NOX Compliance – Now & In the Future

GE Marine Solutions

SMM Hamburg August, 2016

Imagination at work

Four GE businesses operate in the marine industry

Aviation

- Aeroderivative Gas Turbines
- Propulsion System Integration
- Mechanical Drive Packaging
- GT Generator Sets
- Exhaust Energy Recovery
- Hybrid Drive Solutions
- Integrated Diesel/GT Solutions

Oil & Gas

- Drilling & Surface
- Measurement & Control
- Subsea Systems
- Turbomachinery
- Global Services

Energy Connections

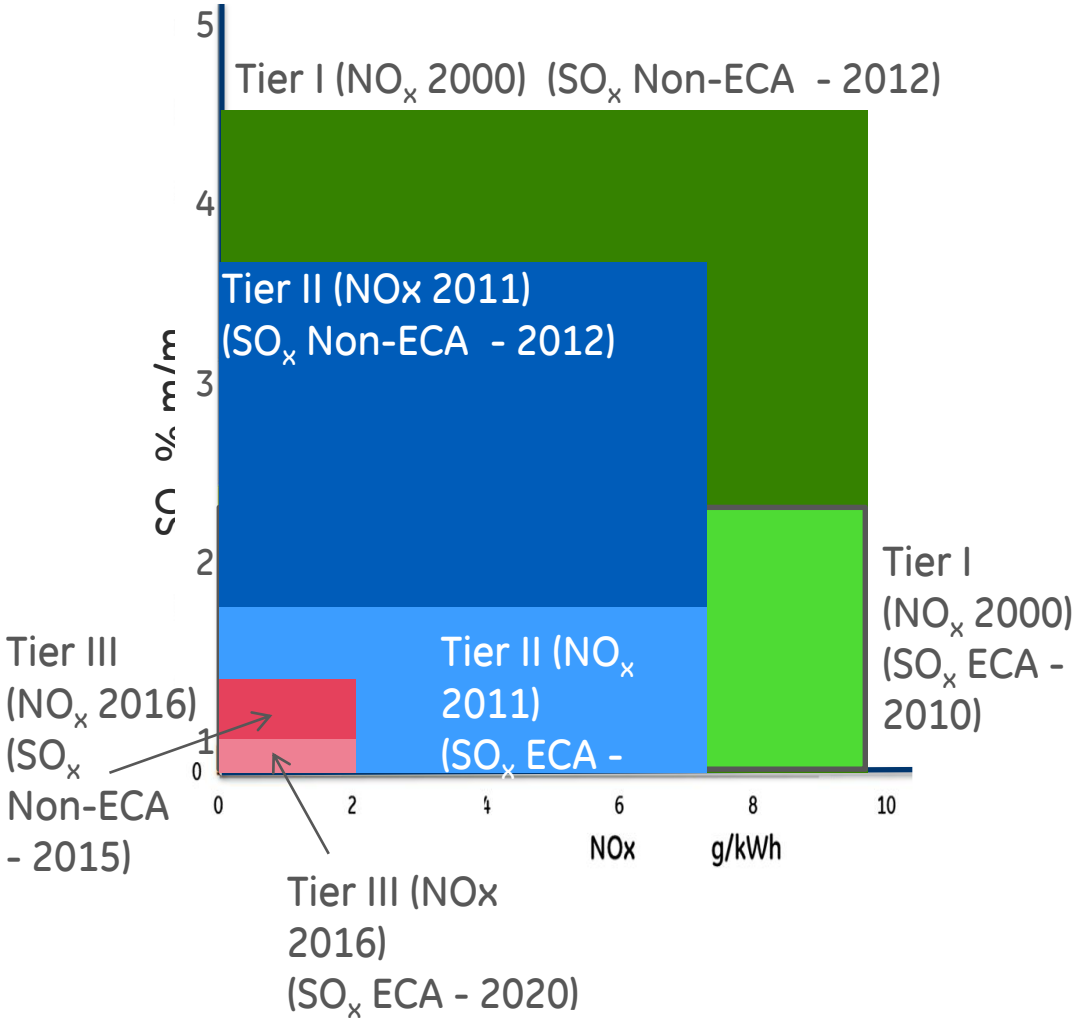
- Dynamic Positioning
- Vessel Automation & Control Systems
- POD Propulsion System
- Drilling (Drive)
- Visor Asset Management System

Transportation

- Diesel Marine Engines
- AC Drilling Motors
- DC Drilling Motors

Large portfolio, spanning the industry

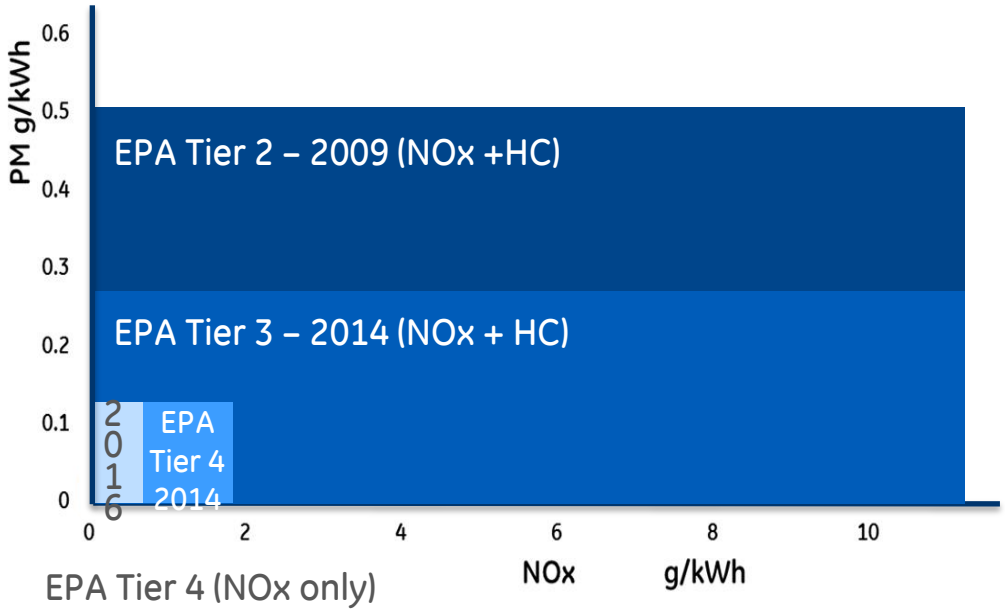
MARPOL Annex VI Regulations



US EPA 40 CFR Regulations

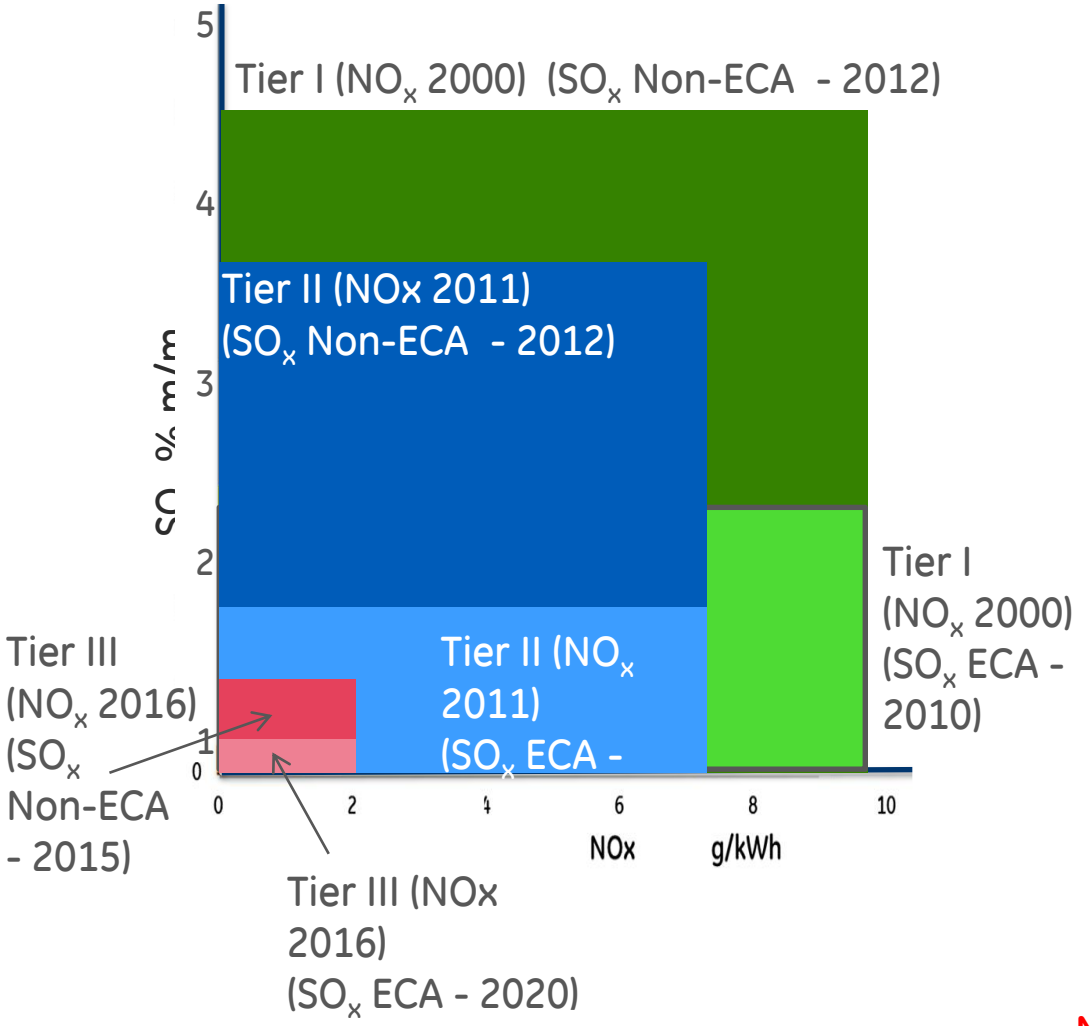
US EPA considers gas turbines a "Category 2" diesel with a displacement of 29 dm^3, >2000 rpm.

US EPA regulates particulate matter (PM). IMO does not.



EPA Tier 4 (NOx only)

MARPOL Annex VI Regulations



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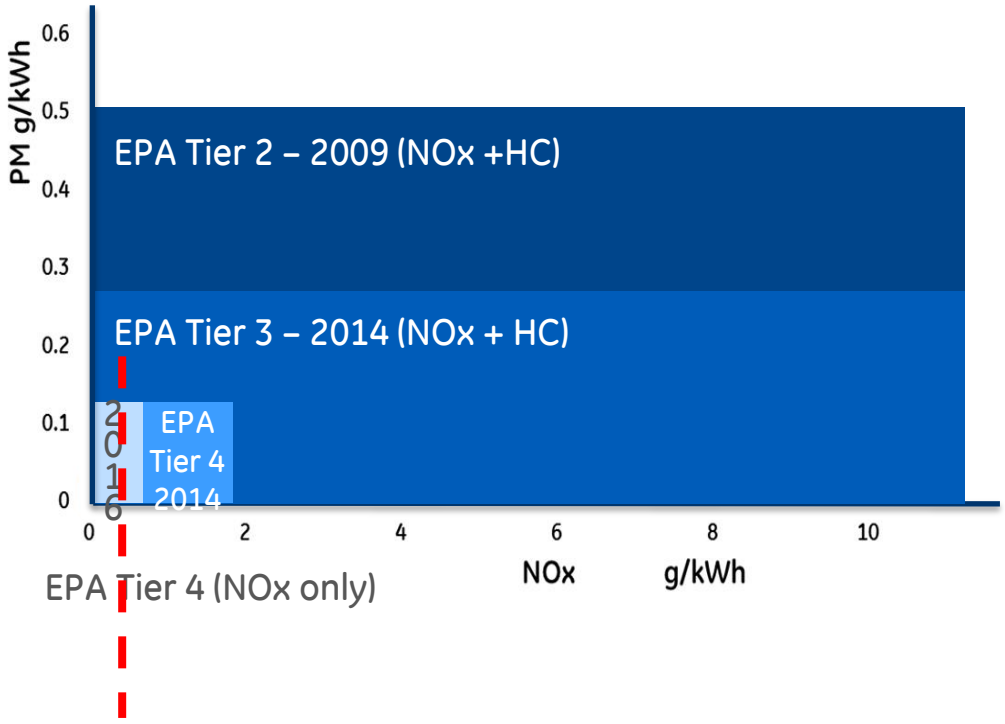


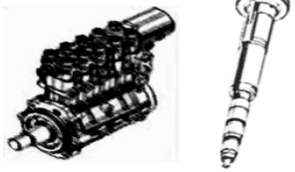
NOX limit for PG/O&G industries

EPA Tier 4 / IMO III Emission Compliance

EPA Tier 4/IMO III Engine Technology

V250MDB – EPA T2/IMO II

V250MDC – EPA T4/IMO III

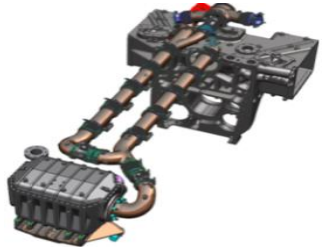


HP Common Rail

- 2200 bar system
- DW w/ Leak Alarm

2 Stage Turbo

- Radial LP turbo
- Radial HP turbo
- Packaging optimization



EGR

- EGR cooling & on engine cooler packaging
- Marine approved shielding

Control System

- On Engine – ECU
- On Engine – AMSC
- Integrated harnessing

Increased PCP Capability

- PA assembly upgrade
- Structural upgrade to V250

TECHNOLOGY - NO SCR AFTER-TREATMENT FOR EPA TIER 4 AND IMO III

- Medium speed diesel engines meet emissions standards and reduce emissions up to 70%
- Breakthrough technology eliminates the need for urea-based after-treatment emissions reduction system to meet EPA Tier 4 and IMO III
- Offering increased power (1,500 – 4,700kW) while maintaining low life cycle cost, enhanced reliability and improved fuel efficiency

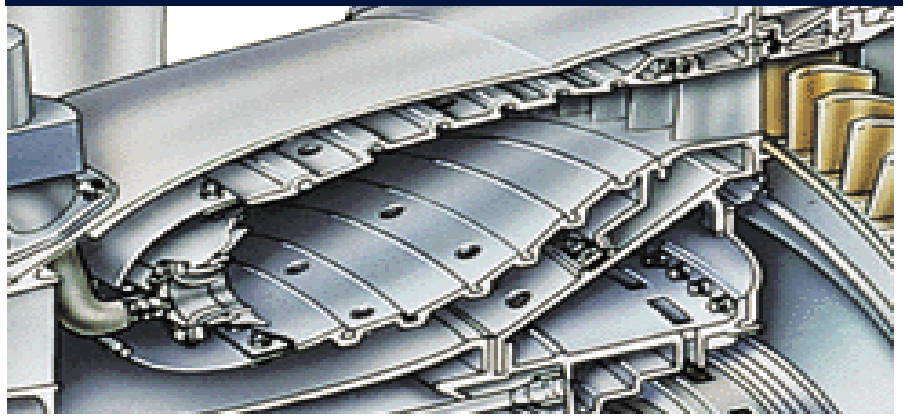
L250 EPA Tier 4
IMO III

V250 EPA Tier 4
IMO III

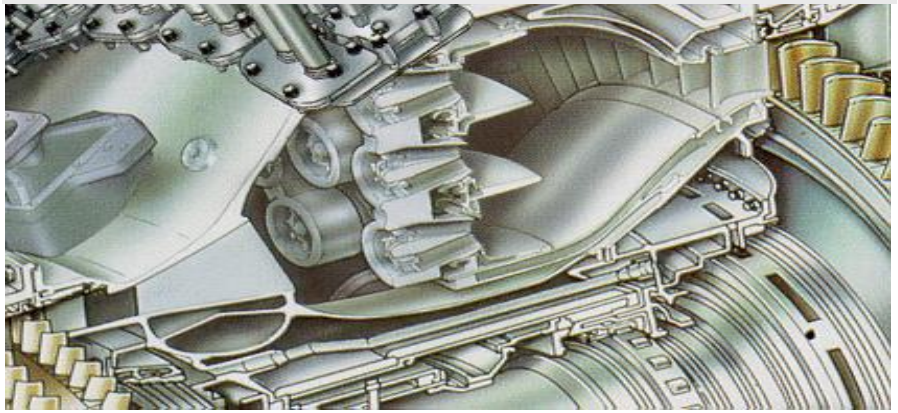
GE imagination at work

Two Basic Approaches to NOx Abatement in Gas Turbines

Diffusion Combustor

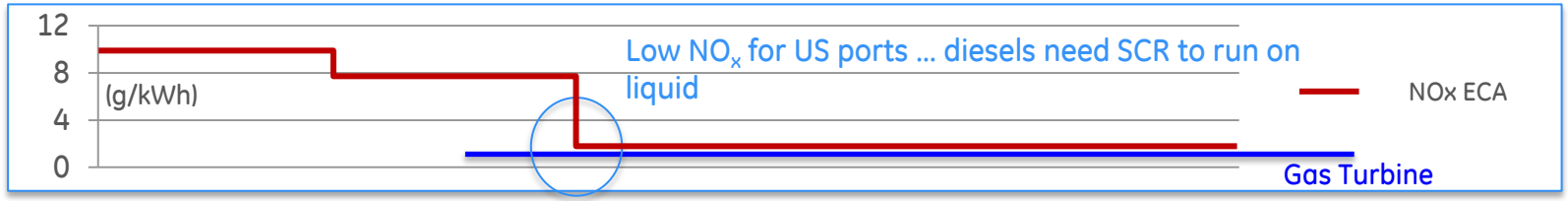


Dry Low Emissions



	WET	DRY
Flame temperature	>4000 F/2204 C	~3000 F/1648 C
NO_x w/o abate	>200 ppm (3.2g/kw-hr)	15-25 ppm (0.22-0.43 g/kw-hr)
NO_x control	Water Injection Steam Injection Reduces NOX to 0.43 g/kw-hr)	Lean Premix

NOX regulations … GT meets regulations proposed today



❶ **Dry Low Emissions (DLE) combustor … high time in ECAs**
- Reduces NOx to 0.32 g/kWe-hr in combined cycle
- Introduced in **1994** … **835** systems, **18M+** operating hours (All LM engines)

❷ **Single Annular Combustor (SAC) … limited time in ECAs**
- Selective NOx control via water injection
- Introduced in **1968** … **3,200+** systems, **76M+** operating hours

No after treatment needed, no methane slip … ever!

NOX compliance observations from PG/O&G industries

- Regulations tied to “Best Available Technology” (BAT) solution…competition drives innovation; new solutions tighten the regulation
- Compliance costs more, delta drops over time
- Reliability can be as good as or better than standard solution…operator training is key
- Emissions compliance applies to the life of the equipment…CEMS, PEMS, & big data