Change Together! 창조적으로 변화하자!

Experienced Emission Reduction Technologies and Eco-friendly Solution of HiMSEN Engine

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Hyundai Heavy Industries

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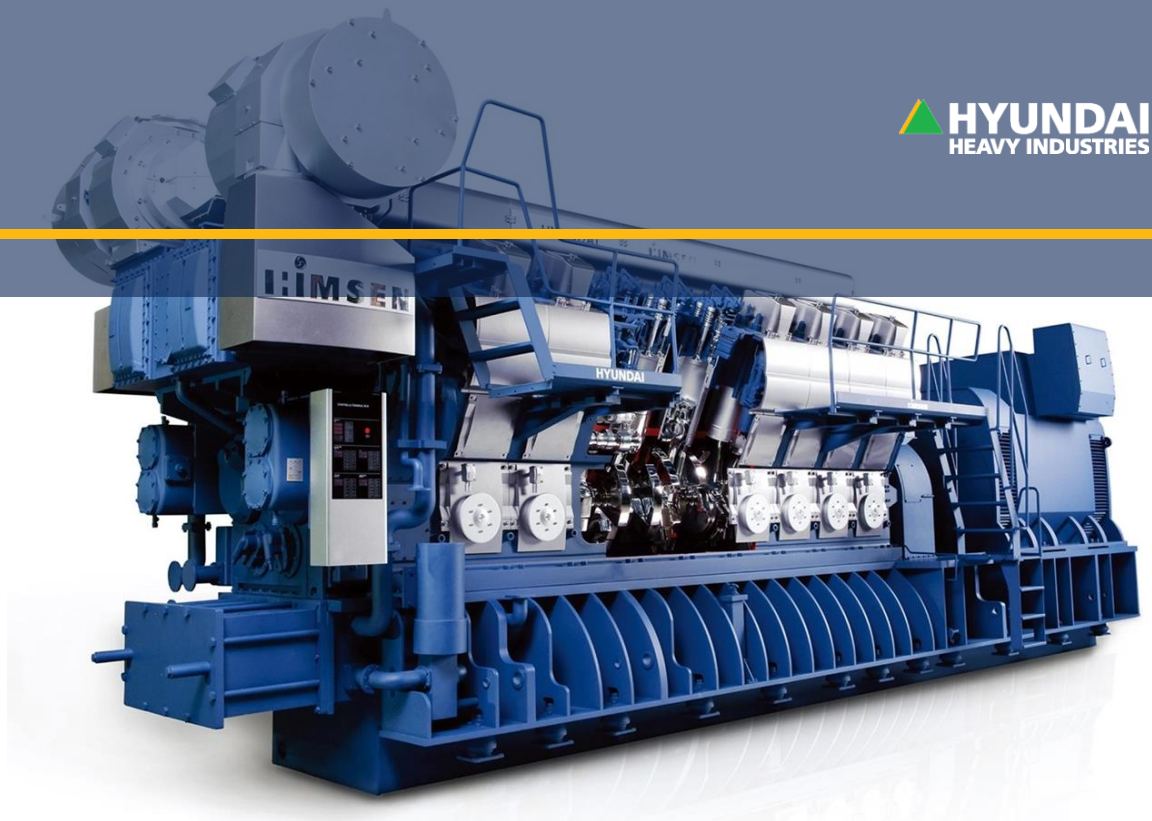

CIMAC

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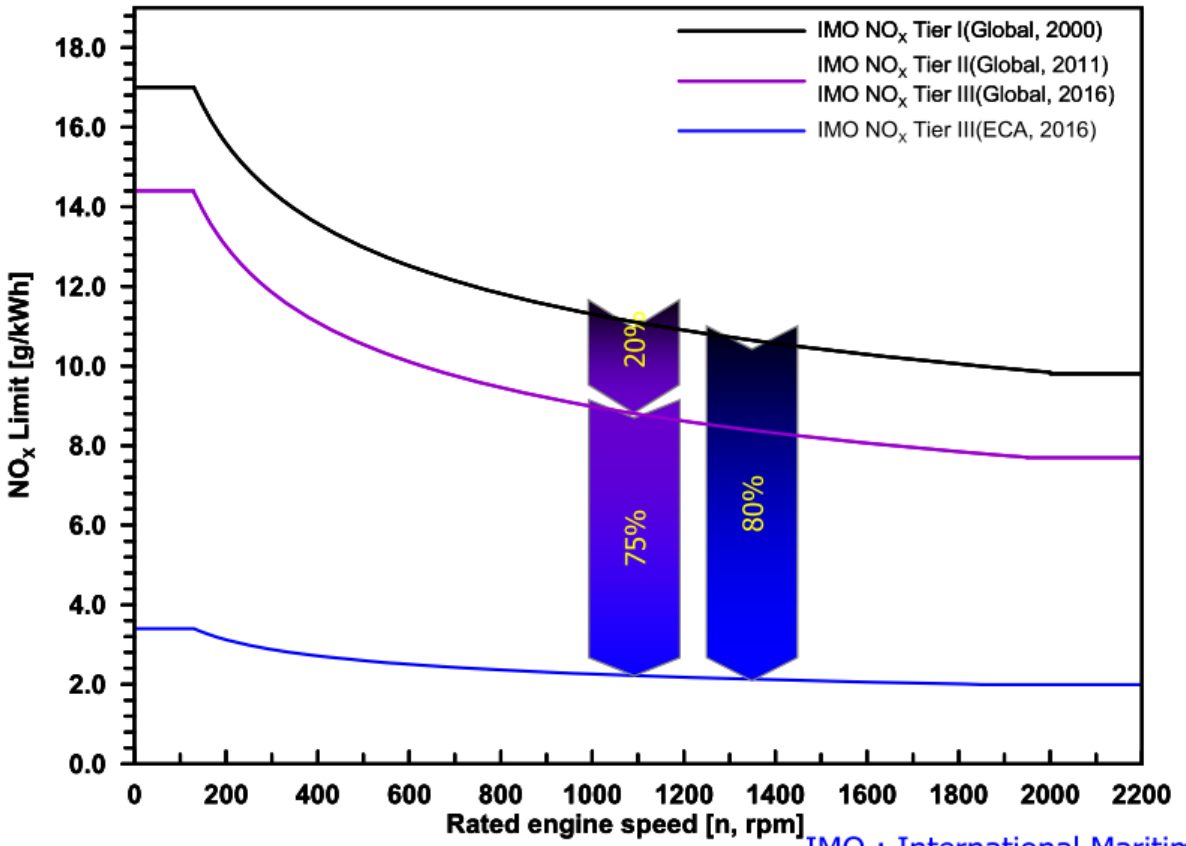
Introduction

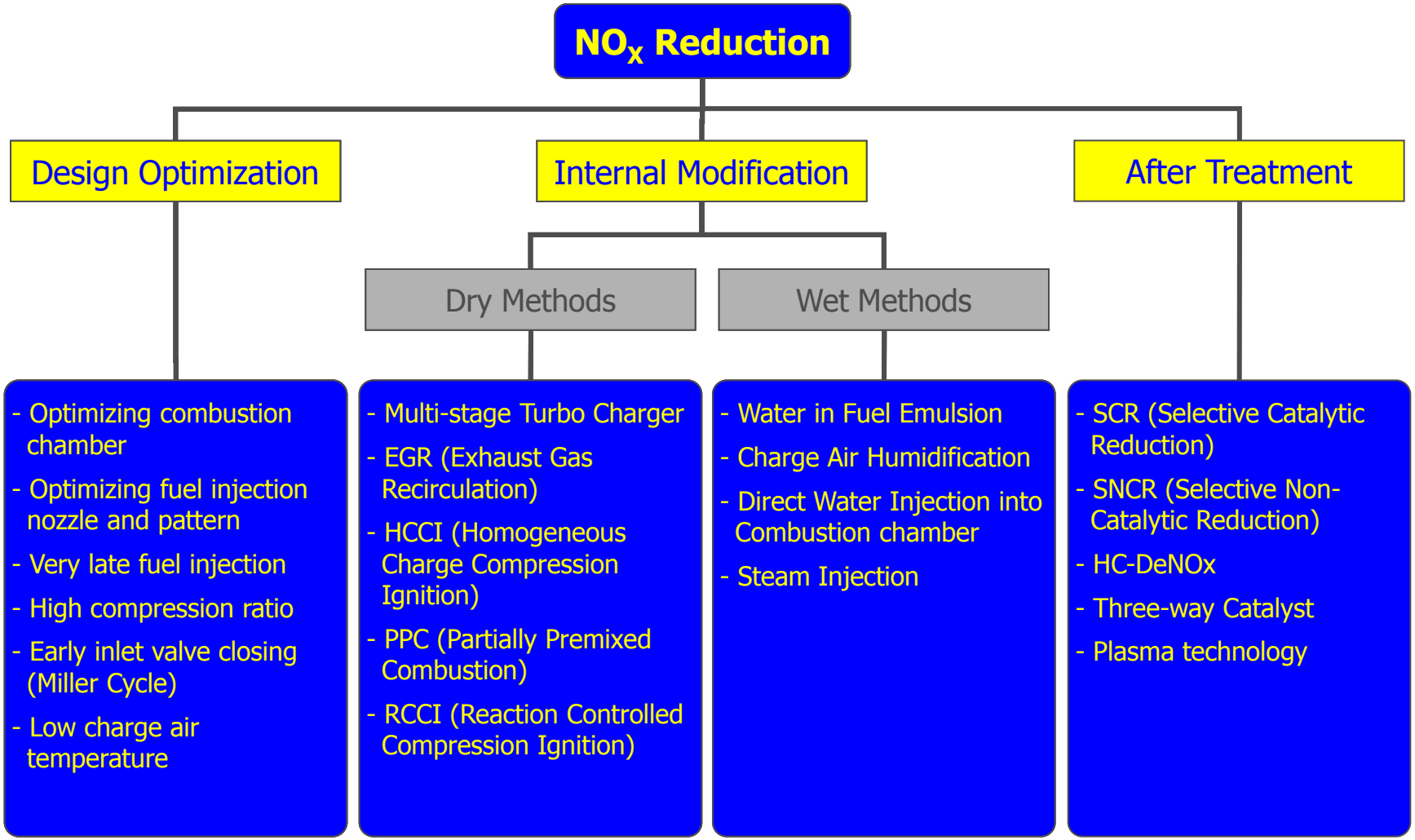
- Emission Limits



IMO : International Maritime Organization
ECA : Emission Control Area

Introduction

- NOx reduction methods



Introduction

- Measures for the IMO Tier III NO_X emission limit
  - There is no exclusive method to be able to comply with IMO Tier III limit except SCR
  - Combination of two reduction methods or more has possibility being able to afford to follow Tier III limit

- Available combinations to follow the Tier III NO_X emission limit
  - EGR & Water addition
  - 2-stage T/C & EGR
  - 2-stage T/C & Water addition

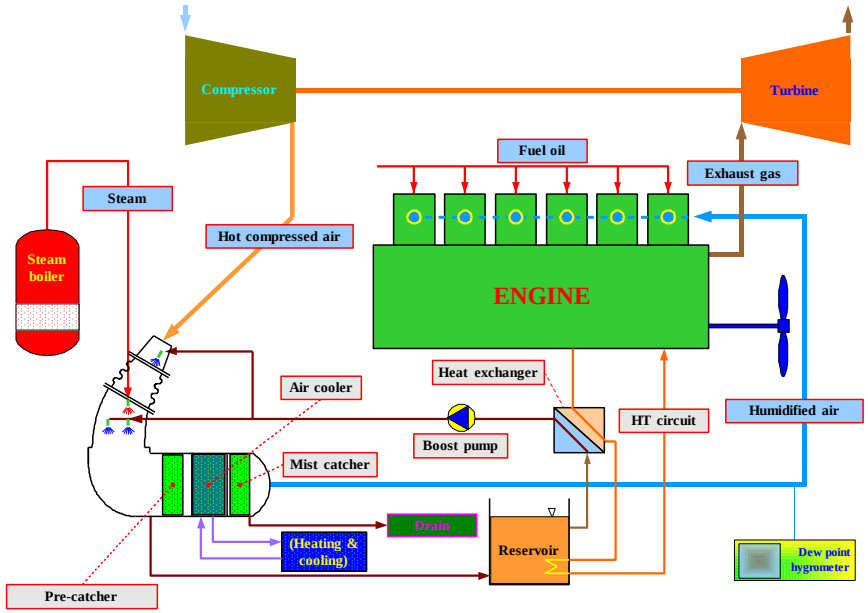
Charge Air Moisturizer (ChAM)

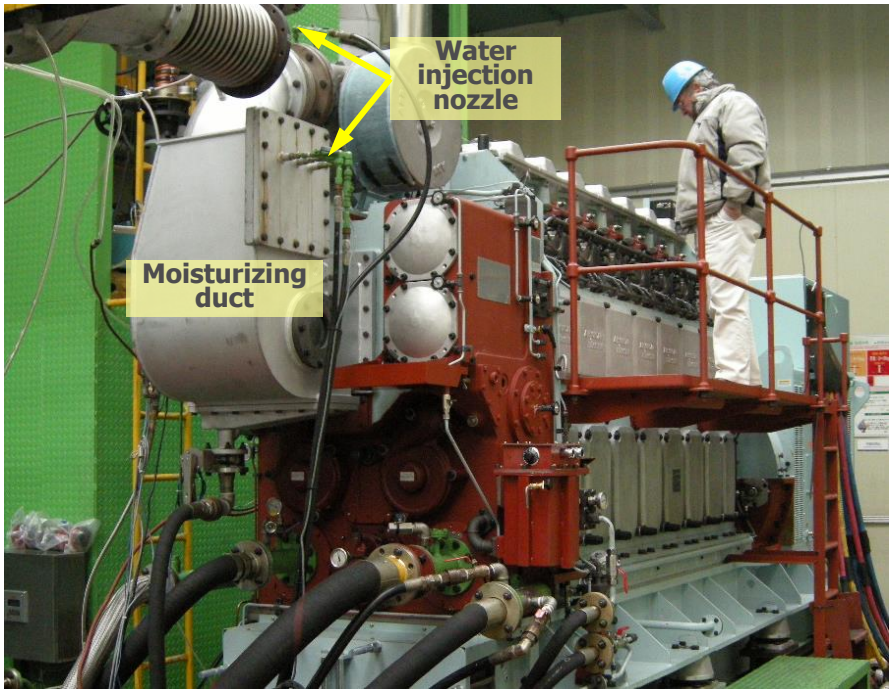
- NO_X reduction by water addition
  - Water addition into combustion chamber
    - → Increase of specific heat of combustion air
    - → Decrease of combustion peak temperature
    - → Reduction of NO_X (thermal NO_X)

- Water addition methods and NO_X reduction rate
  - Water in fuel emulsion : 20 ~ 30%
  - Water injection into combustion chamber : 30 ~ 50%
  - Charge air humidification : 40 ~ 60%

Charge Air Moisturizer (ChAM)

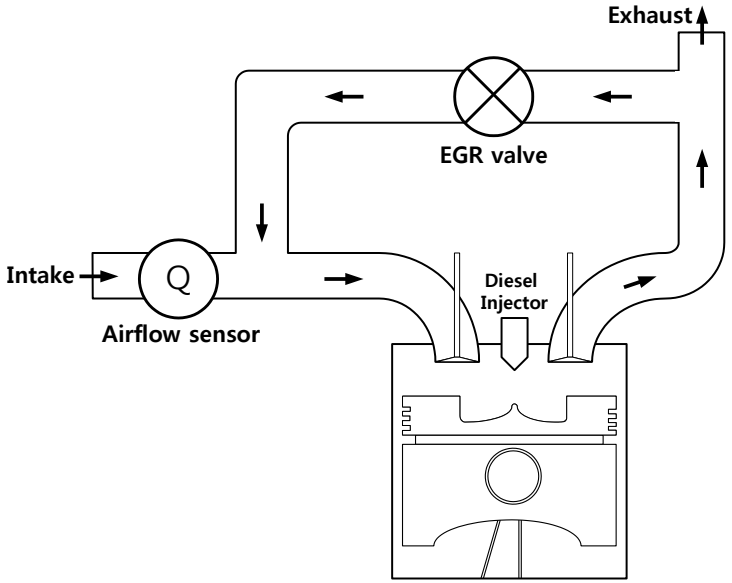
- Charge Air Moisturizer
  - Water and steam injection into intake air
  - Flow of humidified intake air into combustion chamber
  - Reduction of NO_X emission : 40~60%





Exhaust Gas Recirculation(EGR)

- Concept
  - Returning of a portion of engine's exhaust gas into intake air to increase heat capacity and to reduce oxygen content of combustion air
  - Decrease of peak combustion temperature
  - Reduction of NO_X emission : 30~60%



Experimental Setup

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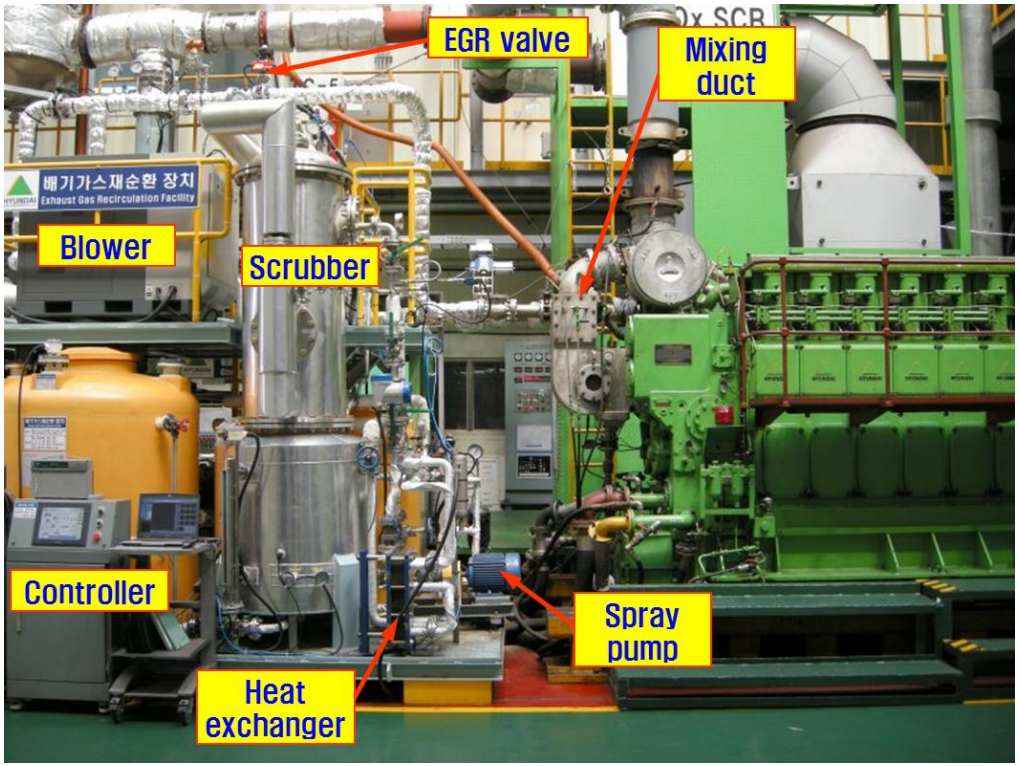
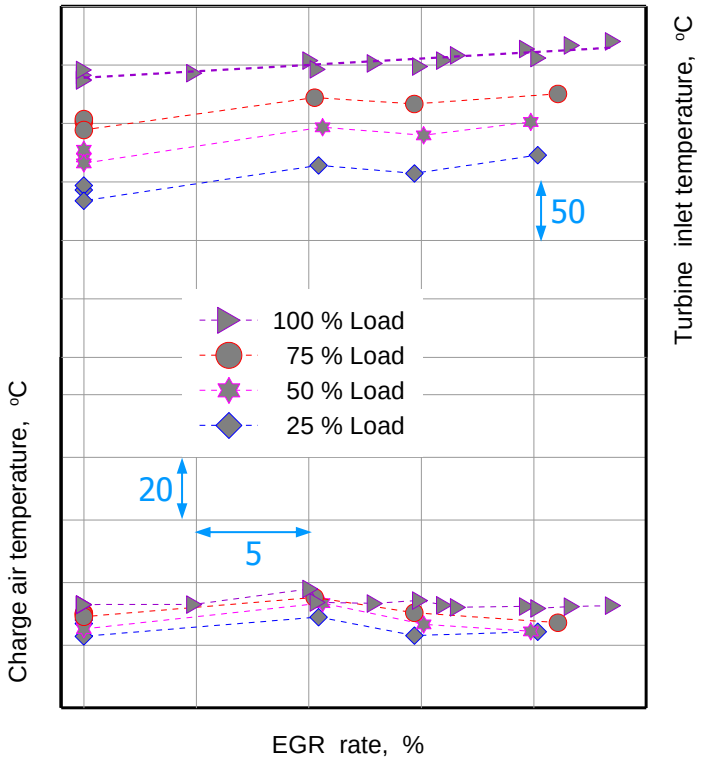
- EGR system



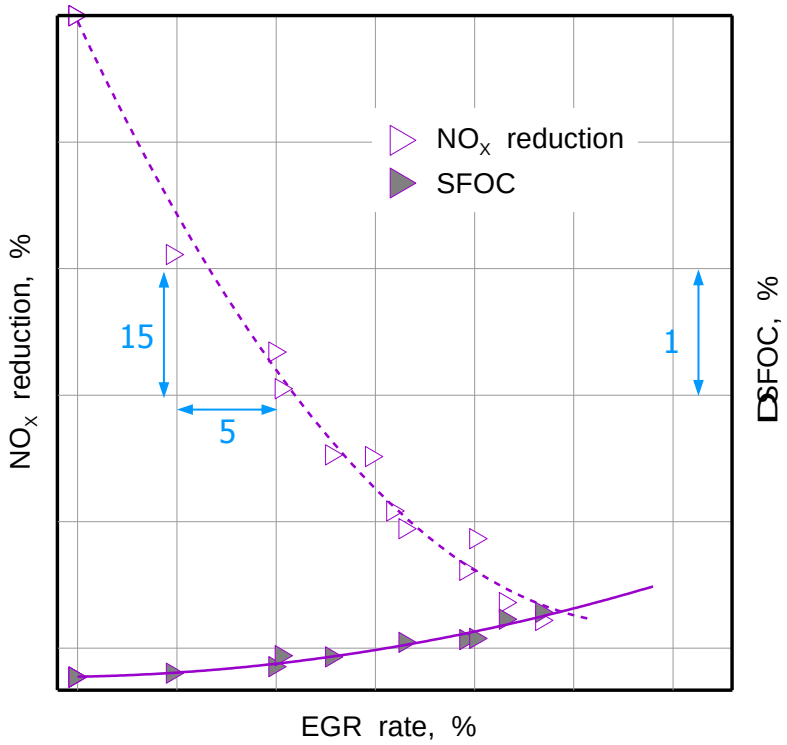
Test Results of EGR System

- Intake air temperature
  - No noticeable variance with EGR rate
  - EGR gas is cooled through scrubber and EGR cooler
  - Mixed gas (charge air and EGR gas) is cooled through air cooler
- Exhaust gas temperature
  - Temperature increase with higher EGR rate
    - Increased later combustion due to decreased combustion rate
    - Reduced charge air flow due to lowered charge air pressure



Test Results of EGR System

- NO_X reduction and SFOC
  - SFOC increases while NO_X decreases with higher EGR rate due to longer burning duration
  - Optimized combustion and fuel injection timing are required to control increased SFOC and smoke with EGR rate

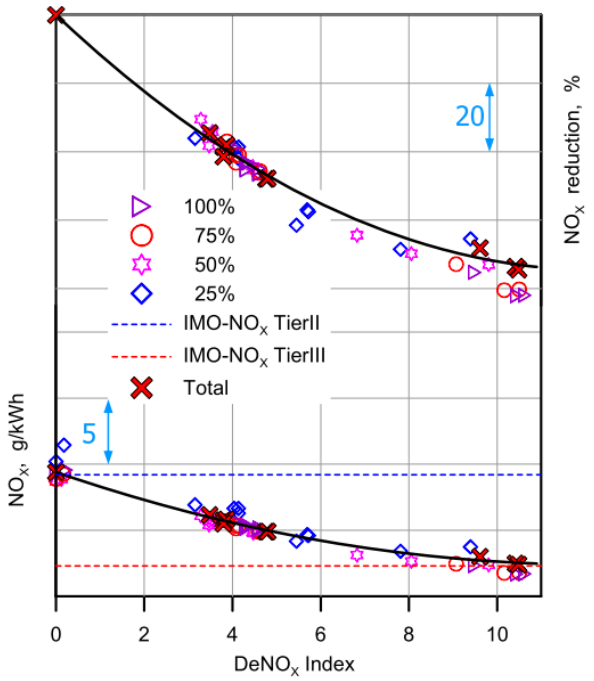


Test Results of ChAM + EGR

- DeNOx index
  - DeNOx index = $\{(\eta_{NOx})_{EGR} + (\eta_{NOx})_{ChAM}\} / 10$

    $(\eta_{NOx})_{EGR}$: NOx reduction efficiency with EGR

    $(\eta_{NOx})_{ChAM}$: NOx reduction efficiency with ChAM



Test Results of ChAM + EGR

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- NOx reduction by ChAM + EGR system
  - ChAM system only : 47.5 %†
  - ChAM + EGR system : 75.4%†

※NOx reduction efficiency

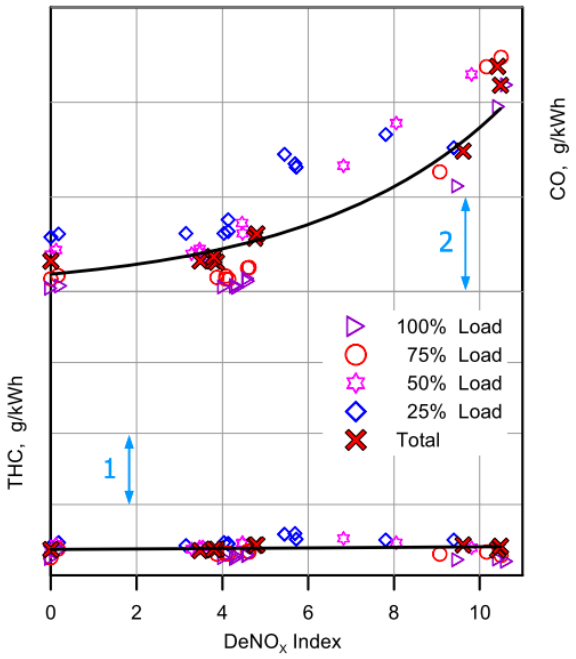
= 100 − NO_x(%) with EGR x NO_x(%) with ChAM

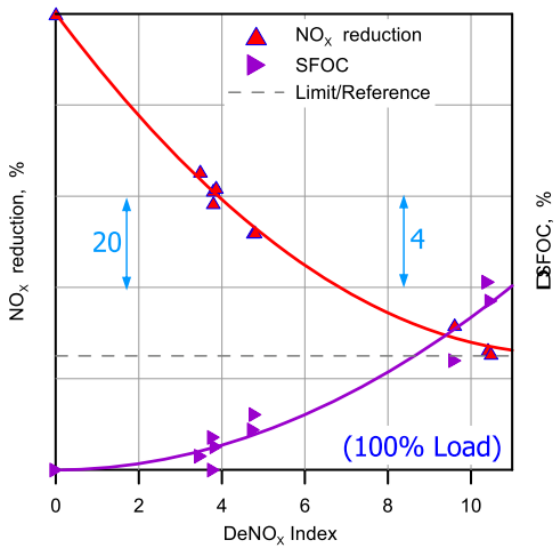
EGR	ChAM	Compound system	
Reduction		Estimated※	Test result
46%	47.5%	72%	68.2%
55%		76.2%	75.4%

† : compared with ref. condition

Test Results of ChAM + EGR

- Emission and SFOC
  - Increase of CO due to poor combustion condition
  - No noticeable increase of THC
  - The more NO_x reduction, the worse SFOC

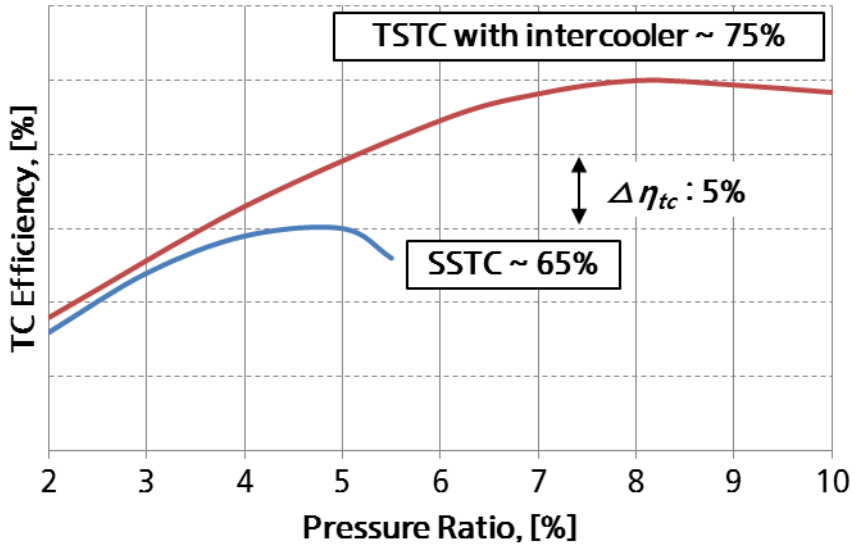




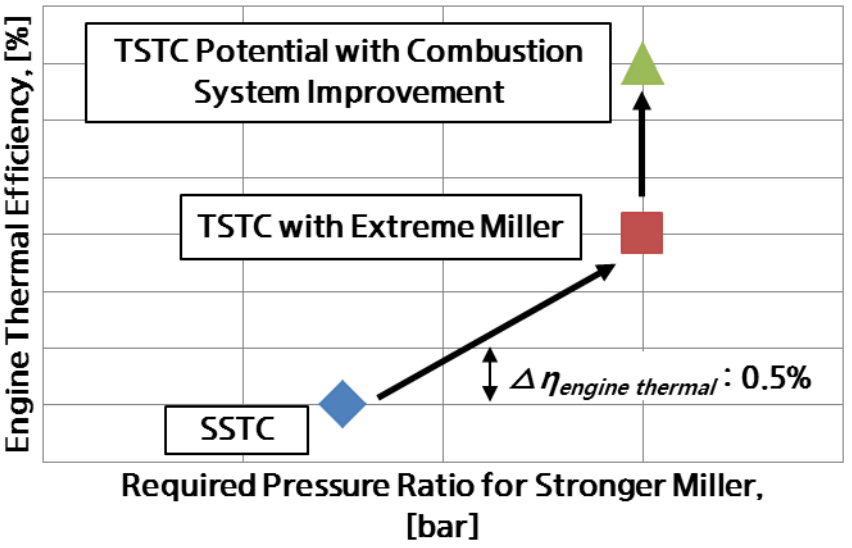
Two Stage Turbo-Charging + EGR

Two Stage Turbo-Charger

- TSTC with intercooler can increase turbocharger efficiency and provide high charge air pressure.
- The availability on the high charge air pressure allows extreme Miller(Adv. IVC) that increase engine thermal efficiency at same NOx emission level.
- There is potential with combustion system improvement to increase engine thermal efficiency.



〈Typical Turbocharger Efficiency vs Pressure Ratio〉



〈Engine Thermal Efficiency Gain with TSTC〉

Experimental Setup

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- TSTC+EGR system

Test Results of TSTC + EGR

- TSTC system IMO Tier II NO_X setting can reduce SFOC by 5%
- TSTC + EGR system can reduce NO_X by 75% or more
  - shows worse SFOC than SSTC Tier II system

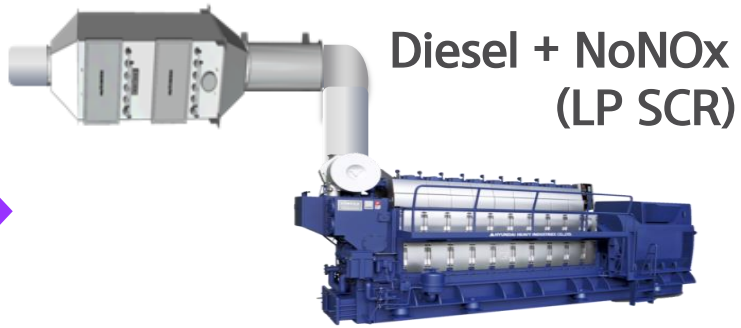
Diesel Engine + SCR

Diesel Engine with SCR

- Conventional diesel combustion for diesel mode
  - Meets IMO Tier II NOx regulation
- SCR reduces NOx emission to meet IMO Tier III regulation

Diesel Engine

Aftertreatment



Diesel Engine with SCR

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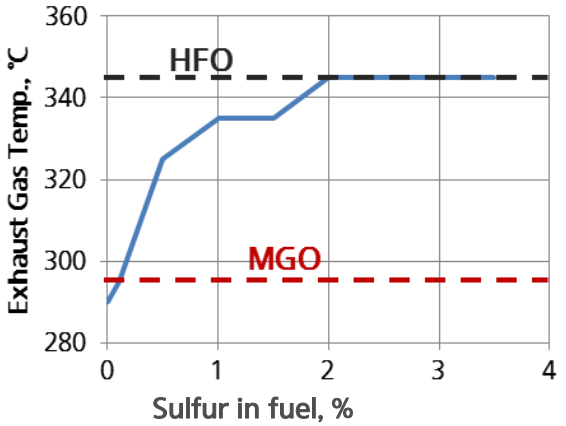
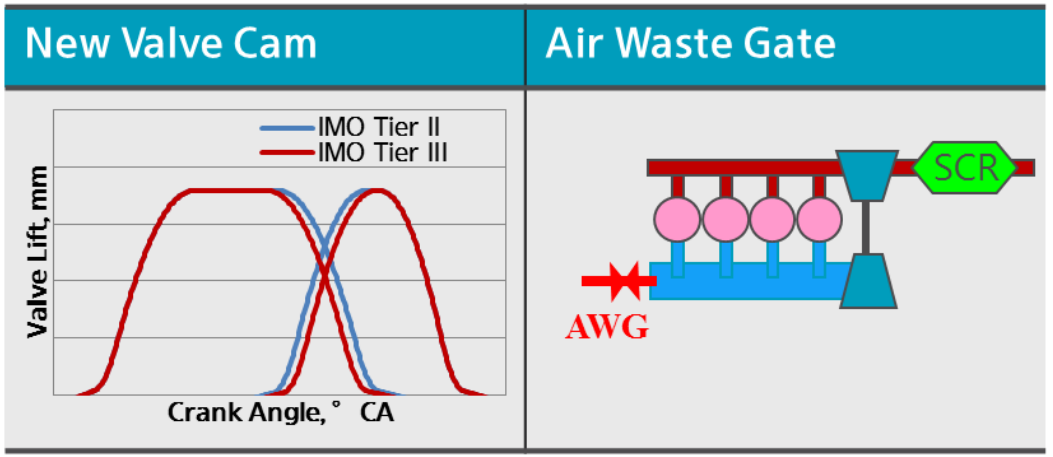
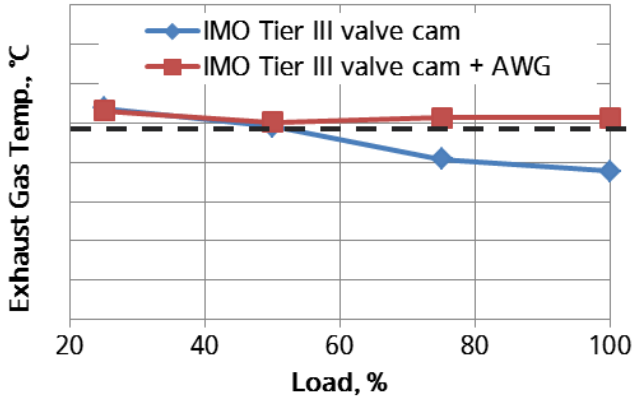
✓ SCR requirements



〈Required Temperature from Engine〉

✓ Solution(major changes)





SCR requirement (HFO)

Engine Type	Application Date
16H32/40Vx4 (SN2100)	2014. 9
6H21/32x4(HMD8173)	2016. 1

〈Application on ships〉

DF(Dual-Fuel) Engine

DF Engine

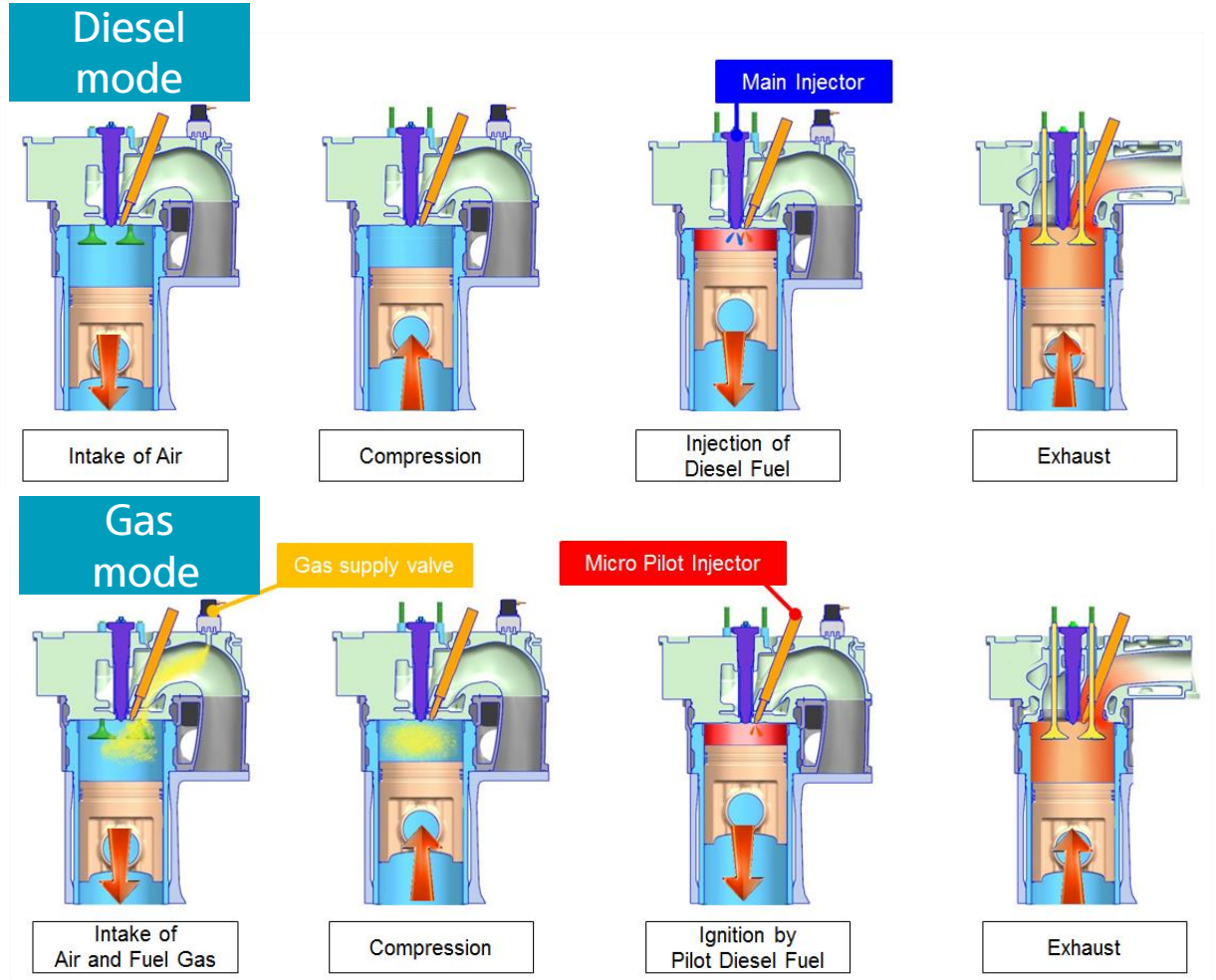
- Conventional diesel combustion for diesel mode
  - Meets IMO Tier II NOx regulation
- Pre-mixed lean combustion for gas mode
  - Meets IMO Tier III NOx regulation

Diesel Engine

Gas/Dual Fuel Engine

DF Engine

- Dual-Fuel Engine: Principle of DF Engine Operation



DF Engine

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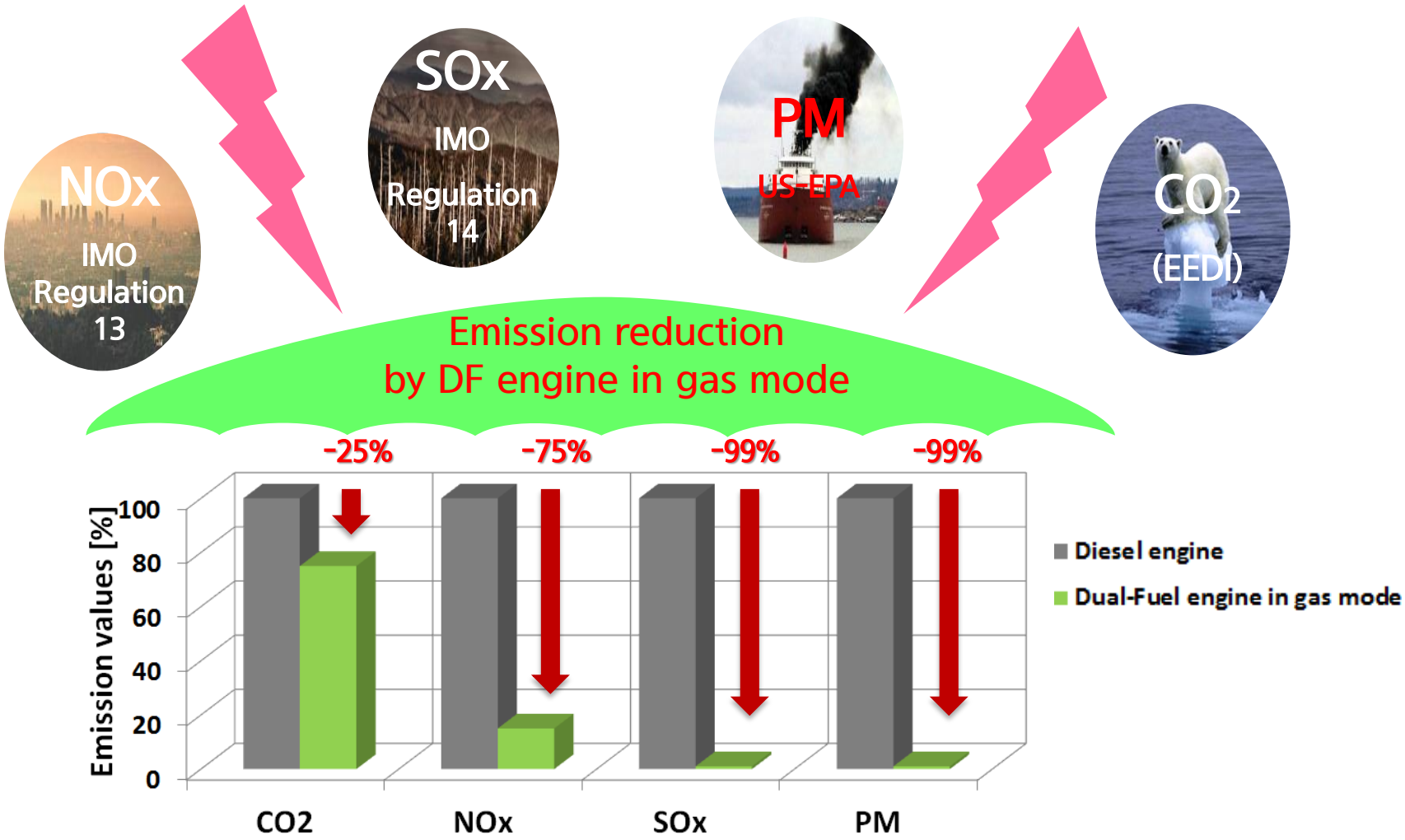

Summary

Summary

- EGR system can reduce NO_X by 60% or more
- EGR + ChaM system can reduce NO_X by 75% or more

- TSTC system with IMO Tier II NO_X setting can reduce SFOC by 5%
- TSTC+ EGR system can reduce NO_X by 75% or more
  - Shows worse SFOC than SSTC system to meet IMO Tier III

- Diesel engine + SCR system can meet IMO Tier III regulation
  - SFOC remains same to IMO Tier II system on IMO Tier II mode

- Dual fuel engine can meet IMO Tier III regulation
  - Gas mode can be a solution for NO_X, SO_X, SMOKE, PM