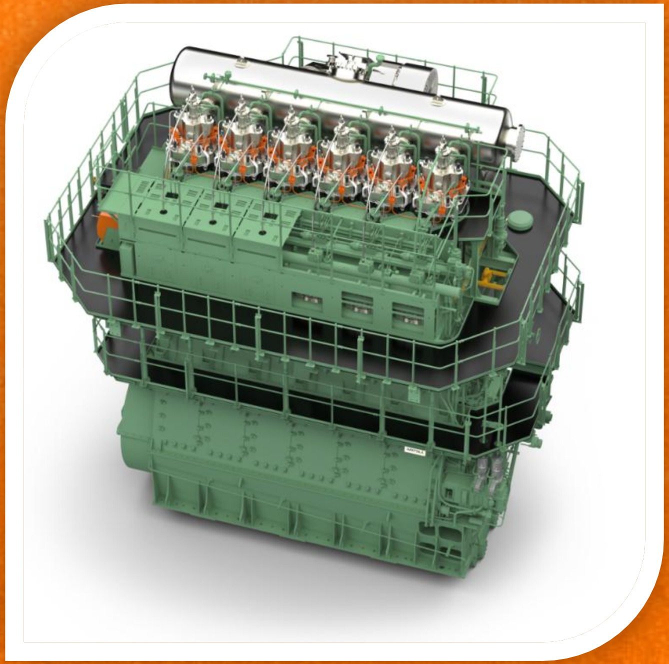
WÄRTSILÄ 2-STROKE DUAL FUEL

TECHNOLOGY RESPONDING TO CHANGING MARKET NEEDS

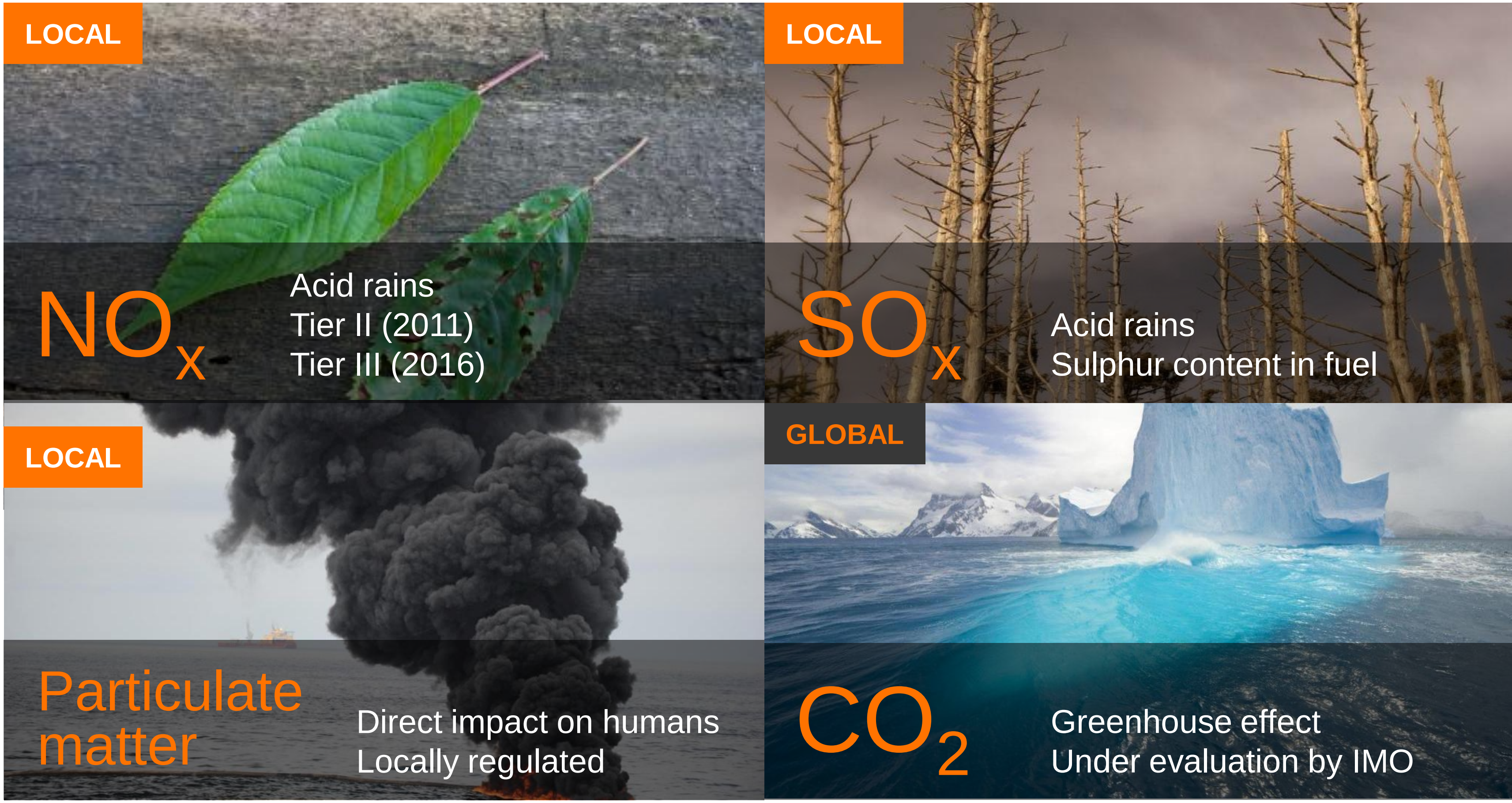


5TH CIMAC CASCADES, BUSAN

MARCEL OTT

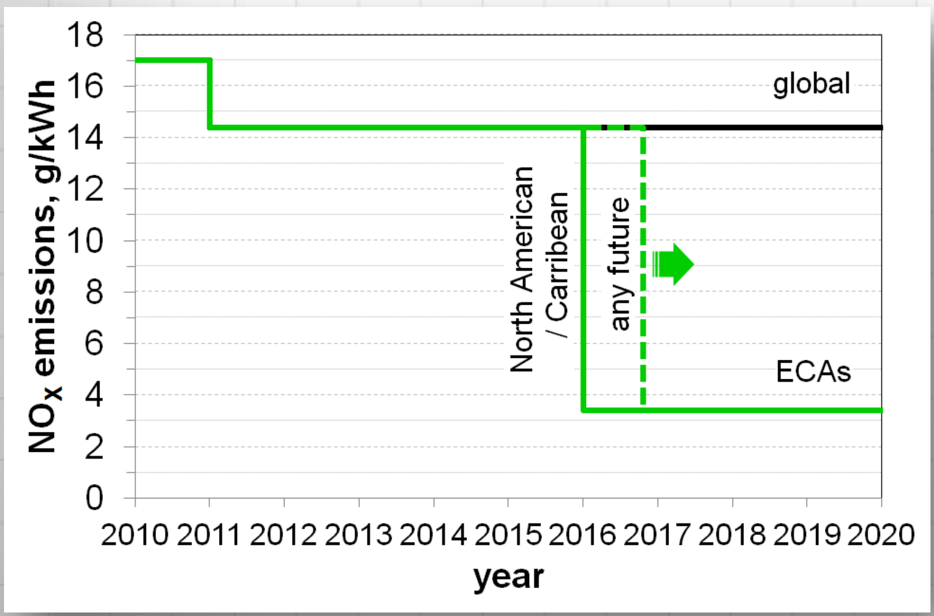
23.10.2014

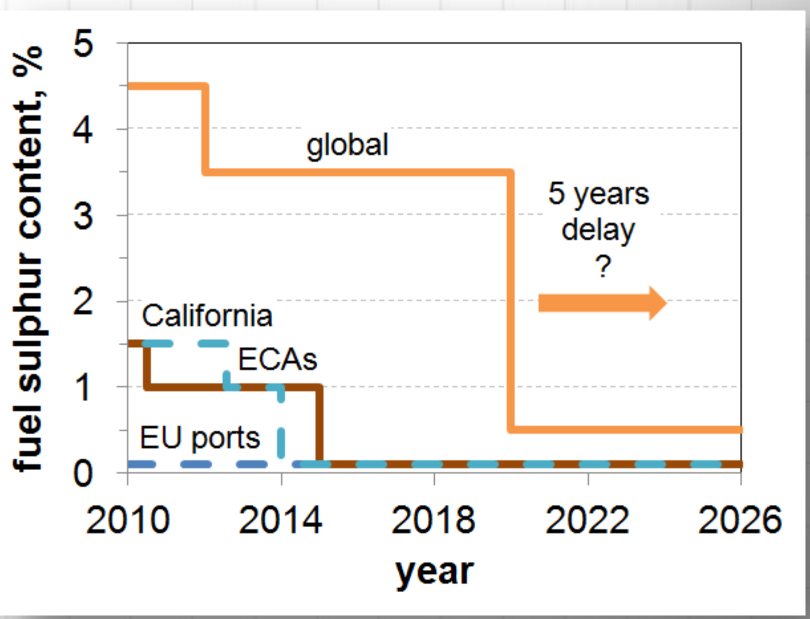
Development drivers - environment



Development drivers – emission legislations

- NOx: targeting newbuilds, SOx: entire fleet
- Different introduction levels and dates
- Compliance with IMO Tier III NOx limits requires additional technology (EGR/SCR/...) or change to gas as fuel





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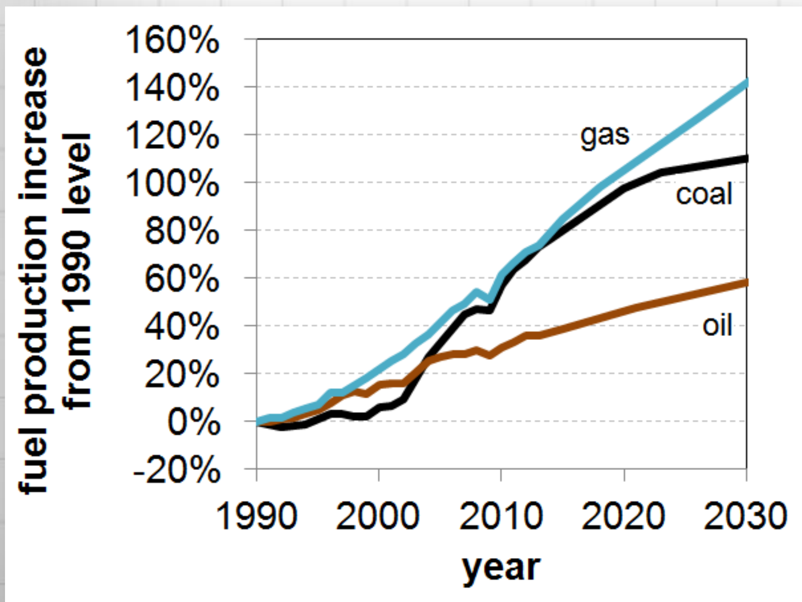
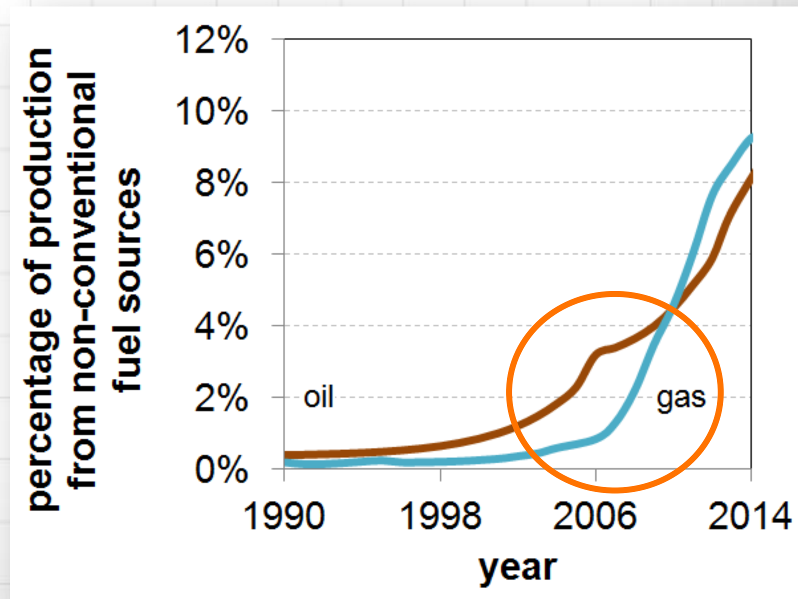
Development drivers - production

- Fast increase in gas production during recent years
- US shale gas boom accelerating shift to gas
- Increase in gas production capacity and availability affecting fuel pricing





Source: BP energy outlook 2035, 2014

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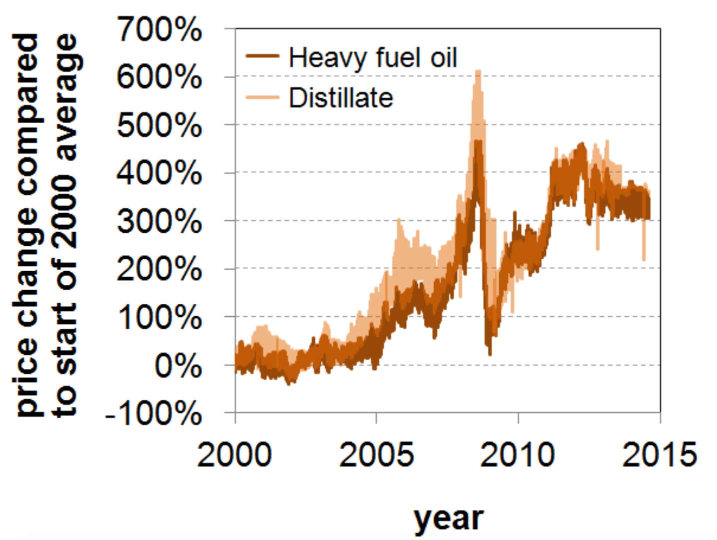
Development drivers – fuel prizes

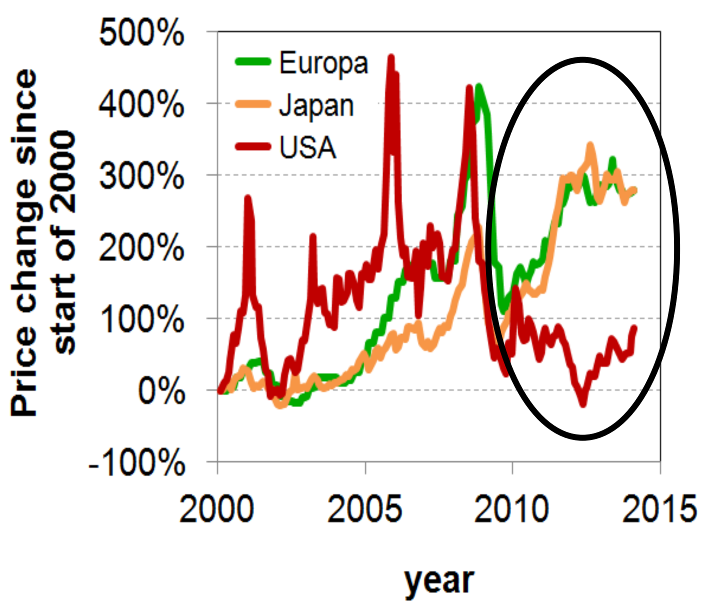
Liquid fuels

- Parallel relative price development for liquid fuels, small spread across regions
- HFO/MDO prices tripled over last 10 years



Gas fuel

- No global market for gas fuel → prices coupled to liquid fuel price in Europe and Asia
- Price coupling history in USA due to gas availability



Source: Clarkson Research Services
The World Bank

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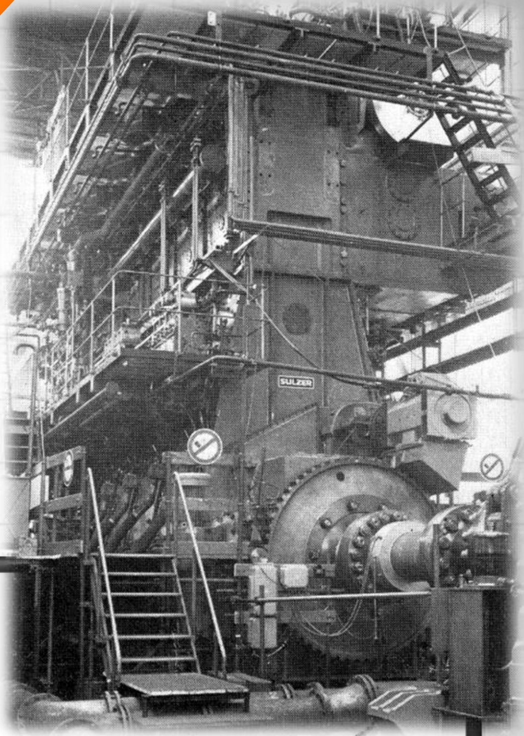
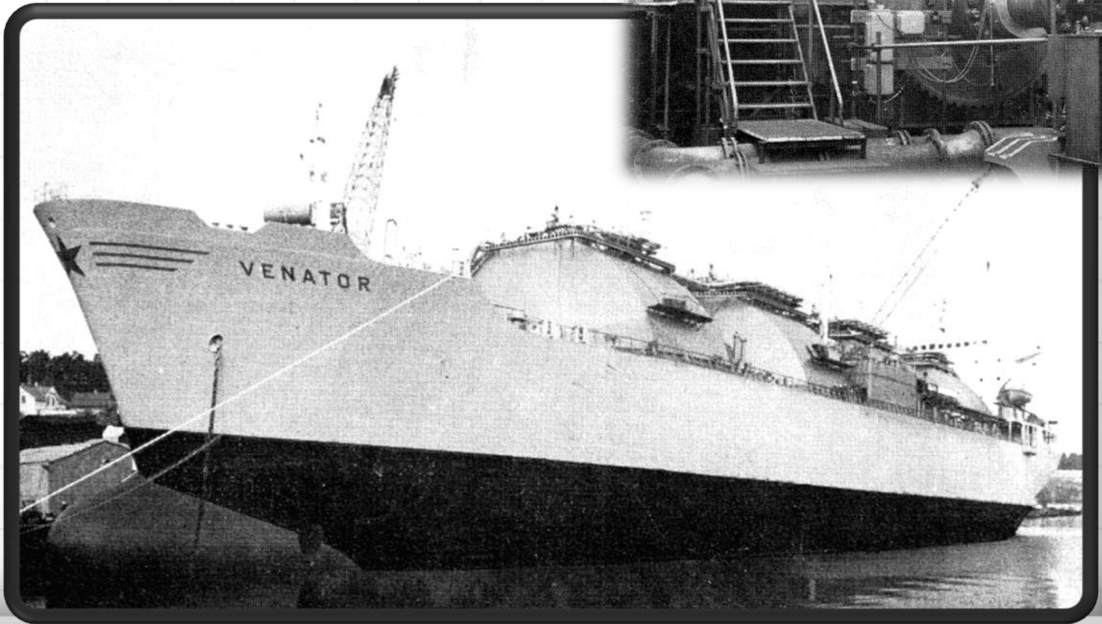
Development history, 2-stroke

- First installation with 2-s low-pressure DF in 1973
- 29’000m3 LNGC ‘MV Venator’
- Sulzer 7RNMD90:
  - 90 cm bore
  - 155 cm stroke
  - 15’150 kW on diesel
  - 10’450 kW on gas





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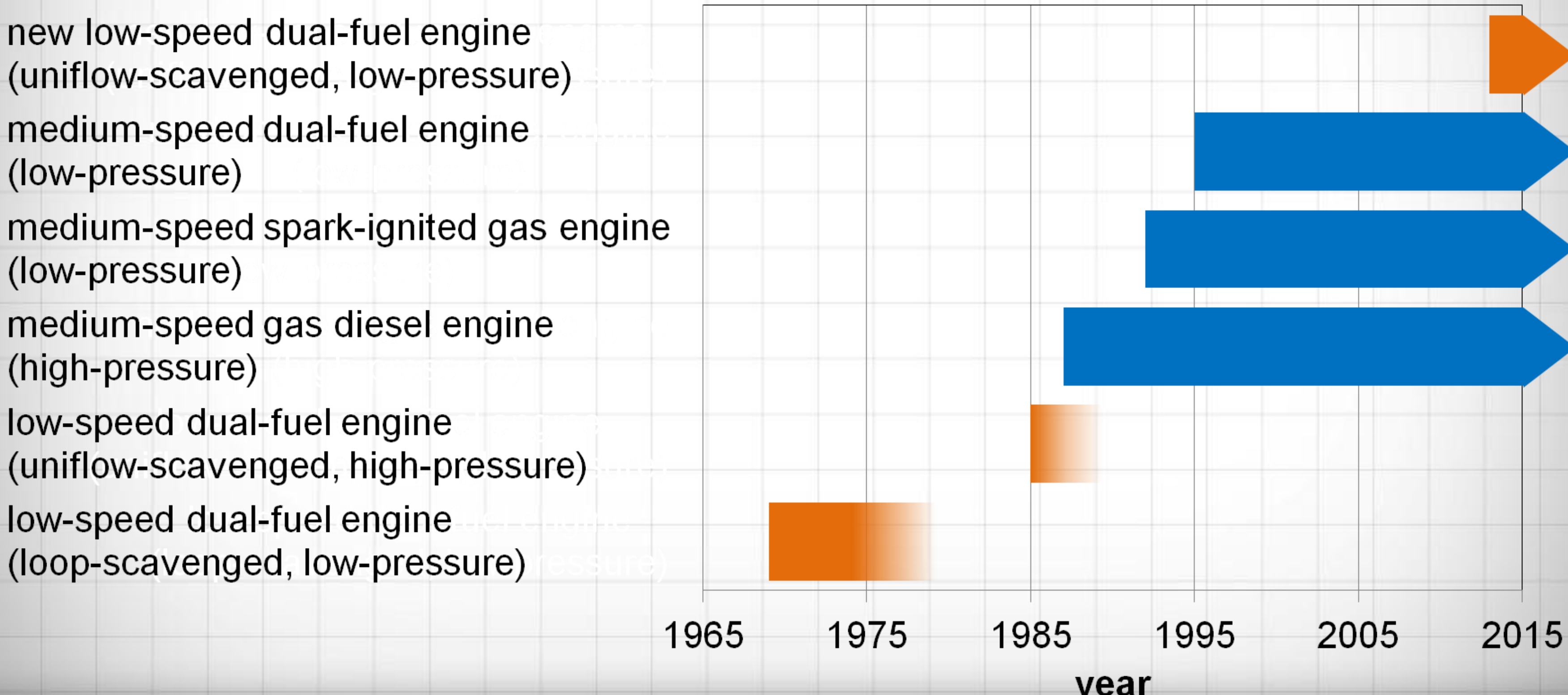
Development history

Various gas and Dual Fuel concepts developed over time, both 2-s and 4-s



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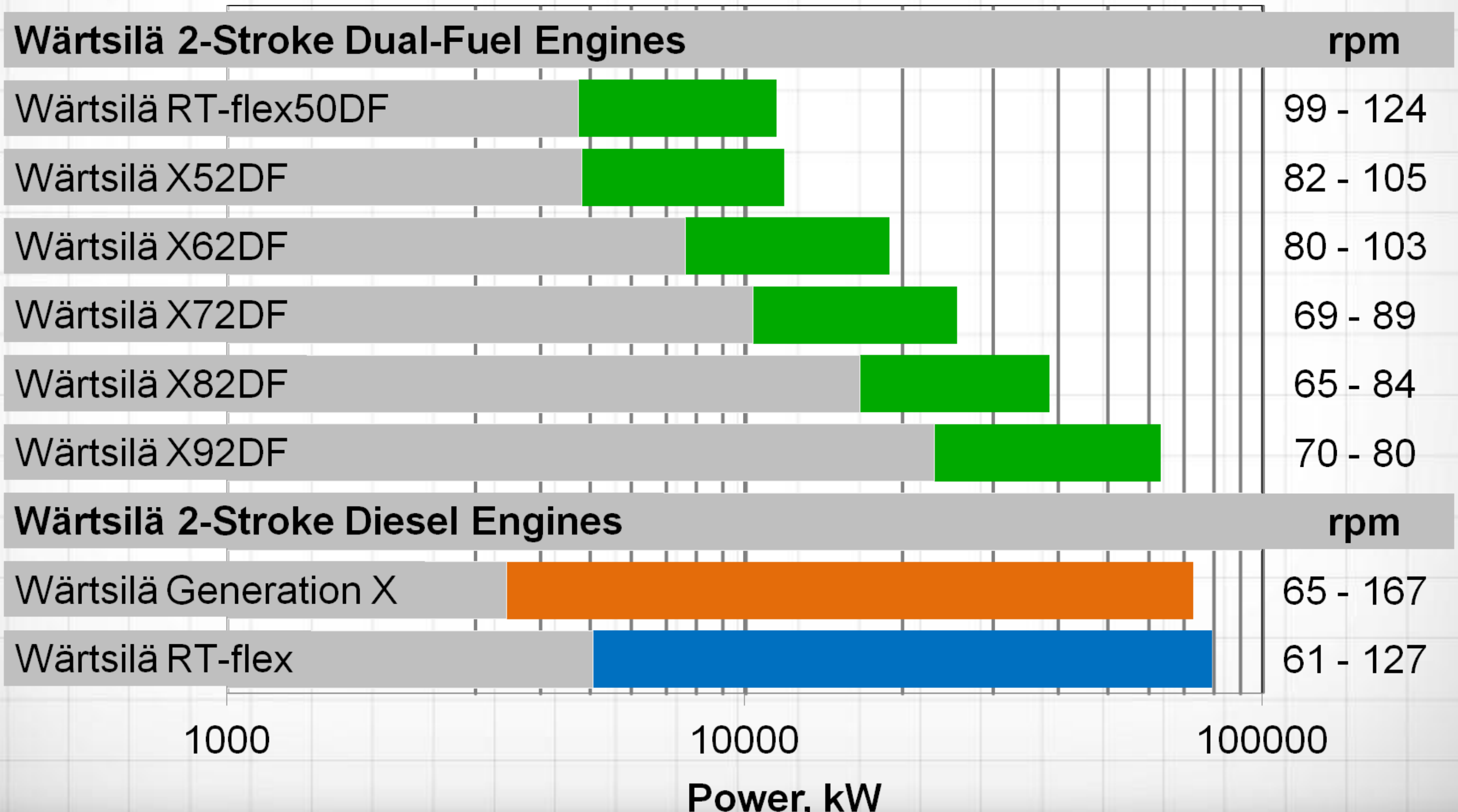
Current 2-stroke DF portfolio

Future 2-stroke Dual Fuel portfolio will cover a wide range of power outputs



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The 2-stroke DF concept

low pressure Dual Fuel

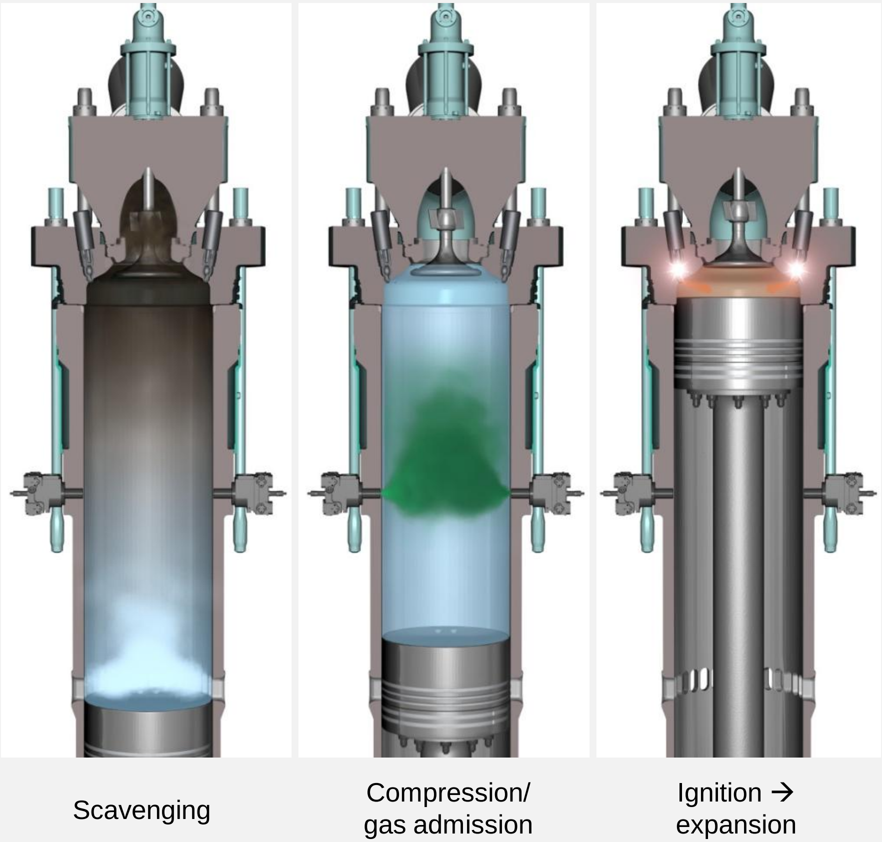
The Principle:

- Engine operating according to the Otto process
- Pre-mixed ‘Lean burn’ technology
- Low pressure gas admission at ’mid stroke’
- Ignition by pilot fuel in prechamber

The 2-stroke DF concept

low pressure Dual Fuel

'Pre-mixed lean-burn' combustion



The main merits:

- Low pressure gas < 16 bar
  - less space…
  - less CAPEX, less OPEX…
  - less maintenance…
    - …needed compared to high pressure gas equipment
- Lean Burn 'Otto' combustion
  - no additional technology…
  - No additional CAPEX…
  - No OPEX increase...
    - …to reach world class emission levels

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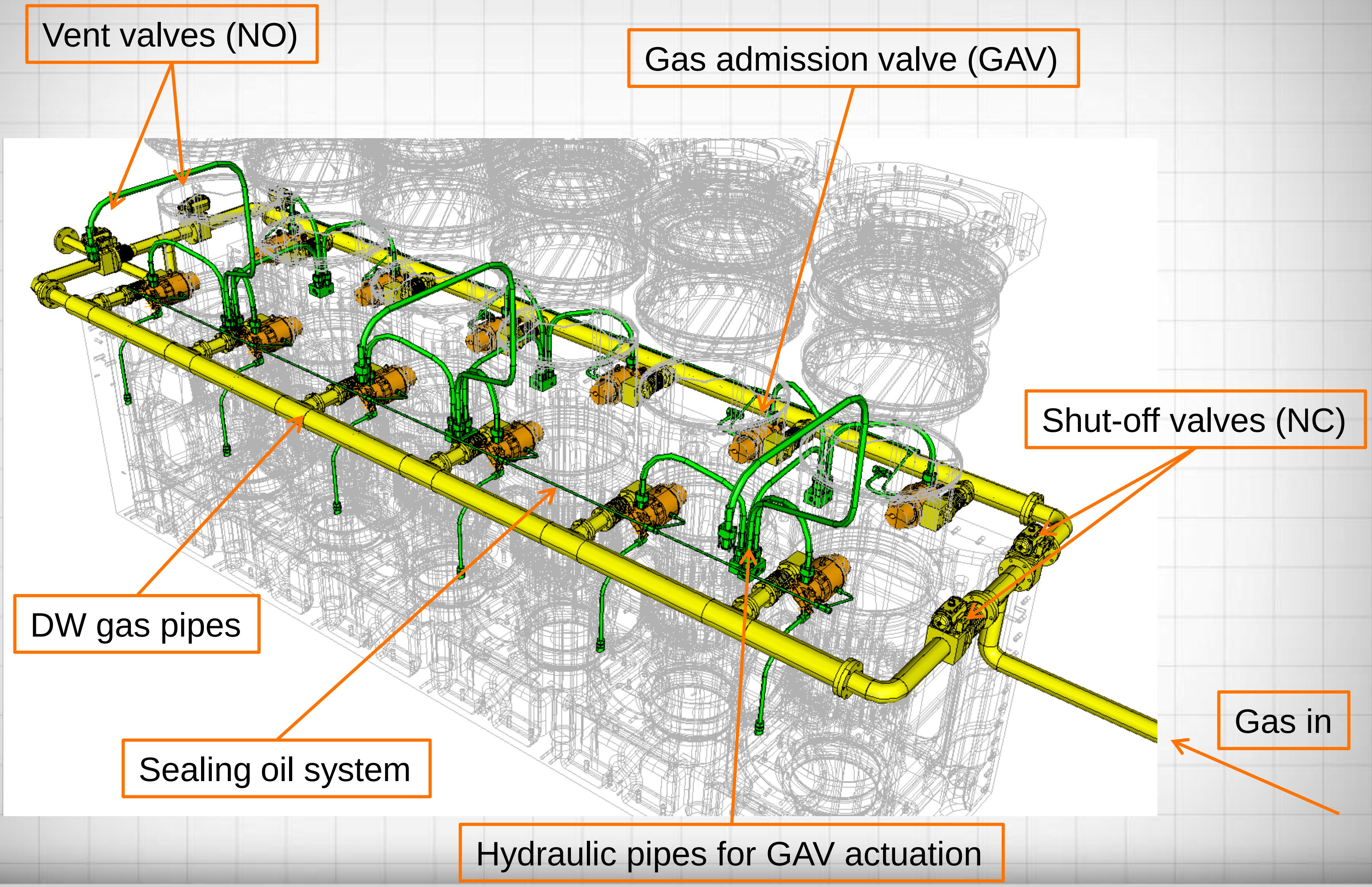
Technology – gas supply



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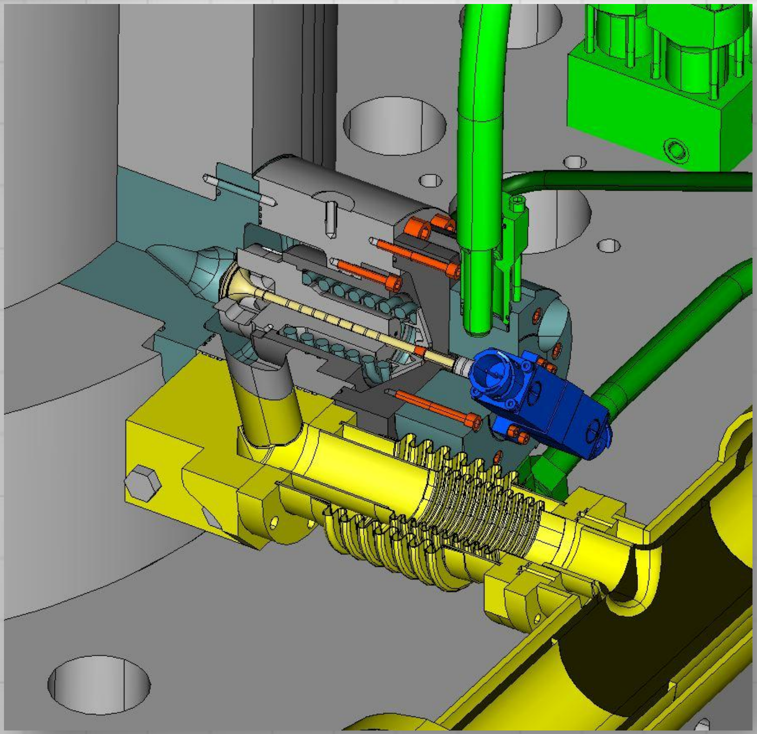
Technology – gas admission



Gas admission valve

- 2 x GAV (Gas Admission Valve) per cylinder
- GAV actuated hydraulically
- Hydraulic power supply from exhaust valve servo oil system
- **Precise gas admission control – from full load to ’idling’**
- Double walled piping for enhanced **safety**

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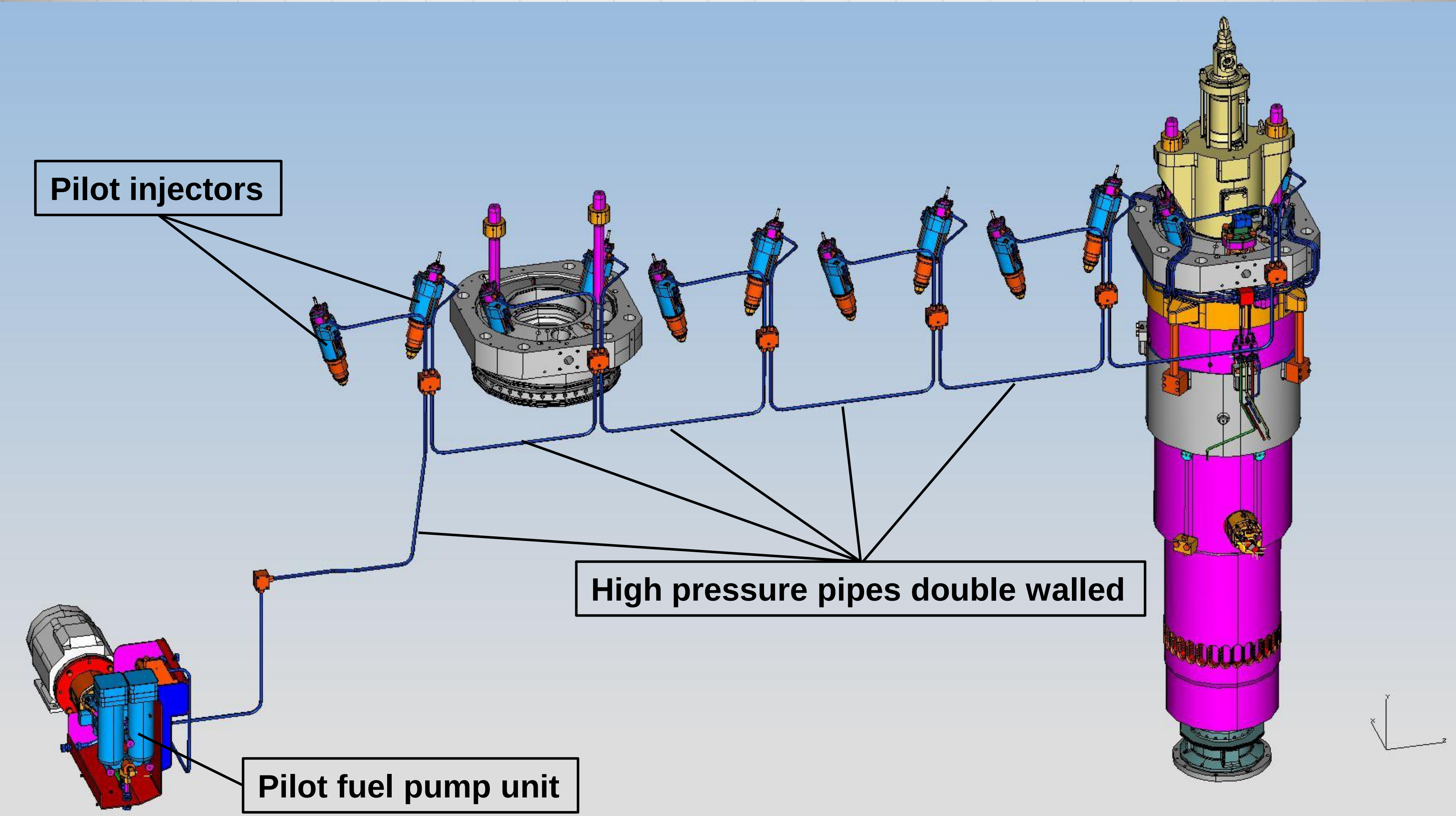
Technology - pilot injection system



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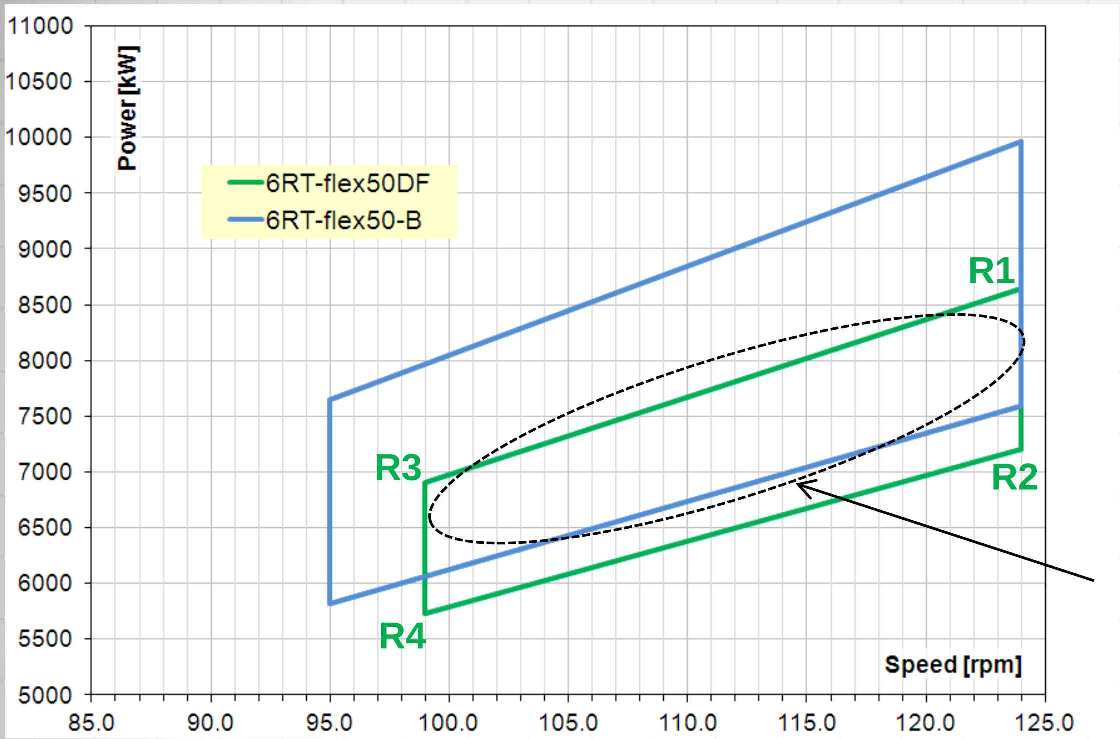
Low pressure DF – engine output

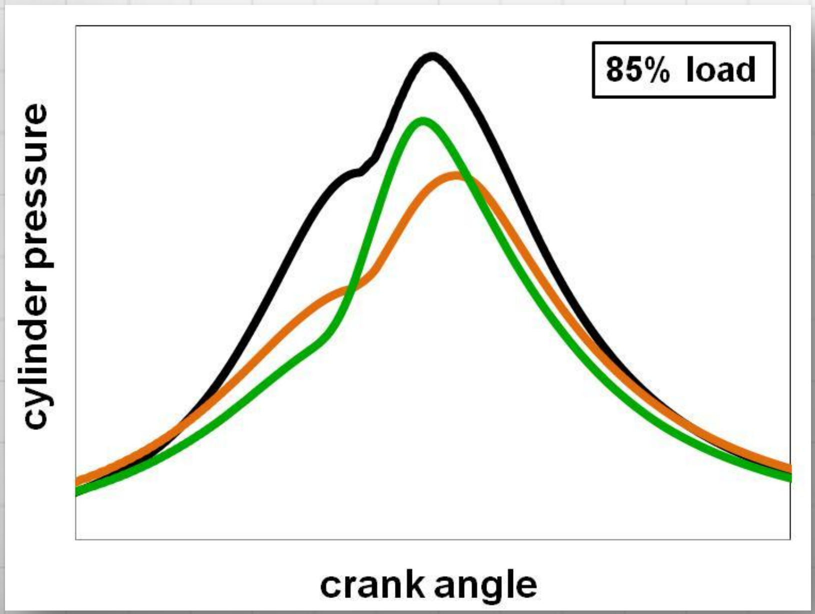


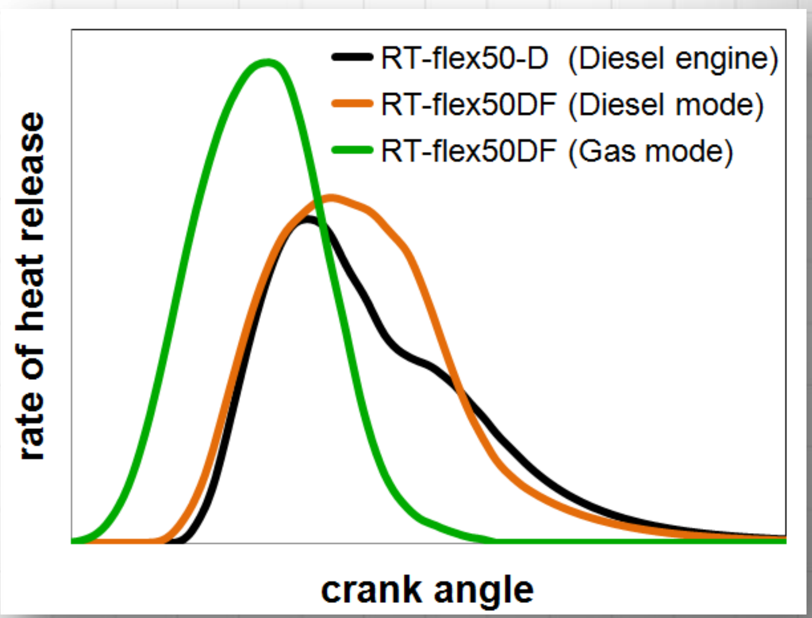
Engine output

- Max rating lower than 'diesel', due to limitations from knocking / pre-ignition
- May in some applications require 1 (one) cylinder more than the 'diesel' engine to reach the required output
- Most applications today run on 'de-rated' output

Technology

- Lower compression ratio of DF engine visible
- Lower compression pressure allows faster combustion in gas mode
- HRR phasing on gas can be advanced since not NOx dictated
- Shaping of rate of heat release improved in diesel mode, due to larger combustion chamber





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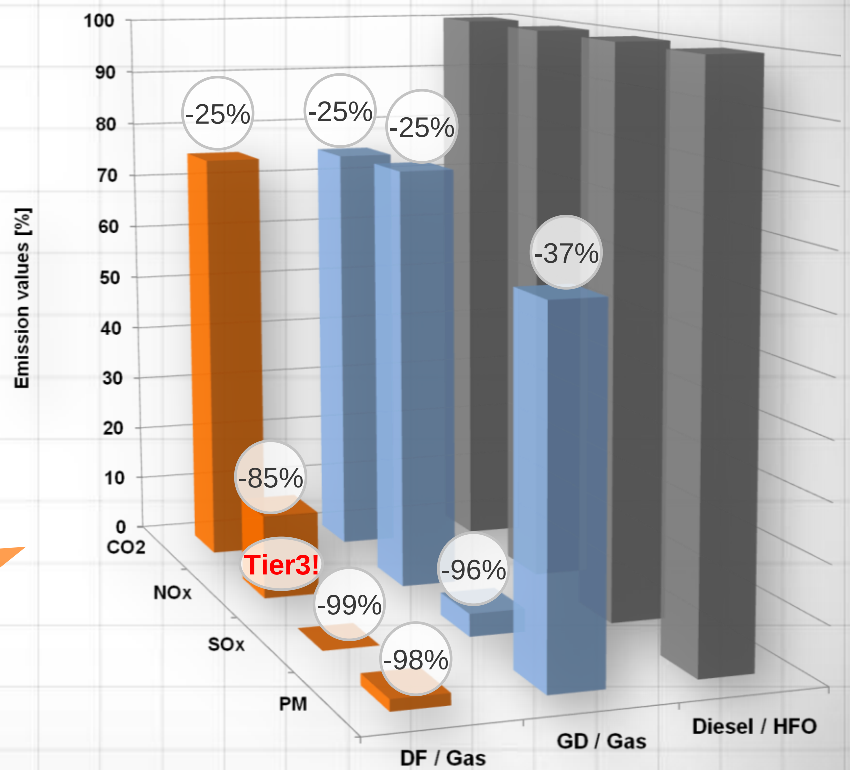
2-stroke DF - total emission picture

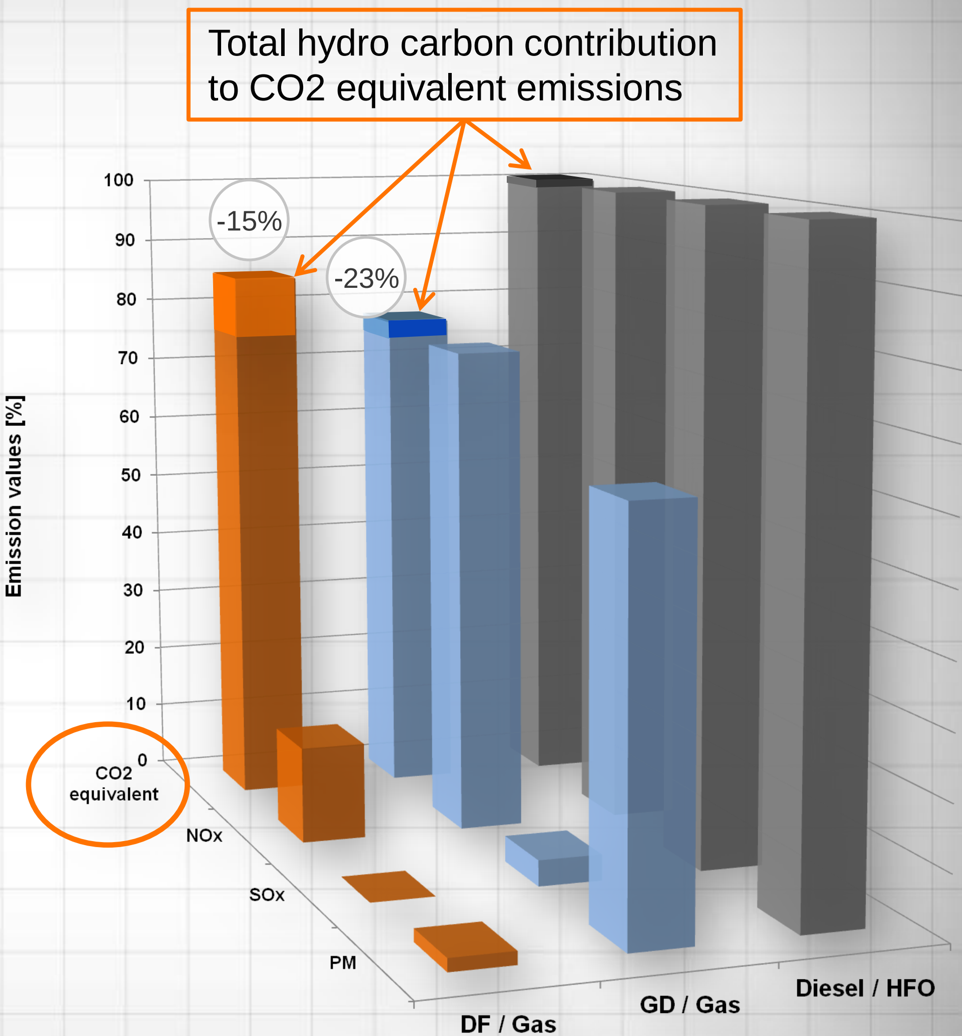
- CO_2 and SO_x reduced in gas operation due to fuel composition
- PM further reduced by the DF technology with Lean-burn Otto-combustion with pre-chamber ignition

NO_x (Tier 3) and SOx levels in ECA's fully met!



What about methane slip?

- ‘Methane slip’ = THC emissions (Total Unburned Hydrocarbons)
- Methane is a 25 times stronger green house gas than CO_2
- Even with current THC levels, **DF contributes positively to reduce the total CO_2 footprint compared to HFO**
- Potential to further reduce the methane slip on 2-s DF



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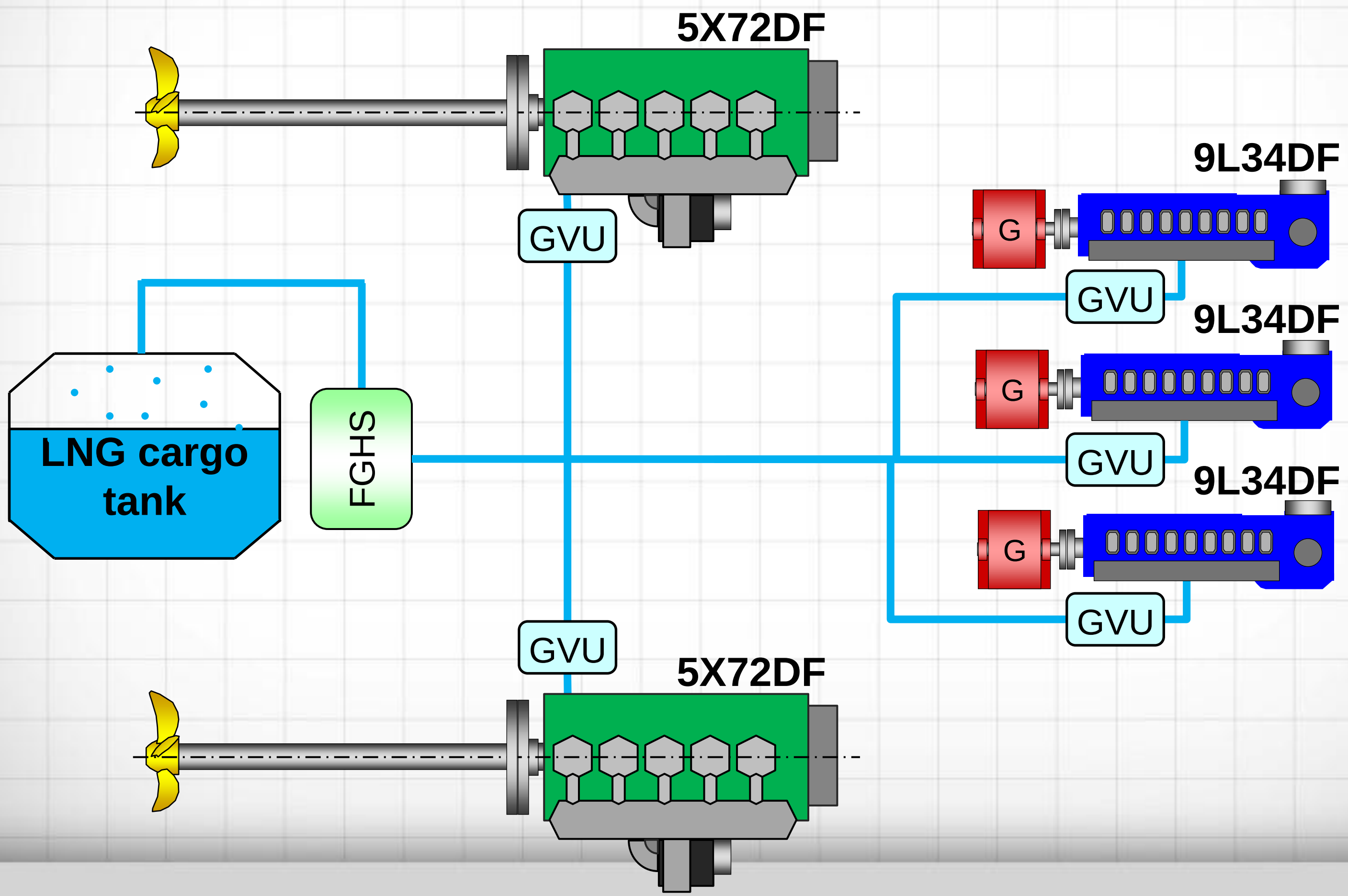
Application examples

175'000 m3 LNGC:

- Twin propulsion for maximized redundancy



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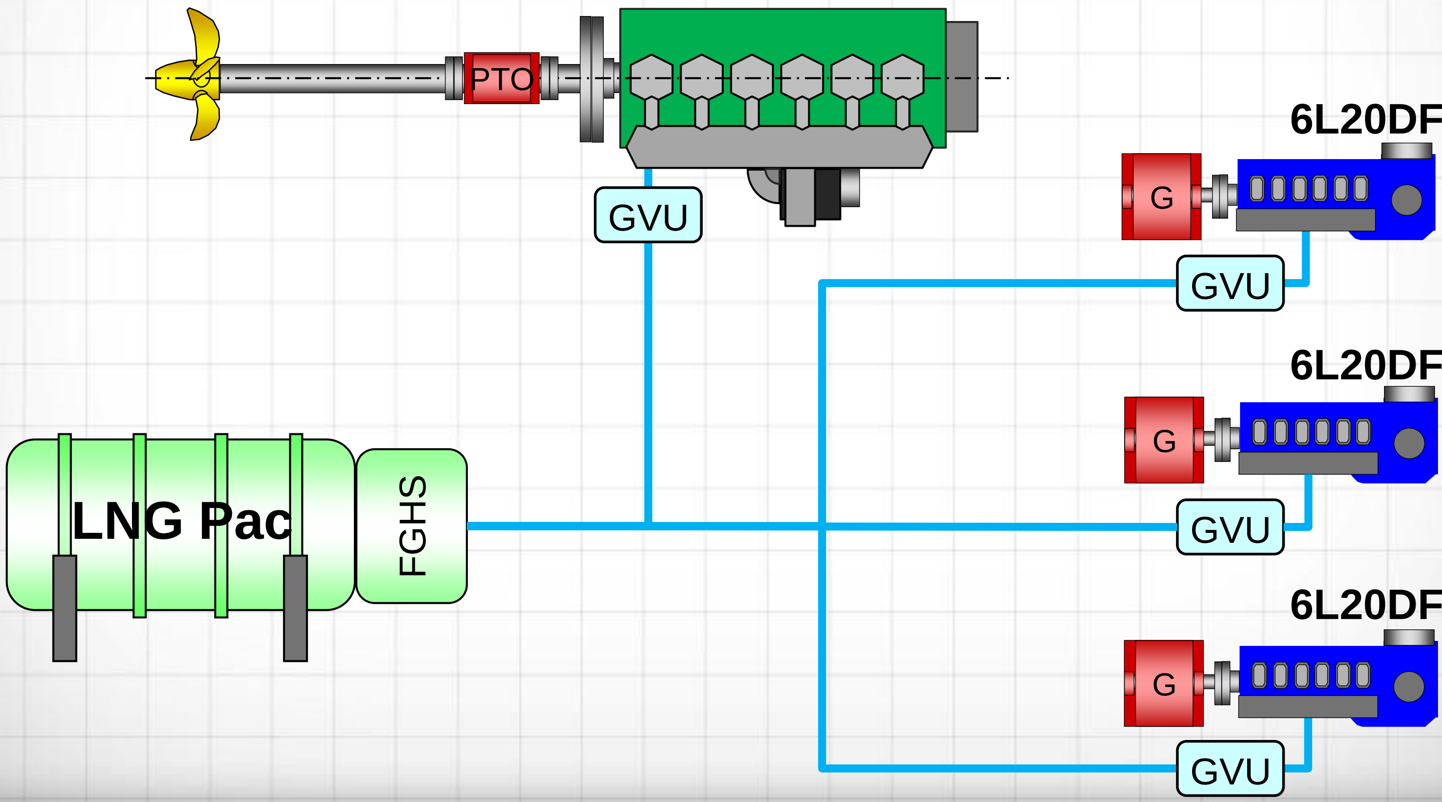
Application examples

1'400 TEU container feeder:

- Simple system, no high pressure gas supply equipment needed



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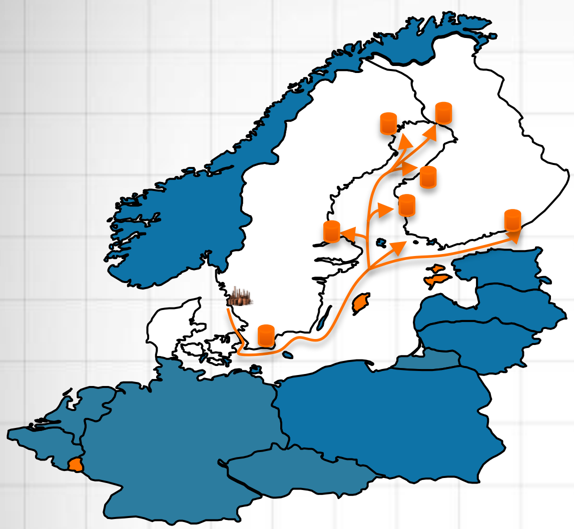
Leading into the Gas Age – Reference 1

INTO the FUTURE - Baltic SO_2lution



TERNTANK
www.terntank.com
NEOT
North European Oil Trade
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- **Ship type** 4 x 15,000 dwt Chemical Tankers, 14.5 kn (v_{DES})
- **Owner** Terntank Rederi AS, Sweden
- **Shipyard** AVIC Dingheng Shipbuilding Co, China
- **Vessel delivery** Q2, 2016
- **Engine type** **Wärtsilä 5RT-flex50DF,** CMCR of 5850 kW

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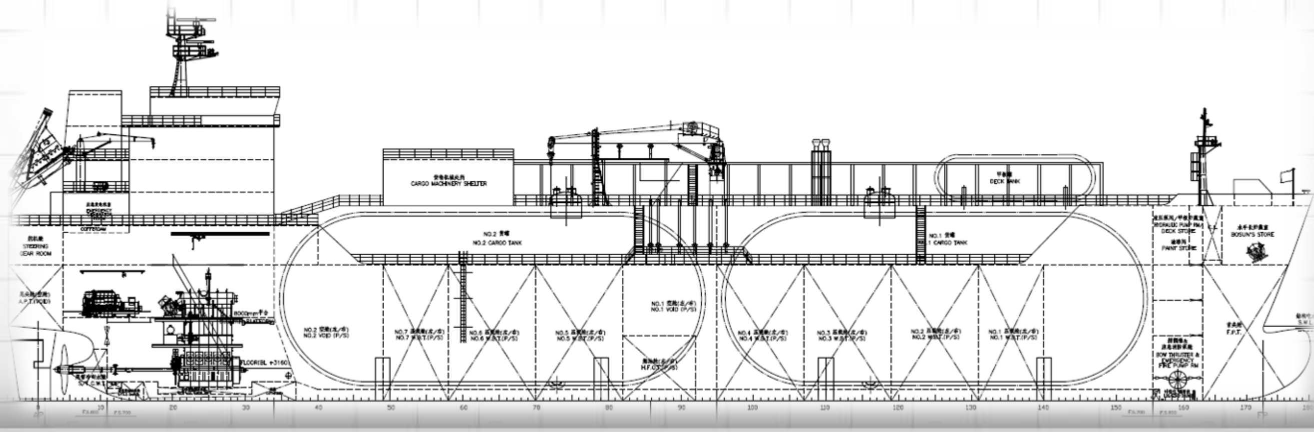
Leading into the Gas Age – Reference 2

First costal LNG Carrier with 2sDF engine

- **Ship type** 14,000 m3 LNG Carrier, 15 kn (v_{DES})
- **Owner** Zhejiang Huaxiang Shipping Co., Ltd
  - Private shipping company
  - Major player in LPG transportation market
  - One of the operators of LNG transportation in China domestic water
- **Shipyard** Qidong Fengshun Ship Heavy Co., Ltd,
- **Vessel delivery** 2015
- **Engine type** **Wärtsilä 5RT-flex50DF,** CMCR of 6000 kW



Leading into the Gas Age – Reference 3

First LNG- fuelled Container Feeder Vessel for Baltic Sea operation

• **Ship type**	3 (+1+2) x 1400 TEU C/V, 18.5 kn (v_{DES}), iceclass 1A
• **Owners**	GNS Shipping / Nordic Hamburg, Germany
• **Charter**	Containerships, Finland
• **Shipyard**	Yangzhou Guoyu Shipbuilding, China
• **Vessel delivery**	Q3, 2016

• **Engine type**	**Wärtsilä 7RT-flex50DF** CMCR of 10070 kW **6L20DF generating set** MCR of 1055 kW

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Leading into the Gas Age – Reference 4

First LNG Carrier with low-speed LOW-PRESSURE DF engines

- **Ship type** — 2 x 180,000 m3 LNG Carrier, 19.5 kn (v_{DES})
  Twin-skeg, twin-screw
- **Owners** — SK Shipping, Korea
  Marubeni Corporation, Japan
- **Charter** — Total SA, France
- **Shipyard** — Samsung Heavy Industries, Korea
- **Vessel delivery** — Q1, 2017
- **Engine type** — **Wärtsilä 2 x 6X62DF main engines**
  CMCR of 13450 kW each
  Wärtsilä 4 x L34DF gensets

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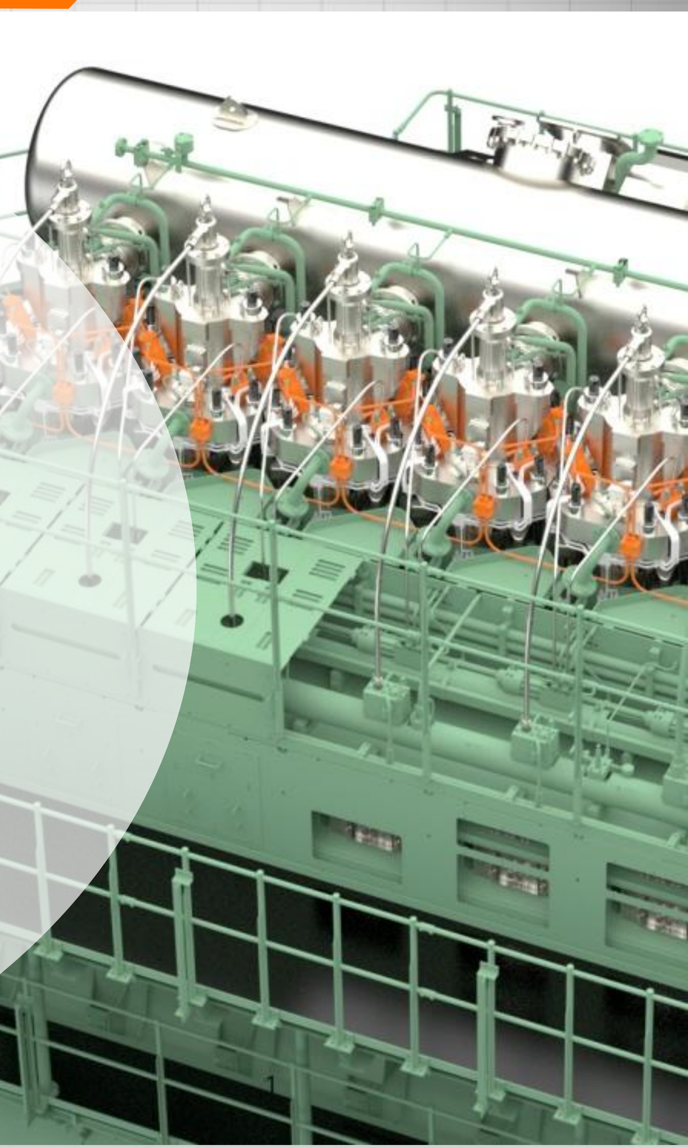
Conclusions

The environmental benefits of LNG as fuel will pave the way of its success
Depending on pricing, faster or slower….

Depending on gas pricing, gas can become the fuel of choice not only for ECA operation

The 2-s low pressure DF Technology is the optimum one for safe, reliable and economical ship propulsion with natural gas



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THANK YOU!

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Leading gas applications in the marine market

Marcel Ott
GM, Dual Fuel Technology Development

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