)

Released conversion packges
W9L32 (Marine)
ZA40 (Marine)

A power plant 20V design for the W32 engine is under development

NH_3

Ammonia

Released products: W9L25DF (Marine)

Same technology can be industrialized for other DF engines and is being currently explored.

H_2

Hydrogen

Our gas engines are already able to blend LNG with up to 25% hydrogen.

An engine concept for 100% H2 is now under development and is expected to be ready by 2026.

Hydrogen – Blending in pipelines and onsite production

PRO's
- No CO2 emissions
- Relatively low production cost

CON's
- Low energy density by volume
- Difficult to transport by truck or marine vessels
- Storage expensive

Likely applications

1. Lower blends of hydrogen in natural gas pipelines
2. On-site production and storage of hydrogen for peaking and seasonal balancing purposes
3. Integration with industrial facilities with hydrogen availability
4. Europe, USA, Australia, India

Ammonia – The best way to transport hydrogen

PRO's
- No CO2 emissions
- More cost efficient than H2 considering transportation
- Engine performance

CON's
- Toxicity
- Supervision of production
- Challenging in residential areas

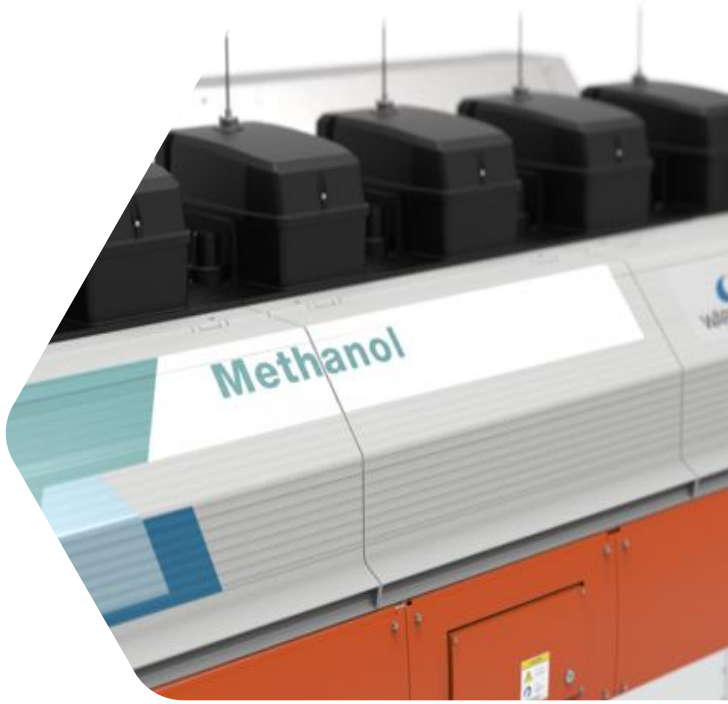
Likely applications

1. Remotely located power plants with w/o pipeline access and a need for long multi-modal fuel transports
2. Local air permits focused on stack CO2eq emissions
3. USA, Japan, Germany, Australia

Methanol/Ethanol – The “easy” fuel

PRO’s
- More cost efficient than H2 considering transportation
- Engine performance
- Methanol and ethanol can be used w/ the same technology

CON’s
- CO2 emissions
- Production includes CCU
- Supervision of production

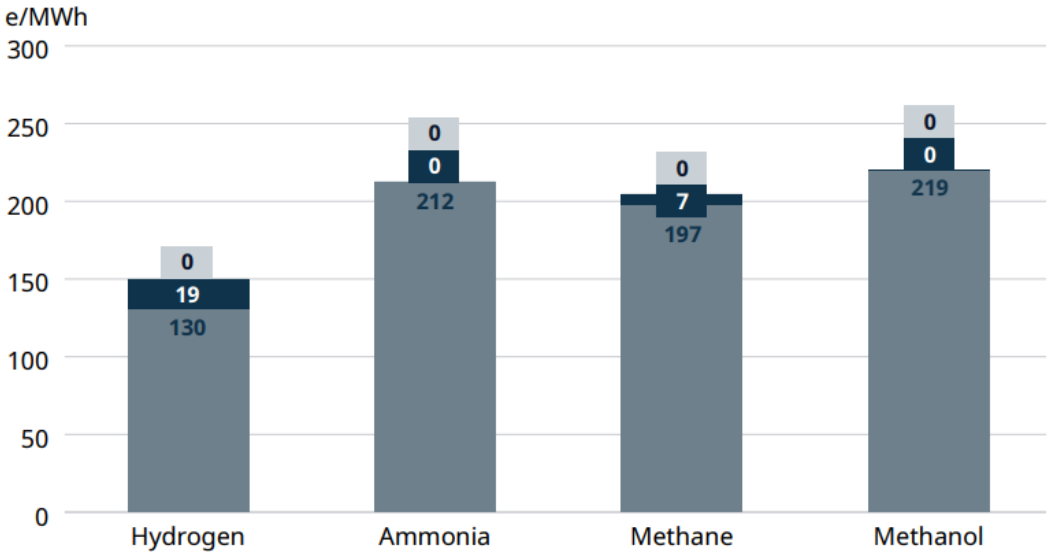


Likely applications

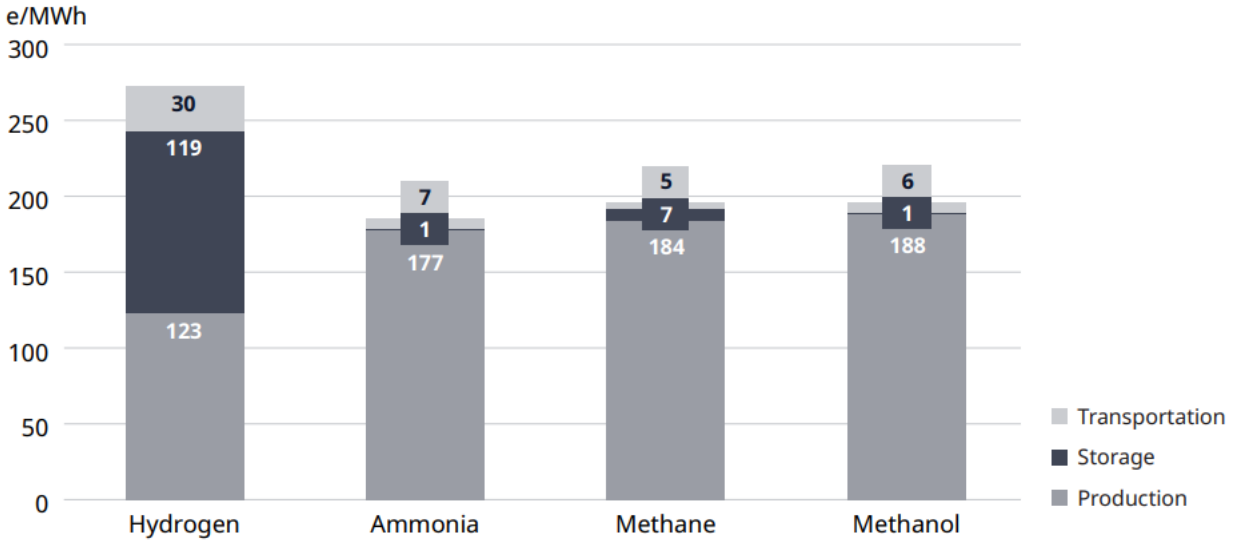
1. Power plants in the vicinity of population, with w/o pipeline access and a need for long multi-modal fuel transports
2. Local air permits focused on overall CO2eq emissions
3. Values the possibility of ethanol as an alternative fuel
4. USA, Europe, Brazil, India,

Cost of transportation and storage is one of the key factors

On-site production

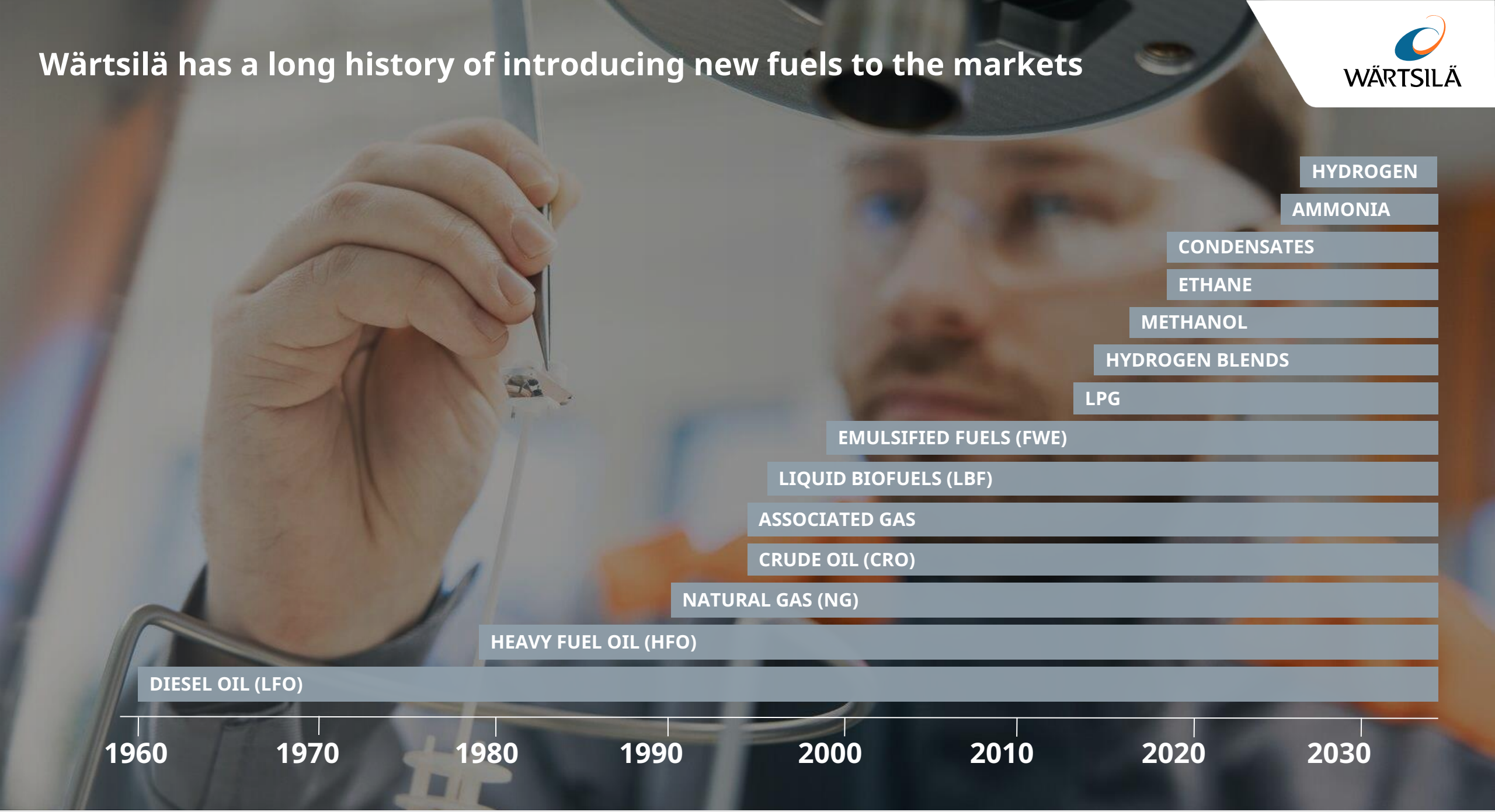


Off-site production with monthly on-site storage cycles and 200km transportation need



Ref: The feasibility of Power-to-X fuels for power generation, Wärtsilä, 2023

Wärtsilä has a long history of introducing new fuels to the markets



DEMONSTRATORS

Mitigate the political risk

Create concrete evidence for stakeholders and authorities of the capability of your plant to operate on sustainable fuels

HYDROGEN | AMMONIA | METHANOL | ETHANOL

Demonstrators are not ready solutions and instead short-term tests of various concepts, and the feasibility must be evaluated case-by-case

A giant leap towards decarbonisation

Together with WEC Energy Group we have successfully completed **hydrogen blend tests on an unmodified Wärtsilä engine.** The results were outstanding: engine efficiency improved when running on the 25 vol% hydrogen blend, while also reducing greenhouse gas emissions. This was a world's first, testifying that **Wärtsilä's technology can support the decarbonisation of the energy industry.**

25 vol%

H2 hydrogen blend with 95% engine load

9.1%

CO_2 CO_2 reductions at 95% load

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