Shipyard's Perspective: Ship Design – LNG Propulsion Systems

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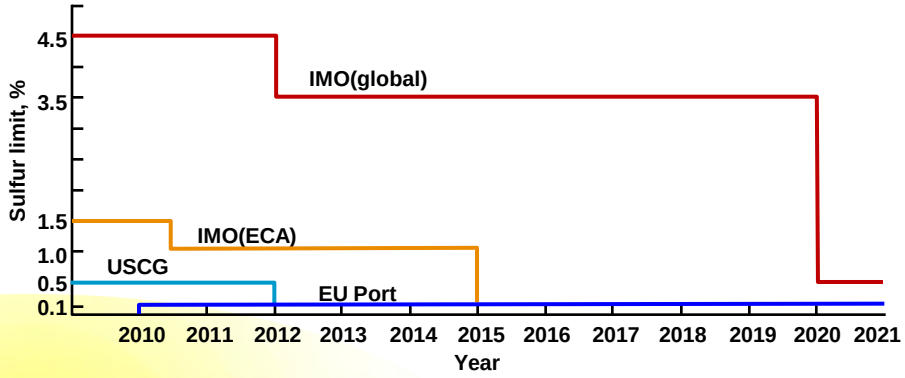
Background

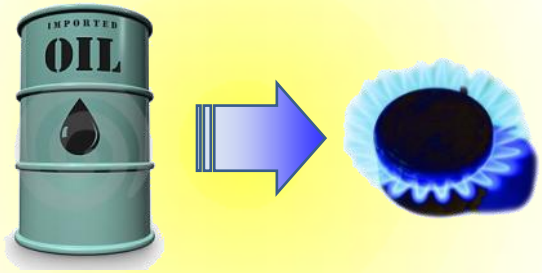
❑ Emission Regulations

- NOx Regulation by IMO
  (MARPOL Annex VI, Regulation 13)

Tier	Construction date on or after	g/kWh (RPM<130)
I	1 January 2000	17.0
II	1 January 2011	14.4
III	1 January 2016	3.4

- SOx Regulation by IMO
  (MARPOL Annex VI, Regulation 14)



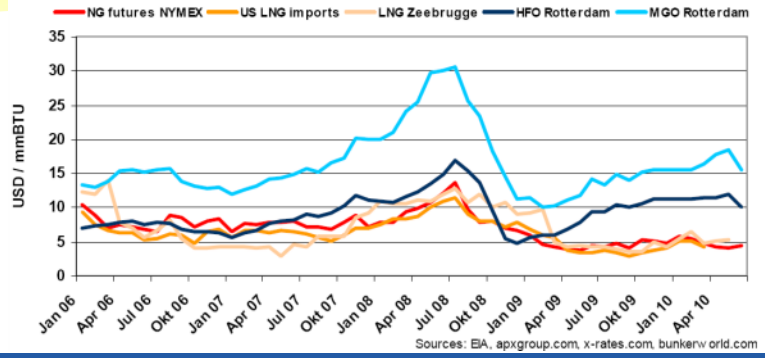


❑ Fuel Price

- Recent Gas & Ship Fuel Price (06 May. 2011)

Fuel	Price	
	($/ton)	($/MMBTU)
HFO (IFO380) @ Singapore	624	16.2
MGO @ Singapore	941	24.5
NG @ Henry Hub	218	4.6

- Gas & Ship Fuel Price (Jan. 2006 ~ Apr. 2010)



Global LNG Fueled Ships (small size)

Vessel	Storage	Year	
A few small ships with CNG	CNG (Compressed Natural Gas)	1982 ~ 1990s	
Glutra (car & passenger ferry)	LNG (2 x 32m^3)	2000	
Viking Energy (platform supply vessel) (+ 1 sister ships)	LNG (1 x 234m^3)	2003	
BergensFjord (car & passenger ferry) (+ 4 sister ships)	LNG (2 x 125m^3)	2007	
Kystvakt (coast guard ship) (+ 2 sister ships)	LNG (1 x 234m^3)	2009	
Moldefjord (car & passenger ferry) (+ 2 sister ships)	LNG (2 x 125m^3)	2009	
Viking Queen (platform supply vessel) (+ 1 sister ships)	LNG (1 x 234m^3)	2009	

For Large Ships

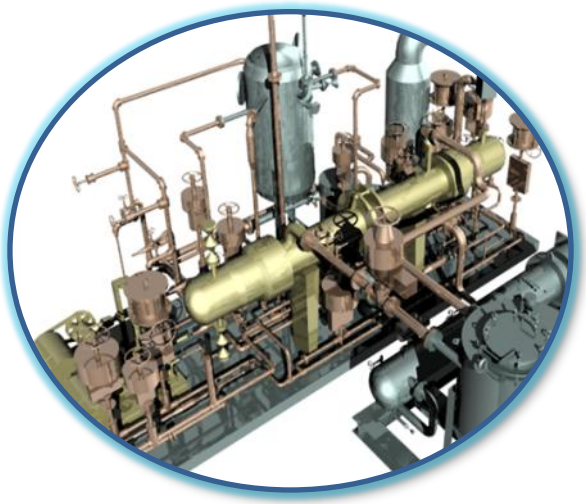
❑ Large ship requires totally different technologies to utilize LNG as its fuel.

	Small Ships	Large Ships	Consideration
Propulsion	4 Stoke Gas or D/F Engine & Electric Propulsion	2 Stoke D/F Engine & Mechanical Propulsion	Large Propulsion Power (Bore 90 or 98)
FGS	LNG/NG Supply by Tank Pressure	New Concept FGS	High GI Pressure
Fuel Tank Type	Type C Pressure Vessel	New Concept Fuel Tank	Huge Tank Volume CAPEX, Volume Efficiency
BOG Management	Not Critical	Careful Attention	MARVS
Fuel Tank Arrangement	Complying with B/5 distance from side hull	Difficult to meet B/5	Cargo Loss, Collision
Bunkering	Not Critical	Critical in Method & Time	Tank Volume & Operation Schedule

LNG Fueled Propulsion System

❑ LNG Fueled Propulsion System for Large Commercial Ships

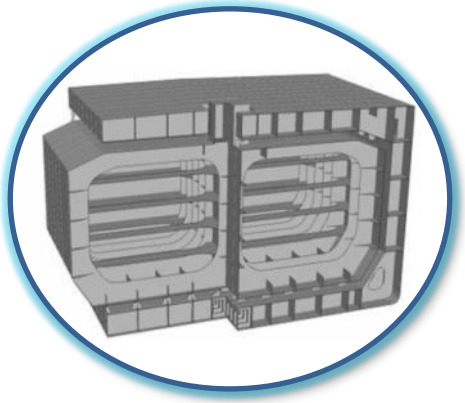
High Pressure NG*



Fuel Gas Supply System

LNG + BOG*

ME-GI* Engine



LNG Fuel Storage Tank

*NG : Natural Gas
*ME-GI : MAN Electronic – Gas Injection
*BOG : Boil-Off Gas

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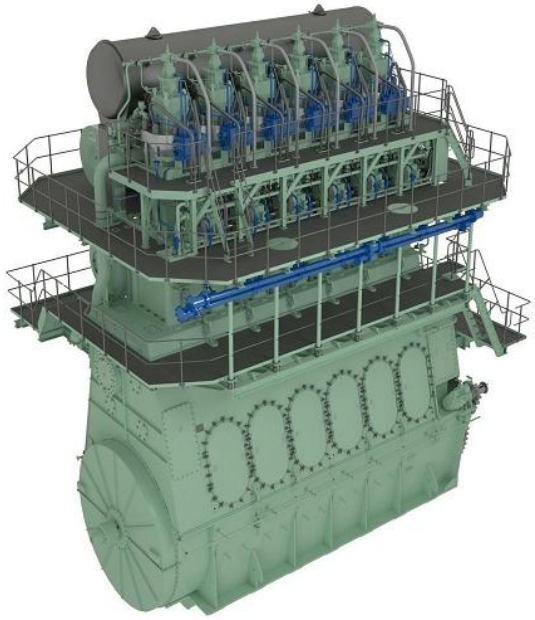
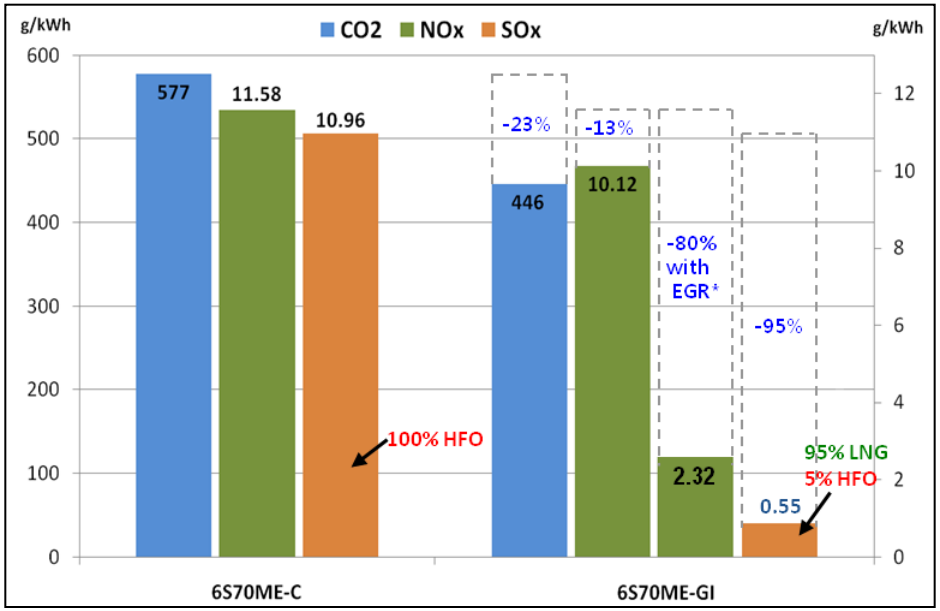
Propulsion Engine: 2-Stroke Dual Fuel Engine

ME-GI Engine (MAN Electronic – Gas Injection)

- 2-stroke dual fuel engine made by MAN Diesel
- Highest efficiency among existing propulsion systems
- Simultaneous Dual Burning (HFO + FG)
- Low CAPEX & OPEX compared to other dual fuel engines
- CO2, NOx, SOx emission reduction

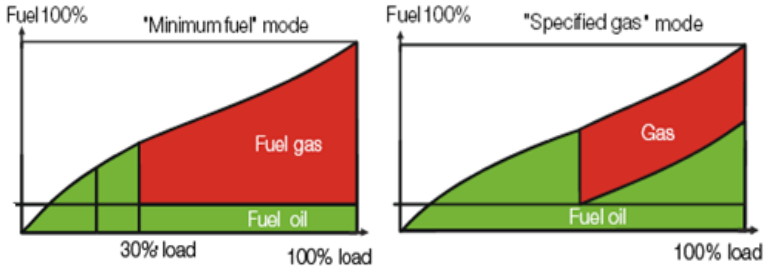


• ME-GI Engine



• Emission Comparison between ME and ME-GI in gas mode

(Refer to "ME-GI Dual Fuel MAN B&W Engines". Graph by DSME)

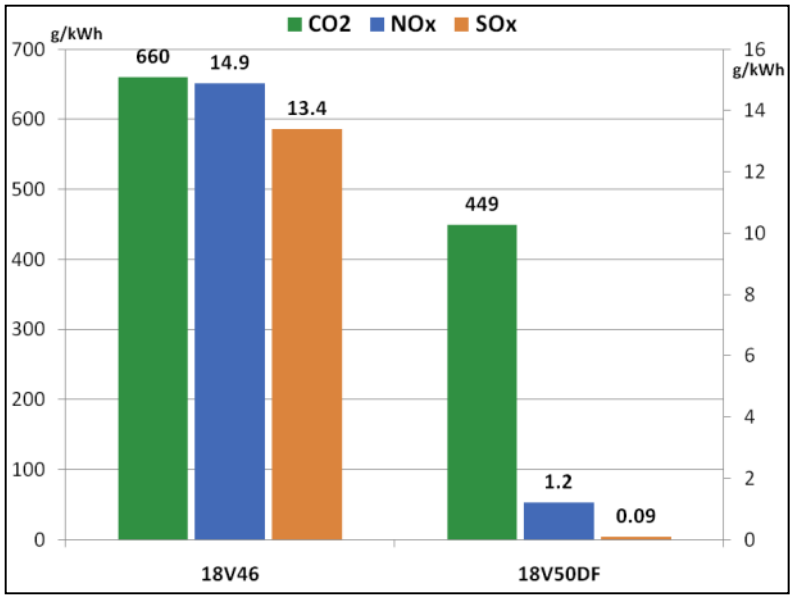


• Variable Gas Operation Mode of ME-GI

Generator Engine: 4-Stroke Gas / Dual Fuel Engine

Gas / Dual Fuel Generator Engine

- 4-stroke, medium speed gas or DF engine
- Oil mode (HFO or MDO, DF engine only) or Gas mode (NG + 1% MDO pilot oil)
- SOx, NOx emission is negligible
- Working gas pressure : 5 ~ 8 bar
- Constant speed (RPM) designed



• **DF Engine Emission Comparison.** **(Ref. "Wartsila 50DF Project Guide")**

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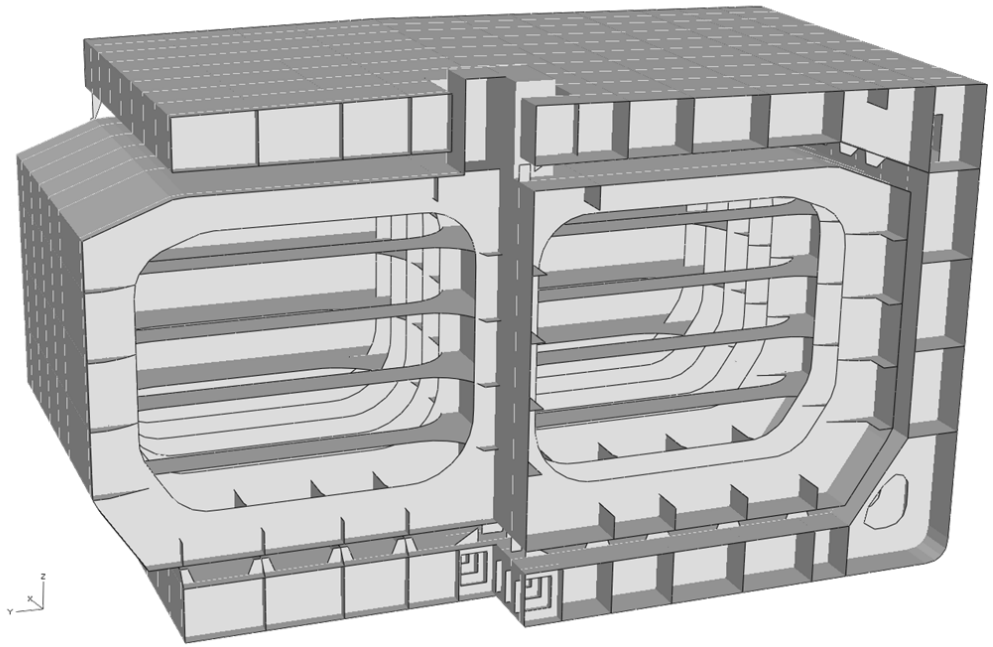
ACT-IB Storage Tank – IMO Independent Type B

ACT-IB Storage Tank (Aluminum Cargo Tank – IMO Independent type B)

- Independent LNG tank
- PUF(Poly-Urethane Foam) panel type insulation
- Inherent increased pressure design
  (typically 0.7 bar gauge)



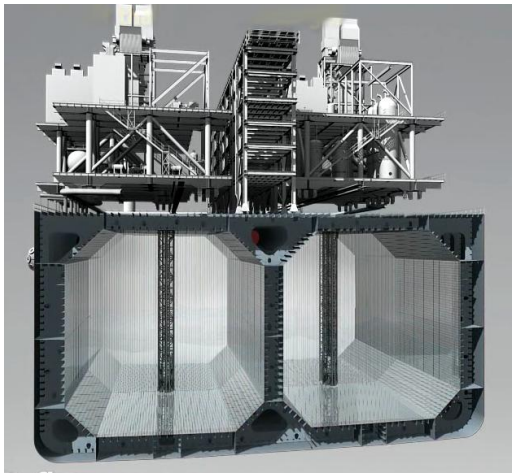
- **Independent LNG Fuel Tank Example (ACT-IB)**

Membrane Tank

❑ IGF interim guideline is expected to amended to allow membrane tank for LNG fueled ships

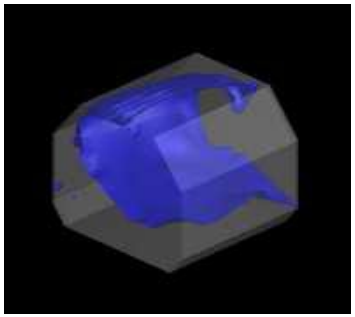
GTT NO 96 system	
Primary membrane	0.7 mm Invar (36% Ni-Fe)
Primary insulation material	Plywood with Perlite
Secondary membrane	0.7 mm Invar (36% Ni-Fe)
Secondary insulation material	Plywood with Perlite
Insulation thickness	530 mm (230 + 300)
Insulation tightening	Securing device set
Note	Anti-sticking treatment between secondary insulation box with hull

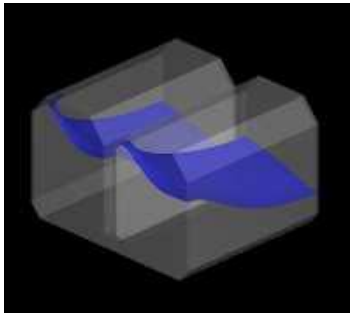
✓ DSME LNG FPSO
applied 2 row LNG tank (NO 96 CCS)



✓ Internal view of NO96 CCS

✓ Result of sloshing in 2 row arrangement of NO 96 CCS





Tank Type Comparison – Owner's Choice

❑ **Comparison between GTT NO 96 and DSME ACT-IB**

	GTT NO 96	ACT-IB
CCS type	Membrane	Independent type B
Shape of tank	Limited (Integrated in hull)	Free (Prismatic)
Pressure	< 0.25 barg (max 0.7)	< 0.7 barg
2nd barrier	Yes	Partly (Drip tray)
Insulation thickness	530 mm (Internal insulation)	270 mm (External insulation)
Material	Invar (36% Ni-Fe) + Plywood with Perlite	Aluminum + Poly Urethane Form
Support & chock	-	Exist
Weight		Increase (internal structure)
Sloshing for partial filling	Two row arrangement and Baffle structure	Swash bulkhead for sloshing
License	GTT	DSME
Experience	Over 70 of LNGC/RV	-

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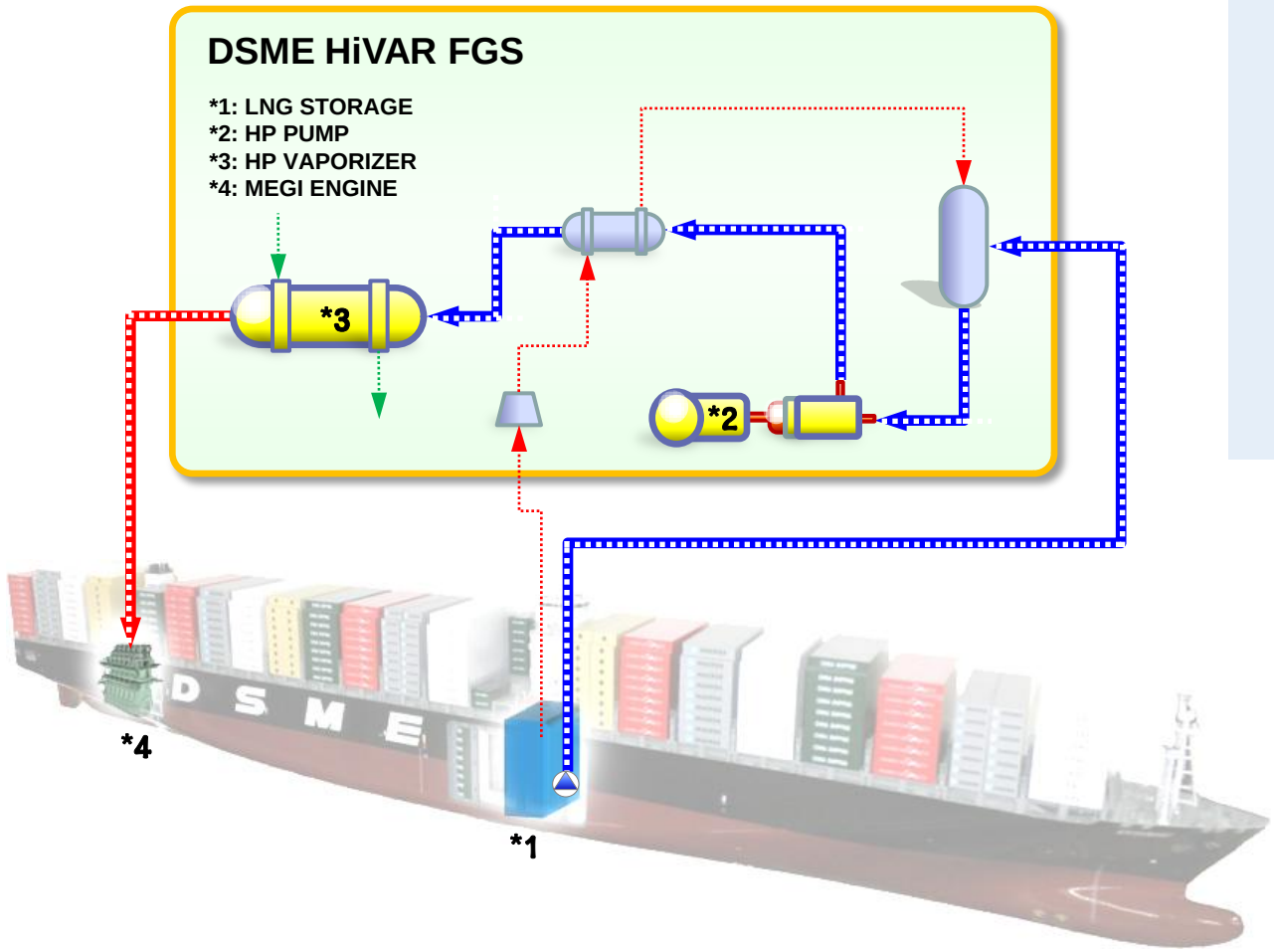
Fuel Gas Supply System – DSME HiVAR

❑ Conceptual Process Flow Diagram



❑ Features

- HP Pump + HP Vaporizer
- 300 bar Design Pressure
- BOG Recondensing
- Compact Size
- Low Power Consumption
- Low Noise & Vibration
- Easy Maintenance

Power Consumption Comparison (for reference)	
HP Compressor System	**HiVAR**
1400 kW	70 kW

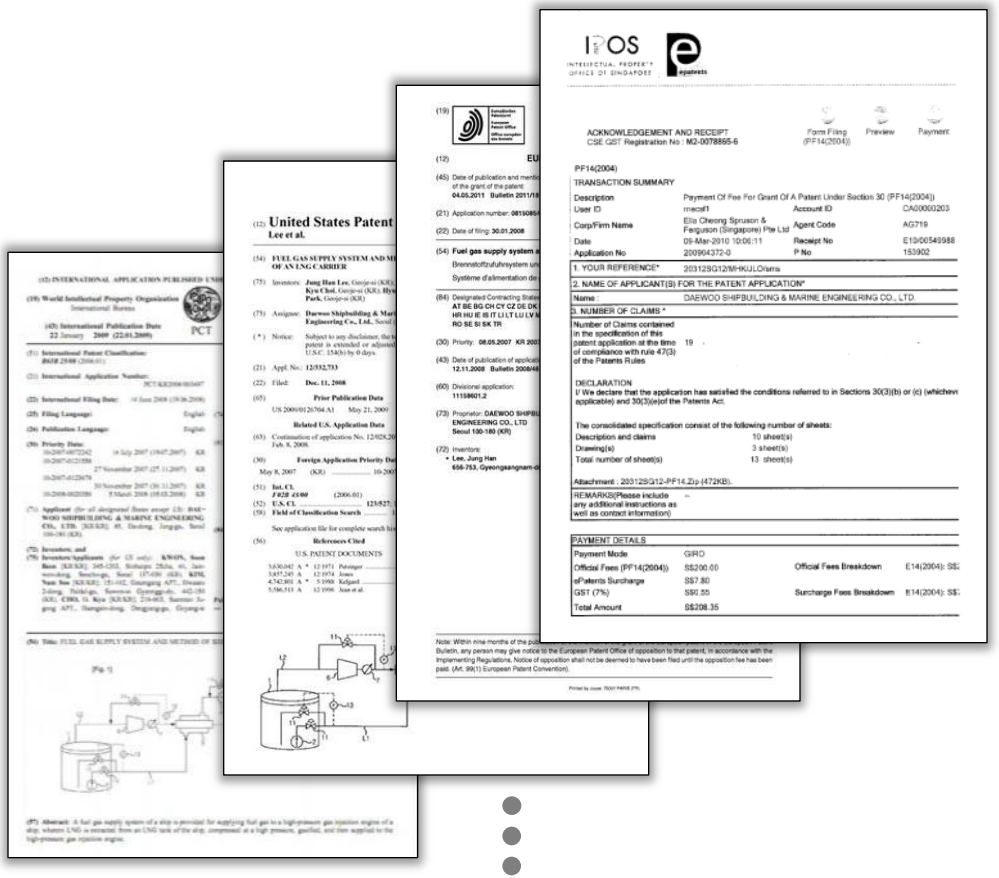
DSME Intellectual Property Rights

DSME Proprietary Technology

Patent List of DSME HiVAR system

- **International Patent Application**
  - ✓ Several patents applied since June 2008
  - ✓ Designated States : EP*(Granted), Singapore(Granted), China, United Arab Emirates
- **United States Patent**
  - ✓ Several patents applied since Dec 2008
- **Patented or Patent Application in Korea**
  - ✓ Several patents applied since May 2007
  - ✓ 20 + granted or pending

※ EP : United Kingdom, Norway, Sweden, Germany, Belgium, France, Denmark, Greece, Switzerland, Finland



- High pressure fuel gas supply using HP pump and HP vaporizer is subject to intellectual and industrial property rights protected by national and international legislation.
- Registered to many countries including US and EU. (Previous arts have been exhaustively checked before registration.)

FGS Operation Test with ME-GI Engine

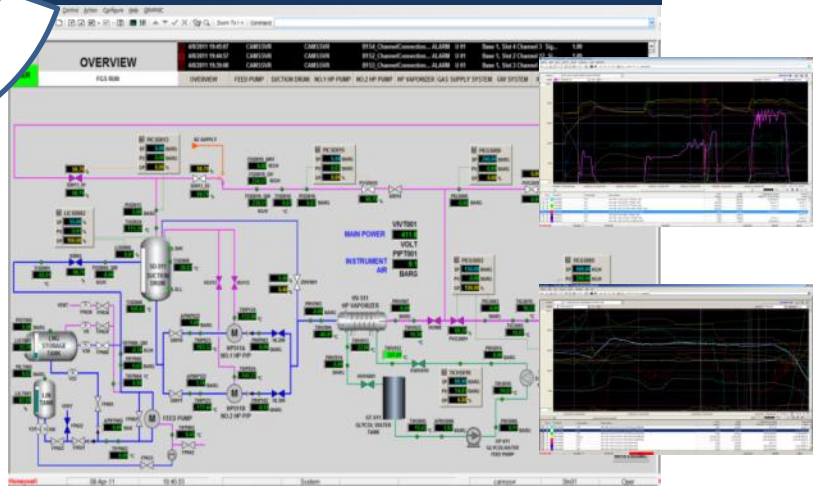
ENGINE CONTROL SITE

FGS SKID SITE

OVERALL SYSTEM INTEGRATION TEST

ENGINE SITE

LOAD TEST with ENGINE(LNG)



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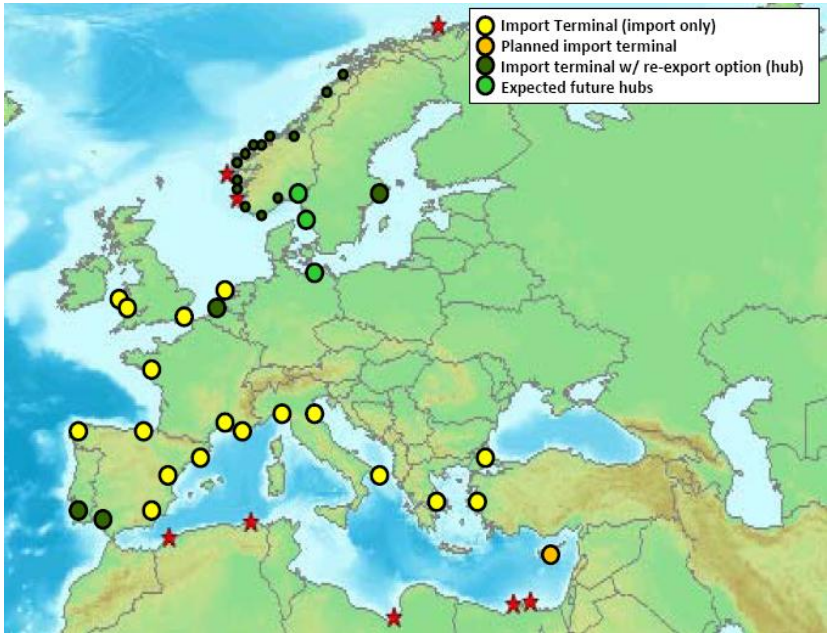
LNG Bunkering

LNG Bunkering Scenarios

- Tank lorry for small ships
- Existing LNG Import or Export Terminals
- Launching local LNG Liquefaction Facilities for bunkering business
- Ship to Ship Transfer utilizing small LNG Bunkering Ships in
  - Container terminals, or
  - Open sea areas



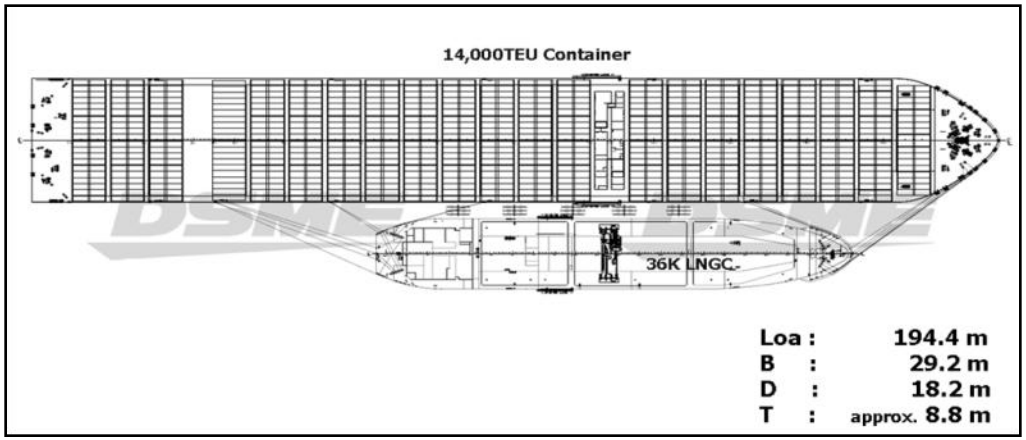
LNG Terminals

Zeebrugge LNG Receiving Terminal w/ Re-Export in Belgium

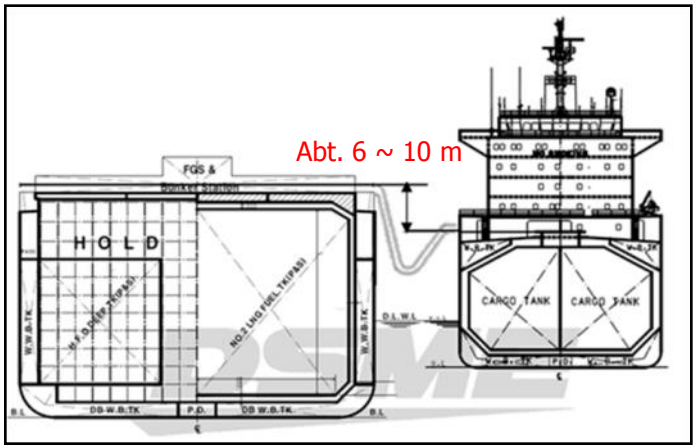
LNG Bunkering Vessel

LNG Bunkering Vessel Concept

- Pre-requisite for LNG fueled containerships and tankers
- Safe mooring
- Manifold mating
- High speed LNG pumping
- Returned flash gas treatment
- Safety monitoring and interface systems



• Side by Side Mooring



• Example of Ship to Ship Transfer

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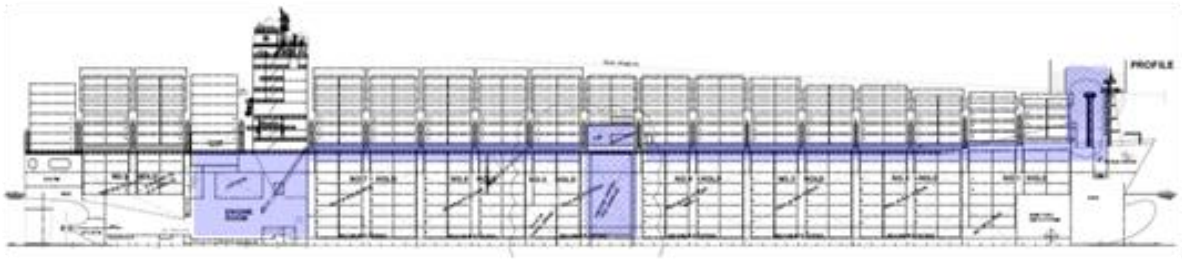
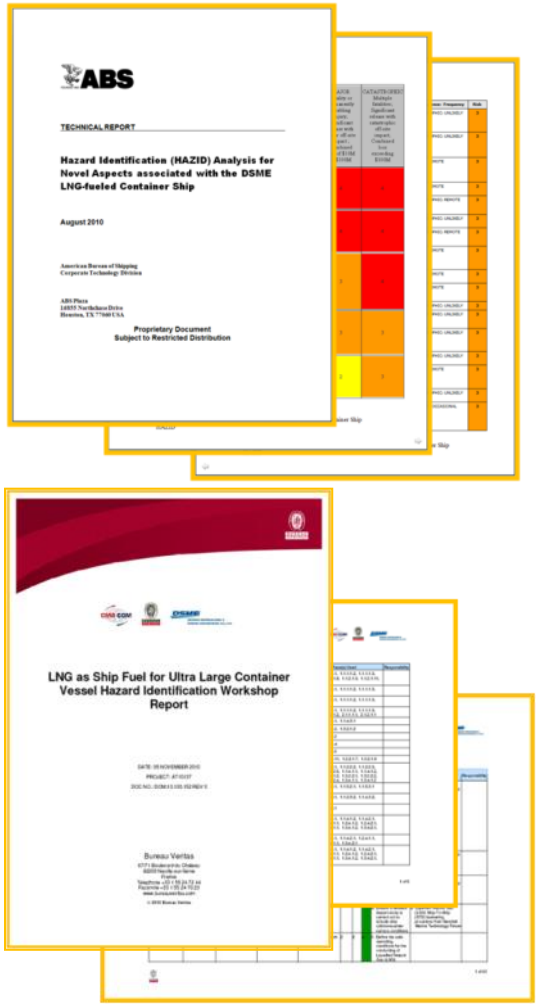
Overall Safety Design



- IGF* compliant design
- HAZID/HAZOP for LNG fuelled commercial ship
  - Gas existing physical spaces :
    LNG fuel tank space, FGS room, E/R, vent mast, bunkering station, passage way, etc.
  - Gas operations :
    LNG bunkering, FG supply at normal seagoing, drying, inerting, aeration, initial cool down, warming up, etc.

* IGF : the International Code of Safety for Gas-fuelled Ships.
Now it stands as an **interim guideline**.

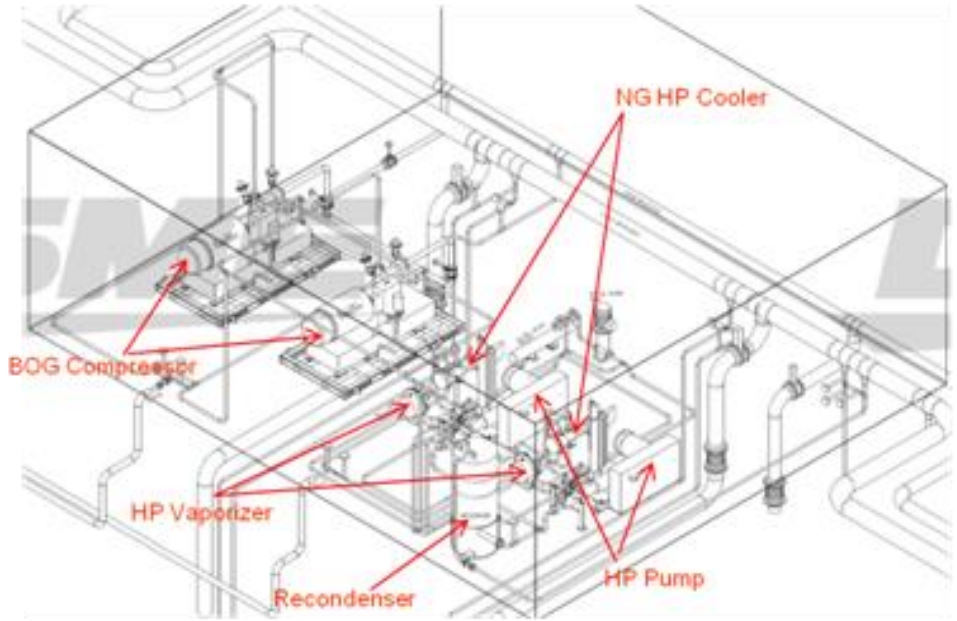
- HAZID for DSME LNG-Fuelled Container Ship (ABS, BV)



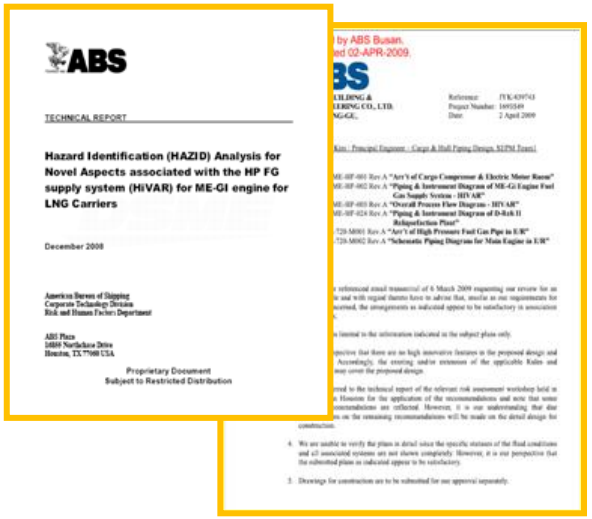
FGS Room

FGS Room Safety

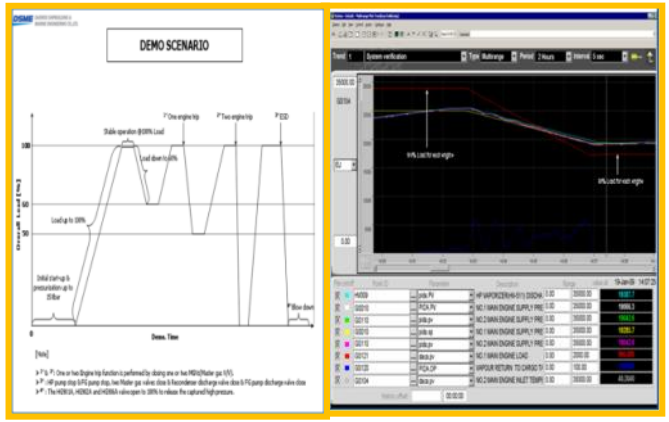
- Explosion proof equipments (motor, etc)
- Ignition source inhibited
- Ventilation systems (30 air change / hour)
- Gas detection & ESD (Emergency Shut Down) system
- Structural integrity against dropping object (container ships)



• HAZID/HAZOP Study and AIP for FGS



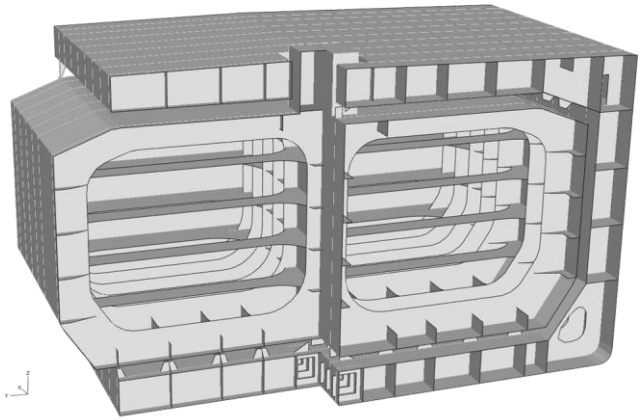
• Dynamic Simulations



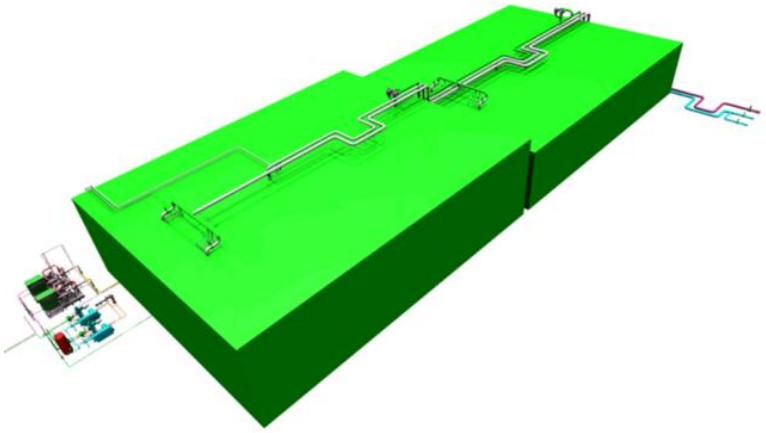
LNG Fuel Tank Space

LNG Fuel Tank Safety

- Tank pressure control by BOG Management
- Emergency venting systems
- Inerting with N2 outside of tank
- Gas detection wystems
- Drip Trays below tank bottom (Secondary Barrier)
- Eductors for drip trays
- Structural integrity against possible collision (container ships)



LNG Fuel Storage Tank in Hold Space (Containership)

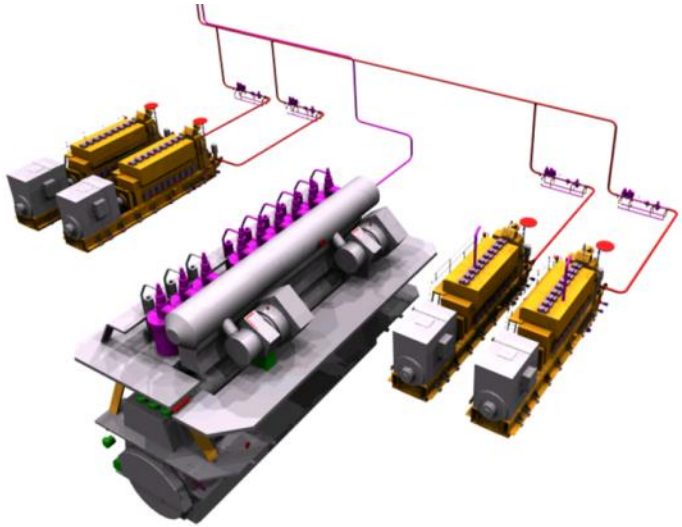


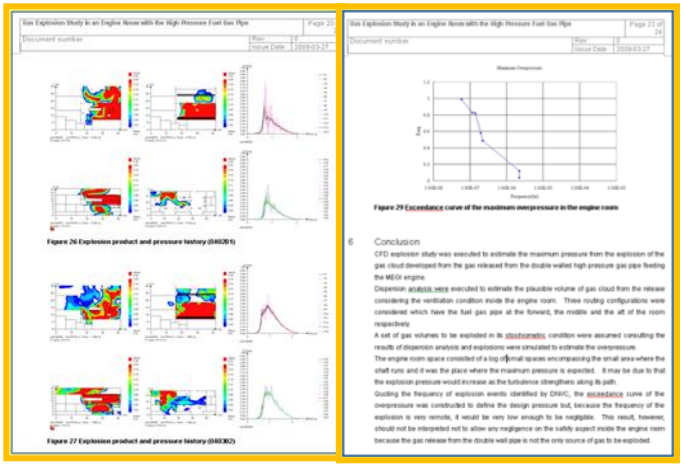
LNG Fuel Storage Tank Upper Deck (VLCC)

Engine Room

Engine Room Safety

- Double wall pipe connections
- GVU (Gas Valve Unit) for each gas fueled engine
  - Double block and bleed valves
  - Enclosed GVU room with ventilation
- Ventilation systems
- Gas detection systems
- ESD (Emergency Shut Down) system





• Gas Explosion Study in E/R

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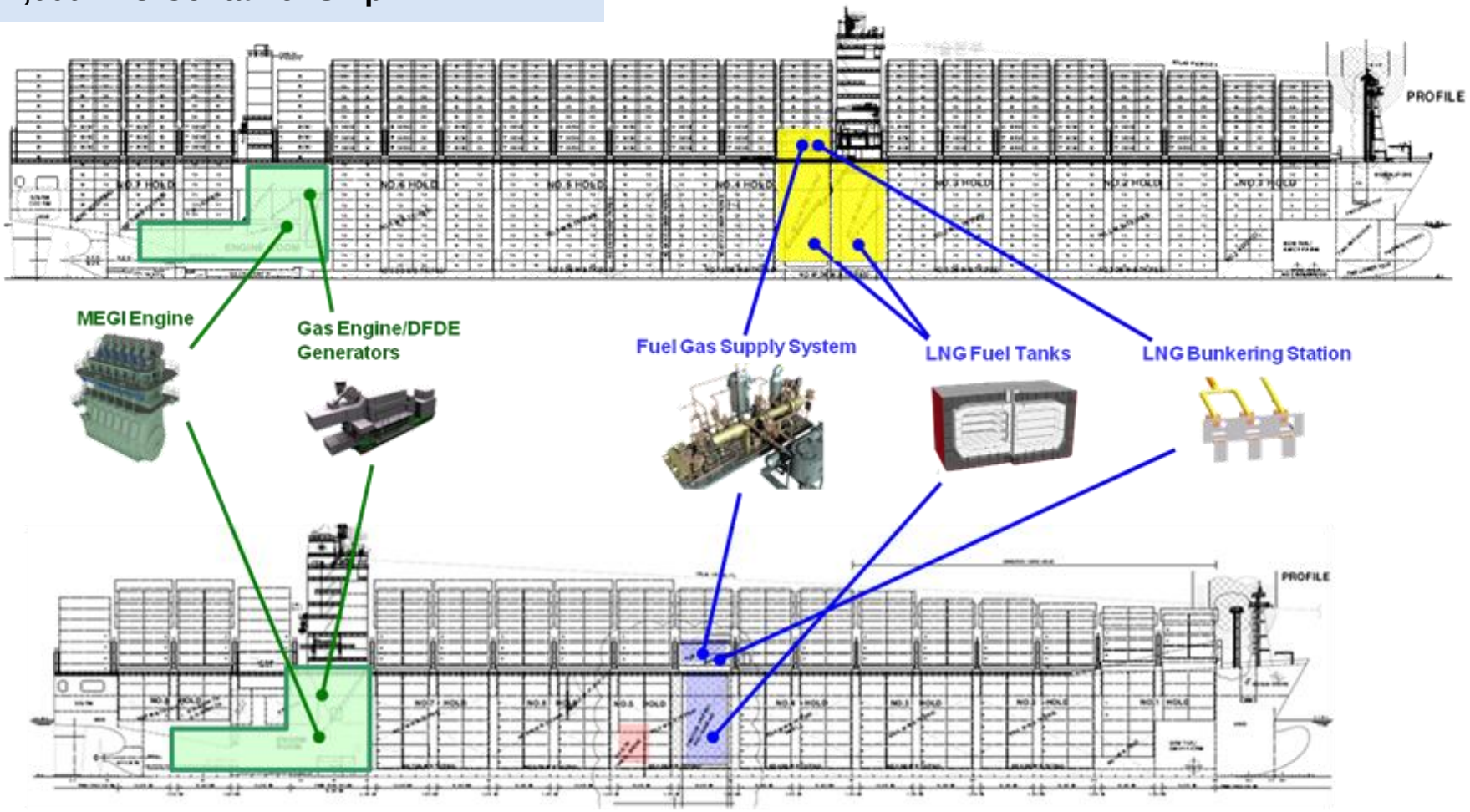
LNG Fueled Container Ship

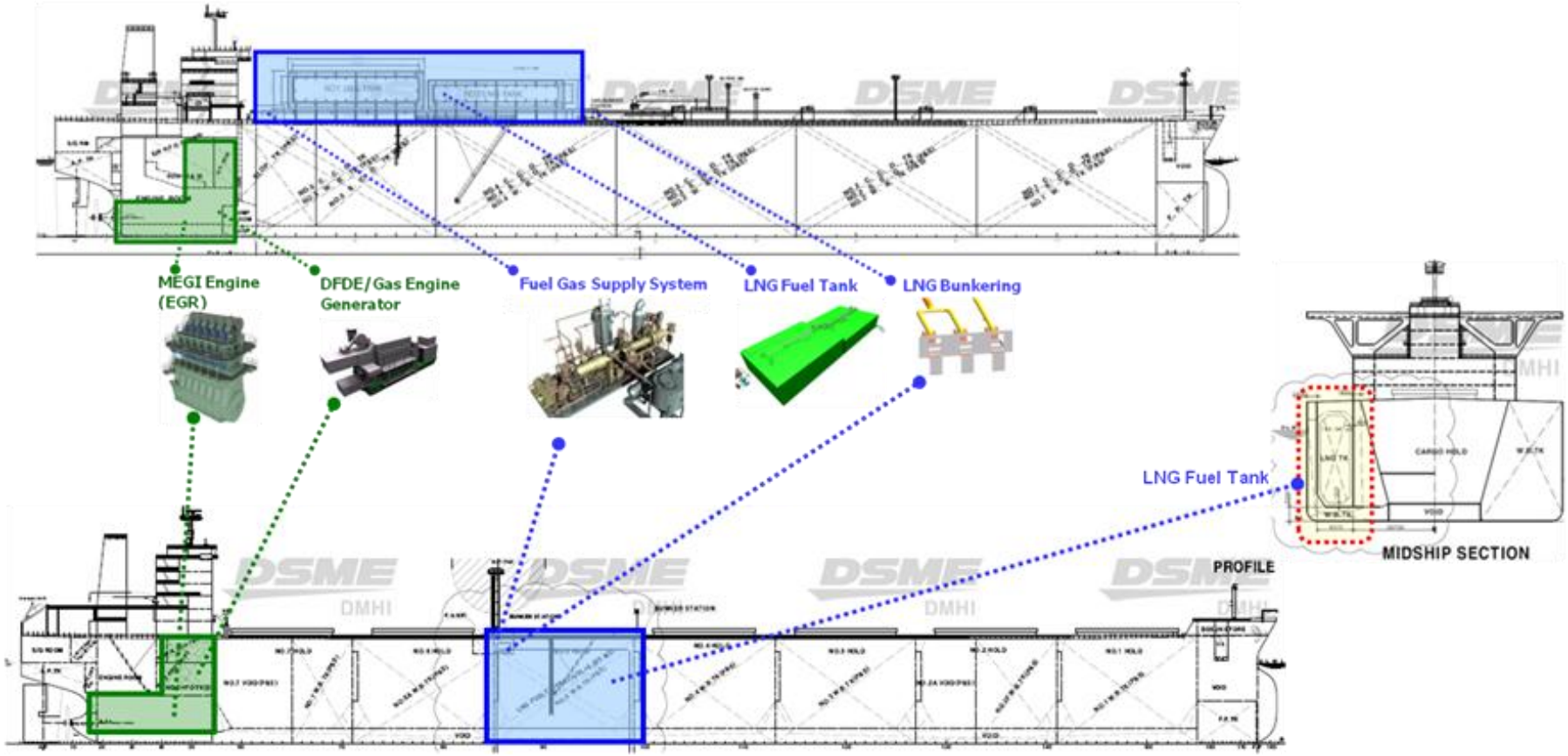
14,000 TEU Container Ship



7,450 TEU Container Ship

LNG Fueled VLCC / VLOC

318,000 DWT VLCC

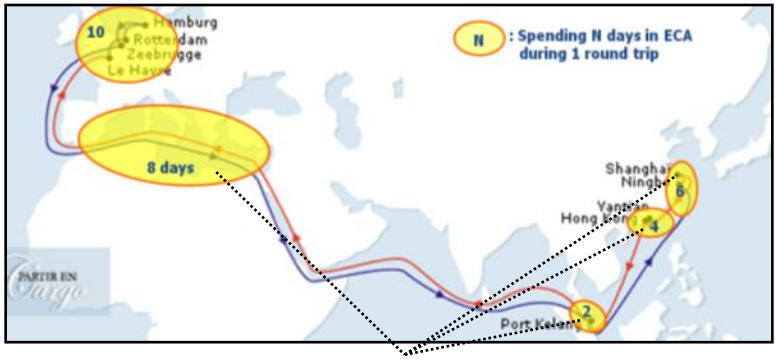


400,000 DWT VLOC

Economic Evaluation

❑ Economic Evaluation Example for 14,000 TEU Container Ship

• Target Route (Europe-Asia Line)



Expected ECA* at 2015

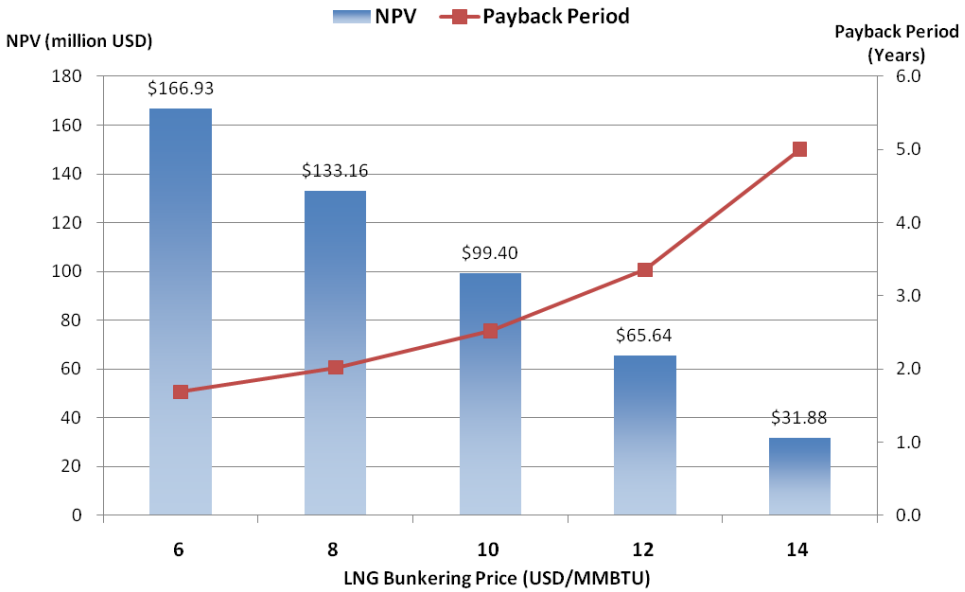
• Economic Evaluation for Various LNG Price Scenarios

HFO	USD/ton	630	(2011-5-19 Singapore IFO380 price)			
MGO	USD/ton	930	(2011-5-19 Singapore MGO price)			
LNG Bunkering Price	USD/mmbtu	6	8	10	12	14
	USD/ton	285.53	380.71	475.88	571.06	666.24
OPEX Saving	USD/year	23,722,196	19,788,869	15,855,543	11,922,216	7,988,890
Fuel Cost Saving	USD/year	26,576,482	22,643,155	18,709,829	14,776,502	10,843,175
Freight Rate Impact	USD/year	-2,854,286	-2,854,286	-2,854,286	-2,854,286	-2,854,286
NPV (9% DR, 30 yrs)	USD	**166,926,746**	**133,164,287**	**99,401,828**	**65,639,369**	**31,876,910**
IRR	%	41.82%	36.29%	30.39%	23.99%	16.90%
Payback Period	Years	**1.7**	**2.0**	**2.5**	**3.4**	**5.0**

• Operating Data (14,000 TEU Container)

Main Engine		
MCR	72,285	kW
Operating Rate	60	%
	43,371	kW
SFOC	168.3	g/kWh
Duration in ECA	19	days
Duration non ECA	25	days
Aux. Engine		
Max.	15,360	kW
Operating Rate	2,000	kW
SFOC	185	g/kWh
Duratin in ECA	29	days
Duration non ECA	27	days
No. of voyage	6.43	

• NPV and Payback Period for Various LNG Price Scenarios



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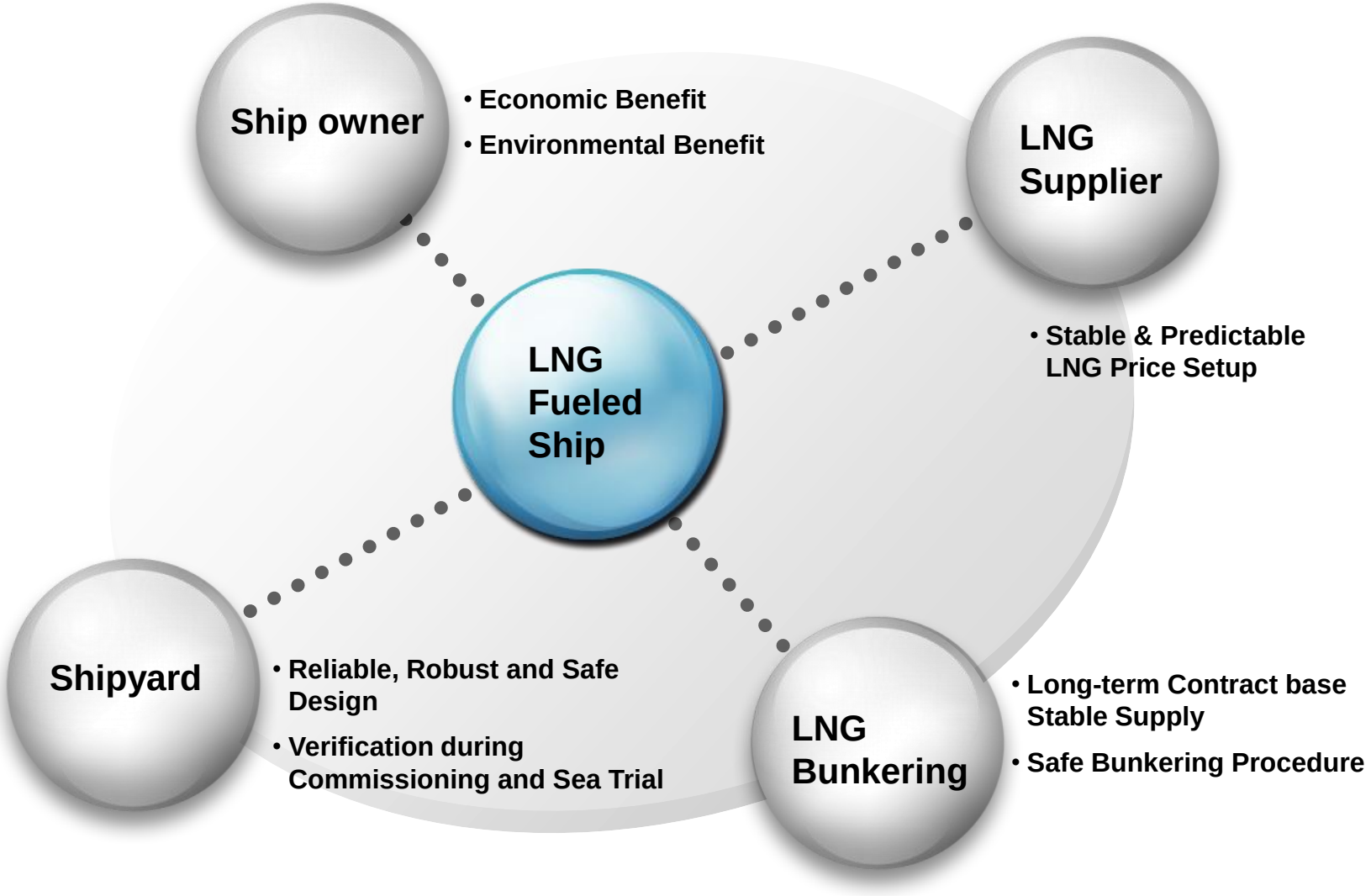
Considerations for LNG Fueled Ship



Summaries and Conclusions

❑ LNG Fueled Large Commercial Ship Design

- Dual fuel engines + Fuel storage tank + FGS system
- LNG bunkering infrastructure
- Safety design & operation procedures
- Development of various LNG fueled ship design

❑ Environment Friendly Operations

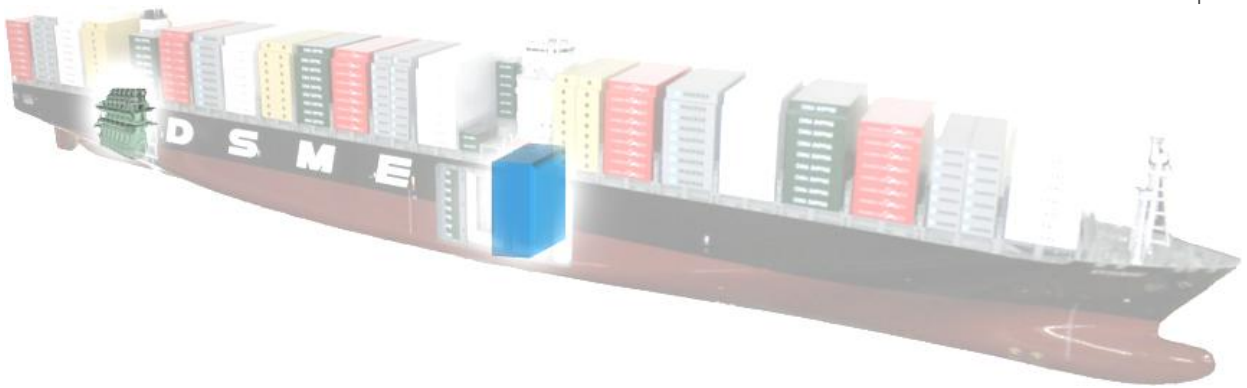
- Reduction of exhaust emission (CO_2, SOx, NOx)

❑ Cost-Effectiveness of LNG Fuel

- Environment and operation cost saving

Ship Type	Annual Fuel Cost Saving
Typical Large Container Ship	Approx. 12 ~ 20 mil. USD per year
Typical VLCC	Approx. 6 ~ 12 mil. USD per year

* Based on fuel prices of HFO($630/ton), MGO($930/ton) and LNG($8 ~ $12/MMBTU)




Thank you for your attention
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