Tier III Solutions

Winterthur Gas & Diesel Ltd.

December 2018

Ibrahim Behairy

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Contents

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Yesterday and Today

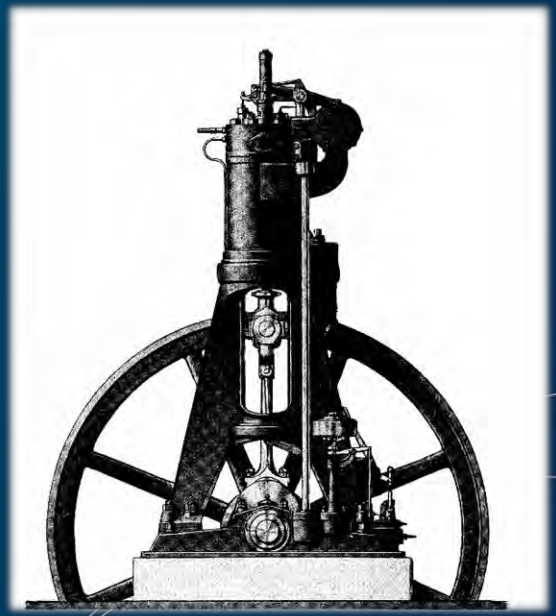
Continuing the long tradition of the Sulzer Diesel Engine business founded in 1893.

Winterthur Gas & Diesel Ltd. (WinGD) is a leading developer of low-speed gas and diesel engines used for propulsion power in all types of merchant, deep-sea ships, worldwide.

WinGD's sets the industry standard for reliability, efficiency and environmental sustainability.

WinGD provides design licences and technical support to manufacturers, shipbuilders and ship operators worldwide.

Headquartered in Winterthur, Switzerland, WinGD employs 353 individuals, from 25 different nations, worldwide.



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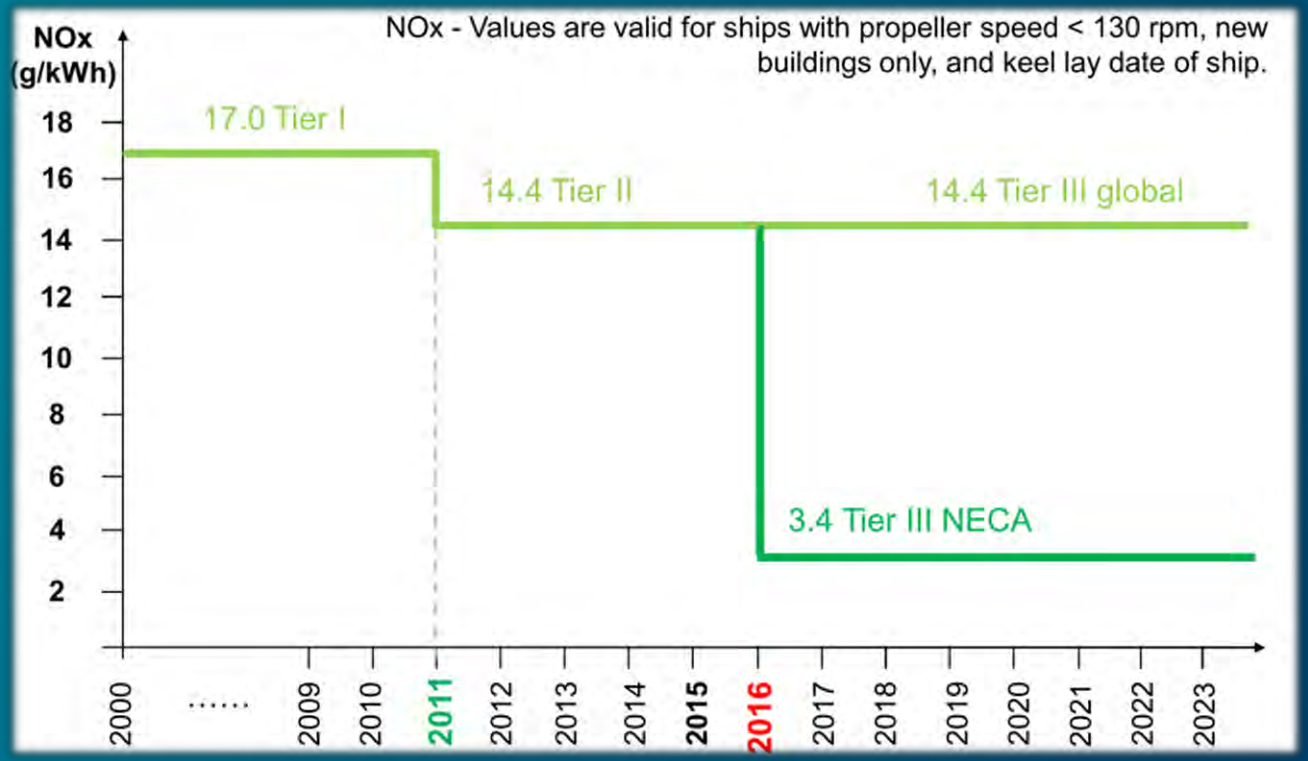
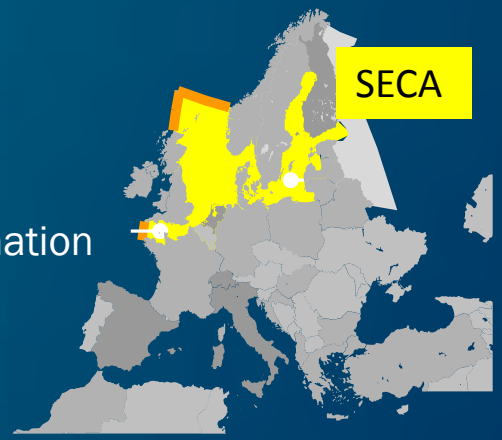
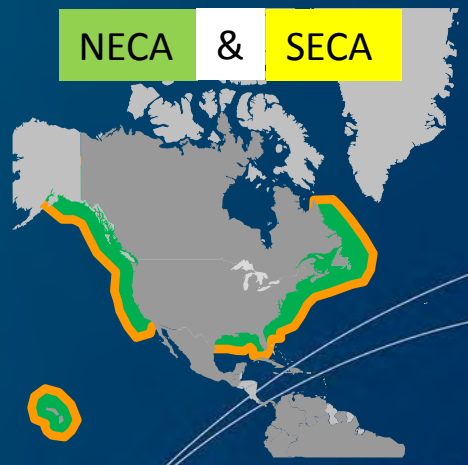
IMO / MARPOL ANNEX VI REGULATION 13 (NOX)

What are the 2-stroke engine relevant NOx emission limits?

- The global Tier II NOx limit is 14.4 g/kWh
- The NOx ECA (NECA) limit will be 3.4 g/kWh
- Effective date (keel lay of ship) 1.1.2016 for American NECA, others after designation







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IMO / MARPOL ANNEX VI REGULATION 13 (SOX)

What are the 2-stroke engine relevant SOx emission limits?

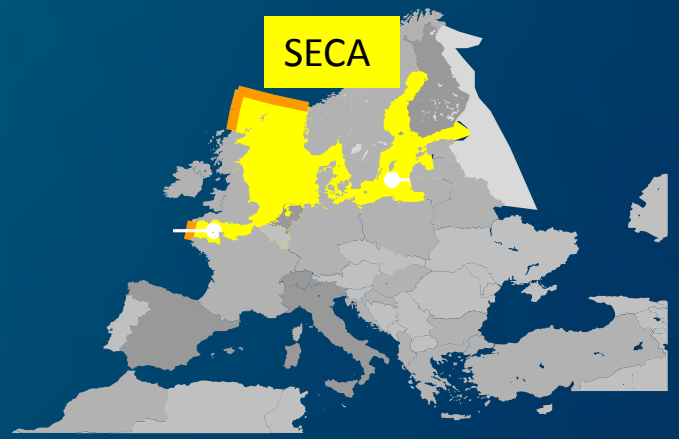
Fuel sulphur caps:

Globally:

Max. 3.5% S	current limit from 1 January 2012
Max. 0.5% S	from 1 January 2020

SECA areas (Baltic, North Sea, etc):

Max. 1.0% S	current limit from 1 July 2010
Max. 0.1% S	from 1 Jan 2015



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Main greenhouse gas (GHG) types

Carbon dioxide (CO_2), Methane (CH_4) and their global warming potential (GWP)

- **CO_2** is defined with a Global Warming Potential (GWP) of 1
  - According to the Intergovernmental Panel on Climate Change (IPCC) report *Climate Change 2014, AR5*
- **CH_4** has a GWP of 28-86 according to the definition:
  - **CH_4** has the same global warming potential as 28-86 g (CO_2), depending on the considered time frame (100 or 20 years) and depending on whether the 'climate-carbon feedback' (cc fb) is included. According to the IPCC report *Climate Change 2014, AR5*
  - IPCC recommends a 100 year time frame for GWP considerations as a 'general scientific practice' without 'climate-carbon feedback'.
  - As per the above definition, **WinGD follows IPCC recommendation** and applies **GWP of 28 for CH_4**
- **N_2O and Black Carbon Particles** are also emission components with an effect on global warming.
  - These components are being discussed e.g. in IMO and IPCC and are not included in this review
- **Particulates Matters (PM), NO_X and SO_X** represent a serious hazard to human health
  - Accordingly, they are also to be considered when comparing different technologies.

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Methane emissions

Sources of methane emissions

- CH_4 (Methane) is the second most common GHG after CO_2
- Methane is emitted into the atmosphere through both, natural (~40 %) and man-made (anthropogenic, ~60 %) sources
- Production and distribution of fossil fuels accounts for about 20 % of anthropogenic methane emissions; see figure 1.
- Stationary and mobile sources (transportation, including shipping) contribute approximately 1 % of anthropogenic methane emissions; see figure 1.

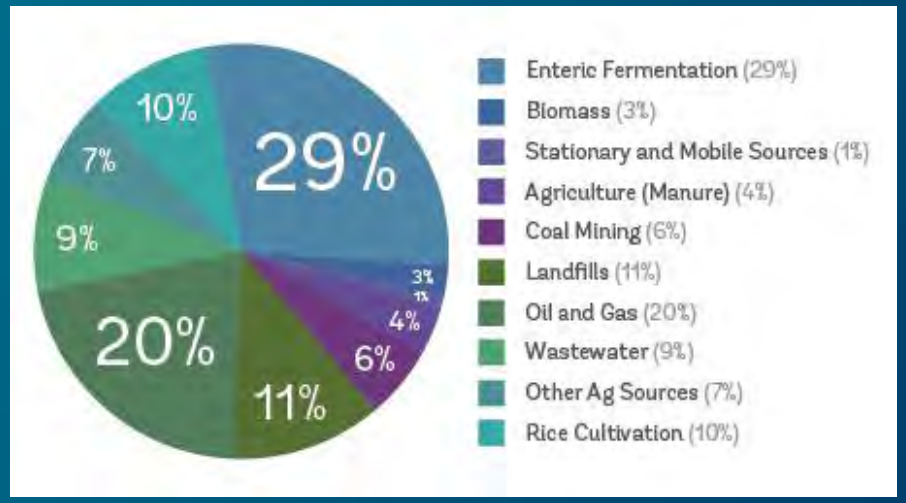

Fig. 1: Estimated global anthropogenic methane emissions by source, 2010. Source: Global Methane Initiative

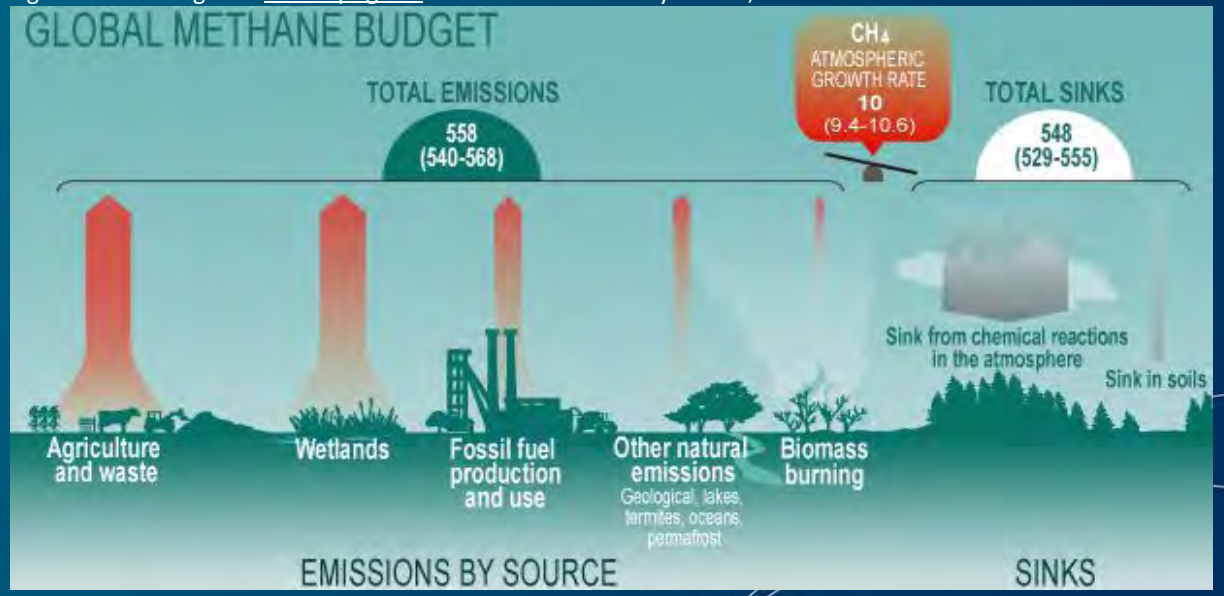

Fig. 2: Estimated methane emissions, natural and anthropogenic Source: www.climate.gov, global methane budget

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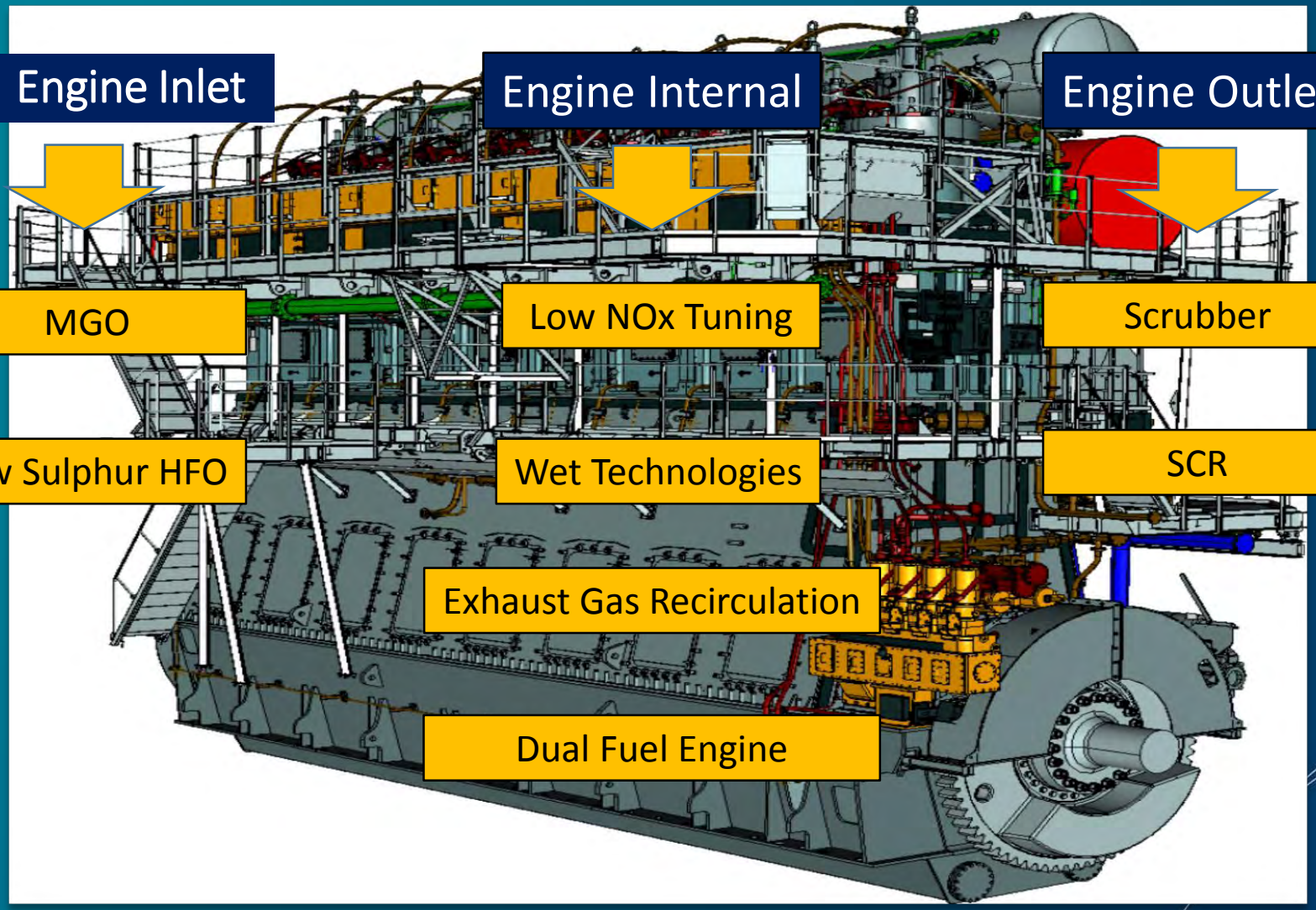
Technology Overview



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Alternatives to Reducing SOx

FUEL SWITCH Switch to low sulphur fuel in SECA.	Flexible Small investment	High operating cost in SECA Fuel change over procedures Lube oil TBN management Fuel availability?
CHANGE TO MGO Run full time on Marine Gas Oil (MGO).	Convenient No change over	High operating cost Future availability?
CONVERT TO LNG Convert engines to run on gas (LNG).	A solution which also reduces NO_x and particulates	Investment cost LNG availability
USE SCRUBBERS Install an exhaust gas cleaning system (scrubber).	Works with high S HFO Lowest total lifecycle cost Use everywhere Easy operation	ROI depends on fuel oil price difference between low S fuel oil and high S HFO

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Methanol (CH_3OH)

- Chemical structure CH_3OH
- High hydrogen content
- Low carbon content
- Liquid content between -93°C to +65°C
- It is a basic building block for many chemical commodities such as plastic, painting and building materials
- Has a low flashpoint of 11 to 12°C
- Can be produced from feed stocks but mainly natural gas and coal

Storage

- Due to its density and lower heating value, the size of fuel tanks can be twice as the traditional fuel

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Price

- Since CH_3OH is produced from natural gas it's price is higher
- Producing methanol from coal may bring the price down but increases GHG
- The best scenario is producing methanol from renewable energy
- Less price less emission

Infrastructure

- Trucks liquid form
- Bunker vessel

Environmental Impact

- Less CO_2 by 10%

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Storage

- Standard fuel tanks
- Special precaution for the low flashpoint

CAPEX

- Cost is one third less than LNG system

OPEX

- Less cost
- No scrubber

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LNG Properties

- **Density:** Lighter than Air and water. In case of leak it will dissipate.

- **Temperature:** It is Cryogenic . It has a very Low Temp -161 Celsius. In Liquid form does not explode, or produce flames.

- **Odorless**: odorant is added for easy leak detection.

- **Colorless:**
- **Non poisonous/non corrosive/non toxic** : easy transport/ safe to handle.
- In **gaseous** form if inhaled, it will cause **asphyxiation** because it limits the Oxygen.

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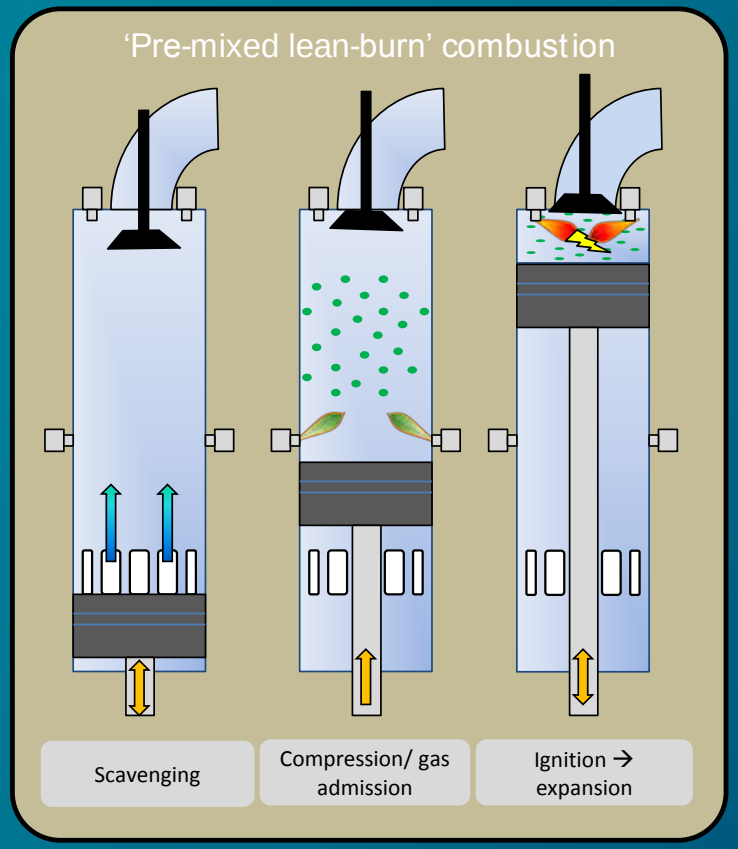
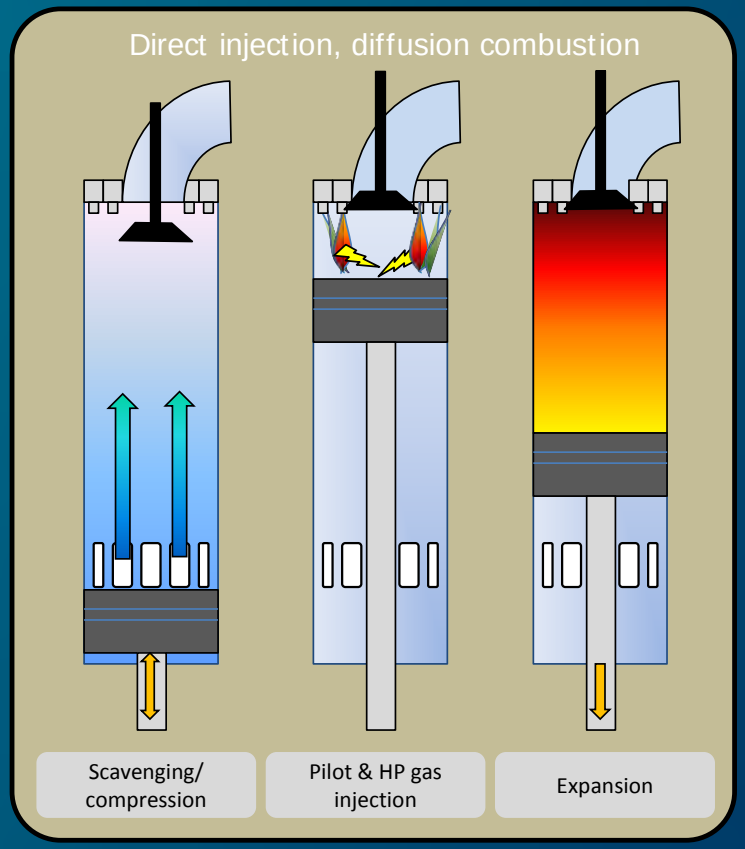
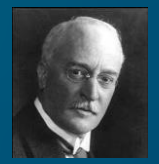
Combustion: comparison Diesel & Otto cycle





Otto cycle



Diesel cycle

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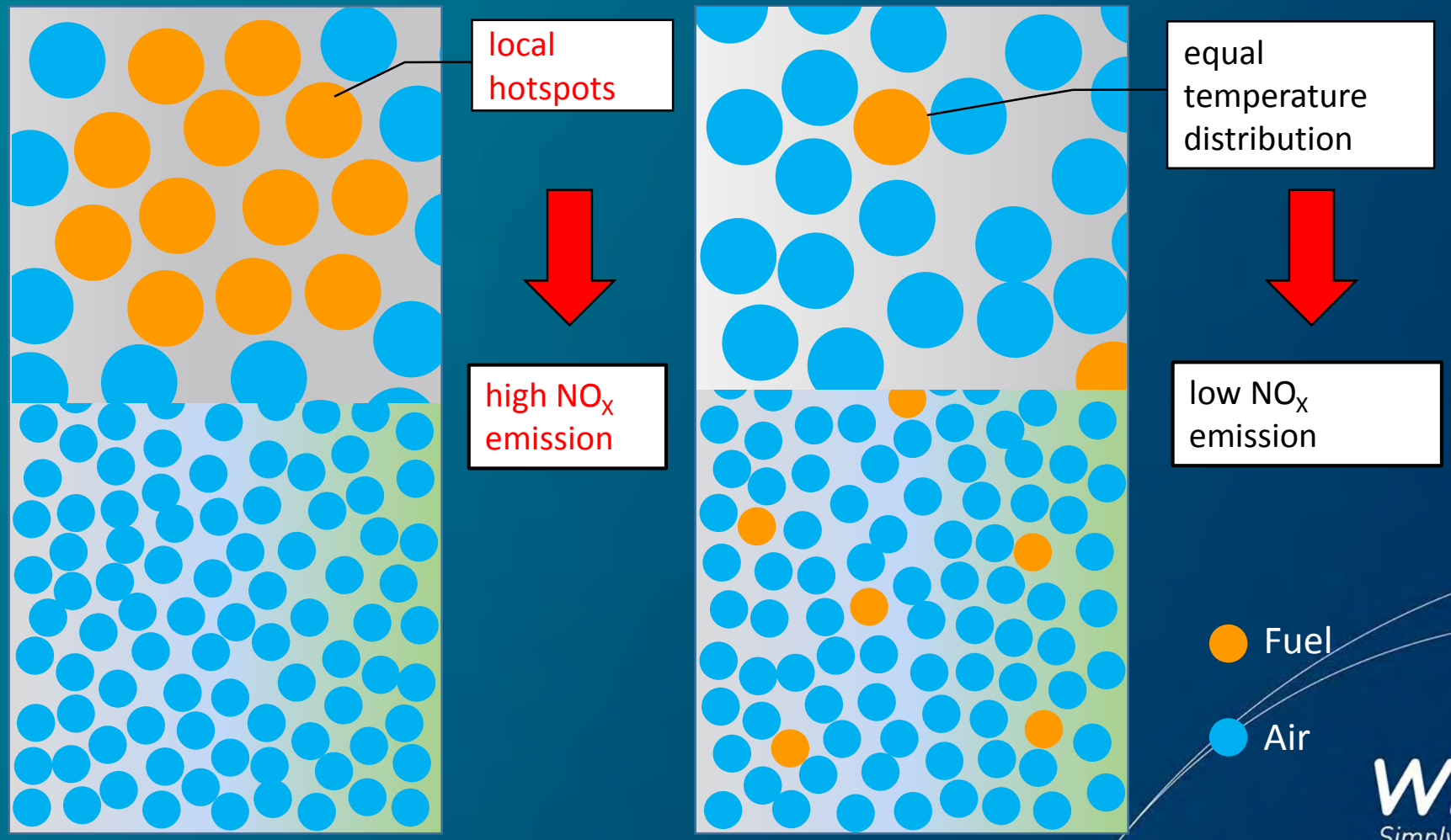
Combustion: comparison Diesel & Otto cycle

Diesel cycle - rich combustion

Otto cycle – lean combustion



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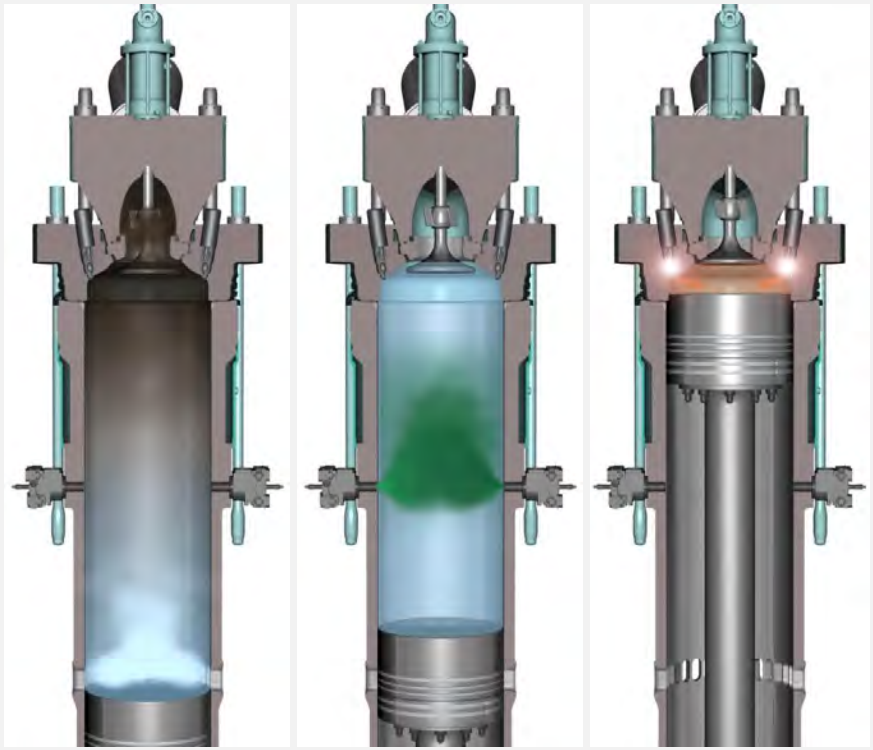
Combustion principle



Scavenging | Compression/ gas admission | Ignition → expansion

- Gas mode: Pre-mixed lean-burn ‘Otto’ combustion
- Diesel mode: Diesel process

The main merits

- Low gas pressure < 13 bar
  - Simple and reliable gas supply system
  - Simple gas sealing
  - Wide selection of proven compressors / pumps
- Lean Burn ‘Otto’ combustion means IMO Tier III compliance:
  - Without additional equipment (EGR/SCR)
  - Without additional fuel consumption
  - Without compromised component reliability

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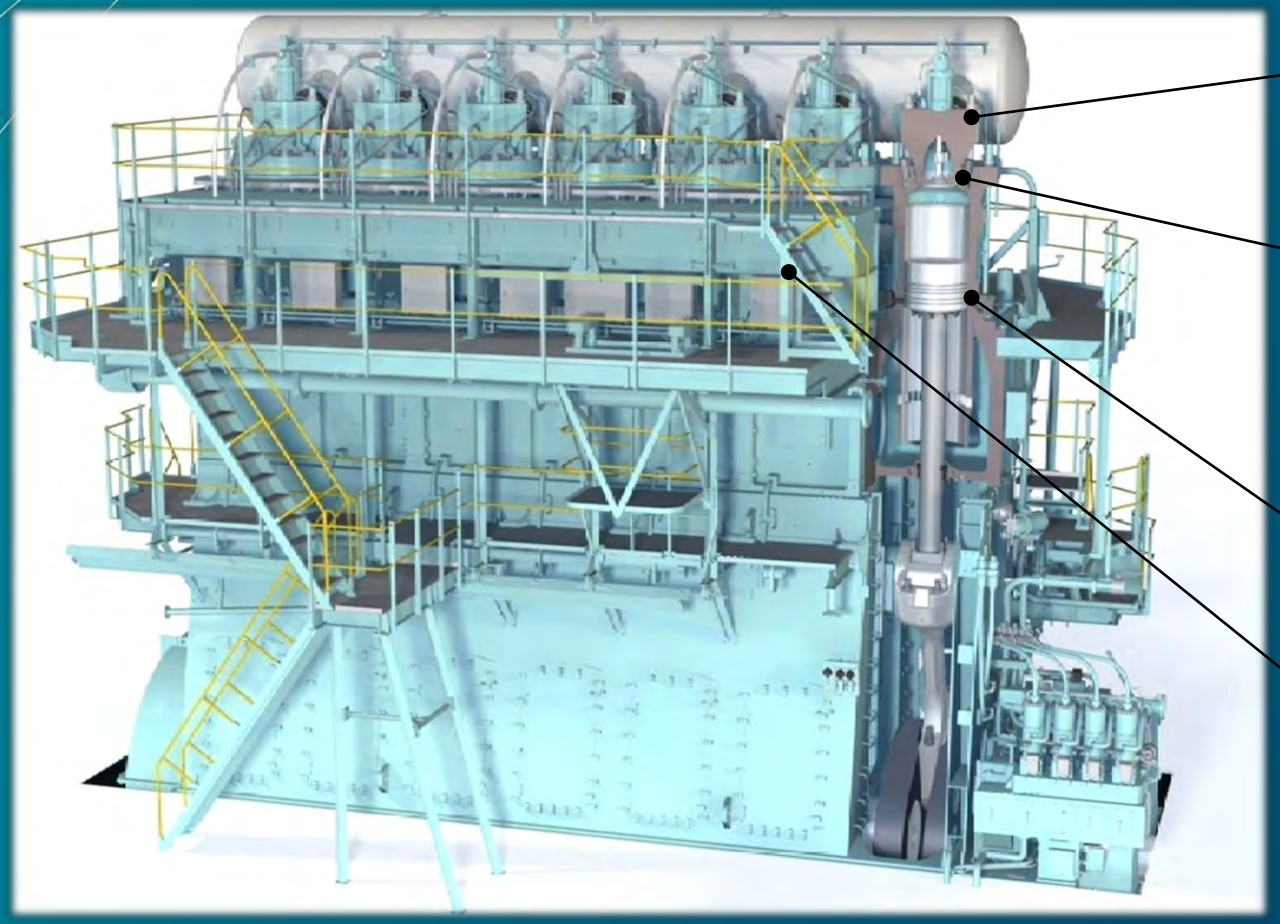
X-DF Low-Pressure key components

- Key technologies that make the difference!



Micro-pilot common-rail system
- Low pilot-fuel consumption < 1%
- Low NO_X

Pre-chamber technology
- Low NOx and THC / 'methane slip'
- Good combustion stability

Gas admission system
- Safe and relible gas admission &
- Simple sealing technology with low-pressure

Engine Control & Automation
- Integrated engine control and safety

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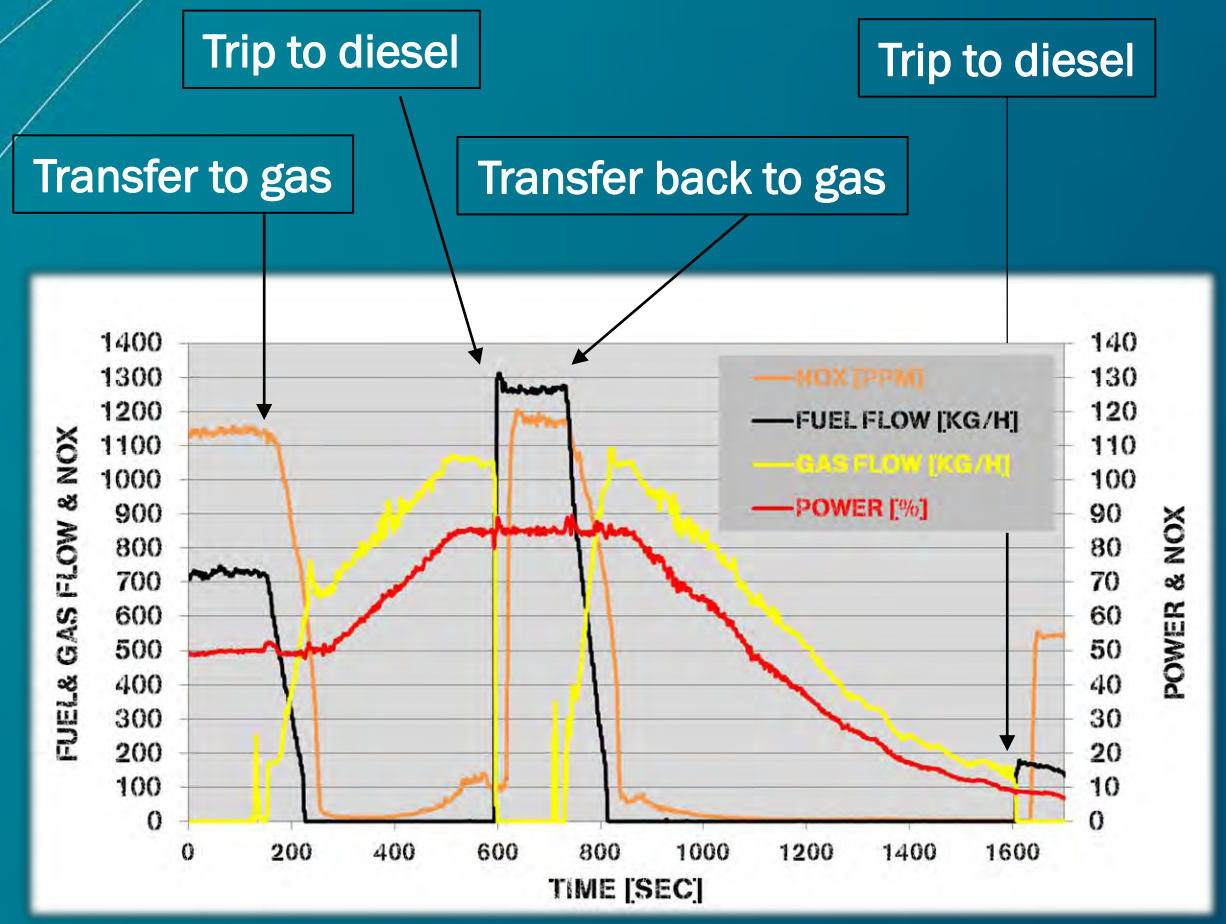
FUEL CHANGE OVER PROCESS



Fuel mode transfer

- Transfer to gas
  - Gradual, speed controlled transfer from Diesel to Gas on engine power up to 85%.
    Fully automatic transfer, just by pressing the push button “gas mode” on the bridge
- Trip to diesel
  - The switch from gas to diesel is instant ‘within 1 revolution’
  - At any load up to 100% to maximize safety
- Engine speed/load remains stable during transfer

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Detection of abnormal combustion

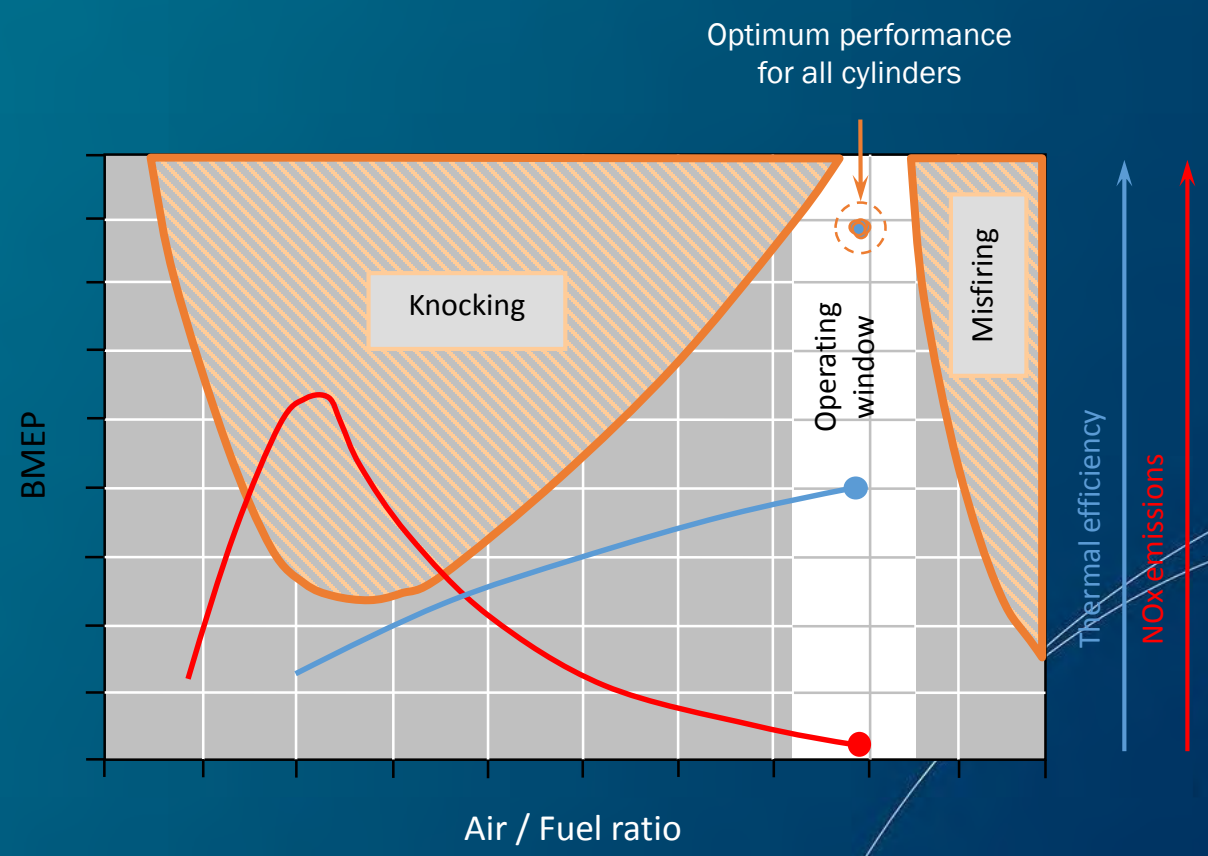
Safety relevant functionalities

- Knock detection
- Misfiring detection

if abnormal combustion: → Trip to diesel, all gas pipes vented

Performance optimization

- Cylinder balancing (compression pressure, firing pressure)
- Maximize efficiency



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Measures for low methane emissions on X-DF engines

Innovative design features and ongoing developments:

<u>Reduction of methane emissions to a minimum through:</u>

- Application of basic design principles to the combustion chamber:
  - Reduction of dead volume and crevices compared to conventional diesel engines
- Engine tuning measures:
  - Lambda control, gas admission valve timings, etc.
  - Optimization of the gas admission valve position and gas injection pattern
- Pre-chamber ignition technology:
  - Optimized ignition and combustion of the gas/air mixture
- Low shaft-speed and long stroke
  - Resulting in a large time window for excellent, homogeneous gas/air mixing and complete combustion with a minimum of unburned fuel emissions.
- Ongoing developments and improvements implemented in production engines

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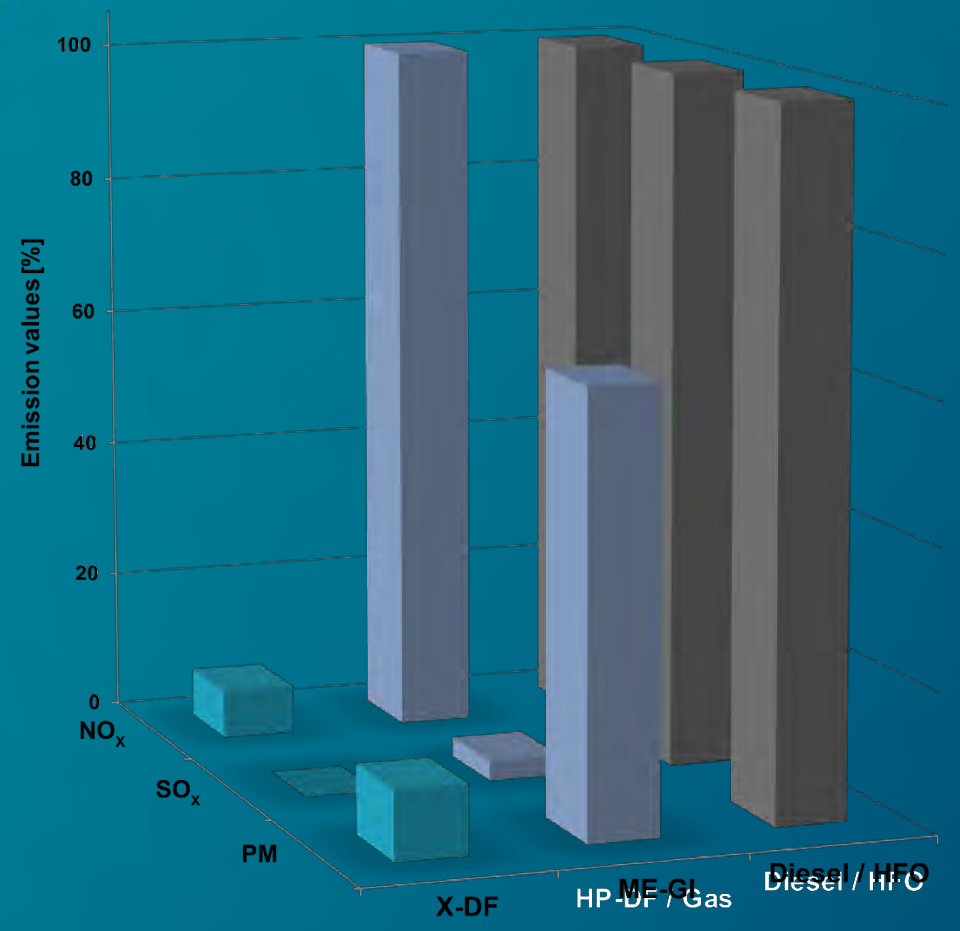
What about non-GHG emissions?

Toxic emission components with different engine technologies



NO_X, SO_X and Particulate Matter (PM) are a serious hazard to human health and are most effectively reduced with X-DF propulsion!

Extract from the latest WHO report, 2018-05-02:
"In 2016, 91 % of the world population was living in places where the WHO air quality guidelines levels were not met.

Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide in 2016."

http://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

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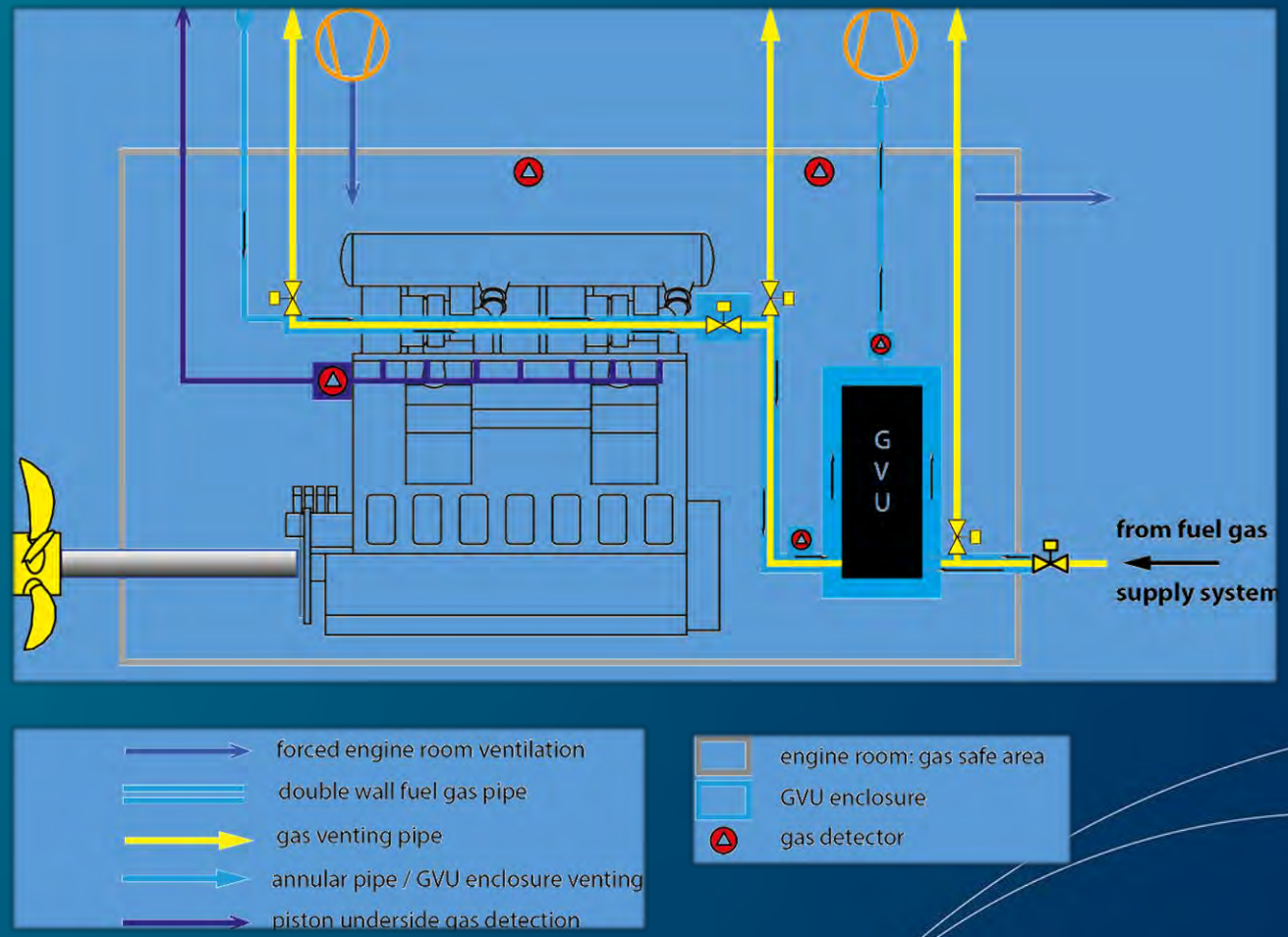
Gas safe machinery space

Double wall gas pipe concept:

- No gas can enter engine room
- Potential gas leakages are detected (detectors in engine room, gas pipes and piston underside)

→ 'gas free engine room' ensured, same as with standard diesel engine



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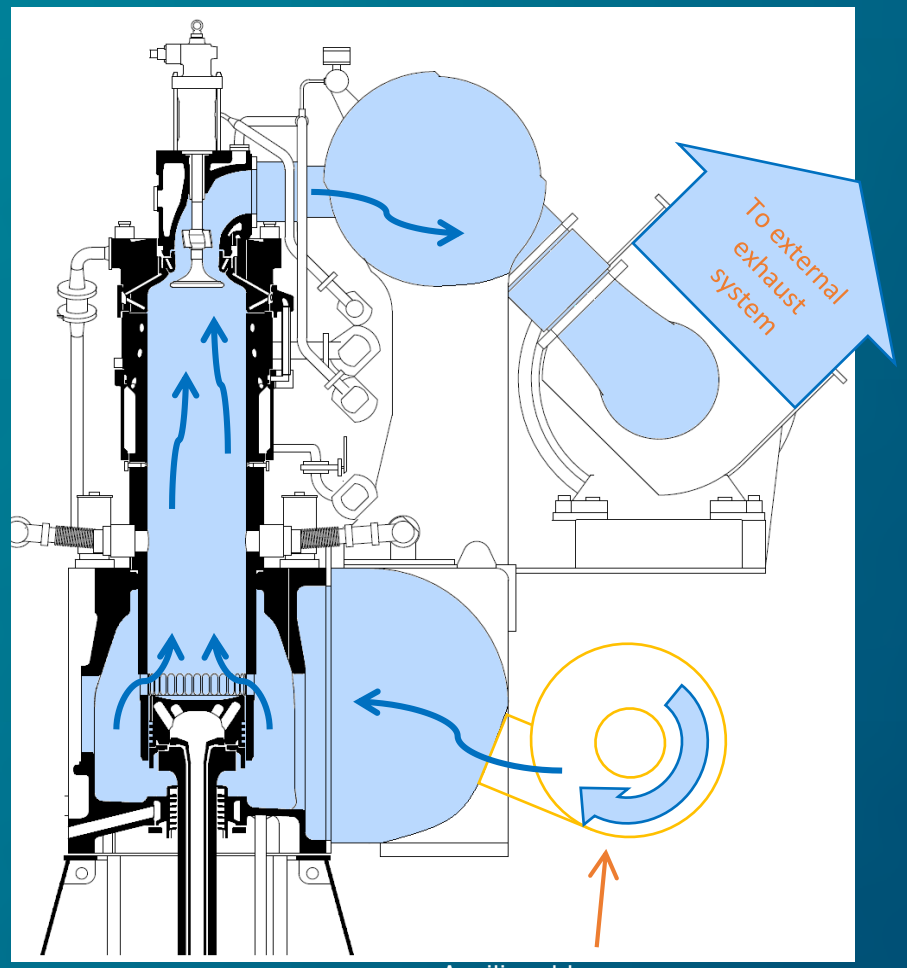
Engine / exhaust system ventilation



Prevent accumulation of gas in the engine and exhaust system

- After emergency stop / shut down in gas mode
- Purging with engine auxiliary blowers
- Exhaust valves automatically opened
- The stainless steel bellows between the pipe sections of the exhaust gas receiver, which are most critical components regarding overpressure, are designed to withstand a possible explosion without bursting

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41 LNG Carriers with X-DF

5RT-flex50DF
1 x 14k m³ Coastal LNGC

6X62DF
5 x 180k m³ LNGC

5X72DF
31 x 174k / 180k m³ LNGC

6X72DF
4 x 180k m³ LNGC

Shipbuilders: SHI, HHI, DSME, Hudong

81 engines on order, hereof 29 delivered, hereof 13 in operation

TOTAL 120 engines + options (end June)

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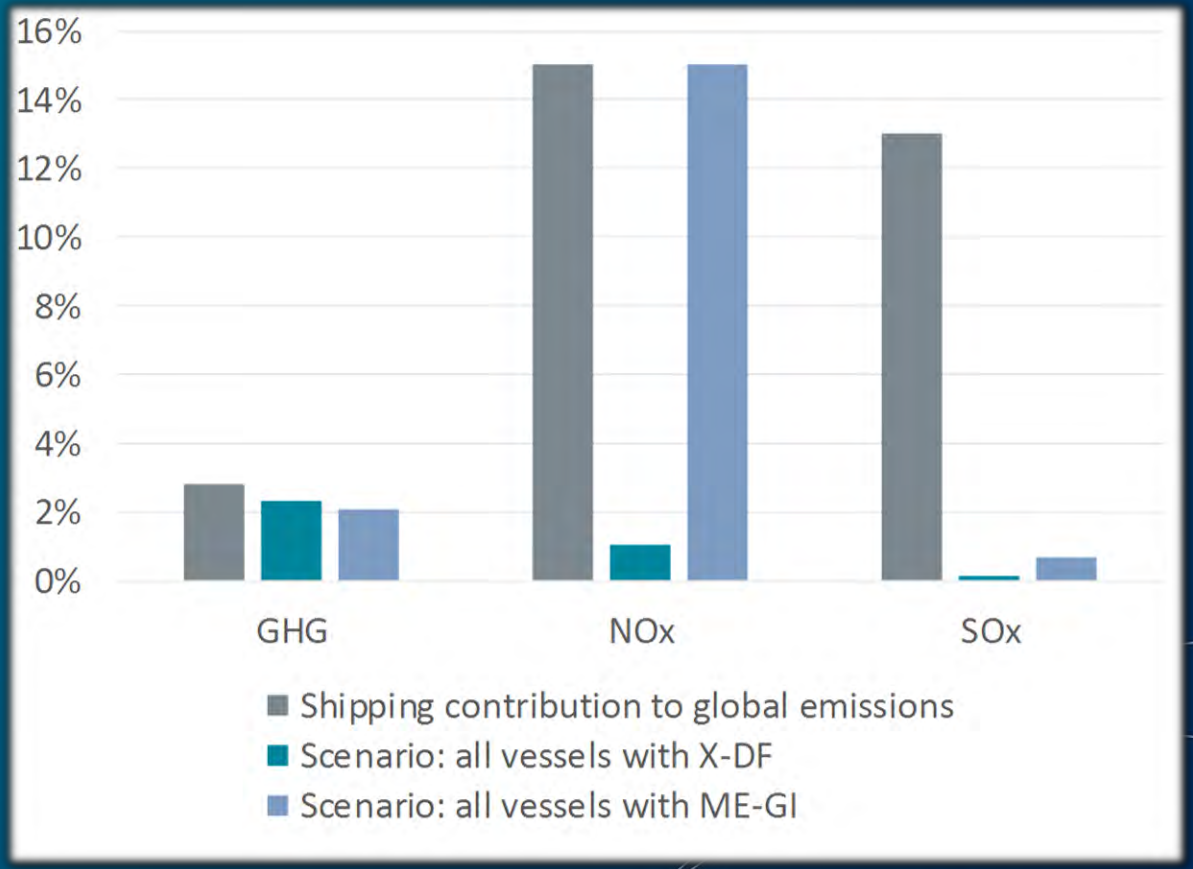
Conclusions

X-DF provides the lowest overall emission footprint

- Third IMO GHG study 2014:
  - Shipping contribution to global emissions:
    - 2.8% of GHG emissions
    - 15% of NOx emissions
    - 13% of SOx emissions
- X-DF engines significantly reduce emissions with toxic effect on human health (NO_X, SO_X, PM) to lowest level in the industry
- GHG emissions are reduced compared to conventional diesel engines
- Methane emissions of the X-DF have insignificant impact on the global GHG emissions
- X-DF engines provide the most environmentally sustainable total emission footprint currently available



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Thank you

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