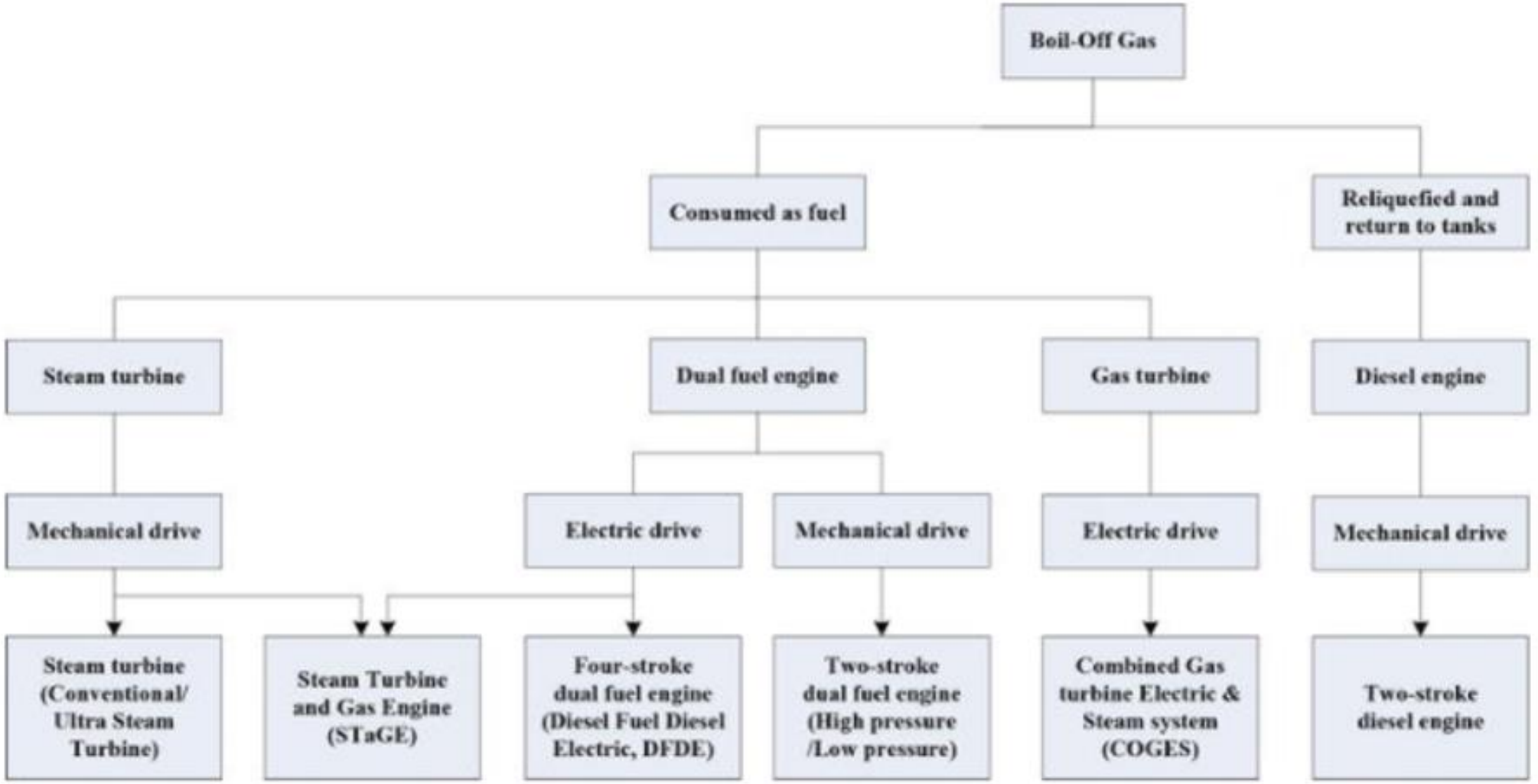
LNG PROPULSION OVERVIEW

Mr. Satish Singh- 20th April 2023

LNG PROPULSION TYPE

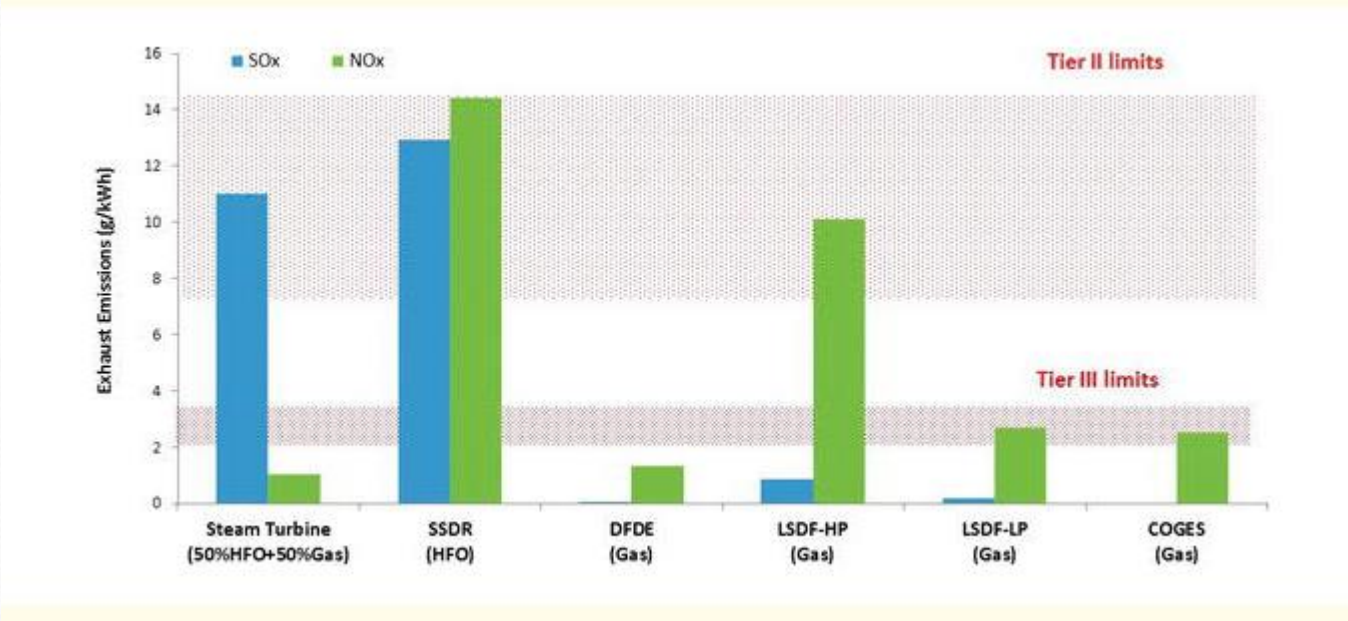
1. SST (SUPERHEATED STEAM TURBINE)
2. DFDE/TFDE (DUEL FUEL/TRI-FUEL MEDIUM SPEED ENGINE WITH ELECTRIC PROPULSION)
3. SSDR (DRL) (SLOW SPEED DIESEL WITH RELIQ. PLANT)
4. DFD (HIGH PRESSURE GAS INJECTION SLOW SPEED DIESEL-MEGI
5. DFD-XDF (LOW PRESSURE SLOW SPEED DIESEL ENGINE), XDF 2.0 , ME-GA
6. GTE (GAS TURBINE ELECTRIC)
7. UST (ULTRA STEAM TURBINE)
8. USCT (ULTRA SUPER-CRITICAL TURBINE)
9. SAYARINGO STaGE (UST + DFDE)
10. OTHER HYBRID OPTION (UST+ GTE etc)


Boil-Off Gas
Consumed as fuel
Reliquefied and return to tanks
Steam turbine
Dual fuel engine
Gas turbine
Diesel engine
Mechanical drive
Electric drive
Mechanical drive
Electric drive
Mechanical drive
Steam turbine (Conventional/ Ultra Steam Turbine)
Steam Turbine and Gas Engine (STaGE)
Four-stroke dual fuel engine (Diesel Fuel Diesel Electric, DFDE)
Two-stroke dual fuel engine (High pressure /Low pressure)
Combined Gas turbine Electric & Steam system (COGES)
Two-stroke diesel engine

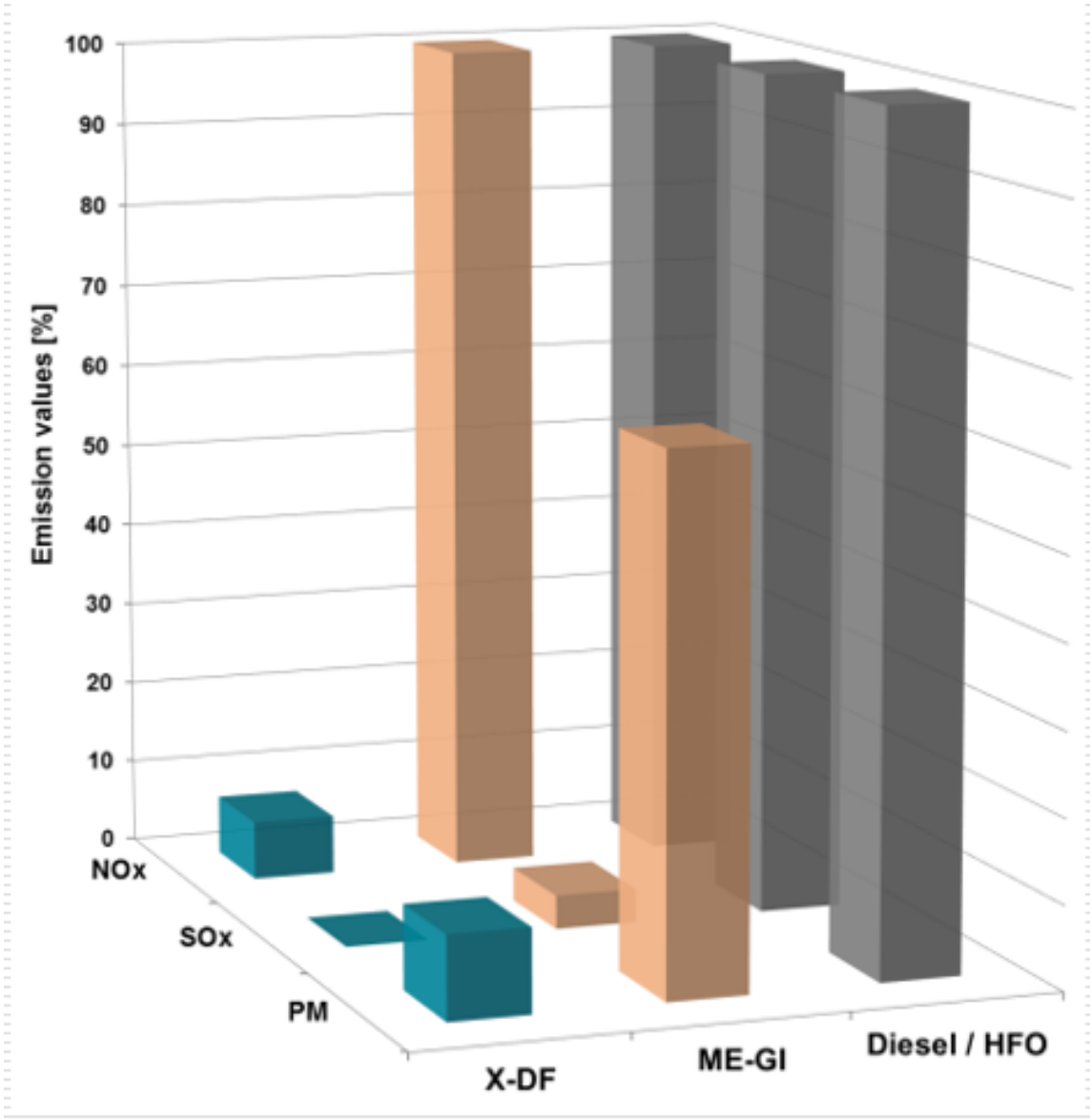
PROPULSION EFFICIENCY

Propulsion Options	ST		DFDE		SSDR		LSDF		COGES	
Thermal efficiency of engines & transmission efficiency of components	• Fuel/BOG: • Boiler: • Steam turbine: (CST/UST) • Gearbox: • Shafting:	1.00 0.88 0.35/ 0.41 0.98 0.99	• Fuel/BOG: • DF engine: • Alternators: • Converters: • E-Motors: • Gearbox: • Shafting:	1.00 0.45 0.97 0.98 0.96 0.98 0.99	• Fuel: • 2-Stroke Engine: • Shafting: • Re-liquefication plant is considered	1.00 0.50 0.99	• Fuel/BOG: • 2-Stroke DF Engine (HP/ LP): • Shafting:	1.00 0.50/ 0.49 0.99	• Fuel/BOG: • Gas turbine(HRSG): • Alternators: • Converters: • E-Motors: • Gearbox: • Shafting:	1.00 0.48 0.97 0.98 0.96 0.98 0.99
Total efficiency	CST: 30% UST: 35%		40%		40%		HP: 49% LP: 48%		42%	

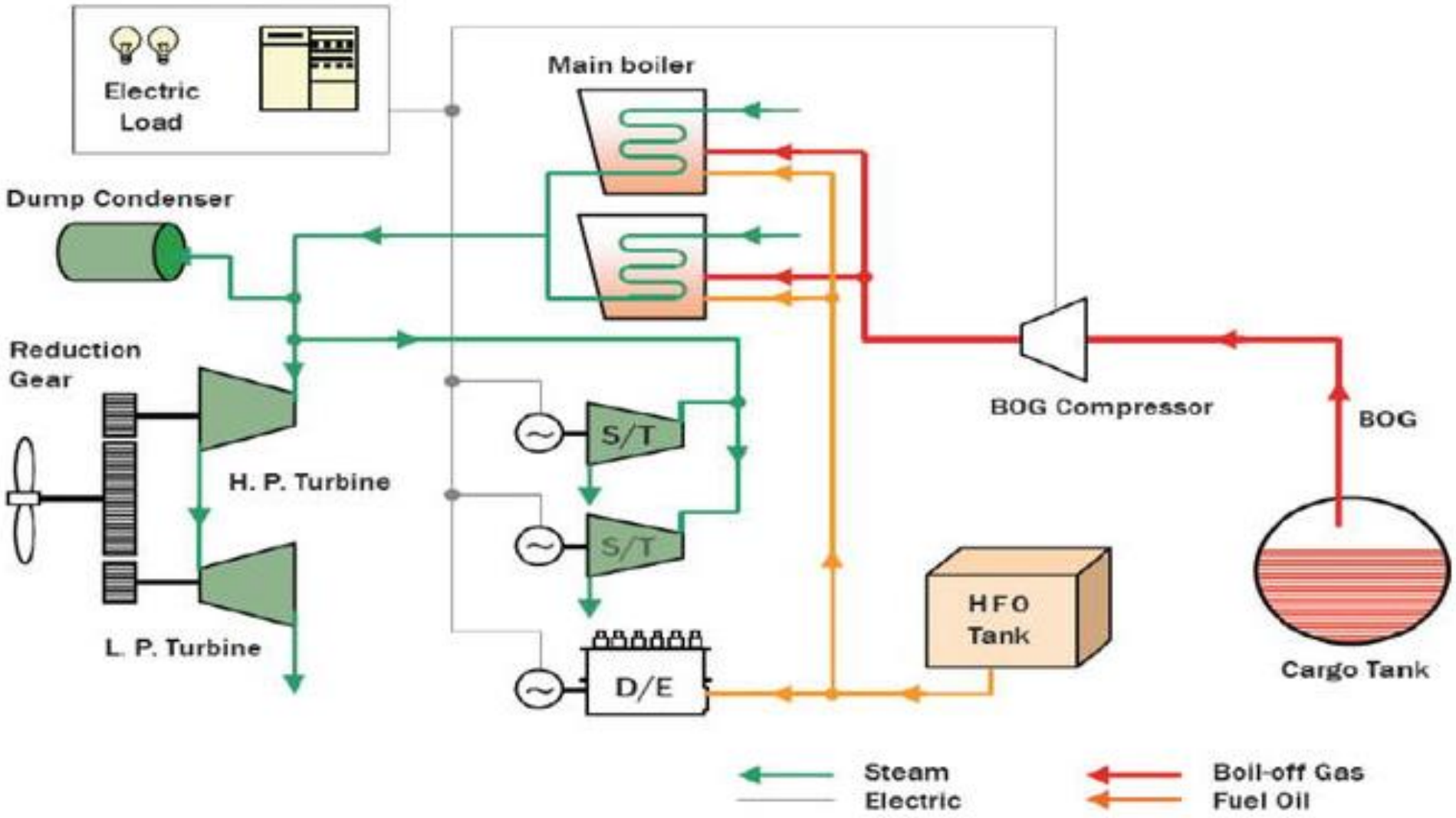
Fuel	DFDE	ME-GI	X-DF	COGES	STaGE
LNG	IMO Tier III	IMO Tier II	IMO Tier III	IMO Tier III	IMO Tier III
MGO	IMO Tier II	IMO Tier II	IMO Tier II	IMO Tier III	IMO Tier II

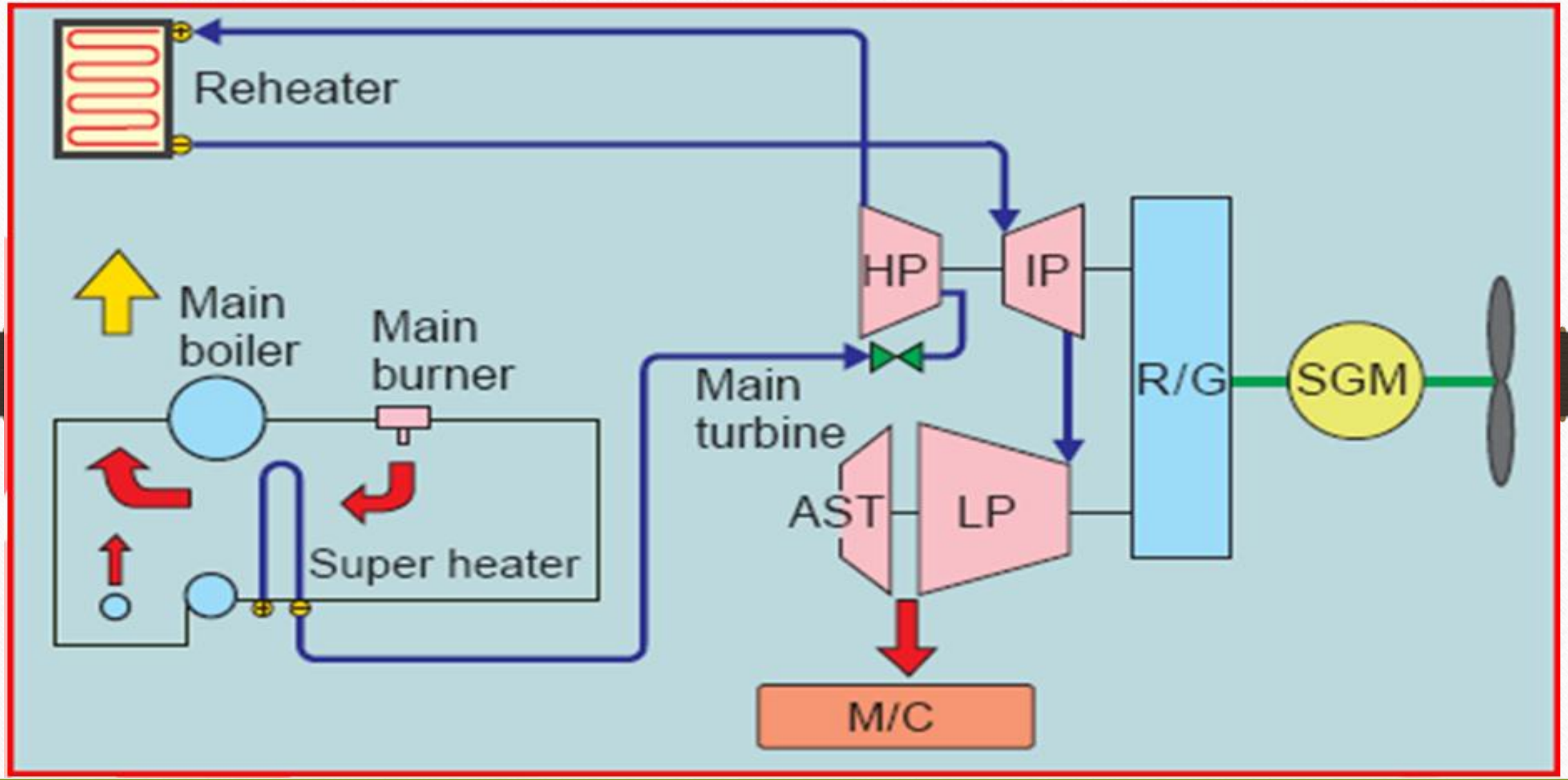


- ENVIRONMENTAL PROFILE



	Environmental Compliance	Thermal Efficiency	Fuel System	Reliability	OPEX
Steam Plant	1. Meets Tier III (gas mode) 2. SCR required. for TIER III (FO mode) 3. High CO2 emission	η_{cst}= 0.30 η_{rehcat}=0.41	3 fuel modes: Gas only Dual fuel(any ratio) FO only	High Low redundancy	Low High Fuel costs
DFDE/TFDE	1. Meets Tier III (gas mode) 2. SCR for TIER III (FO mode)	η_{DE}= 0.42	2 modes: Fuel only Gas mode (min load 10% +1% pilot fuel)	<Steam plant High redundancy	High Engine maintenance costs
DRL	1. EGR or SCR for TIER III (FO mode) 2. Scrubber or LS Fuel for SECA regions	η_{DRL}= 0.47	No gas burning (min load 10% +3-5% pilot fuel)	<Steam plant propulsion redundancy	High Engine maintenance costs
DF SSD	1. EGR required for TIER III 2. Low CO2 emission	η_{MEC}= 0.51	FO only(MDO/HFO) Gas shear mode	Unknown propulsion redundancy	High Engine and compressors maintenance costs
COGES	Meets TIER III (gas mode or MDO)	η_{c}= 0.41	FO only (MDO) Gas burning (3-5% pilot fuel)	Not proven for LNG carriers	<DFDE >Steam plant

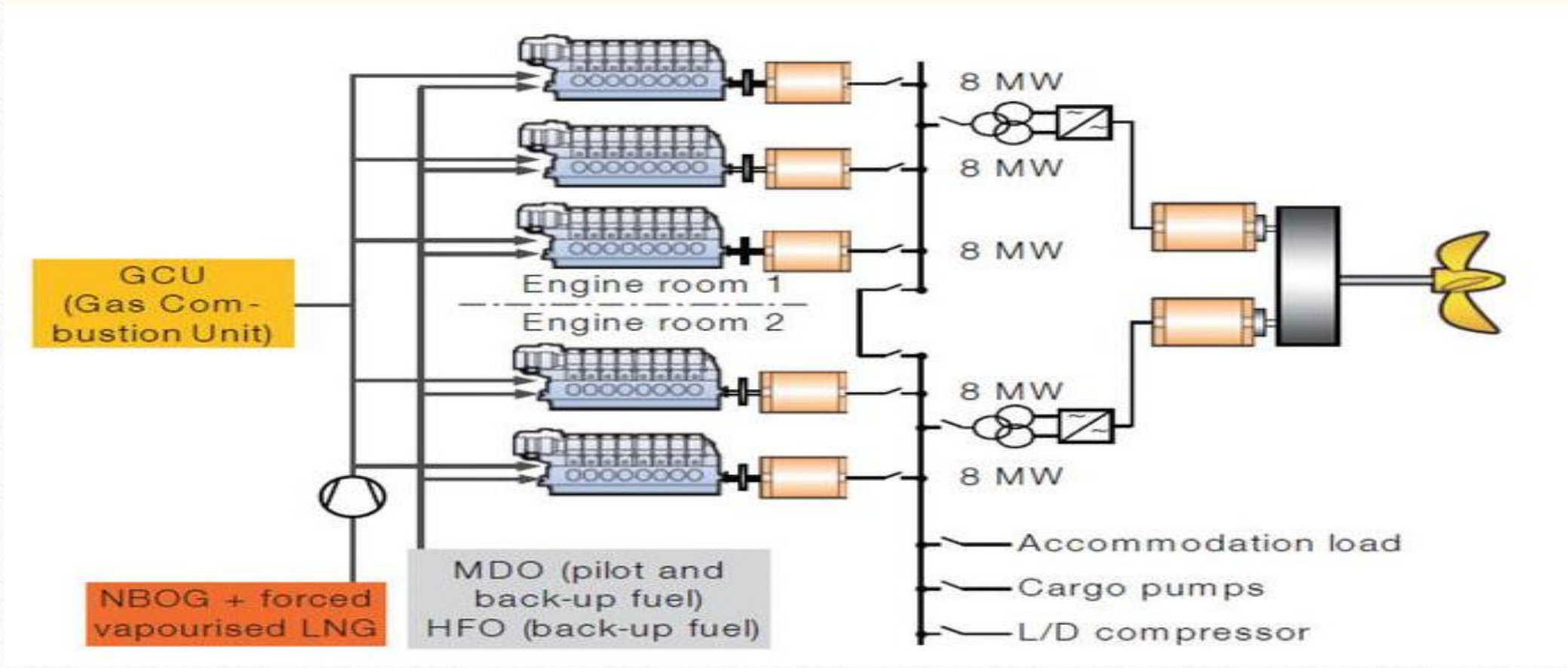

Electric
Load
Main boiler
Dump Condenser
Reduction
Gear
H. P. Turbine
L. P. Turbine
S/T
S/T
D/E
BOG Compressor
BOG
HFO
Tank
Cargo Tank
Steam
Electric
Boil-off Gas
Fuel Oil


Reheater
Main boiler
Main burner
Super heater
Main turbine
HP
IP
AST
LP
R/G
SGM
M/C

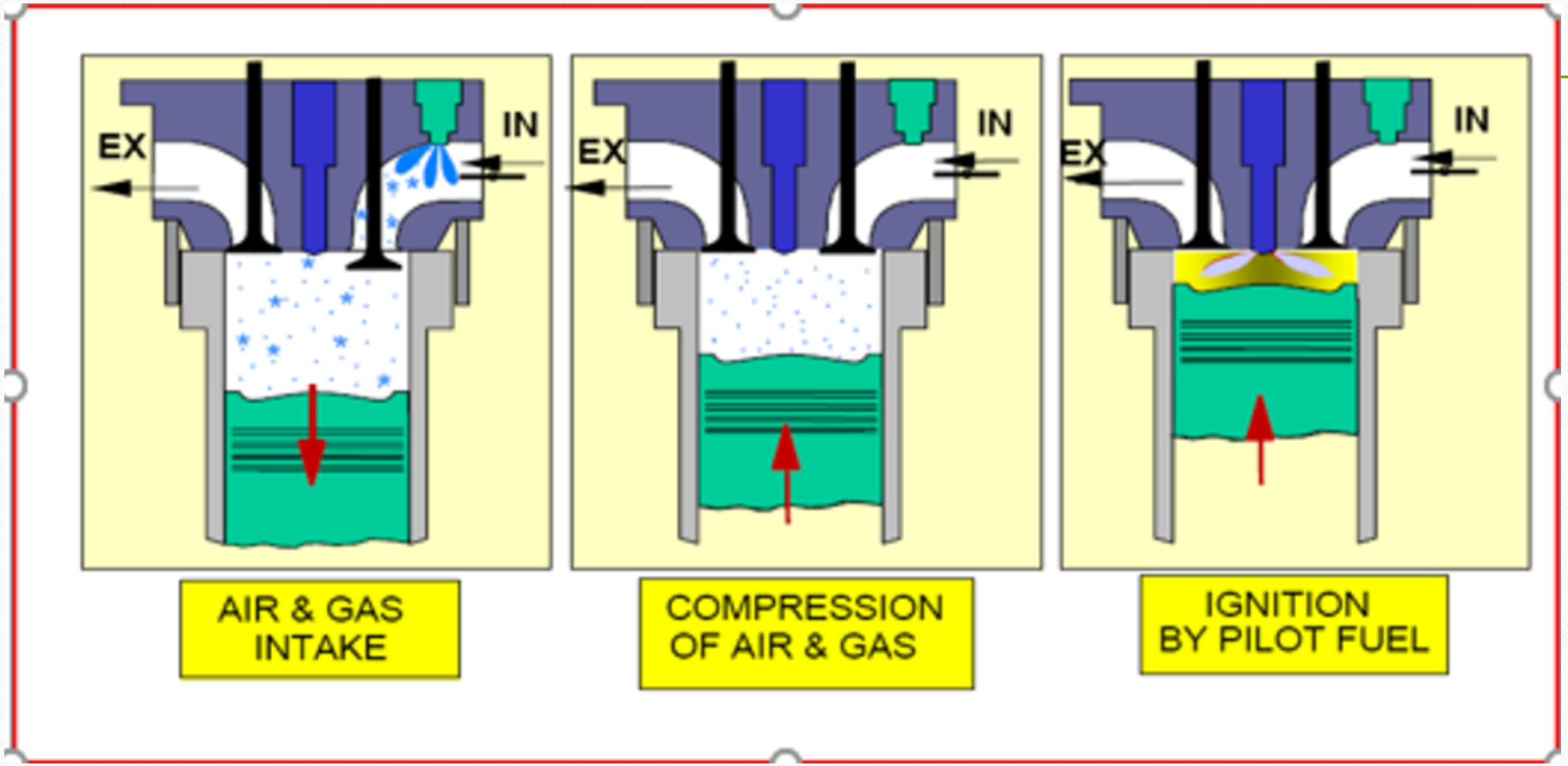
SST,UST,USCT

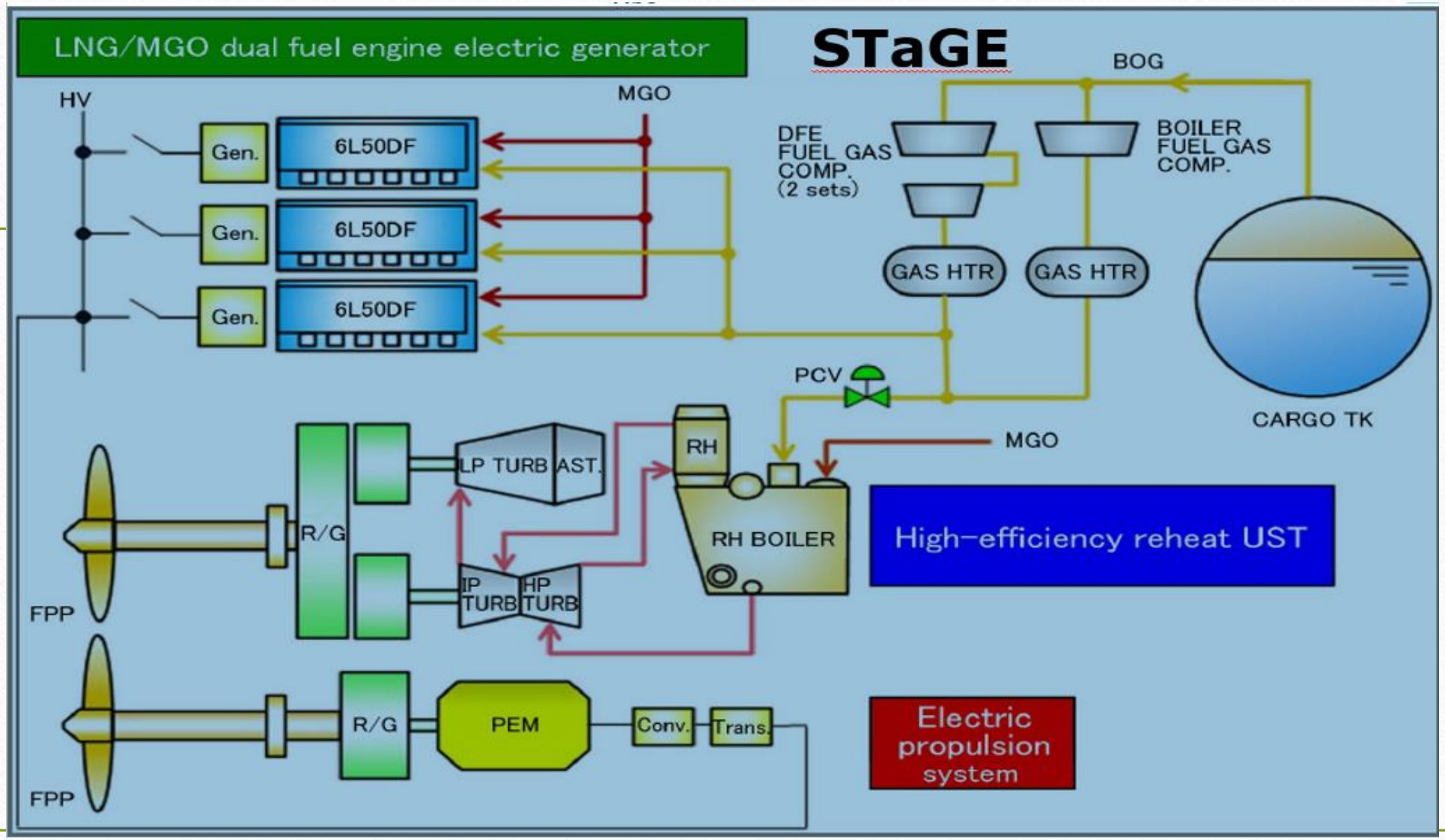
TYPE	EFFICIENCY	STEAM PR.	STEAM TEMP
SST	27~31%	60 BAR	515 DEG. C
UST	40~45%	100 BAR	560 DEG. C
USCT	45~48%	300 BAR	650 DEG. C.
FUTURE USCT	48 ~52%	350 BAR	720 DEG. C.

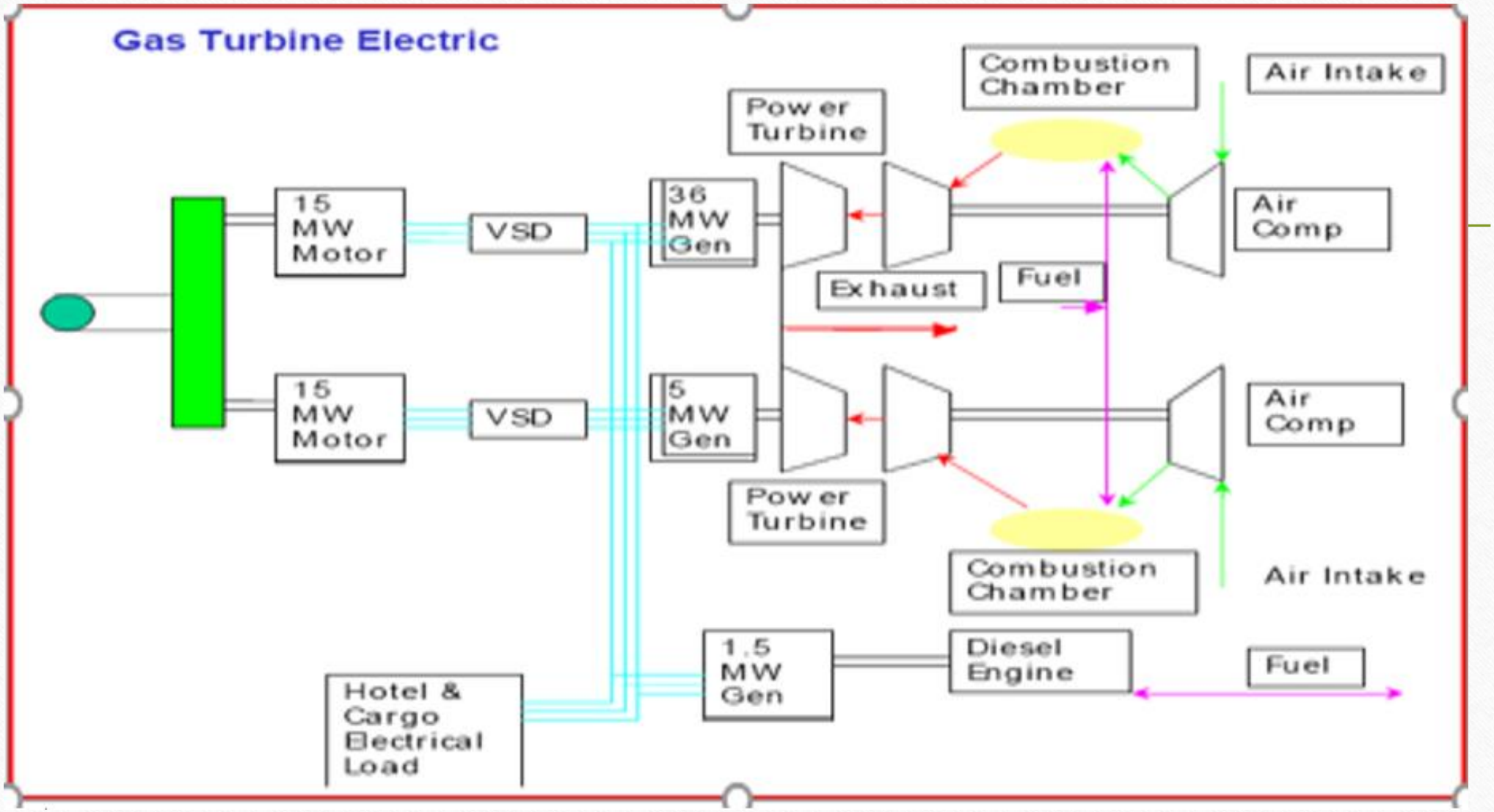
TFDE


GCU
(Gas Com-
bustion Unit)
Engine room 1
Engine room 2
8 MW
8 MW
8 MW
8 MW
8 MW
Accommodation load
Cargo pumps
L/D compressor
NBOG + forced
vapourised LNG
MDO (pilot and
back-up fuel)
HFO (back-up fuel)

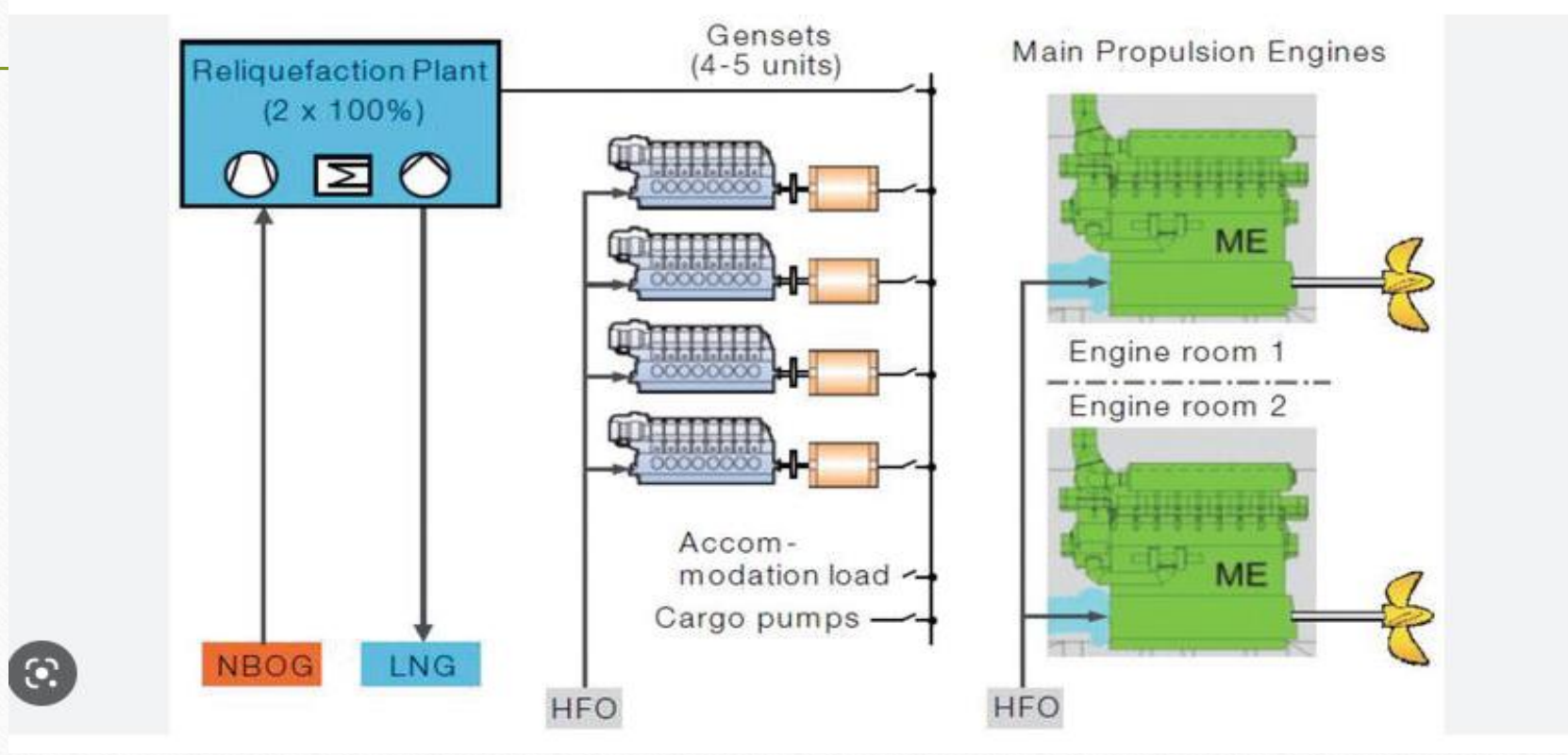
TFDE


EX
IN
AIR & GAS INTAKE
EX
IN
COMPRESSION OF AIR & GAS
EX
IN
IGNITION BY PILOT FUEL

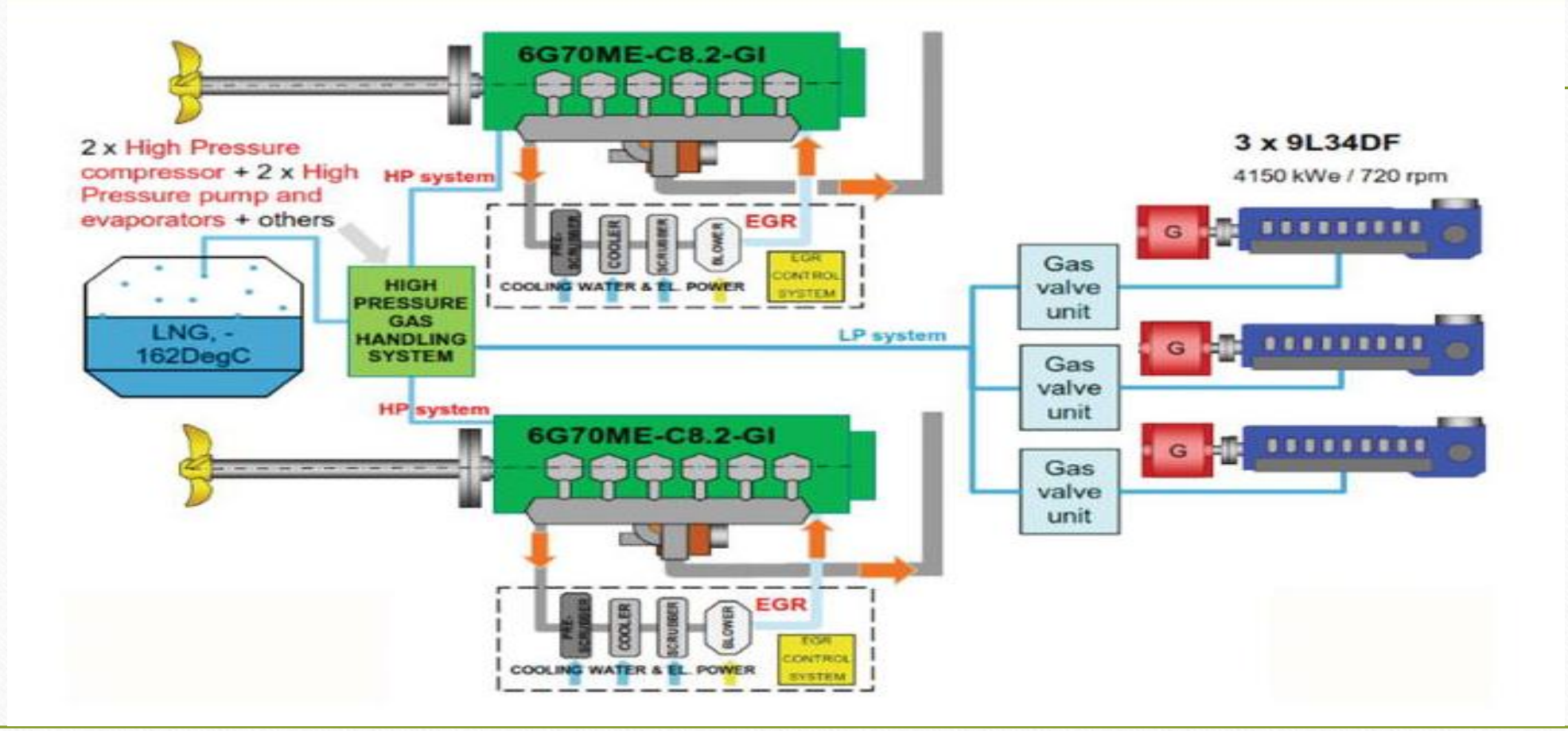

LNG/MGO dual fuel engine electric generator
STaGE
HV
MGO
BOG
Gen.
6L50DF
Gen.
6L50DF
Gen.
6L50DF
DFE
FUEL GAS
COMP.
(2 sets)
BOILER
FUEL GAS
COMP.
GAS HTR
GAS HTR
CARGO TK
PCV
MGO
RH
LP TURB
AST.
R/G
RH BOILER
High-efficiency reheat UST
IP
TURB
HP
TURB
FPP
R/G
PEM
Conv.
Trans.
Electric
propulsion
system
FPP


Gas Turbine Electric
Combustion Chamber
Air Intake
Power Turbine
15 MW Motor
VSD
36 MW Gen
Air Comp
Exhaust
Fuel
15 MW Motor
VSD
5 MW Gen
Air Comp
Power Turbine
Combustion Chamber
Air Intake
1.5 MW Gen
Diesel Engine
Fuel
Hotel & Cargo Electrical Load

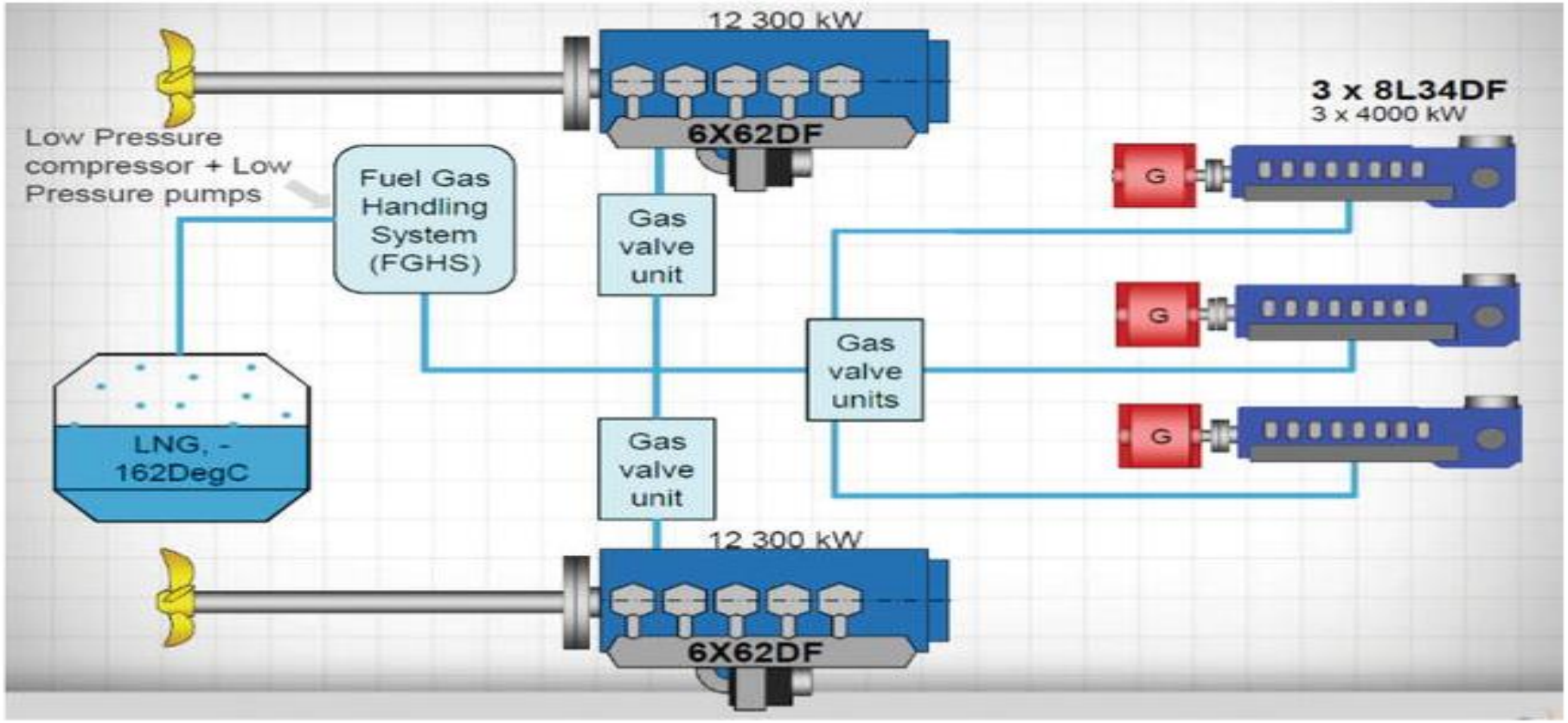
SLOW SPEED DIESEL PROPULSION



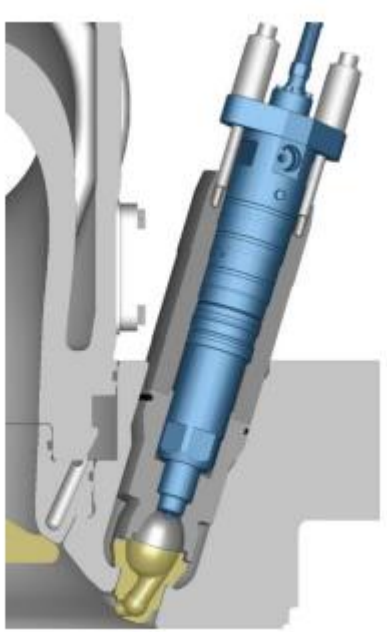
ME-GI

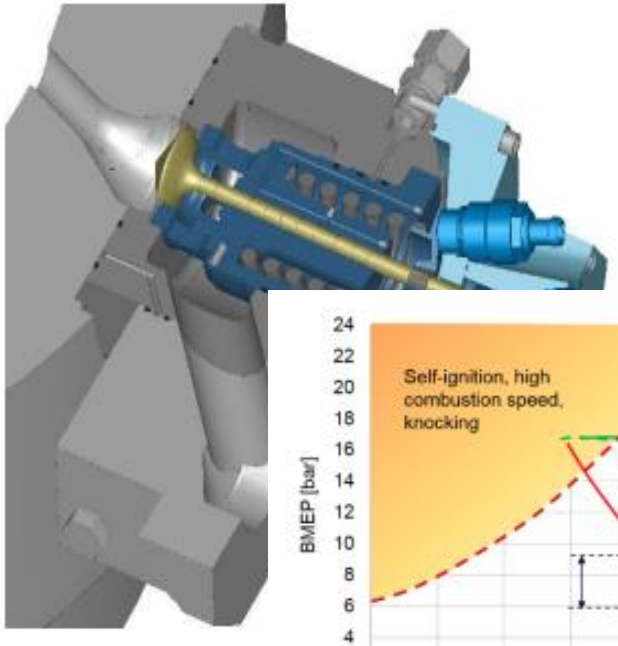

6G70ME-C8.2-GI
2 x High Pressure compressor + 2 x High Pressure pump and evaporators + others
HP system
EGR
COOLING WATER & EL. POWER
EGR CONTROL SYSTEM
LNG, -162DegC
HIGH PRESSURE GAS HANDLING SYSTEM
LP system
HP system
6G70ME-C8.2-GI
EGR
COOLING WATER & EL. POWER
EGR CONTROL SYSTEM
3 x 9L34DF
4150 kWe / 720 rpm
Gas valve unit
Gas valve unit
Gas valve unit
G
G
G

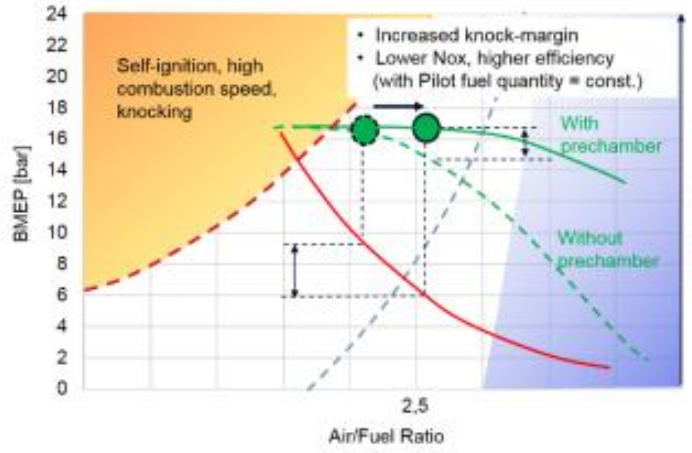
X-DF

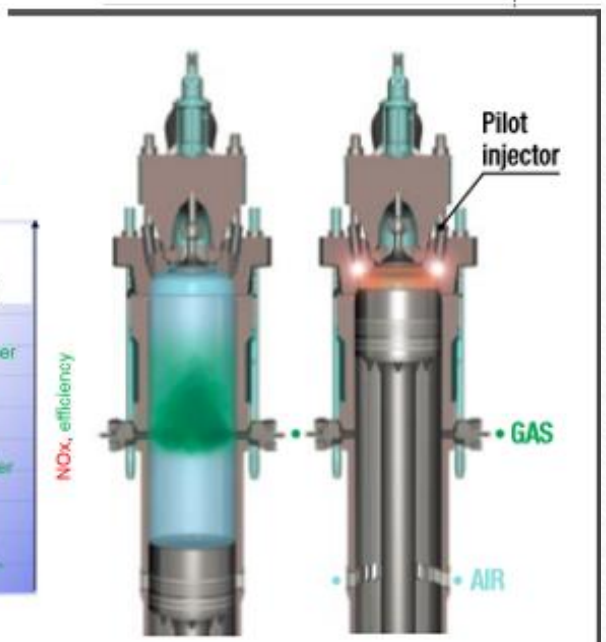

12 300 kW
6X62DF
3 x 8L34DF
3 x 4000 kW
Low Pressure compressor + Low Pressure pumps
Fuel Gas Handling System (FGHS)
Gas valve unit
Gas valve units
Gas valve unit
G
G
G
LNG, -162DegC
12 300 kW
6X62DF

X-DF/OTTO CYCLE/LEAN BURN









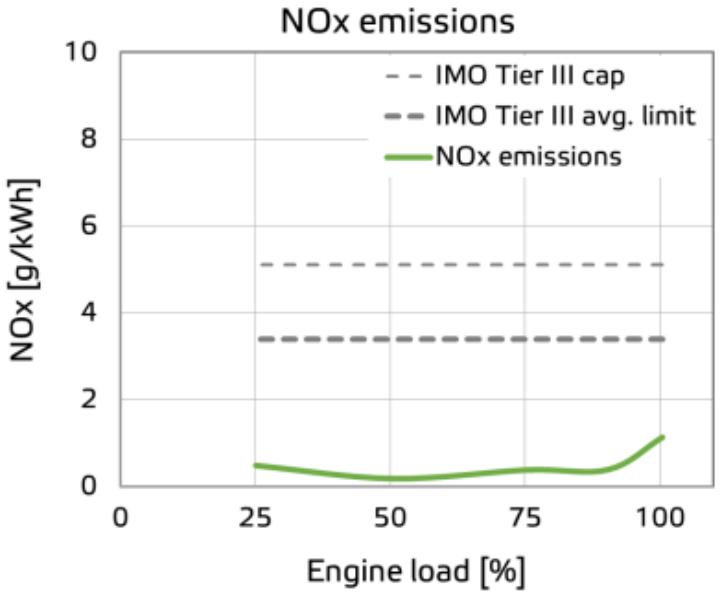
The 2-stroke DF principle with gas admission (left) and ignition (right).

	X-DF engine	High-pressure gas engine
Pilot fuel consumption [g/kWh]	0.8 g/kWh @ 100 % power 1.8 g/kWh @ 30 % power	0.8 - 5 g/kWh @ 100% power* 1.9 - 11 g/kWh @ 30% power* * depending on selected pilot oil energy fraction

Low-pressure X-DF engines	High-pressure gas engines
Low-pressure gas supply means low investment costs for the Fuel Gas Supply System (FGSS), low electrical power consumption and low maintenance costs	High-pressure gas supply means more expensive Fuel Gas Supply System (compressors and/or pumps, components etc.), higher electrical energy consumption and higher maintenance costs
Low pilot fuel quantity, ranging from 0.5 - 1% of total energy consumption over engine power	Higher pilot fuel quantity, ranging from 0.5 - 8% of total energy consumption over engine power
X-DF engines can be operated on gas down to 5% power. Start/stop is requested in diesel mode. Manoeuvring for vessels with CPP could be in gas mode, if accepted by class rules	High-pressure gas engines can only be operated when engine power is above 10% in gas mode
Low NOx emissions, Tier III compliant without exhaust gas treatment system	Tier II compliant only and an exhaust gas treatment system like EGR or SCR is needed for Tier III compliance
Particulate matter emissions are significantly reduced compared to diesel engines	Particulate matter emissions still significant

"Ultra-low" NOx emissions

IMO weighted avg. <1 g/kWh

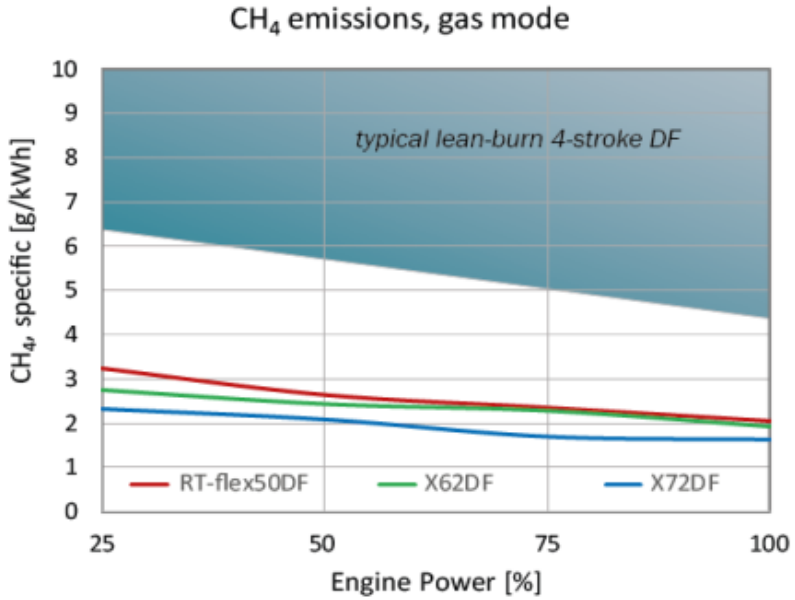


'Ultra-low' NOx emissions during 100% of gas operation time !

E.g. 180k LNGC: (7'500 h at sea at CSR)
regular Tier II ~2300 t/year
X-DF on gas ~150 t/year

Low CH_4 emissions

Methane emissions confirmed to be low, also in part load operation



CH_4 emissions in the range of 1.5% of gas consumption

Even if considering GHG potential of methane slip, total GHG footprint is positive in comparison to conventional diesel engine

GHG EMISSION

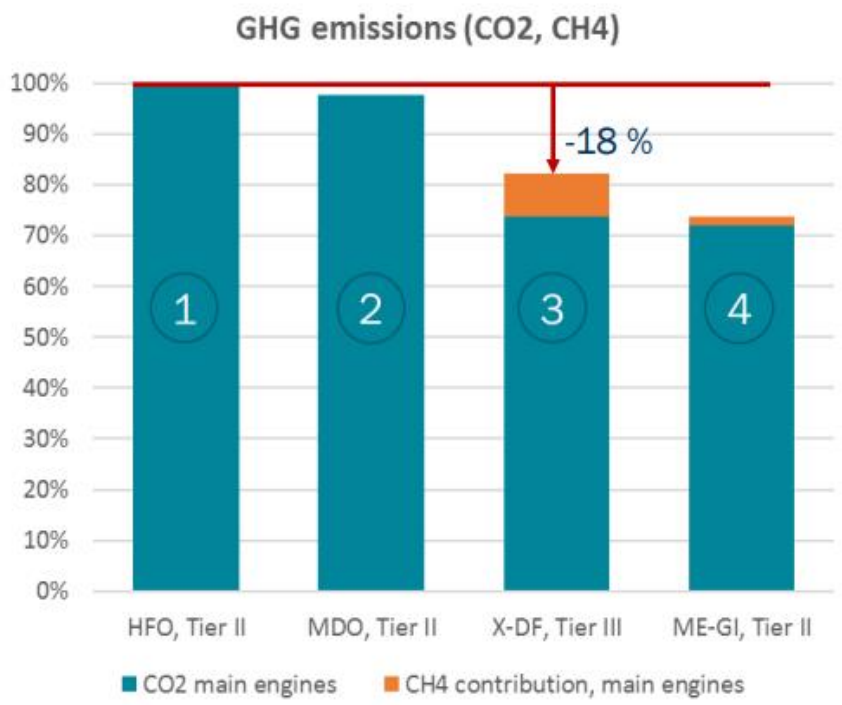
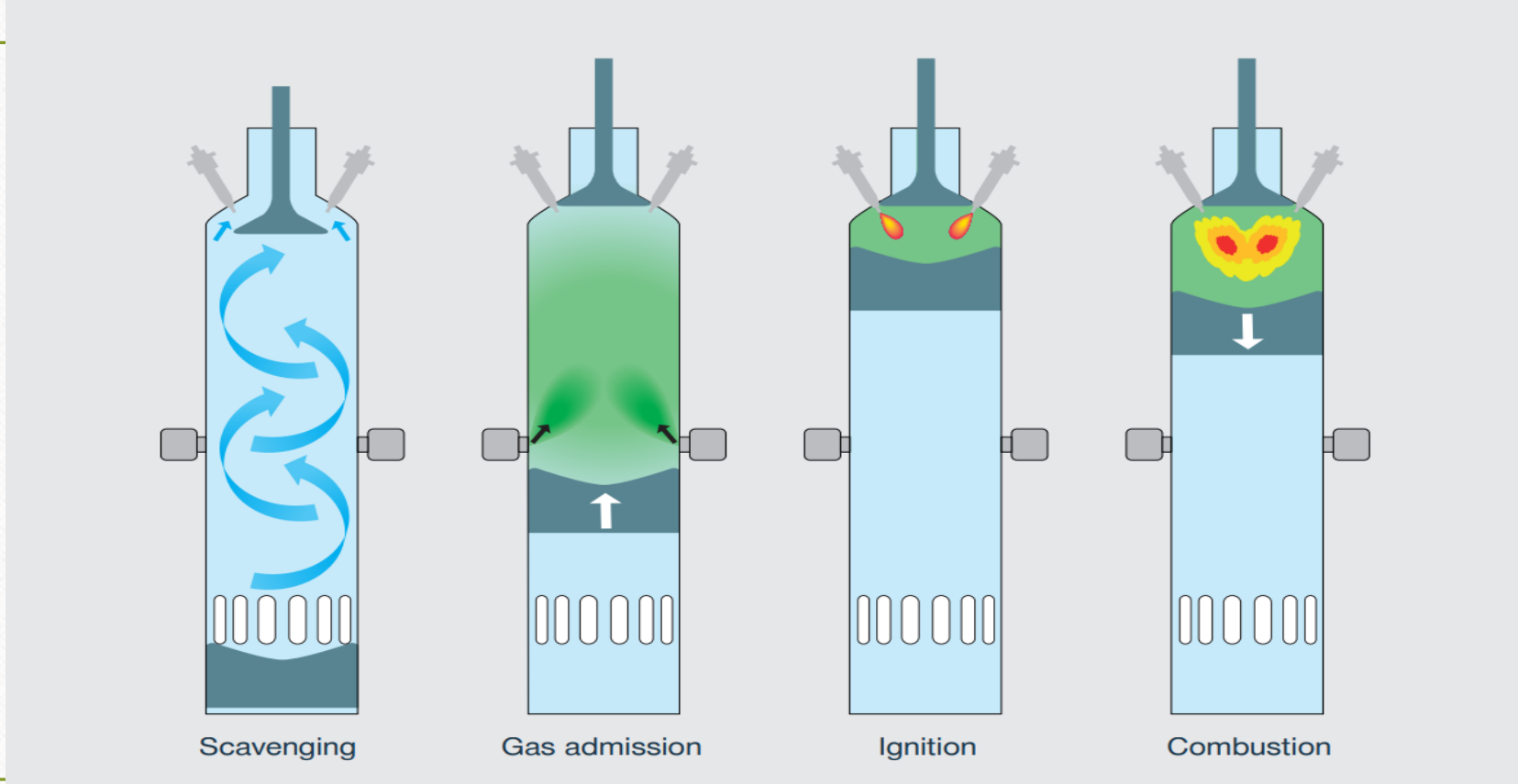
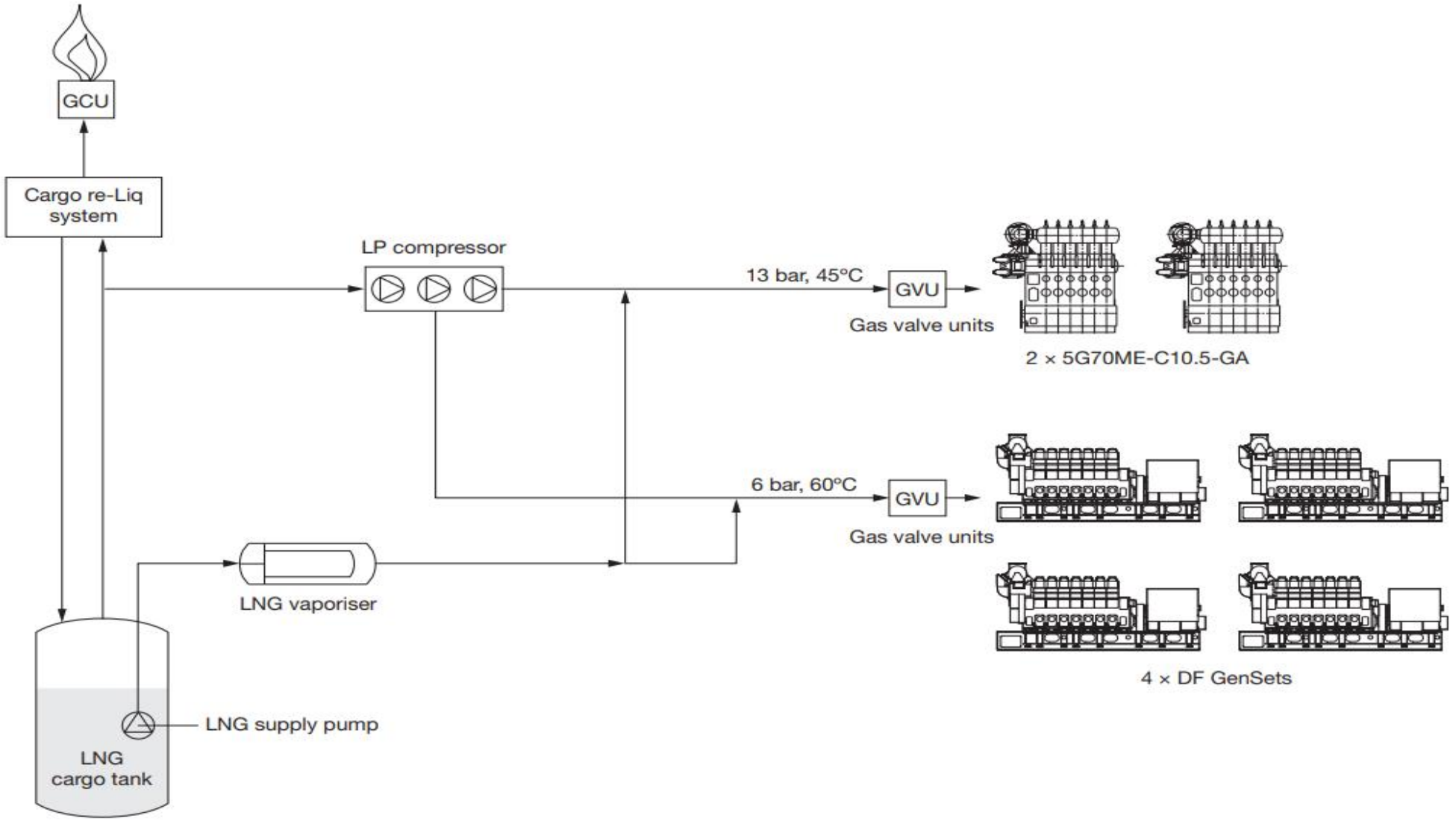


Fig. 3: GHG comparison: X-DF vs. ME-GI

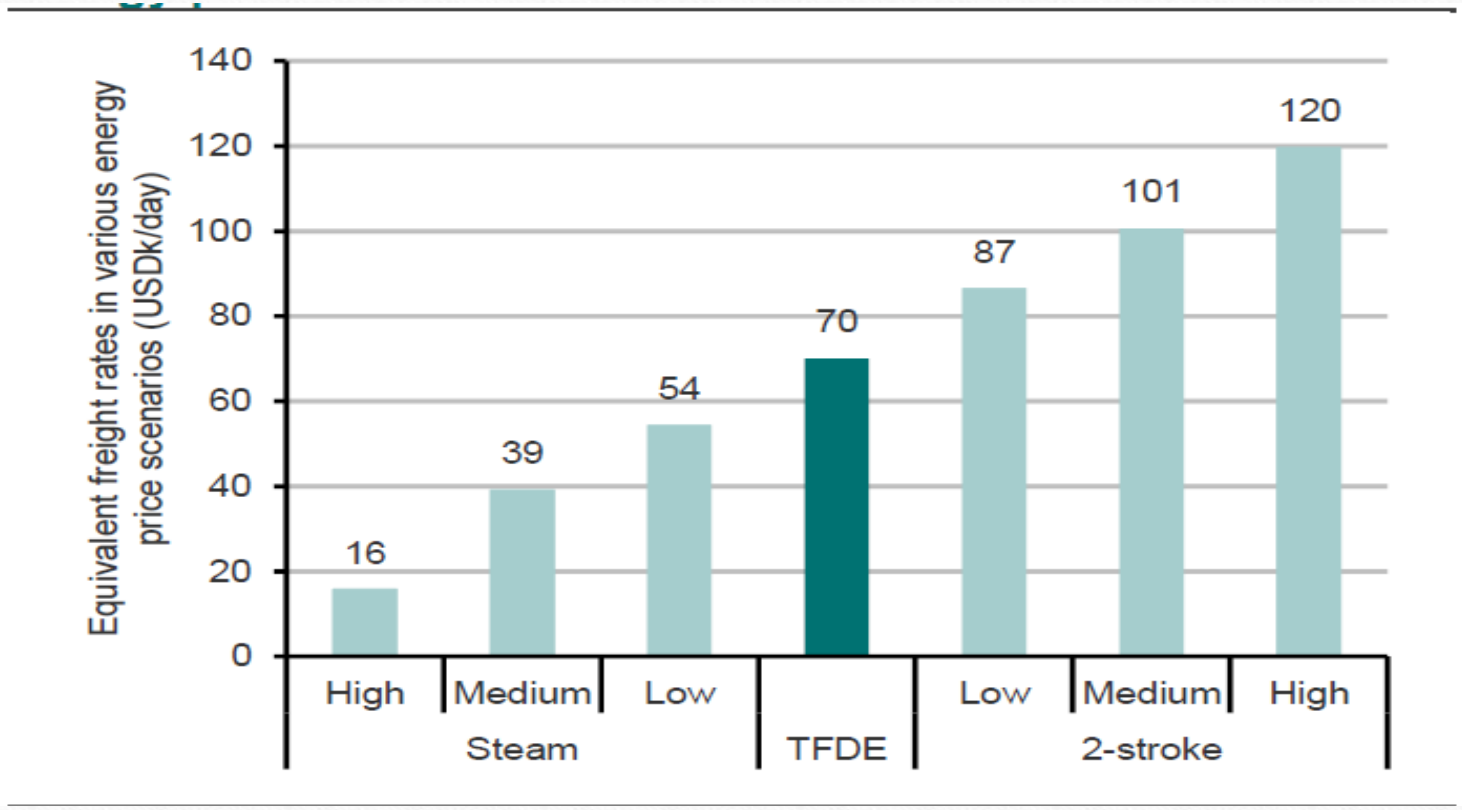
- Diesel engine on HFO Tier II set as a reference (100 %) 1
- Diesel engine on MDO Tier II emits slightly less CO_2 due to lower carbon intensity of MDO compared to HFO 2
- Significant reduction in CO_2 emissions with gas as a fuel (approx. 25 % - 30 % less compared to HFO) Benefit is partly reduced by CH_4 emissions
- As a net effect, GHG emissions of X-DF are still 18% lower compared to a diesel engine on HFO 3
- Solely considering main engines, ME-GI results in slightly lower GHG emissions. Including auxiliary power for gas compressors and Tier III compliance of the ME-GI, GHG emissions of X-DF and ME-GI are typically similar *(see following pages)* 4

ME-GA

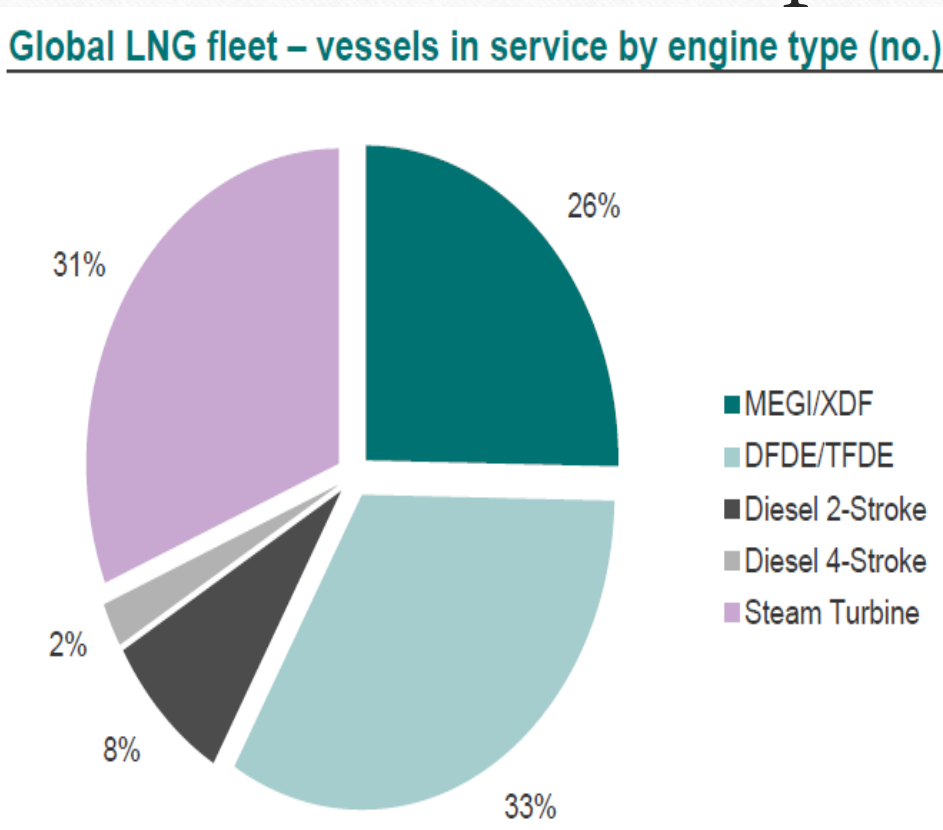


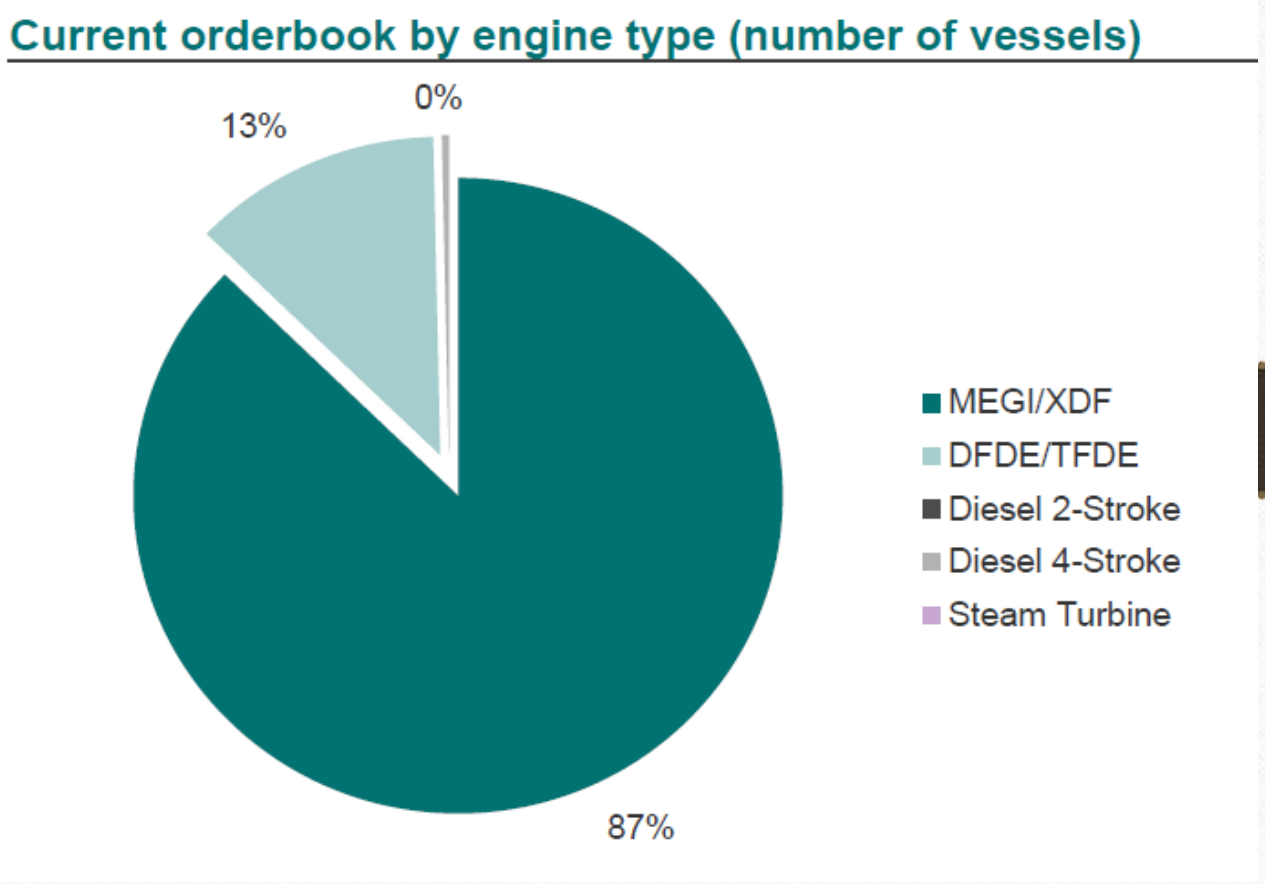

GCU
Cargo re-Liq system
LP compressor
13 bar, 45°C
GVU
Gas valve units
2 × 5G70ME-C10.5-GA
6 bar, 60°C
GVU
Gas valve units
LNG vaporiser
LNG supply pump
LNG cargo tank
4 × DF GenSets

FRIEGHT RATES



672 LNG Ships in Operation- 323 on Order





Trending Now

- WinGD X-DF vs MAN B&W ME-GA