

Design of LNG Powered Ships



Joint PNW SNAME – CIMarE – SAE Meeting

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PRESENTATION OVERVIEW

- Company Background
- Market Forces for LNG Propulsion Consideration
- LNG Propulsion and Arrangement
- LNG Platform Supply Vessels & the Evolution of PSV's in North America
- LNG Ferry
- Conclusion

COMPANY BACKGROUND



Some STX LNG Projects



Gaz de France Energy
World's First Diesel Electric LNG Carrier
Dual Fuel
STX France SA
Delivered 2008



4 x Fjord 1
World's First LNG powered Ferries
Pure Gas / Diesel Electric
STX OSV Langsten
Delivered 2007



3 x LNG Fuelled Ferries for
Oslo Norway

STX France SA
Delivered 2009



2800 Passenger Cruise Ferry, Baltic Sea
Dual Fuel Diesel Electric
STX Finland Turku
Delivery 2013



MARINE LNG PROPULSION DRIVERS

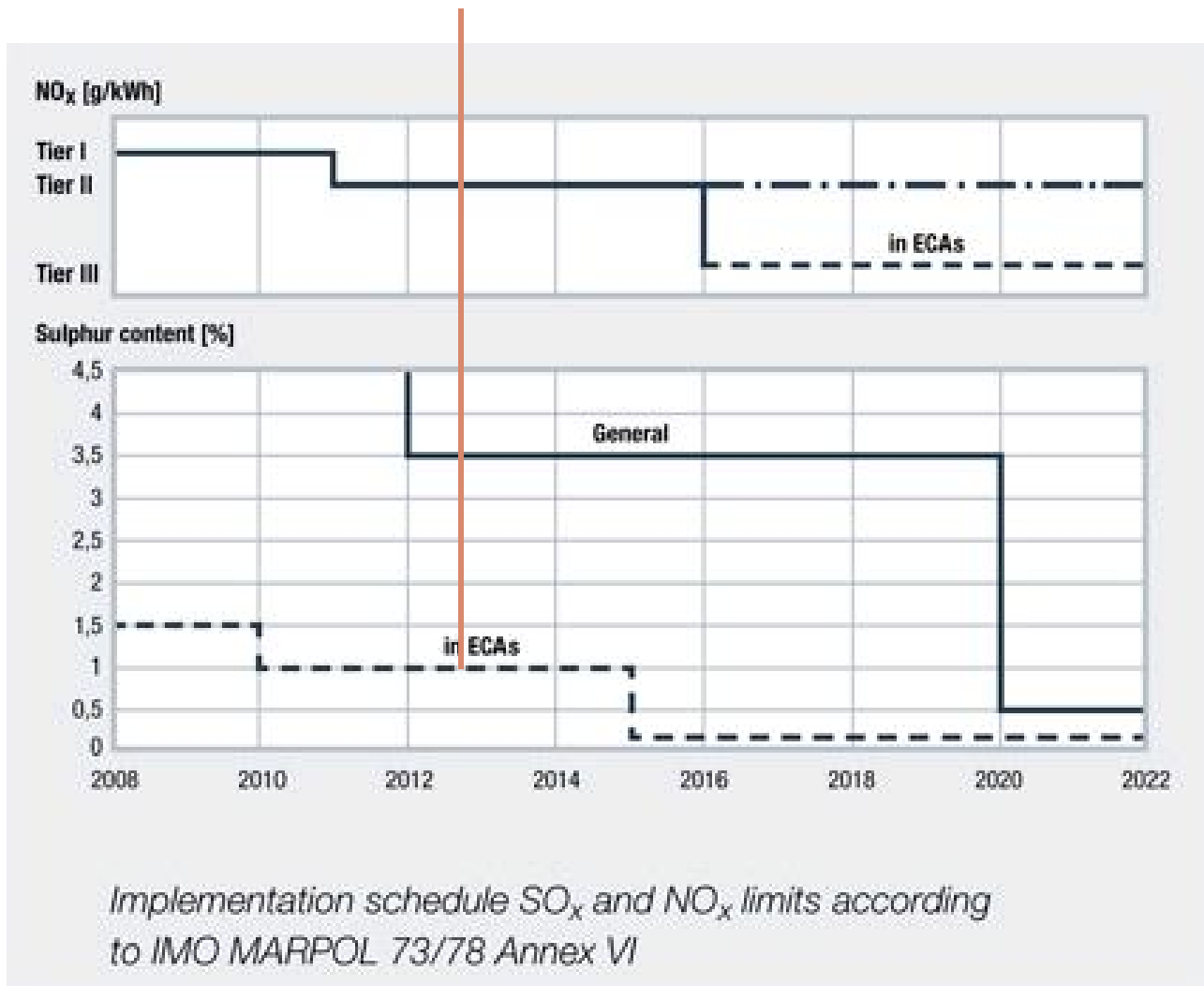
- Regulatory Drivers
- Economic Drivers
- Green Image/branding



MARINE LNG REGULATORY DRIVERS

- IMO and EPA have updated and implemented stringent controls on air pollution from ships
- Both organizations regulate sulfur oxide (SOx), nitrogen oxide (NOx), and particulate matter emissions from ship exhaust
- The emission standards will continue to become stricter in the future and increasingly difficult to meet using conventional fuels and engines
- Technological advancements will be necessary with potentially greater complexity

MARINE LNG REGULATORY DRIVERS - CONTINUED





MARINE LNG REGULATORY DRIVERS - CONTINUED

- The US Department of Interior (DOI) Bureau of Safety and Environmental Enforcement (BSEE) Offshore Exploration and Production Permits are hard to acquire but could be more favorable to operators with cleaner technology
- Certain areas in the Gulf of Mexico and along the West Coast of the US require EPA Air Quality Permits with stricter air quality emission limits
- In EPA outer continental shelf (OSC) zones pollution sources, including exploration rigs, must apply for EPA Air Quality Permits.



MARINE LNG REGULATORY DRIVERS - CONTINUED

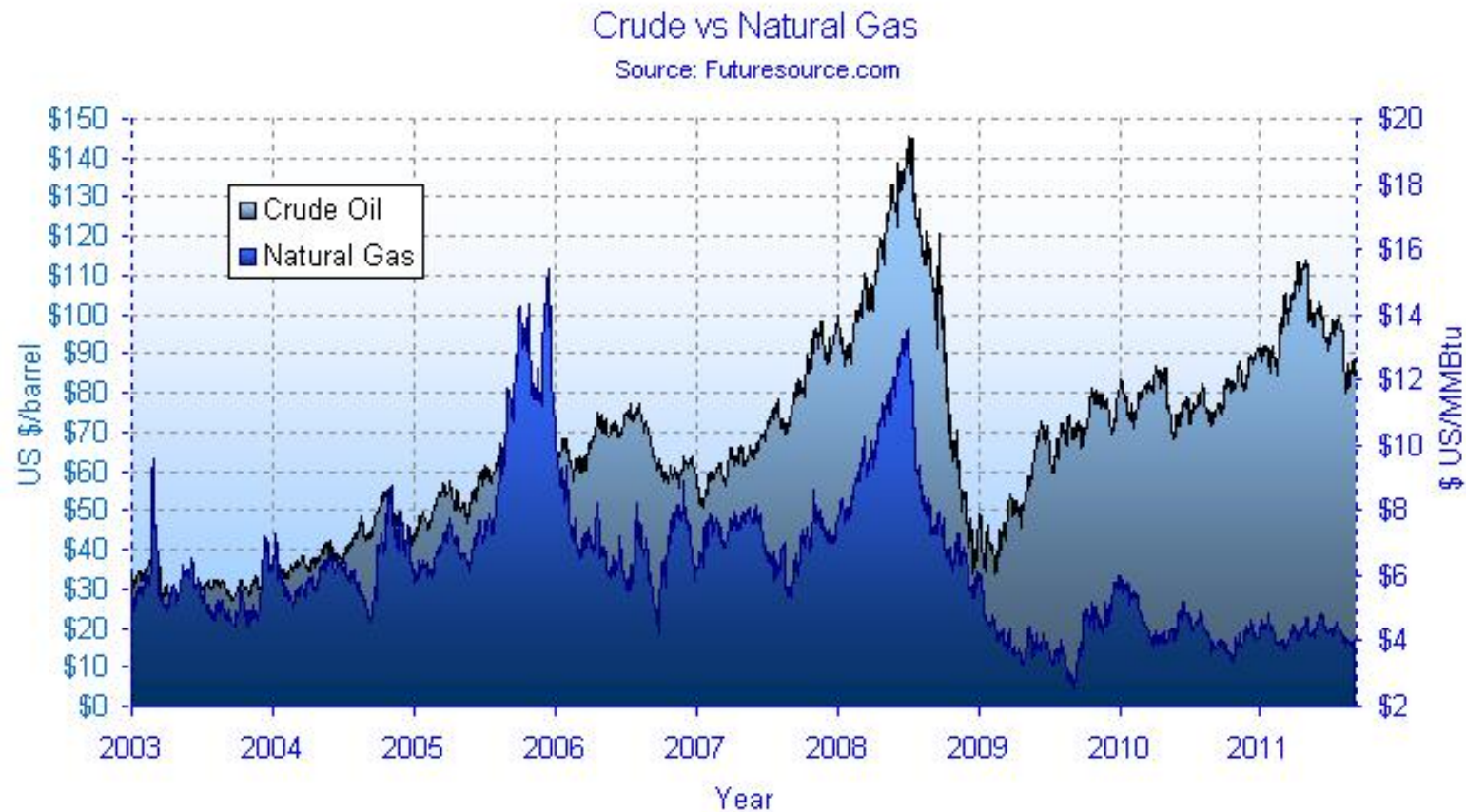
- Although SOx scrubbers and NOx SCR are available and have been proven effective, they take up valuable, hard to find space, require maintenance and carry additional risks
- Future regulations and controls (i.e.: EPA Tier III and Tier VI) could further drive the use of LNG as a fuel because of the SCR and scrubbing challenges
- Natural gas, with negligible sulphur content and considerably lower NOx emissions, readily meet the emission limits that exist today and the higher standards in the future



ECONOMIC DRIVERS

- Current Marine Fuels are in the range of:
 - \$930 to \$1,050 per ton for distillates (MGO, MDO)
 - \$610 to \$680 per ton for residual fuel oils (HFO)
- With upcoming sulfur controls, the distillate costs are expected to rise considerably and residual fuels are forecasted to fall short of future sulfur limits
- Presently, the global marine demand is approximately 0.2 Mt/day for distillate fuel and 0.8Mt/day of residual. If the need for residual fuel is replaced with distillate, there will be a major world impact

ECONOMIC DRIVERS - CONTINUED



Images courtesy of Athena Energy
<http://www.athena-energy.com/en/other-factors.php>

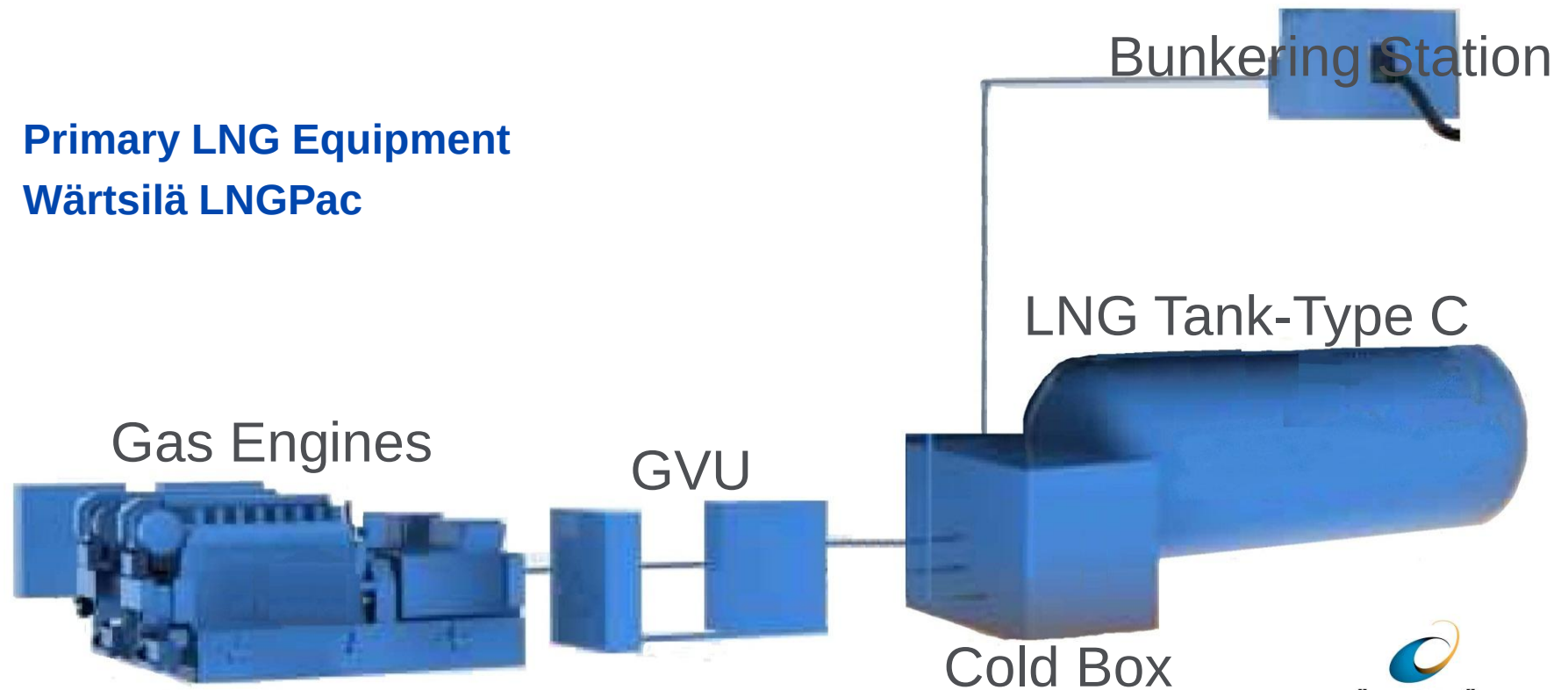
stx Canada Marine

ECONOMIC DRIVERS - CONTINUED

- LNG is comparably cheaper
 - In Europe the cost at the ship is \$450/tonne
 - In North America the current cost is much less
 - LNG Cost to North American ship operator:
 - Henry hub cost
 - + \$2 per million BTU for liquefaction
 - + \$7 to \$25 per million BTU for transportation
- Approximate LNG costs = \$210 USD/ton

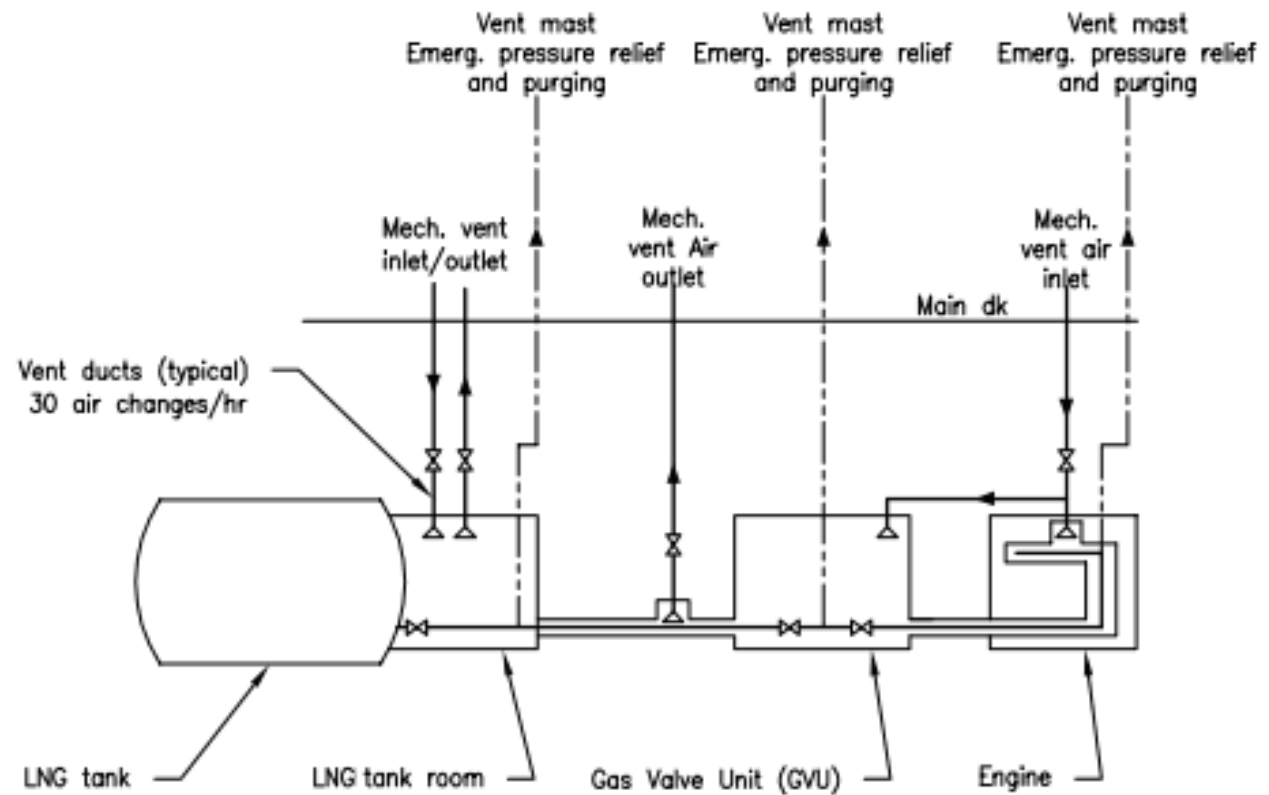
LNG PROPULSION EQUIPMENT

Primary LNG Equipment
Wärtsilä LNGPac



LNG PROPULSION EQUIPMENT

- Ventilation
- Venting
- Bunkering
- Nitrogen Purge



LNG PROPULSION EQUIPMENT

- Vacuum insulated
- Double skinned Type-C tank
- Stainless steel inner tank
- Integral cold box / tank room
 - Contains master gas valve
 - Vaporizer (heat exchanger)



LNG PROPULSION EQUIPMENT

Ventilation system requirements

- Redundant supply fans with isolation
- Circulation fans in the engine rooms
- Suction fans in the GVU spaces
- Strict gas safe distance requirements

Exhaust system requirements

- Explosion relief valves on the exhaust piping
- Exhaust gas ventilation system (fans to blow exhaust clear before startup and after low power/idle period)

Nitrogen purge system

- Inert gas purge
 - Following bunkering
 - For tank inspection and maintenance

DESIGN CONSIDERATIONS

- LNG is a lower density (460 kg/cu.m.) than other Liquid Fuels and therefore requires more space for fuel storage.
- Storage tanks and gasification equipment add cost to the propulsion plant.
- Dual Fuel engines must change to diesel fuel during extended operation at low load
- Single fuel engines either need redundant gas system or carry diesel generators.
- Source of supply for LNG
 - Tanker trucks
 - Shore side Liquefaction Facility
- Single source supplier for LNG propulsion system
- Crew training

VESSEL DESCRIPTION - PSV

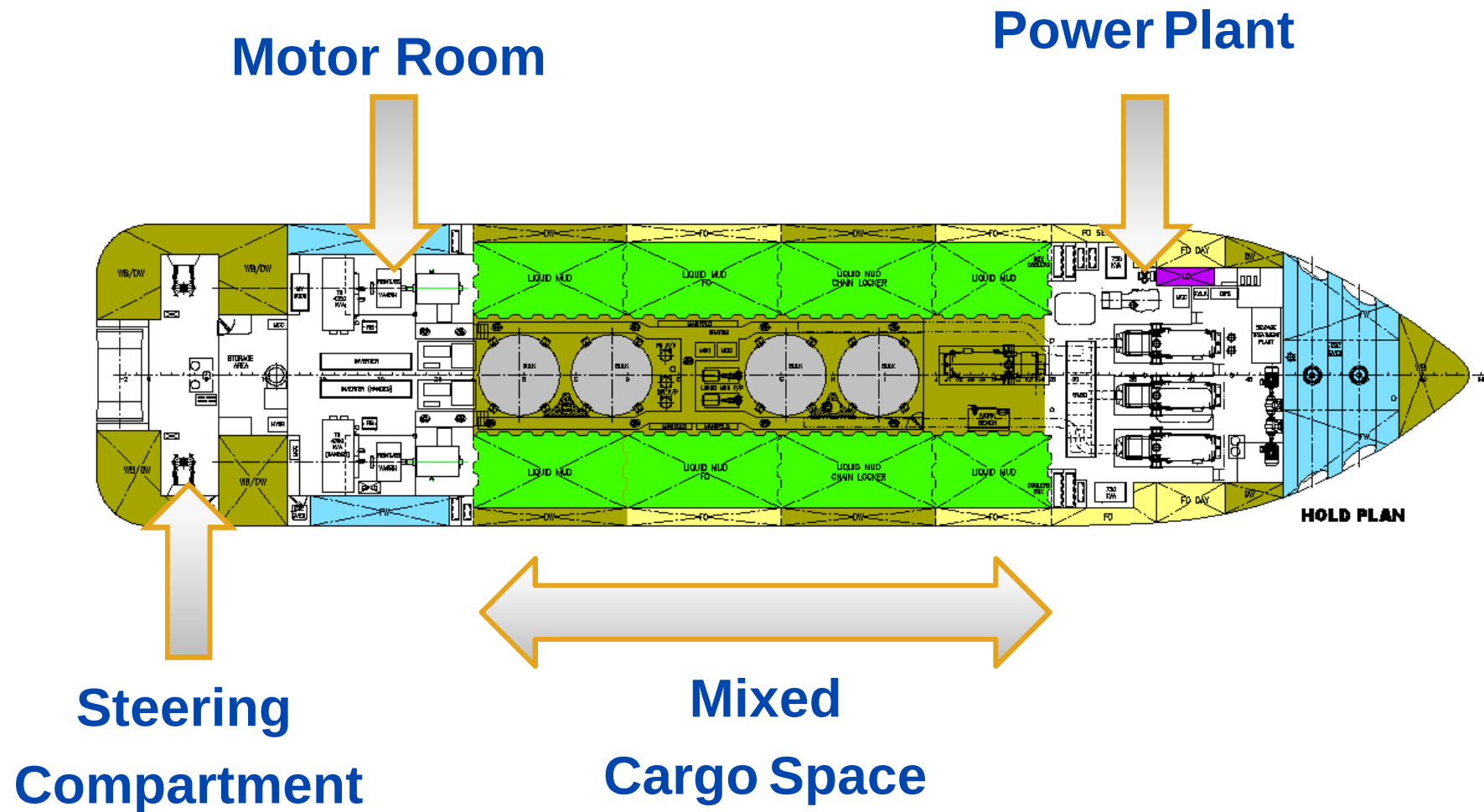
- The Platform Supply Vessel (PSV) is used to transport deck cargo, various bulk cargoes and fluids (liquid mud, dry bulk mud, fuel, methanol, etc.) to and from offshore oil rigs
- Cargo is offloaded with the vessel either backing in or alongside the rig in order to be dynamically positioned (DP) while cranes on the rig offload the cargo
- Dynamic positioning is critical in keeping the PSV close to the rig while avoiding collision. Minimum DP-2 Class notation for redundancy key to ensure safety in close proximity to rigs



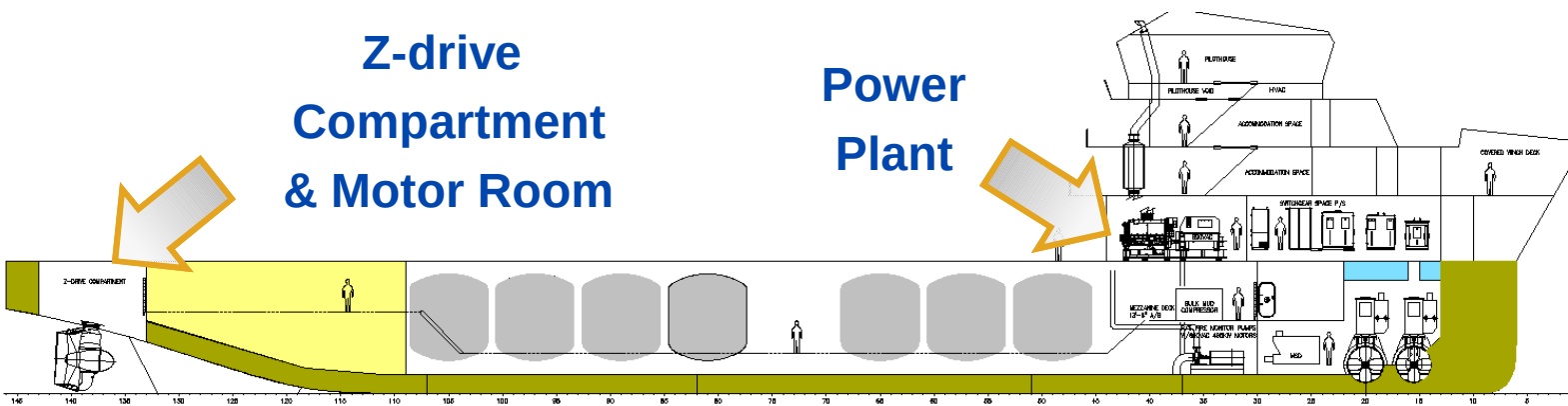
VESSEL DESCRIPTION - CONTINUED

- PSVs are double hulled to comply and exceed MARPOL 12A Oil Fuel Tank Protection and Clean Design Notation.
- Traditional PSVs accommodate engines, electrical equipment, and cargo (including fuel) in the hull
- The addition of the double hull requires an increase in volumetric efficiency to carry the same amount of cargo, otherwise an increase in a principal dimension is needed
- An increase in volumetric efficiency of 11% - 17% can be achieved by removing propulsion equipment from hull and placing it above the Main deck

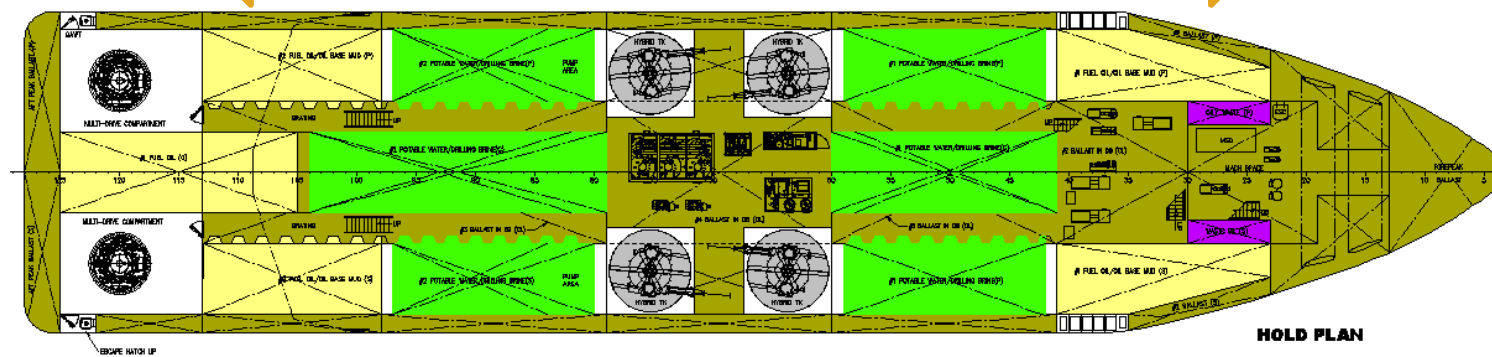
TRADITIONAL PSV



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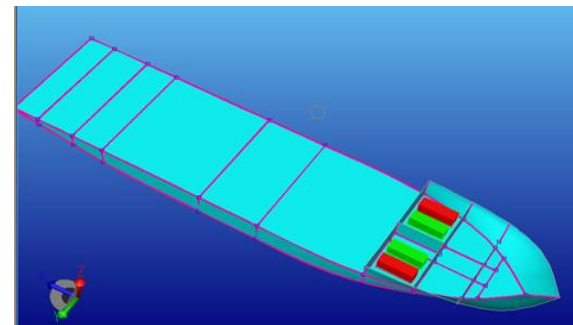
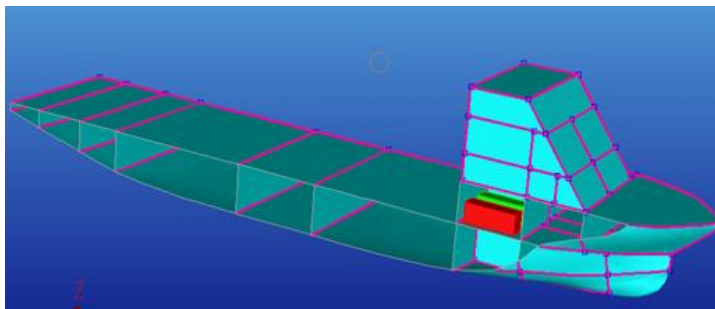


Extended Cargo Space



EVOLVED PSV- KEY FEATURES

- Key feature of the design is the diesel electric power plant on the main deck: freeing up space inside the hull for cargo volume and an LNG tank
- Main electrical rooms are located forward of engine rooms, segregated port and starboard to emphasize the redundancy requirements of DP-2 notation
- Ambient noise and structural borne noise are controlled to accommodation spaces above



EVOLVED PSV – STX SV310 - LNG



- Harvey Gulf International Marine
- STX Marine
- Wärtsilä



ECONOMIC CASE STUDY

- Two PSVs are compared with same dimensions, propulsion type and equipment
- They only differ through the propulsion engines: supporting either diesel or natural gas/diesel dual fuel
 - Diesel version uses four high speed generator sets at 1,900kW each
 - Dual fuel version uses three medium speed engines at 2,510 kW each
- A simple day trip operating profile was used for comparison

ECONOMIC CASE STUDY - CONTINUED

Costs

		Diesel Propulsion Plant	Dual Fuel Propulsion Plant
Annual Diesel Fuel Consumption (Tons)	Transit to rig	1425	27.3
	Loitering/ Offloading	1566	22
	Transit to Port	1425	27.3
Annual LNG fuel consumption (tons)	Transit to rig	-	1085
	Loitering/ offloading	-	1171
	Transit to Port	-	1085
40 trips/year	First Year Fuel Costs	\$4,241,000 USD	\$776,000 USD
	Capital Costs	\$1,920,000 USD	\$5,585,000 USD
	First Year Costs	\$6,165,000 USD	\$6,361,000 USD

○ Cost for Diesel: \$960.35/ton

○ Cost for LNG: \$210.37/ton

LNG Ro-Ro FERRY FOR STQ

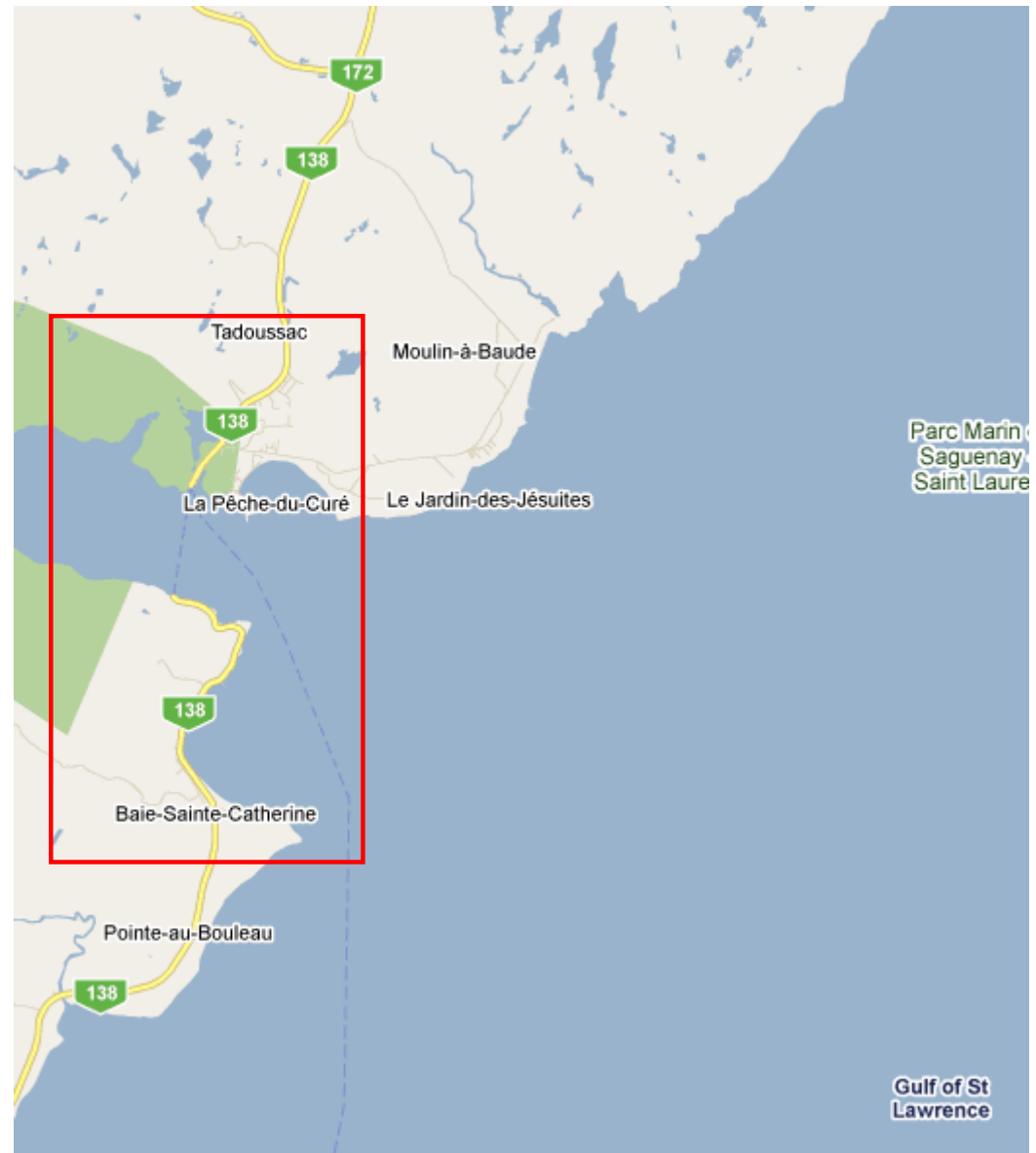


LNG Double Ended Ferry for STQ

Tadoussac

Baie St. Catherine

- Confluence of the St. Lawrence and Saguenay Rivers.
- Ferry route borders a national marine conservation area to protect a beluga breeding ground.
- Tadoussac village is the oldest surviving French settlement in the Americas.



LNG Double Ended Ferry New Design Requirements

- To be as reliable as the 1980's ferries (almost 99% ferry service, year-round)
- To be more fuel efficient while meeting or exceeding emission regulations
- Hull to be ice class 1A and the propulsion system to be ice class 1AS to ensure maximum survivability
- Reduce radiated noise (airborne and water borne)
- Increased Maneuverability

LNG Double Ended Ferry

Principle Characteristics

- Overall length: 92m
 - LWL: 86.9m
- Overall breadth: 26.4
- Moulded depth: 7m
- Draft: 4.5m
- Displacement: 3500 tonnes
- 8 crew
- 432 passengers
- 115 AEQ
- 800 tonnes payload
- Transport Canada - Near coastal voyage, Sheltered waters

LNG Double Ended Ferry

High Speed Diesel Engines

- Twin, double ended propellers
- Twin, double ended z-drives (shafted with cardan shafts)
- Twin, Voith Schneider units (shafted with cardan shafts)

Medium Speed Diesel Engines

- Twin, double ended propellers
- Twin, double ended z-drive (shafted with cardan shafts)

High Speed Diesel Electric

- Twin, double ended propeller
- Quadruple, double ended z-drives
- Twin, double ended z-drives

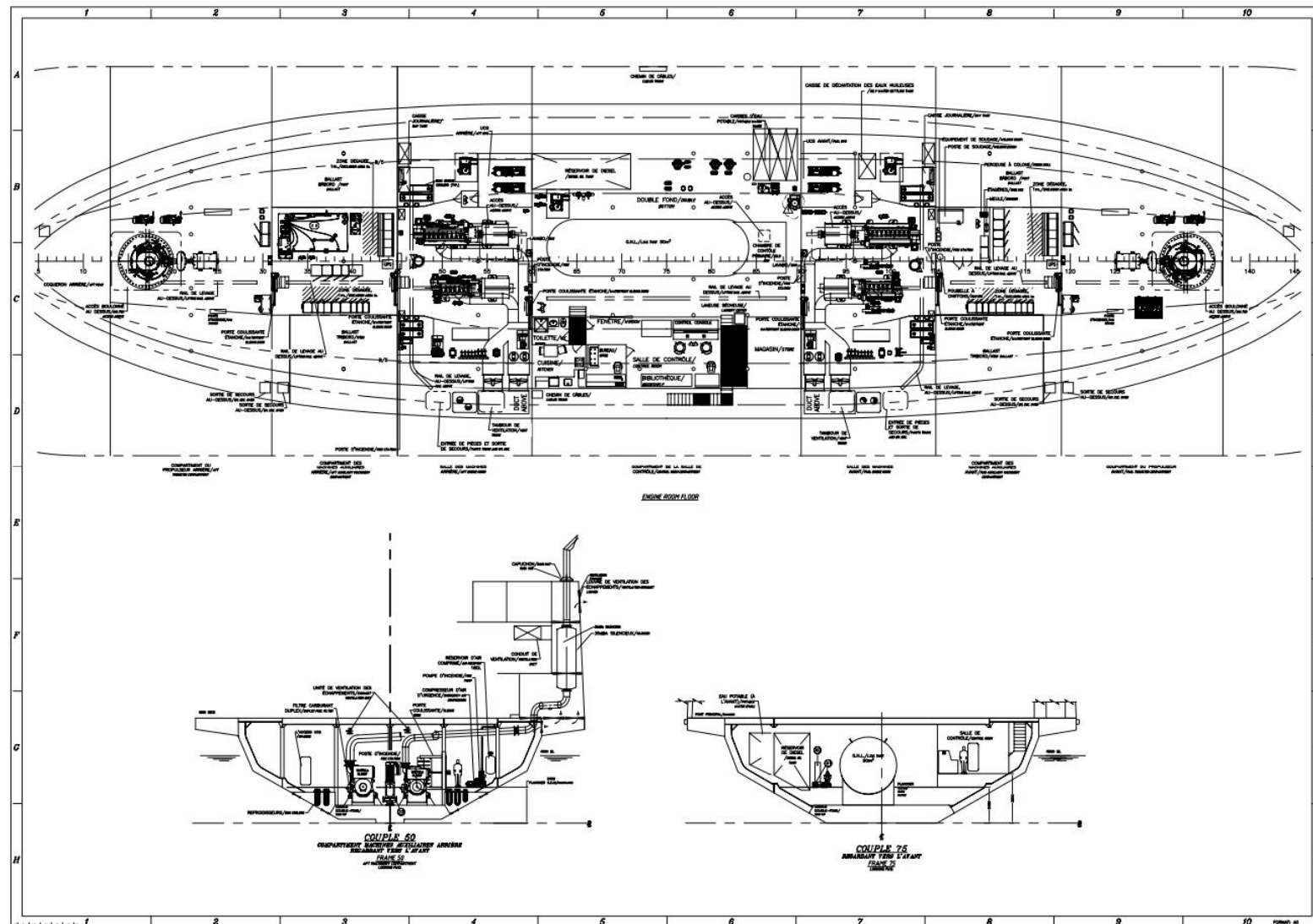
Medium Speed Diesel Electric

- Twin, double ended propeller
- Quadruple, double ended z-drives
- Twin, double ended z-drives

Medium Speed Dual Fuel Electric

- Twin, double ended propeller
- Twin, double ended z-drives

LNG Double Ended Ferry





CONCLUSIONS

- Conventional diesel engines will struggle to meet upcoming IMO/EPA regulations without after treatments
- Costs of low sulfur and ultra-low sulfur distillate fuel is expected to increase as residual fuel is phased out and demand may outstrip availability
- Natural gas as a fuel meets or exceeds all emission regulations and is considerably cheaper in North America
- Although challenging to fit LNG propulsion into a ship, economic and regulatory drivers are persuasive enough to overcome the challenges.



Thank you for your attention.