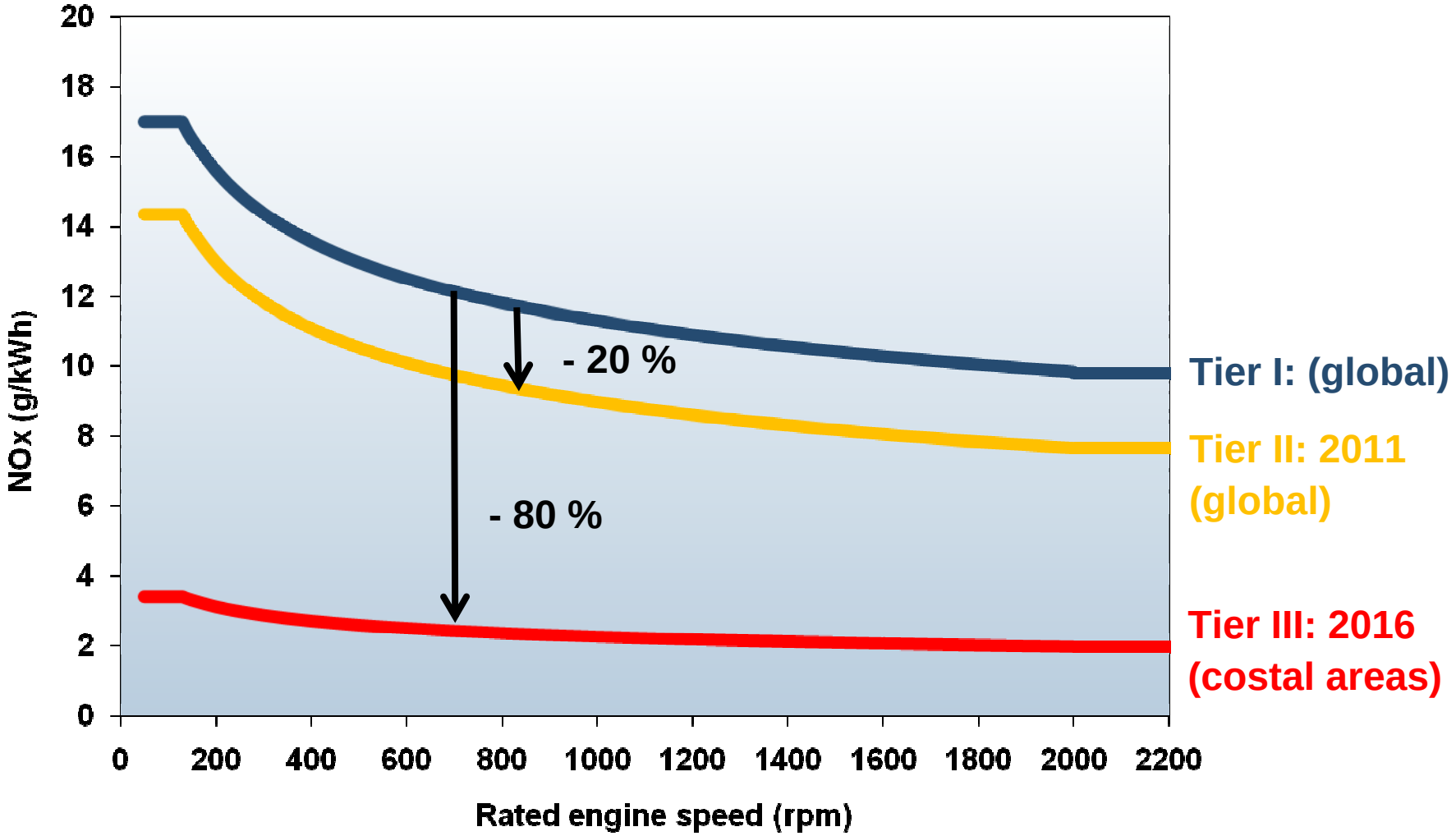
NO_x measures for IMO Tier II & III

Dr.-Ing. Stefan Spindler

Member of the Executive Board

IMO Tier II & III legislation



Tier II legislation

Requirement:

- NO_x-reduction of -20% compared to Tier I

Results:

- Several design changes (technology packages) and engine control adjustments necessary
- High charge air pressure required
- Smokeless engine
- Maintenance intervals and reliability continue to be improved
- Fuel flexibility fully remains

IMO Tier II can be fulfilled with internal measures only!

Internal measures

- **Combustion Process:**
  - Miller Process / Variable Valve Timing
  - Compression Ratio
  - Optimization of Combustion Chamber
- **Fuel Injection:**
  - Common Rail
  - Variable Injection Timing, mult. injections
  - Injection Rate Shaping beyond common rail
- **Optimized Turbocharging:**
  - 2-stage turbocharging
  - Variable Turbine Area

Tier 3 legislation

Requirement:

- NO_x-reduction of -80% compared to Tier I

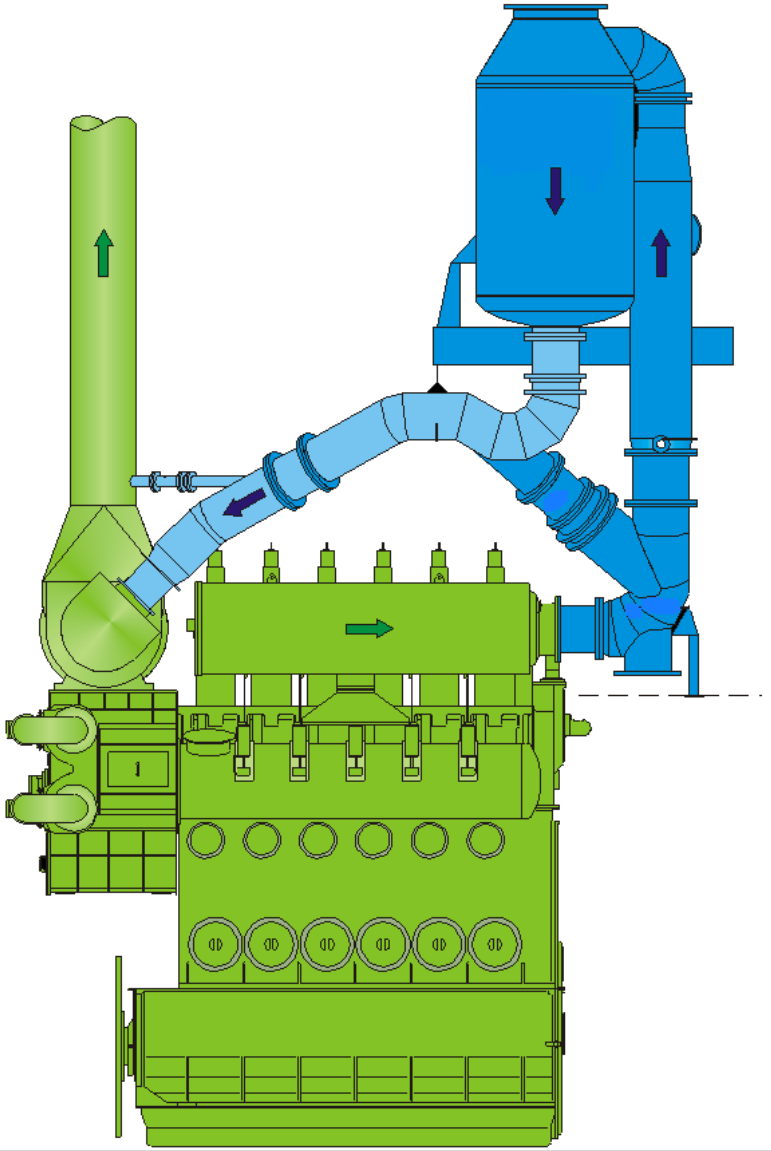
Results:

- Engine external measures available but necessity currently not clear
- Challenging target with internal measures
- Tier III compliance with internal measures is presently under investigation
- Options include combination of measures
- For external measures low sulfur fuel is required

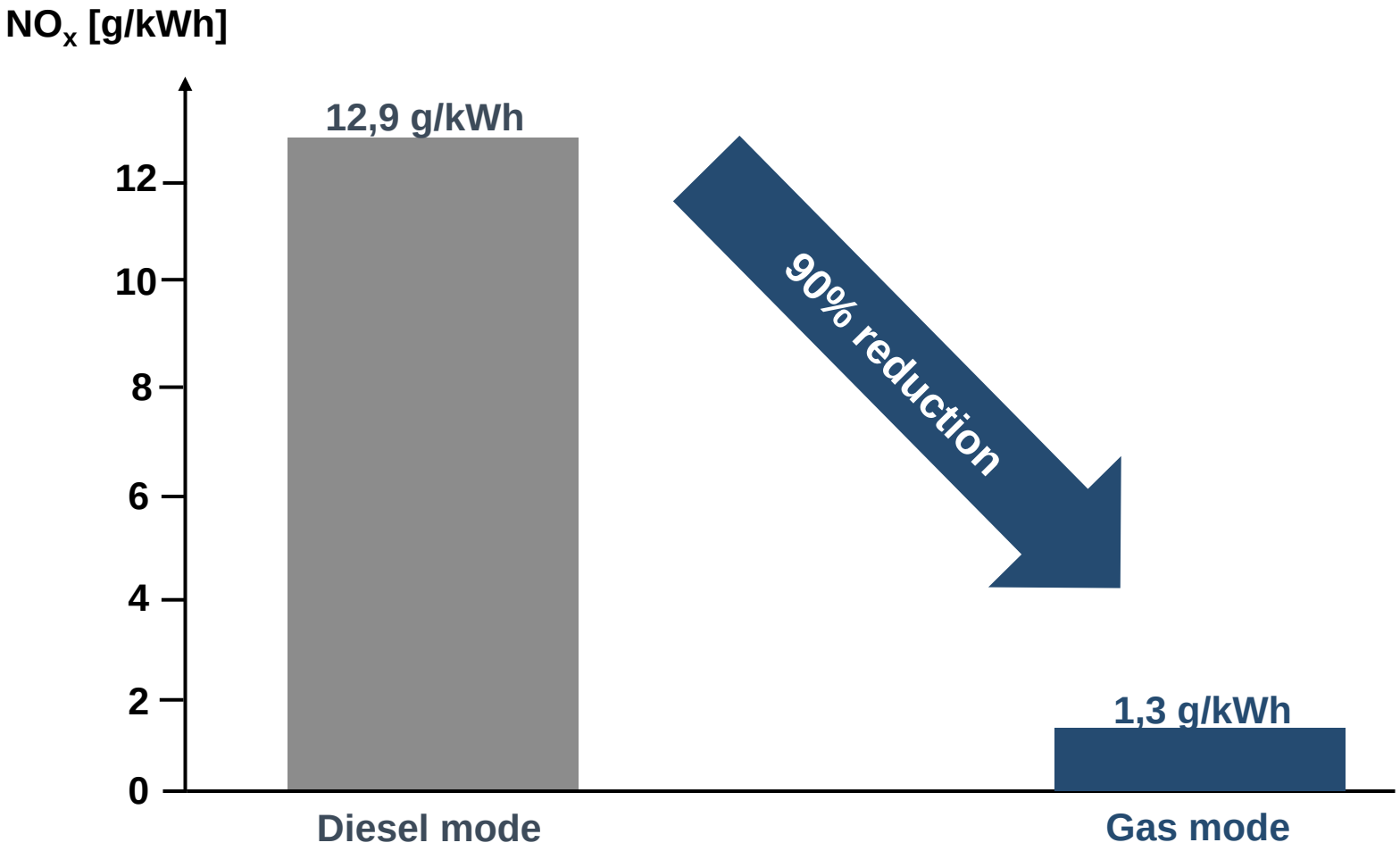
Optimal solutions for Tier III under development!

Additional measures

- **Humidifying Measures:**
  - Fuel Water Emulsion
  - Charge Air Humidification
- **Catalytic Measures:**
  - Selective Catalytic Reduction
- **Gas recirculation:**
  - Exhaust Gas Recirculation with scrubber
- **Gaseous Fuels:**
  - Dual fuel (DF & ME-GI) engines
  - Pure gas engines



Dual Fuel engines: Example of the 51/60 DF



Legislation for existing engines after 2011

Requirement:

- Affects only engines built 1990-1999 with engine output >5000 kW and >90l/cylinder
- Tier I emission level needs to be met

Assessment:

- No mandatory retrofit if it would result in:
  - 1% load reduction
  - 2% higher sfoc
  - Excessive investment cost
  - Negative influence on reliability
- Retrofit example:
  slide-valve-type fuel injector for 2-S engines

Different retrofit packages will be offered!

Summary

Tier II:

- Technical solutions are available
- Engine producers can ensure Tier II compliance with internal measures only

Tier III:

- Several technical solutions under investigation
- Options include:
  - Sfoc-optimized engine + SCR
  - Internal measures with fuel penalties
  - Combination of internal & additional measures

Demands for maintenance intervals and reliability can be reached for both Tier II & III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