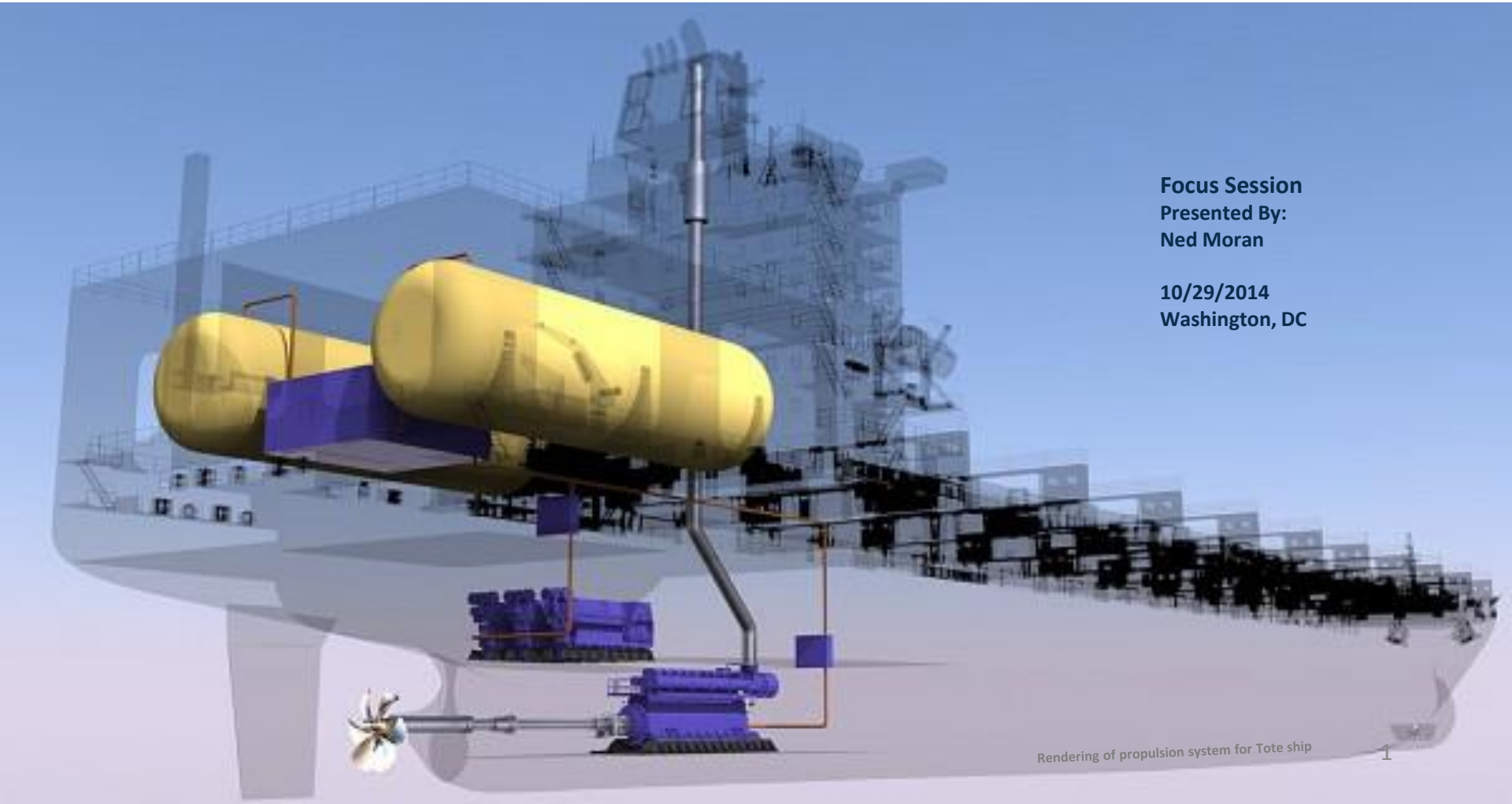
Marine Board of The National Academies
LNG as a Marine Fuel



Focus Session
Presented By:
Ned Moran

10/29/2014
Washington, DC

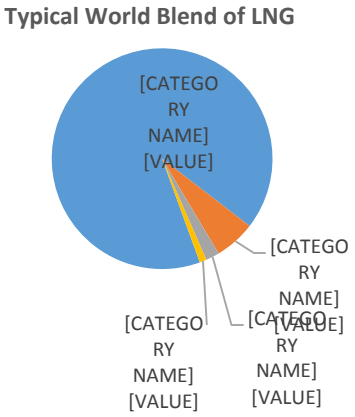
Rendering of propulsion system for Tote ship

AGENDA

- BASICS OF LNG
- HISTORY OF LNG IN THE MARINE ENVIRONMENT
- DRIVERS FOR LNG AS A MARINE FUEL – WHY NOW?
- FIRST MOVERS
- OTHER USERS OF LNG AS A FUEL

What is LNG?

- Liquefied Natural Gas (LNG), is natural gas that has been cooled to - 260° Fahrenheit where it becomes a liquid.
- Converting natural gas to LNG reduces its volume by 600 times and allows it to be transported efficiently and economically.
- LNG is warmed back into its original gaseous state so that it can be used just like existing natural gas supplies.
- The energy density of LNG is approximately 2.4 times greater than Compressed Natural Gas (CNG) but is only 60% that of diesel and 70% that of gasoline.



	LNG	CNG	Diesel
Btu Per Gallon	82,644	34,435	139,00
Gallons Per MMBTU	12.10	29.04	7.19
Relative Energy Density	1.00	.42	1.68
Ignition Temperature (F)	1,004	1,163	437
Leaks and Spills	Vaporizes to Atmosphere	Disperses to Atmosphere	Puddles on ground
Boiling Point	-260	N/A	370+
Cost per Henry Hub MMBTU Equivalent	$4.00	$4.00	$28.76 @ $4.00 per gallon

LNG Marine History – Cargo & Fuel

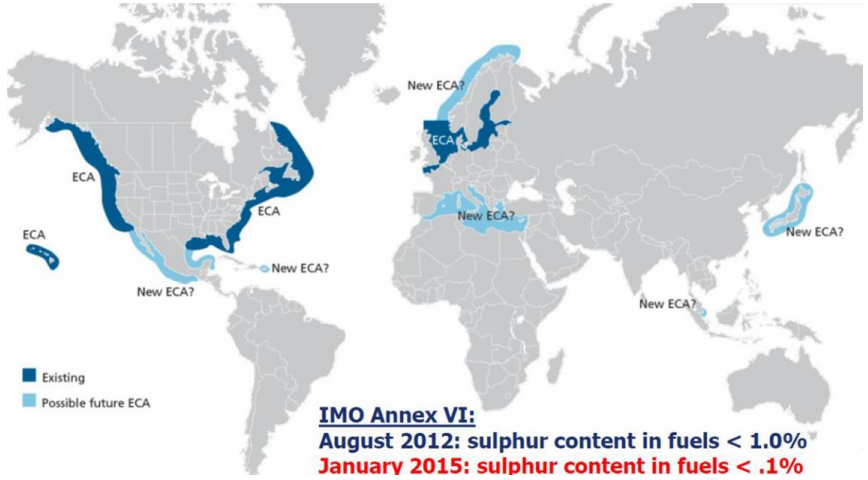
- Safely shipped for over 50 Years
- Safely consumed in ship's engines for 40 years
- LNG is transported by specialized carriers with insulated walls that are specifically designed to handle the low temperature of LNG
- Ships have traveled more than 151 million miles without a major incident and delivered over 250,000 cargoes
- Outstanding safety record can be attributed to continuous improvement in technology and safety equipment, as well as to comprehensive safety regulations and effective government oversight.

Characteristics of the Methane Pioneer

- First LNG Carrier in the World
- LNG transportation between Louisiana in the United States to the Islands of Canvey in Great Britain

Drivers for LNG as a Marine Fuel

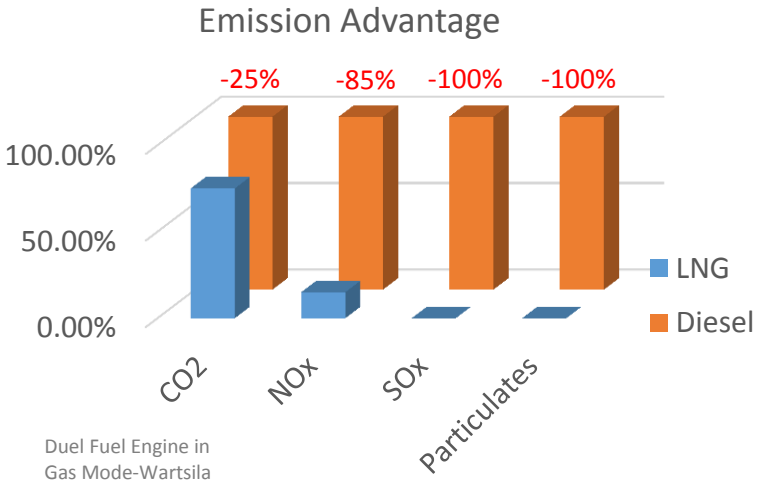
- Price & Availability
- Emissions Control Areas (ECA)
  - Three choices to comply
    - Scrubbers
    - Ultra Low
    - LNG



IMO Annex VI:
August 2012: sulphur content in fuels < 1.0%
January 2015: sulphur content in fuels < .1%

MARPOL Annex VI
SOx reduction requirements

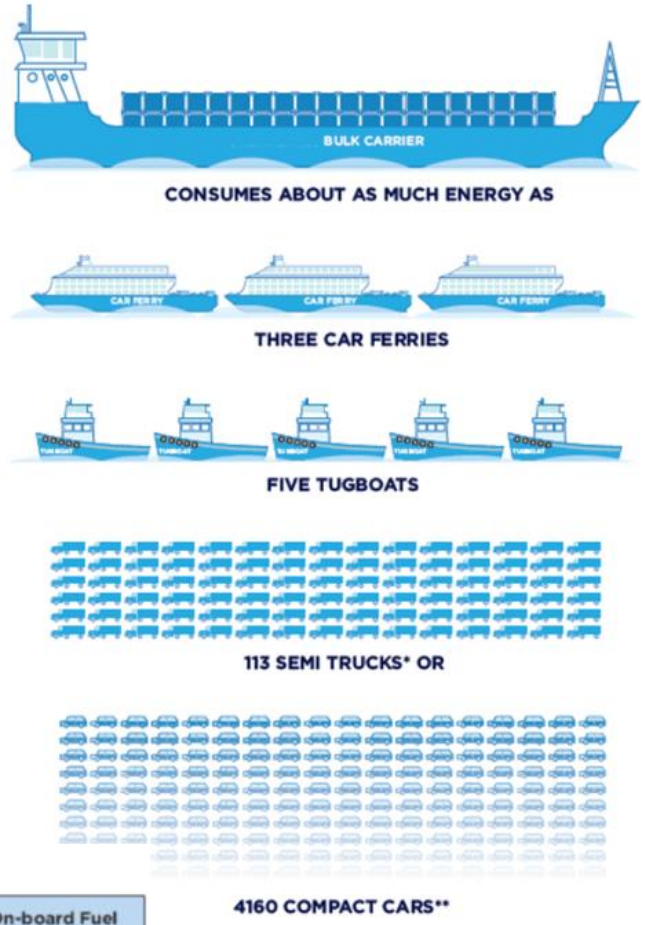
	Low sulphur fuel oil MDO / MGO	Scrubber + high sulphur fuel	LNG
Options			
Issues	Low sulphur fuel availability; Price relative to alternatives	Installation cost, waste disposal, high sulphur fuel cost	LNG equipment costs, conversion time and cost; LNG, LNG bunker facility availability and cost
Pros & cons	+ No extra fuel tanks or handling needed - Higher fuel costs - Scrubbers needed to meet Tier III NOx - Low sulphur fuel availability and cost - Ships required to use low sulphur fuel, but refiners not required to produce / supply	+ Scrubbers available + HFO and bunkering facilities available + Fuel price - Capital investment and off hire time for conversion - How many scrubbers will be required / available in 2020? - Waste disposal facility availability and cost	+ Meets SOx, particulate and NOx Tier III requirements - More shipboard storage capacity required - Capital investment in LNG equipment - LNG and fuelling facility availability outside limited areas - Price – what is the basis?



Duel Fuel Engine in Gas Mode-Wartsila

Status of LNG as a Marine Fuel in the U.S.

- What's holding back wide-spread use?
  - “Chicken & Egg” Dilemma
  - More Storage Space Required/Less Cargo
  - Supply & Reliable Infrastructure
  - Customer Demand
  - Construction & Conversion Costs
  - Price Margin & Payback
  - Rules & Regulations
    - Vessels
    - Personnel
    - Operations



Fuel Usage and Fuel Storage Volumes for Typical Marine Vessels

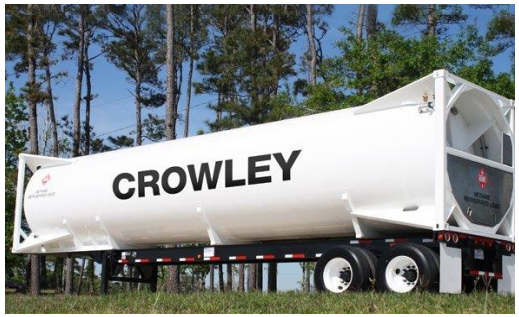
Vessel	Fuel Type	HP	Daily Fuel Use	Typical Minimum On-board Fuel Storage		Volume of On-board Fuel Storage		
						Dist. or Residual	LNG	CNG
			[gal]	[days]	[gal]	[ft3]	[ft3]	[ft3]
Towing Tug	Distillate	3,000	1,417	14	20,000	2,674	4,830	12,178
100-car Ferry	Distillate	6,000	2,268	7	16,000	2,139	3,864	9,742
Great Lakes Ore Carrier	Residual	10,000	6,934	21	145,000	19,385	38,183	96,264

Current & Potential Marine Users

- U.S. second behind Europe
- Ports now adopting LNG
  - Antwerp
  - Baltics
  - Hamburg
  - Rotterdam
- Potential U.S. Vessels
  - Container Ships
  - Tugs & Barges (Coastal & Inland)
  - Passenger Ferries
  - Supply Vessels

Other Users of LNG

- Trucks & Buses
- Trains
- Utilities
- Industrial
- Remote locations with limited energy infrastructure



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