



Environmentally Friendly & Superior Solution with LNG as Fuel

ClassNK R&D Project
LNG-Fuelled Vessel Technologies Seminar
July 2014

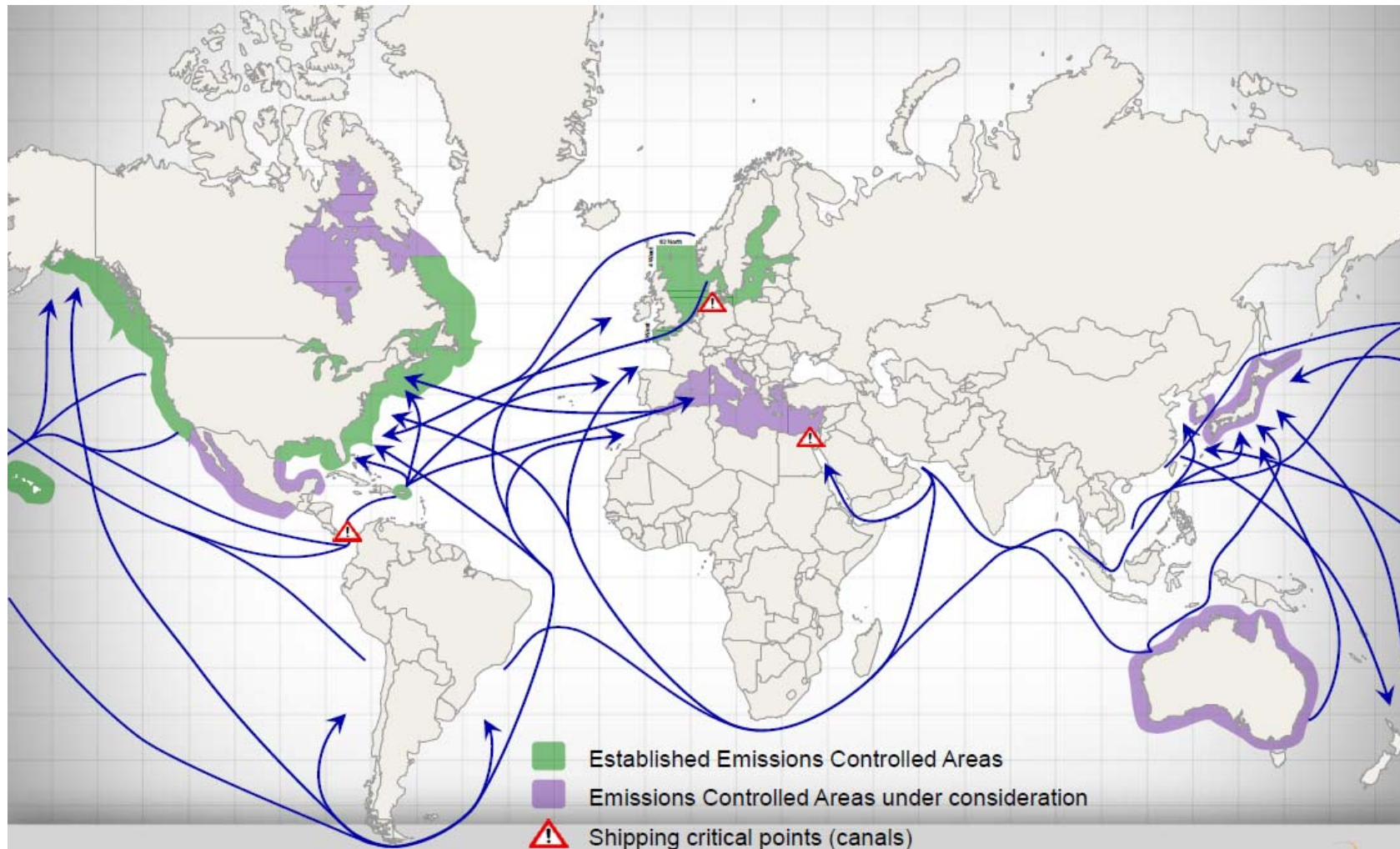
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- ① Environment Issues
- ② Topics of LNG as Fuel
- ③ LNG Fuelled Ship
- ④ MHI LNG Fuelled ship
- ⑤ **MHI-GEMS™**
(Gas ship Equipment Module and System)



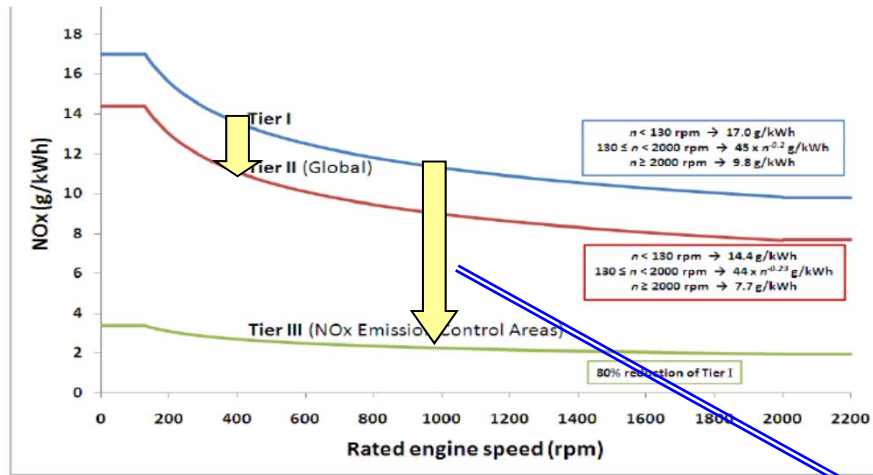
① Environments Issues

World wide Ocean lane distribution & ECA / SECA



① Environments Issues (NOx, SOx, CO2)

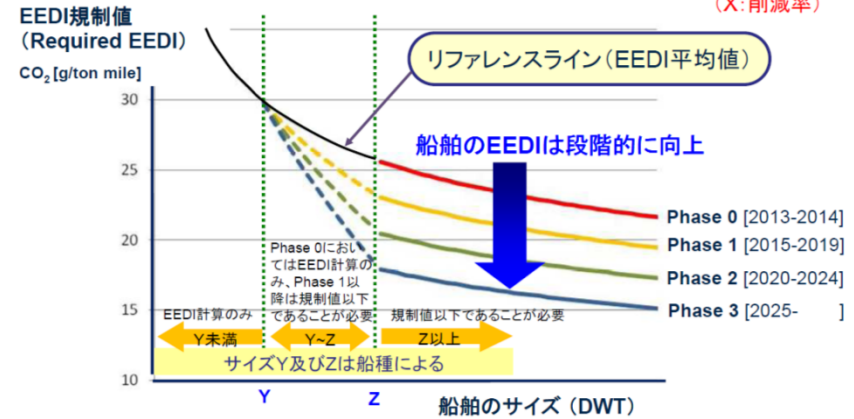
IMO NOx Regulation (Tier III: Only for ECA/SECA)



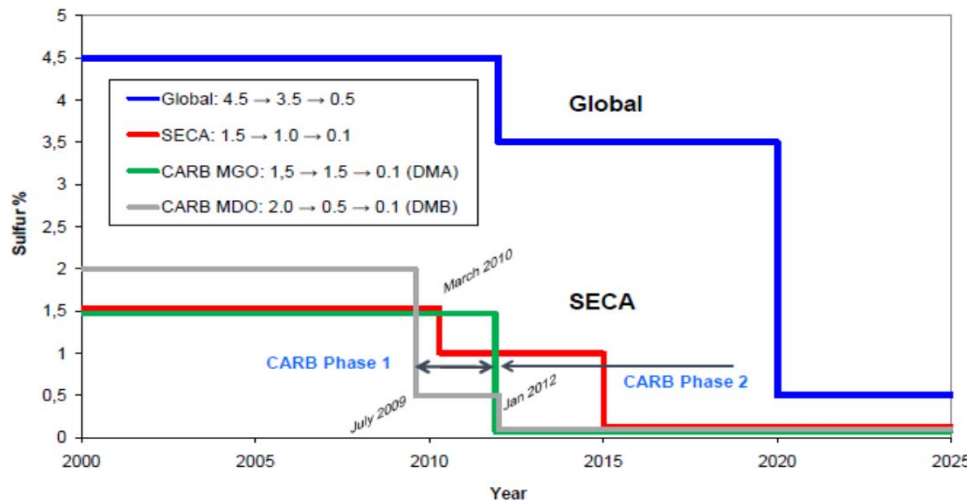
IMO EEDI

$$\text{Attained EEDI} \leq \text{Required EEDI} = (1-X/100) \times \text{Reference line value}$$

(X: 削減率)



MEPC 57 IMO & CARB Fuel-Sulfur Content Limits



Δ 80%: Some limit to Engine tuning technology

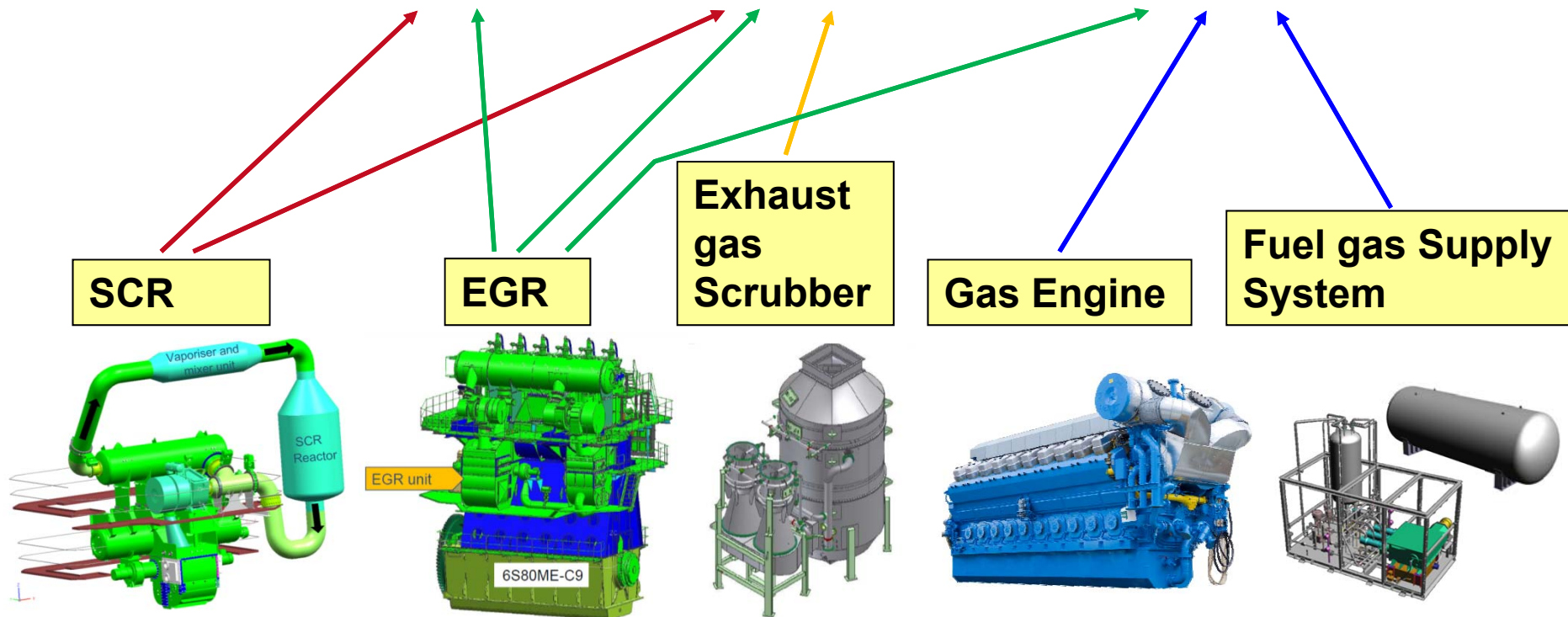
NOx regulation will conflict with EEDI

SOx regulation have some concern on Bunker price jumping

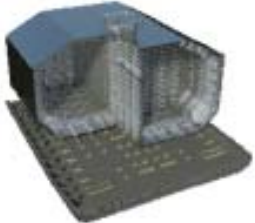




① Environments Issues

To Comply with IMO MARPOL Annex VI

Measure	1	2	3
	Fuel Change	Emission technologies	LNG as Fuel
In ECA & SECA	Low Sulfur Fuel oil with SCR or EGR	HFO with Exhaust Gas Scrubber & SCR or EGR	LNG as Fuel with Gas engine, DF engine & Fuel Gas Supply System (EGR for MAN MEGI)



② Topics of LNG as Fuel

Tank Type	Prismatic Tank	Spherical Tank	Cylindrical Tank		Tank Truck
					
IMO Type	B	B or C	C		
Heat Insulation	External		External	Vacuum	Vacuum
Max. Pressure	0.7 bar	1 bar	10 Bar		10 Bar
Space efficiency	High	Low	Medium		Low/Medium
Gas Delivery	Pumping Out		Pressure Built-Up Type		
Design Cost	High	Medium	Low	Low	-
BOG Treatment	Necessary		Not Necessary		
Suitable Cap.	>5,000m ³	>5,000m ³	30-1,000m ³	30-1,000m ³	< 100m ³
Cost	High	High	Medium	Medium	Low/Medium

② Topics of LNG as Fuel

LNG Fuel engine	Gas Engine	Dual Fuel diesel	Dual Fuel diesel	Steam Turbine
	4 Cycle	4 Cycle	2 Cycle	
Pilot fuel	Spark igniter	Micro pilot fuel	Micro pilot fuel	--
LNG Tank required	2-tanks or more	1-Tank		
NOx-Tier III	Meet	Meet	Additional treatment unit	Meet
Stand-by propulsion	Needs	--	--	--
Emergency	Change over to stand-by propulsion	Change over to H.F.O.	Change over to H.F.O.	Change over to H.F.O.
Remarks	Methane slip 1~2%	Methane slip 1~2%	Gas burning >15% load	Limited operator

LNG Bunkering



Tank Lorry onboard



Tank Lorry



Bunkering Tanker

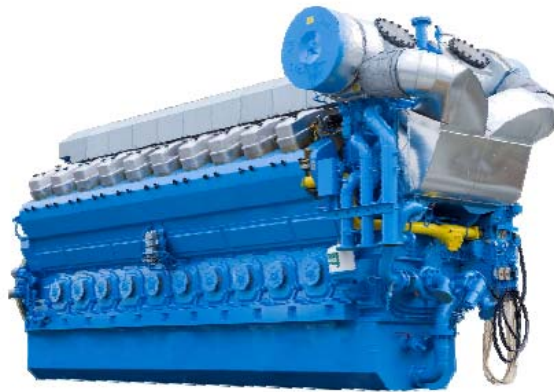


LNG Terminal

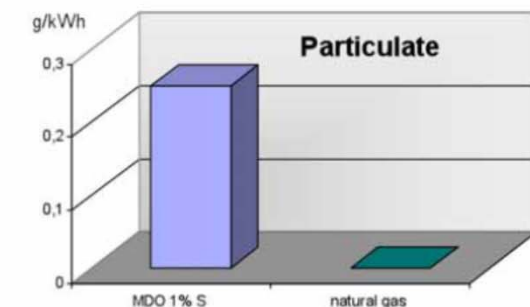
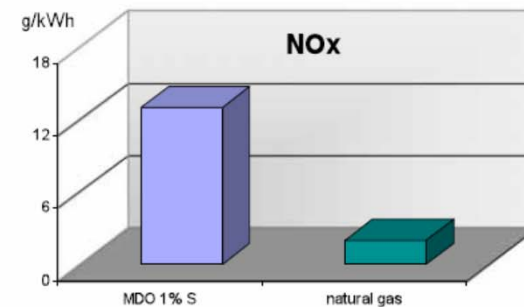
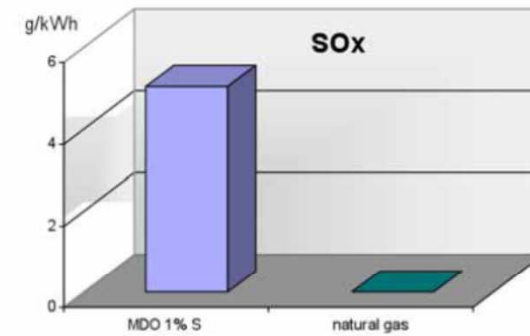
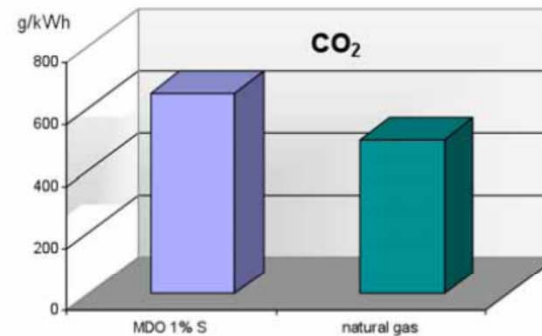
② Topics of LNG as Fuel

Ex. Gas Engine Performance

Emissions - MDO versus Natural gas



Rolls-Royce
Spark Ignited Gas Engine



CO₂ = Δ23%, NO_x = Δ92%, SO_x = Δ100%, PM = Δ98%

Effective in abatement for both Emissions & EEDI

ROLLS-ROYCE presentation material

③ LNG Fuelled Ship (in the World)

LNG fuelled ships in operation or on order

Ship type	In operation	On order	Total	Owners
Car/passenger ferry	22	8	30	Fjord 1, Torghatten, Norled, Tide Sjö,
Offshore support vessels	12	14	28	Solstad, Olympic Shipping, Island Offshore, ...
Container vessels	0	8	8	ToTe shipping, Crowley, Matson
RoRo vessels	0	6	6	Seacargo, NorLines, ToTe
Gas Carrier	0	5	5	SABIC, Evergas
Large cruise/RoPax ferries	3	1	4	Viking Line, Fjord Line, Brittany Ferries
Patrol vessel	3	1	4	Finnish goverment, Remoy
TUG	3	1	4	Buksér&Berging, CNOOC
General Cargo	2	2	4	Nordnorsk Shipping, Egil Ulvan rederi,
Product/chemical tanker	1	3	4	Tarbit Shipping, Terntank, Bergen tankers
Harbour vessel	1	0	1	Incheon Port Authority
High speed ferry	1	0	1	Buquebus
Icebreaker	0	1	1	Finnish Transport A.
TOTAL	48	50	98	

③ LNG Fuelled Ship (in Europe)



③ LNG Fuelled Ship (in Europe : Feeder)



③ LNG Fuelled Ship (in North America)



③ LNG Fuelled Ship (in Japan)

By Ship-owner

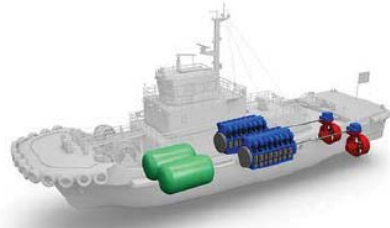
NYK (UECC) 3800 PCTC

- 2Cyc. DF Diesel
- LNG Tank : Type-C



NYK TUG

- 4Cyc. DF Diesel x 2
- LNG Tank : Type-C



K-LINE 2000 PCTC

- 4Cyc. Gas engine x 2 + 1 CPP
- LNG Tank : Type-C



MOL ISHIN-II Ferry

- 4Cyc. DFE-CRP Pod
- LNG Tank : Type-C



KHI 9,000TEU C/S

- 2Cyc. DF Diesel x 1
- LNG Tank : IMO type-B



By Ship yard

IHI-MU 10,000TEU C/ S

- 2Cyc. DF Diesel x 2
- LNG Tank : SPB



OSHIMA

“OHBC ECO-Ship 2020”

- 4Cyc. Gas engine x 2 + 2 Shaft
- LNG Tank : Type-C



③ LNG Fuelled Ship (in Japanese Government)

(1) Japan Ship Technology Research Association (JSTRA)

- ① “Framework for energy efficiency improvement in international marine Business”
Survey of LNG fuel supply infrastructure.
- ② “LNG fuel tank Committee”
Make a proposal for IGF code reflect HAZID results of experimental LNG fuel ship design.

(2) Ministry of Land, transport and Tourism :

2012 Synthetic research in LNG fuel ships

Research	Contents	
Safety Standards	1. Hard	Design standard of High pressure gas supply system (Mini. plant examination)
		Bunkering manual to prevent excess pressurization, i.e. Roll-Over
	2. Soft	Normal operation, Maneuvering (Crew line-up)
		Ship to Ship (Hard ware)
		Safety & Disaster prevention
		Bunkering : Ship to Ship (Berthing & Anchoring)
		Bunkering : Pipe Line
		Bunkering : Lorry
	3. Survey	Inspection standards
		International Strategy

④ LNG Fuelled Ship by MHI

Potential Vessel with LNG as Fuel

Kind of Vessel	Operation route	ECA, SECA	Potential of LNG as Fuel	Remarks
RORO/ROPAX	Japan domestic			
	Europe	✓	✓	
PCTC	Europe – Asia	✓		Short-term operation in ECA/SECA. Circumstances alter movement of Mediterranean sea.
	North America – Asia	✓	✓	Cheaper LNG come form shale gas perhaps will be supplied by Ship to Ship bunkering procedure in North America.
	Europe	✓	✓	
Container Ship	Europe – Asia	✓		Short-term operation in ECA/SECA. Circumstances alter movement of Mediterranean sea.
	North America – Asia	✓	✓	Cheaper LNG come form shale gas perhaps will be supplied by Ship to Ship bunkering procedure in North America.
	North and South	✓	✓	
VLCC	PG - World wide	Few		
Bulk Carrier	World wide	Few		



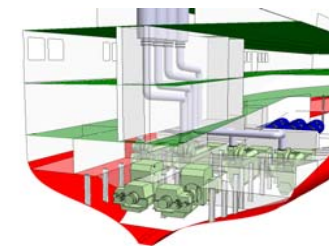
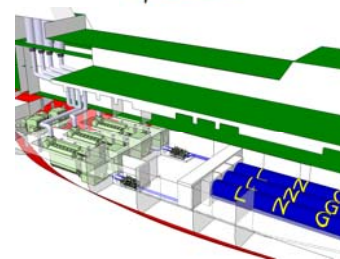
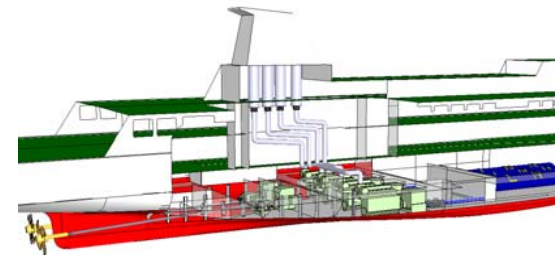
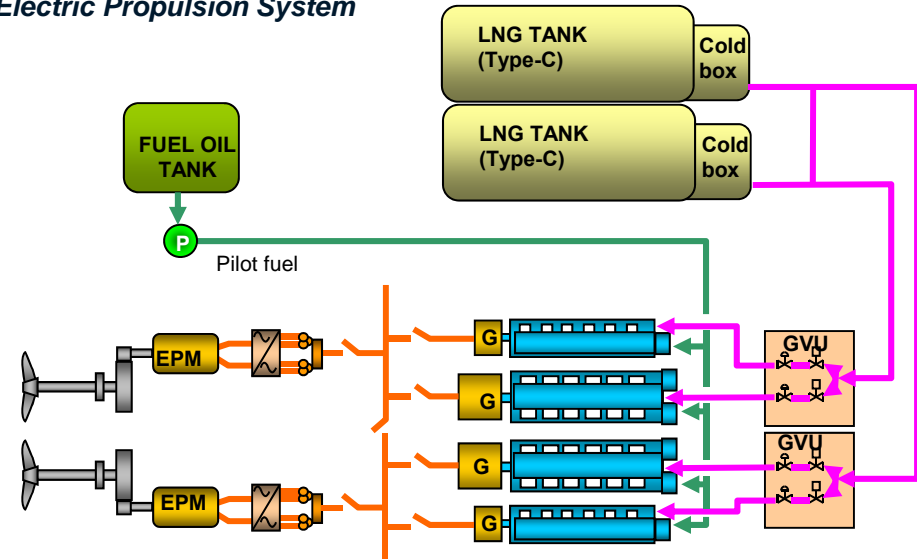
④ LNG Fuelled Ship by MHI (ROPAX)



600 passenger, 155 trailers,
23 knots, 450 sm

ROPAX Emission calculation				
		Conventional Twin CPP Diesel Driven	4Cyc. DFDE with LNG as fuel	
PAX		600		
Trailers / Cars	12m Trailers	155		
	Cars	50	--	
Vessel speed		23 kts		
Main propulsion engine		12,000 kw x 2sets	--	
Main generator		--	8,400 kw x 2sets	
Auxiliary generator		1,270 kw x 3sets	5,400 kw x 2sets	
Operation hours / Voyage		19.5 hrs		
Voyage days / year		300 days		
Fuel consumption / year	FO. (k-ton/y)	26	0.2	
	LNG (k-ton/y)	--	23	
Emission	CO2 (k-ton/y)	82	62	-25%
	NO x (ton/y)	1,398	233	-83%
	SO x (ton/y)	1,432	28	-98%

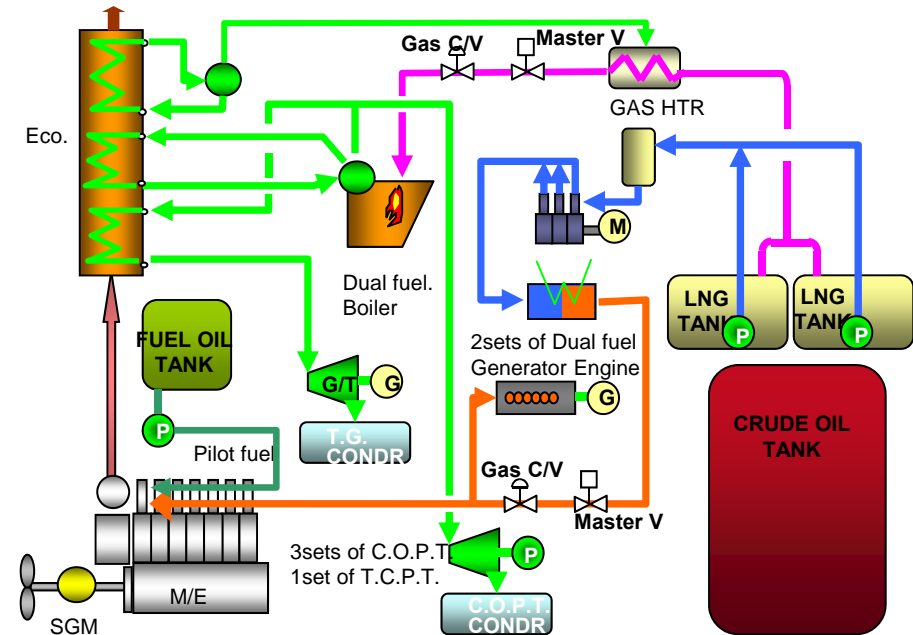
Dual Fuel Diesel Electric Propulsion System



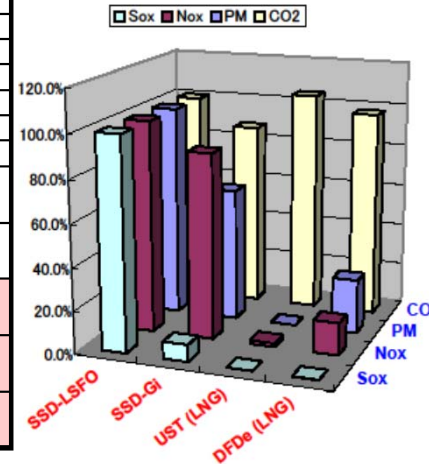
④ LNG Fuelled Ship by MHI (VLCC)



VLCC Emission calculation				H.F.O.:3% S, MDO: 0.5% S		
Main Propulsion	Slow-speed Diesel (H.F.O.)	DF Slow-speed Diesel (LNG)	DF Slow-speed Diesel (LNG)			
		Plant-A	Plant-B			
Vessel speed	15.5 kt					
Propulsion power	27,000 kw x 76 rpm		25,000 kw x 63 rpm			
Electric. Gene	T/G	1,100kw x 1set	2,000kw x 1set	---		
	STG	---	---	2,000kw x 1set		
	D/G	1,100 kw x 2sets	1,400 kw x 2sets	1,400 kw x 2sets		
	SGM	---	1,000kw x 1set	1,000kw x 1set		
Cargo capacity	355,000	326,000	326,000			
Voyagedays / year	300 days					
Fuel consumption	FO (ton/day)	90	5.2	5.5		
	LNG (ton/day)	---	81.8	66		
Emission	CO2 (k-ton/y)	84,605	72,401	-14.4%	59,649	-29.5%
	NOx (ton/y)	1,913	1,672	-12.6%	1,548	-19.1%
	SOx (ton/y)	1,811	145	-92.0%	135	-92.6%



Comparison of Emission



- SSD-LSFO:** Slow Speed Diesel - Low Sulfur Fuel Oil
- Base Plant**
- SSD-GI:** Slow Speed Diesel - Gas injection
- Minimum CO2**
- (NOx tier-III: + SCR or EGR)**
- DFDe:** 4Cycle D.F. Diesel Electric Propulsion system
- Fulfill NOx tier-III / SOx**
- UST:** Ultra Steam Turbine Propulsion system
- CO2 slightly increase,**
- Almost zero of NOx / SOx / PM**

④ LNG Fuelled Ship by MHI (C/S & O/C)

14,000TEU Container ship, 23knots, Asia-Europe

Arrange – 1: Δ 800TEU for all route

Δ 330TEU for the present ECA and the Mediterranean Sea

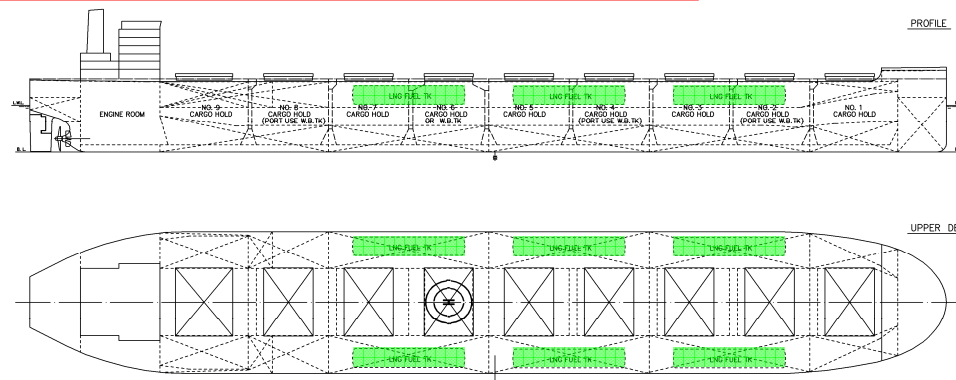


Arrange – 2: Δ 480TEU for all route

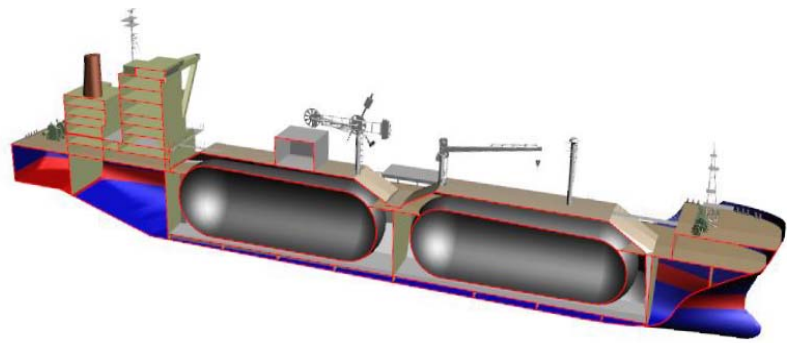
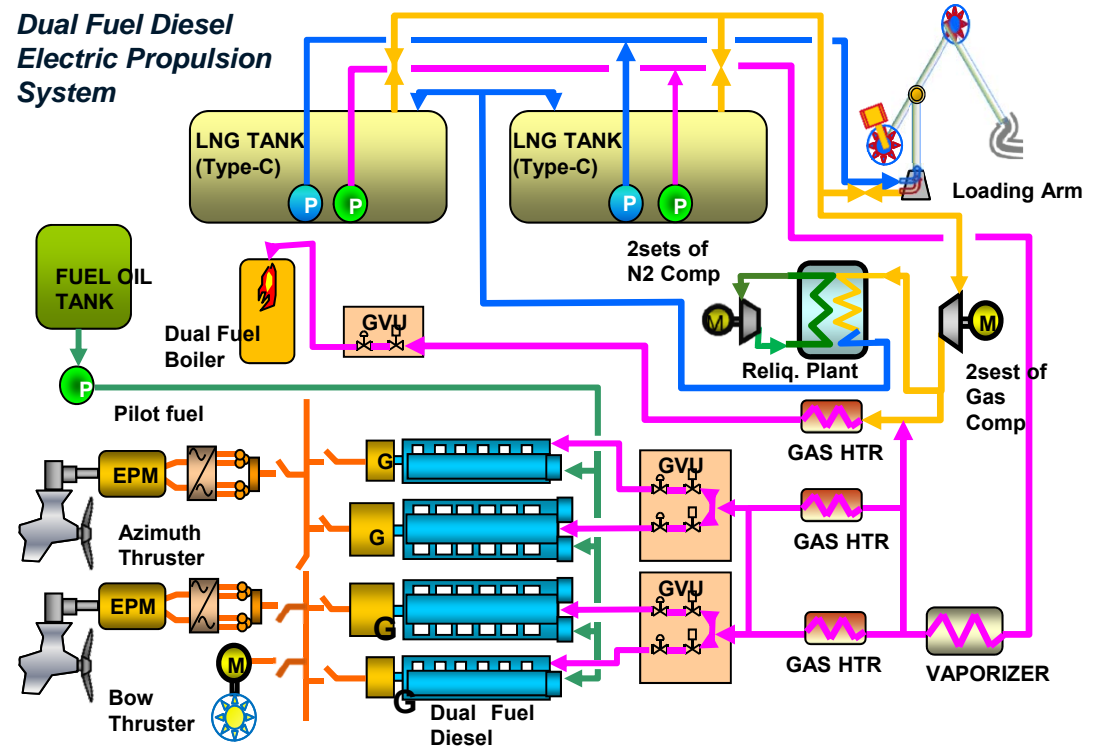
Δ 180TEU for the present ECA and the Mediterranean Sea



205 Ore Carrier, 14.2 knots, Brazil -Asia



④ LNG Fuelled Ship by MHI (LNG Bunker Ship)



- Features for LNG Ship to Ship Bunkering**
- Loading Arm
 - Rubber Floating Fender
 - Return Gas treatment system
 - Custody Transfer System
 - LNG/BOG Equilibrium Simulator

④ LNG Fuelled Ship (Other issue)

Preparation work before & after regular Dry Dock inspection (ex. ROPAX)

➤ Operation:

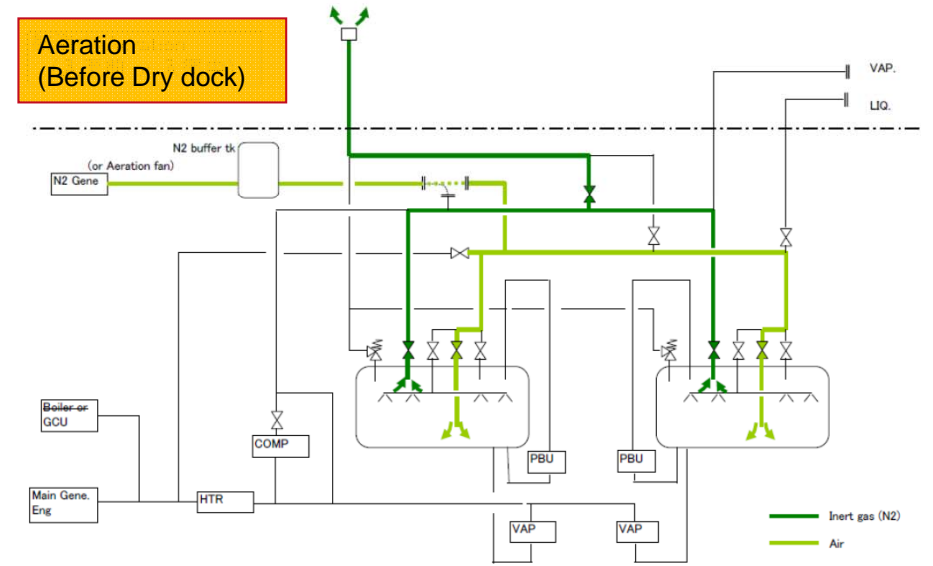
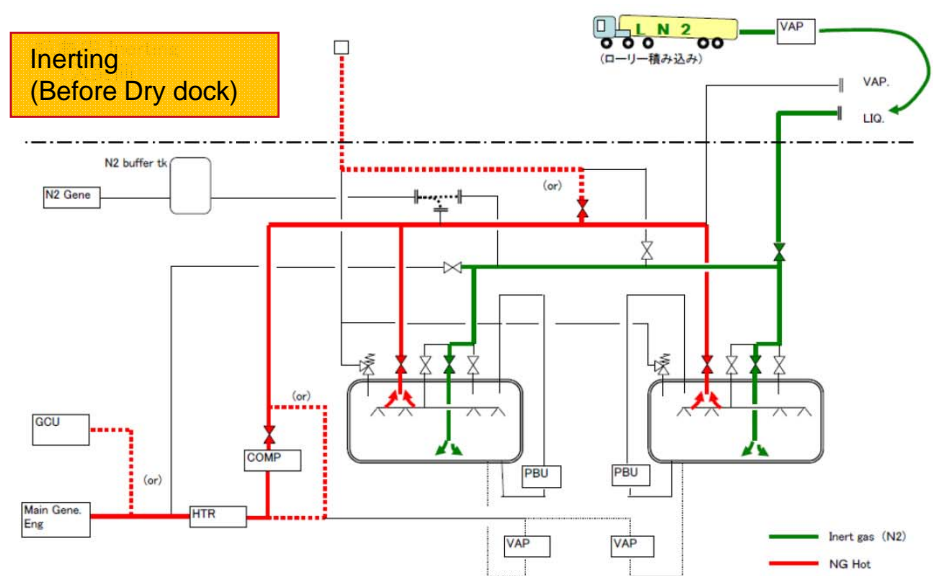
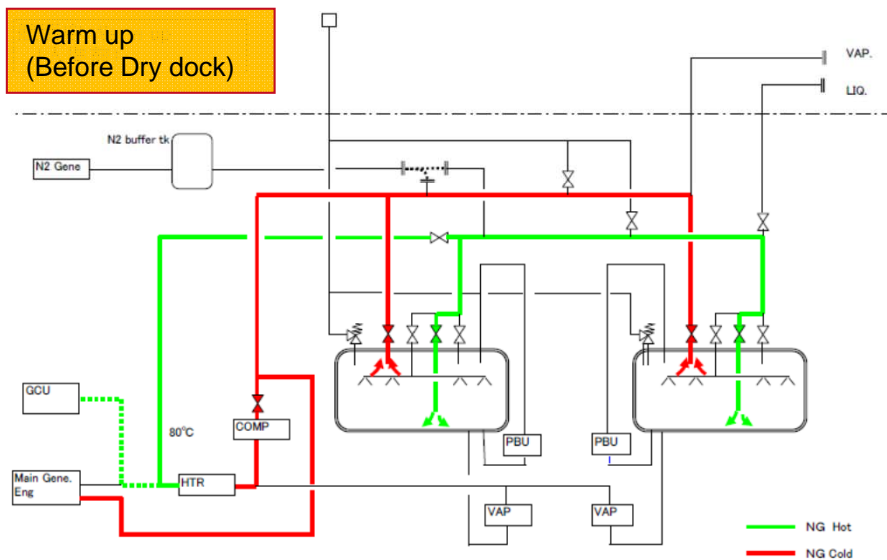
1. LNG tank warm-up
2. Inerting
3. Aeration

Dry dock

4. Inerting
5. Cool down
6. Initial LNG filling

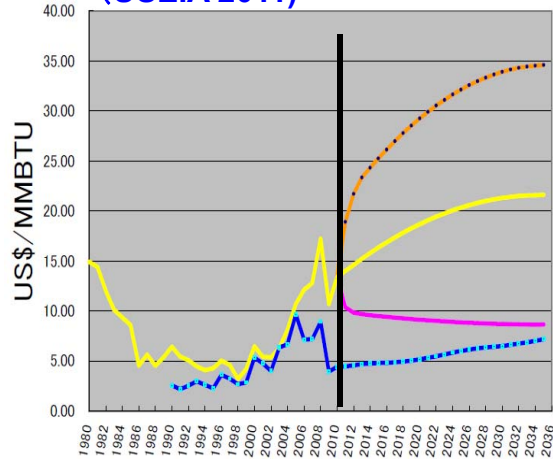
➤ Considering Equipment:

Compressor / Heater / GCU / N2 Gene.



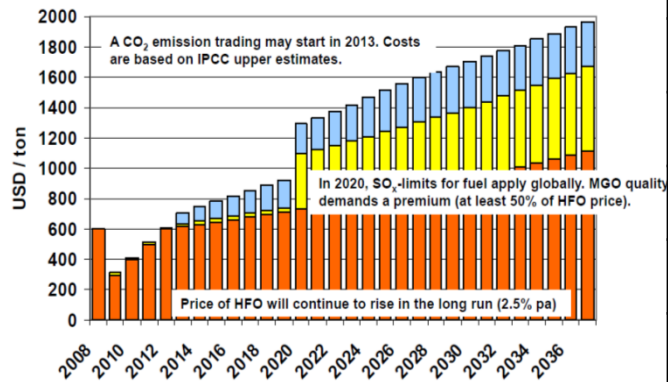
④ LNG Fuelled Ship (Other issue)

Trend data (NG and Crude oil)
(USEIA 2011)



— High oil price — Low oil price
— Oil reference — Natural gas
— (Henry Hab Spot Market)

IFO 380 MGO premium CO2 surcharge



Ref. Germanischer Lloyd AG

Equal value calculation of LNG price against H.F.O. price in Japan (ex. ROPAX + eGF)

*1 :	Index : HFO x 1.31
*2 :	49.10MJ/kg
*3 :	1MBTU=1,055.056MJ
*4 :	80¥/US\$

H.F.O. charges			Equal value calculation of LNG						
H.F.O. consumption			MDO (Pilot oil) consumption			Equal price of LNG			
Unit ¥	Consumption	Charge	Unit ¥	Consumption	Charge	③	④	Unit price 1	Unit price 2
(¥/Mt)	(ton/y)	(M¥/y)	(¥/Mt)	(ton/y)	(M¥/y)	(M¥/y)	(ton/y)	(¥/Mt)	(\$/MMBTU)
			*1			(①-②)		(③/④)	*2, *3, *4
45,000	9,116	410.2	58,950	79	4.7	410.2	8,136	50,420	13.5
46,000	9,116	419.3	60,260	79	4.8	414.6	8,136	50,956	13.7
50,000	9,116	455.8	65,500	79	5.2	450.6	8,136	55,387	14.9
55,000	9,116	501.4	72,050	79	5.7	495.7	8,136	60,925	16.4
60,000	9,116	547.0	78,600	79	6.2	540.8	8,136	66,464	17.9
65,000	9,116	592.5	85,150	79	6.7	585.8	8,136	72,003	19.3
70,000	9,116	638.1	91,700	79	7.2	630.9	8,136	77,541	20.8

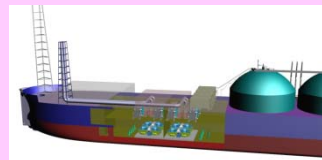
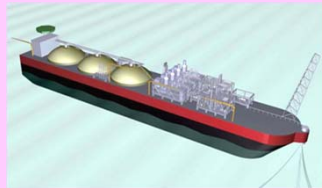
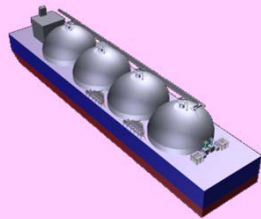
④ LNG Fuelled Ship by MHI

All kind of LNG Vessel Solution

Transportation



Terminal



Bankering



LNG Fuelled Ship



Gas handling Cryogenic Technologies & Equipment



Fuel Gas
Supply

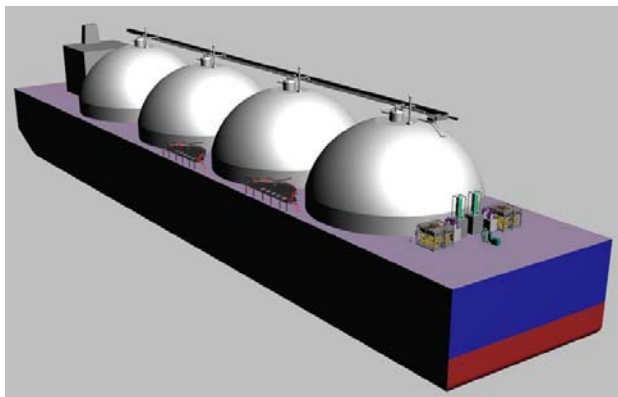


LNG
Storage



Gas
Combustion

BOG
Liquefaction



LNG
Gasification

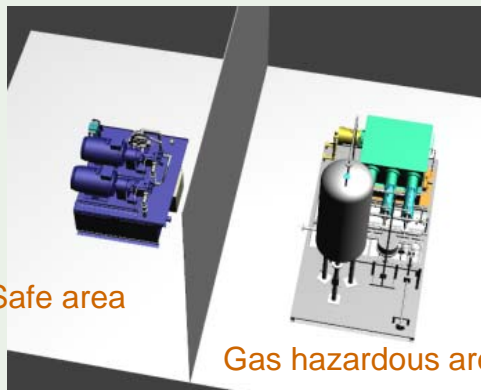


MHI-GEMS™ module lineup
(Gas ship Equipment Module and System)

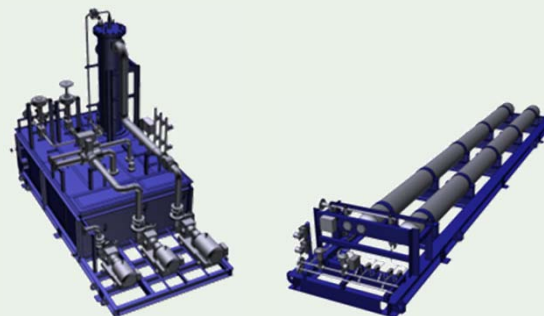
MHI-GEMS™ module lineup

Fuel Gas Supply System(FGSS) for GI engine / DF engine / Gas engine

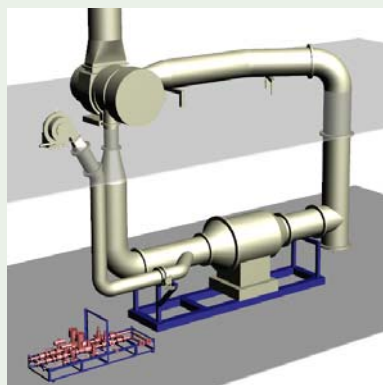
LNG pressurizing (~40MPa)



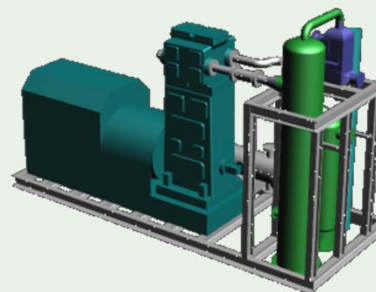
CNG production and regulation



Gas combustion



BOG fuelling (~1MPa)



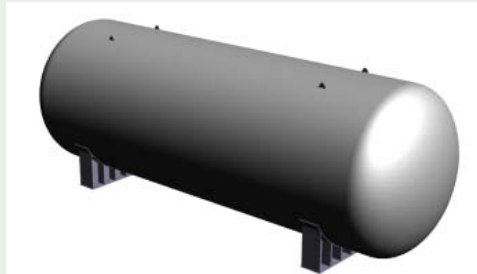
MHI-GEMS™ module lineup

LNG storage tank

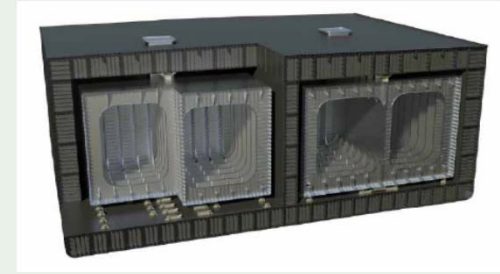
Storage / Double wall tank



Storage / IMO type C tank

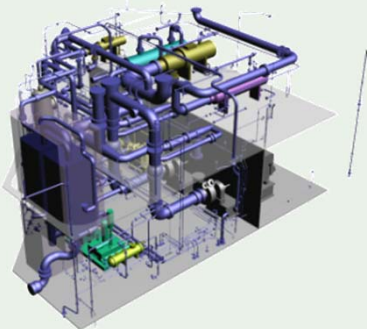


Storage / IMO type B tank

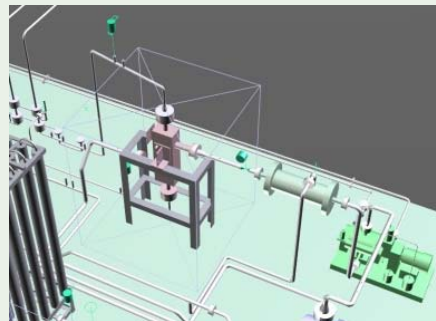


LNG re-liquefaction system for LNGC

LNG re-liquefaction

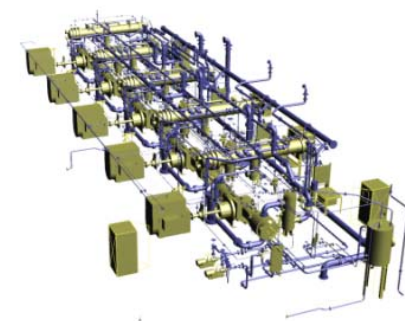


LNG cold heat recovery



LNG re-liquefaction system for LPGC

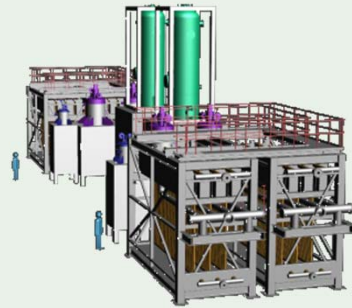
LPG re-liquefaction



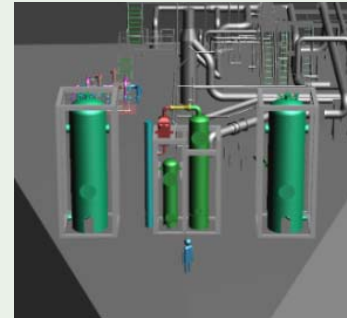
MHI-GEMS™ module lineup

LNG re-gasification system for FSRU

Marine ORV / Re-gasification

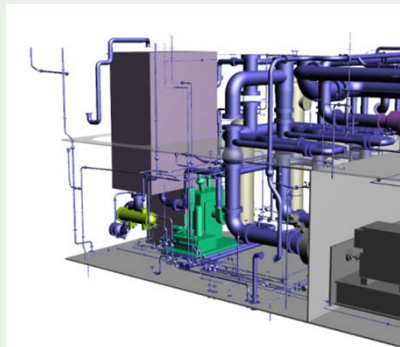


BOG re-condensing

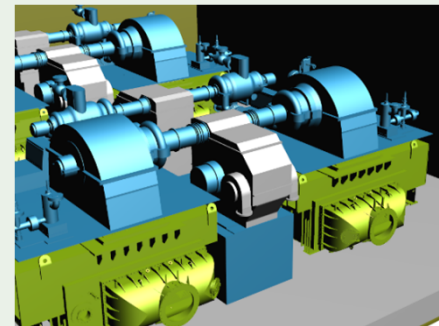


Gas liquefaction system for FLNG

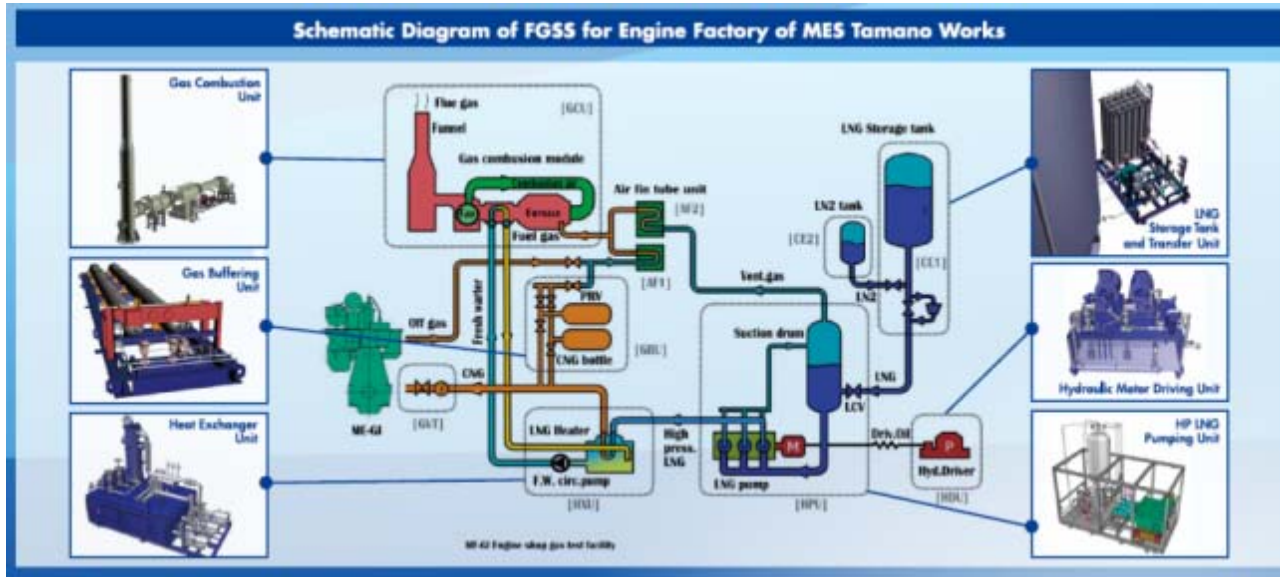
Cold box module



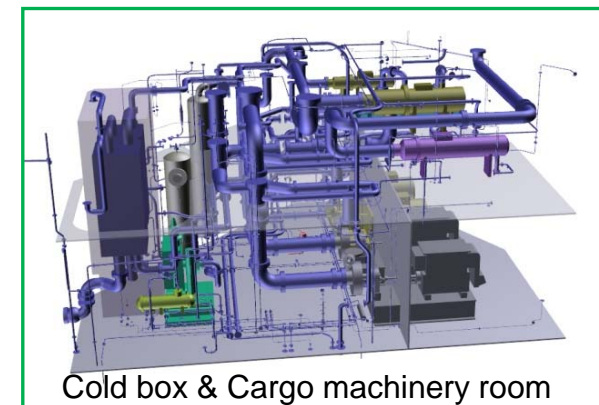
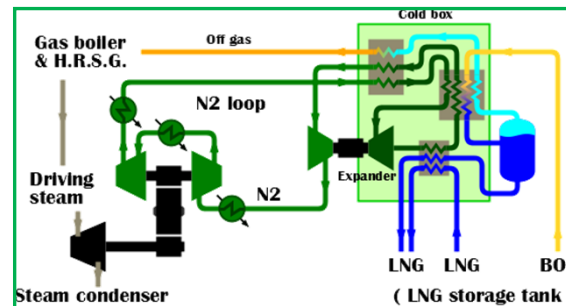
Steam turbine and compressor unit



FGSS : Large scale Gas Supply System for Engine Shop in MES TAMANO



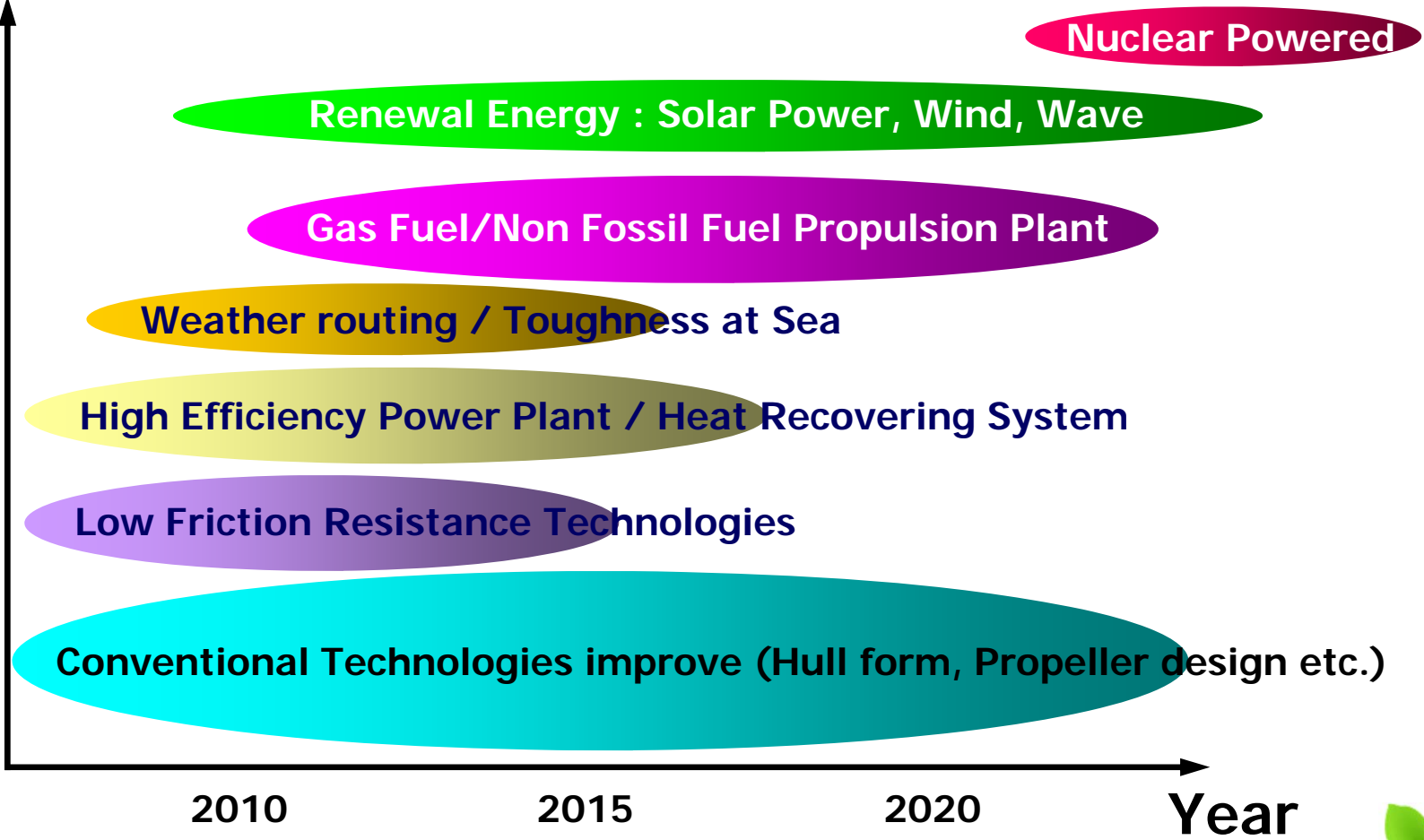
BOG Re-Liquefaction System on S/S LNG Jamal (World first unit)

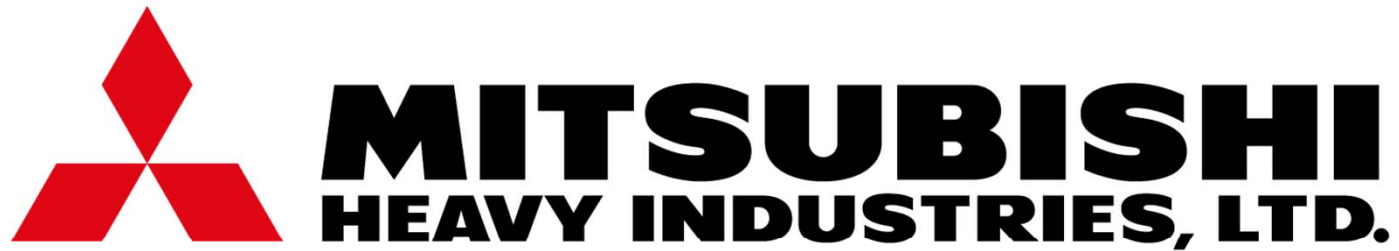


Road Map for Reduction of GHG

Zero Emission

Less GHG





Our Technologies, Your Tomorrow

Thanks for your attentions!



ClassNK
R&D PROJECT

This technology was developed with the support of ClassNK as part of the ClassNK Joint R&D for Industry Program.