Chinese...........Channel 1
Japanese.........Channel 2
Korean............Channel 4
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The Emergence of LNG Fuel in the Maritime Industry

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Choosing a Marine Fuel

OWNER

- **Fuel Suitability – Support operational** mission?
- **Range** – Fuel space and weight considerations
- **Infrastructure** – Is fuel widely available?
- **Safety** – Any significant new safety issues?
- **Capital Cost – Can higher Capex be recovered?**
- **Fuel Cost – Will Opex savings support ROI?**
- **Globally Available fuel?**

SOCIETY

- **Criteria Pollutants** – Clean? IMO Tier3/EPA Tier 4?
- **EPACT (US)** – Energy security
- **LCFS/RFS** – Low Carbon Intensity? Renewable?
- **Energy Efficiency** – Improved Fuel Economy?

Why LNG & WHY NOW?

Operability Drivers

- Compressed natural gas (CNG) not practical

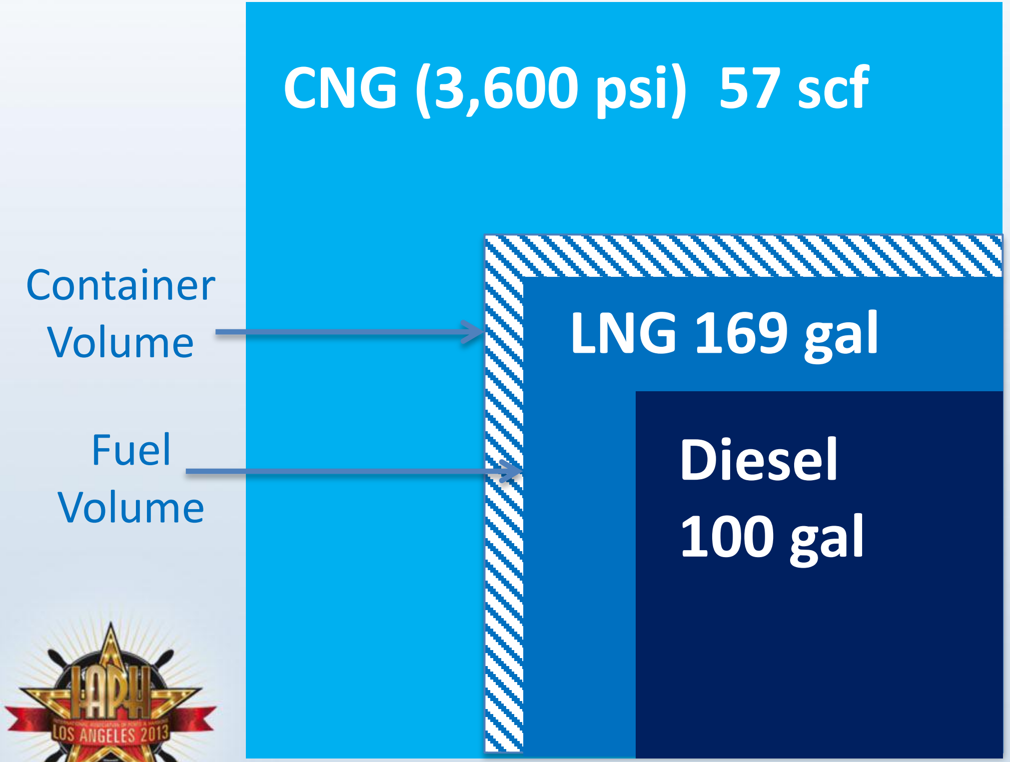
EPA Regulatory Drivers

- Tier 4 emissions from 2015 onward (new builds now)
- EPA/IMO fuel sulfur limits

Cost Drivers

- Fuel up to 50% of annual budget for marine operators
- LNG can be half the price of diesel per unit of energy

LNG vs CNG



Compressed NG (CNG)

- High pressure gas
- 23% volumetric energy density of diesel fuel
- Sold as SCF or therm (100,000 btu)

Liquefied NG (LNG)

- Cryogenic liquid (-160˚C)
- 60% volumetric energy density of diesel fuel
- Sold as gallon (76,000 btu)

EPA Emissions Regulation

Clean Air Act

- Intended to improve ambient air quality
- Allows EPA to set emission standards for new engines

Ambient Air Quality Concerns

- OZONE – human health, climate, ecosystem effects
  - ✓NOx and VOC are ozone precursors
- PM - human health, climate (black carbon) effects
  - ✓Direct PM from fuel combustion
  - ✓Secondary PM from oxidized fuel sulfur

EPA Marine Engine & Fuel Standards

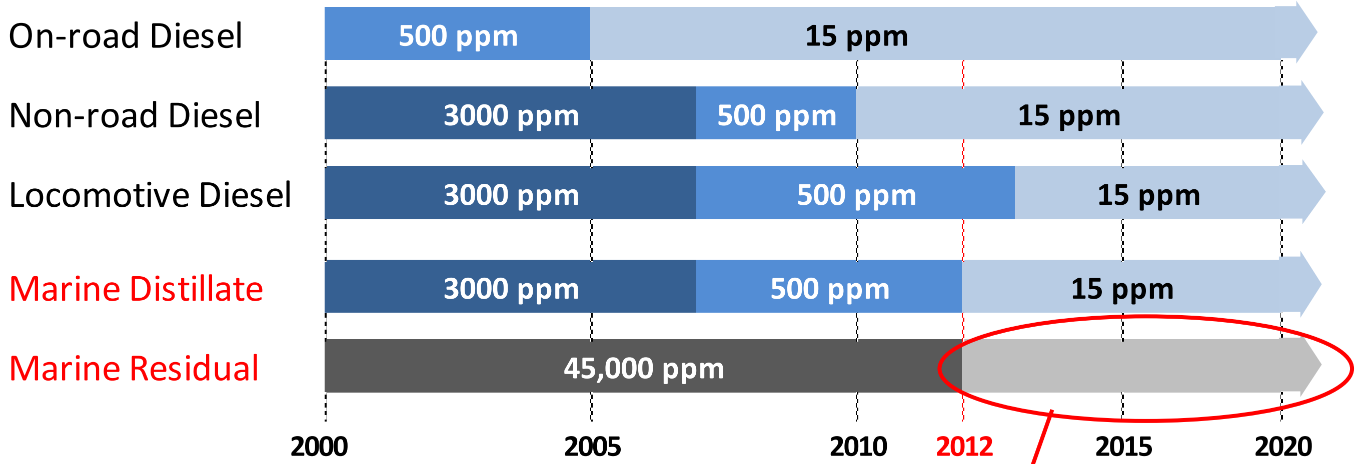
EPA Tier 4 / IMO Tier 3 for New Engines

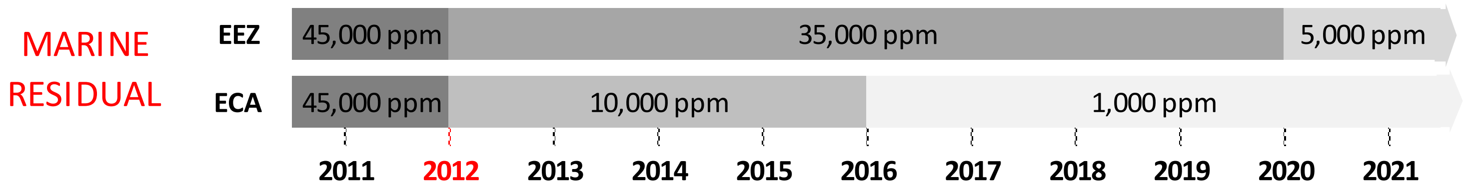
- After 2016 all new US vessels will require EPA Tier 4 engines, internationally flagged vessels will require IMO Tier 3
- EPA Tier 4 will require SCR and DOC, perhaps DPF
- LNG engines can meet Tier 4 with only Oxidation Catalyst

Fuel Sulfur Reductions

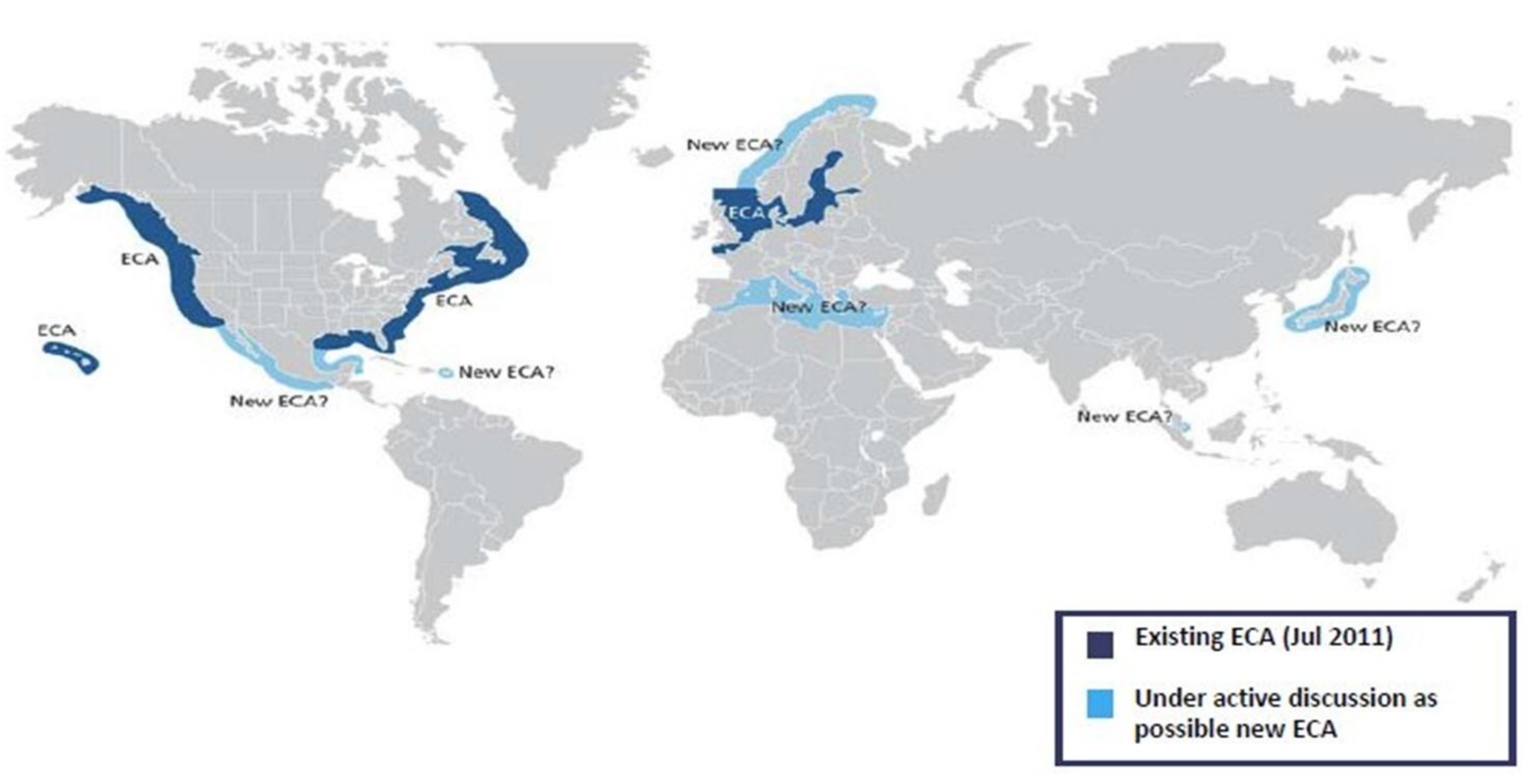
- Significant reductions in allowable fuel sulfur - in US waters and Emission Control Areas worldwide
- Will require switch to distillate or scrubbers with residual
- LNG has virtually no sulfur – meets most stringent standards

The War on Fuel Sulfur (and PM)

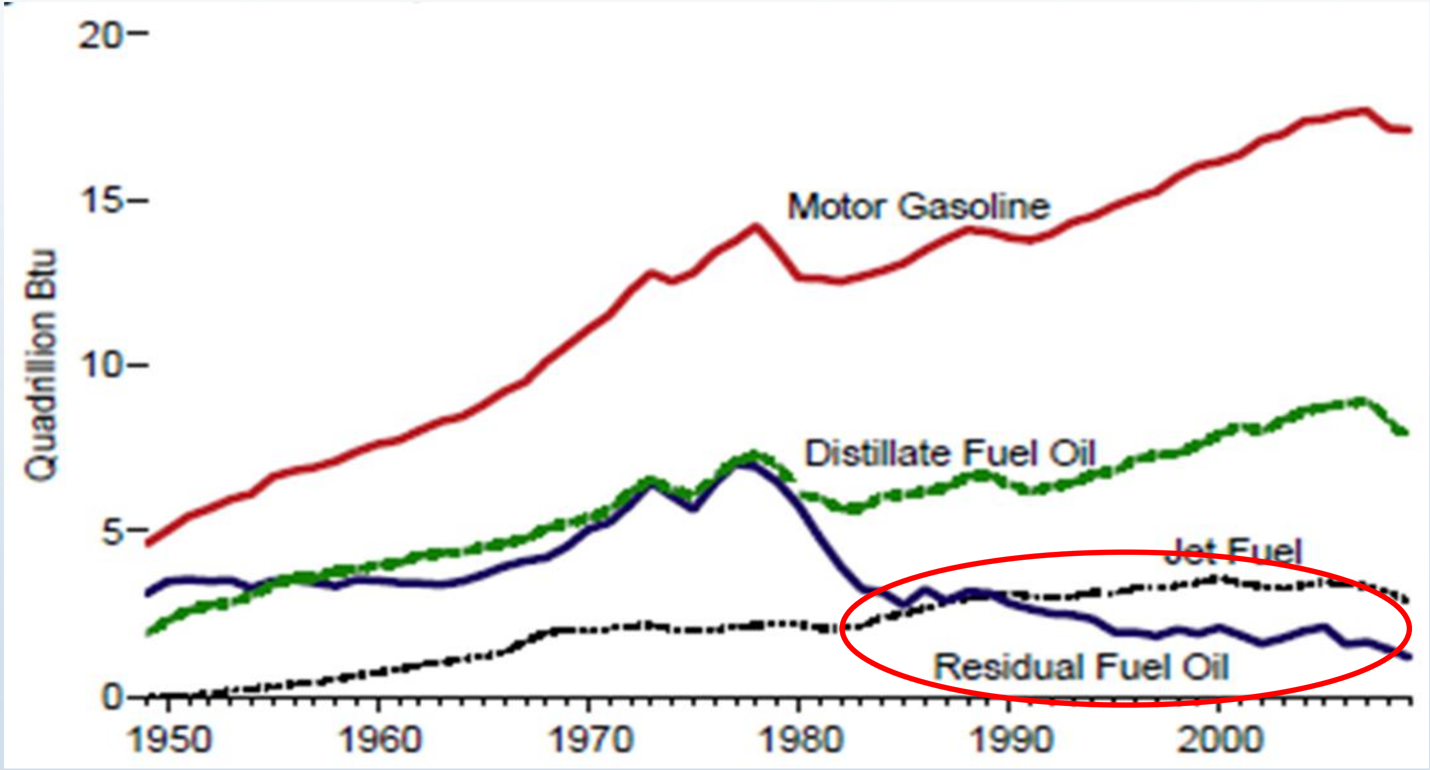




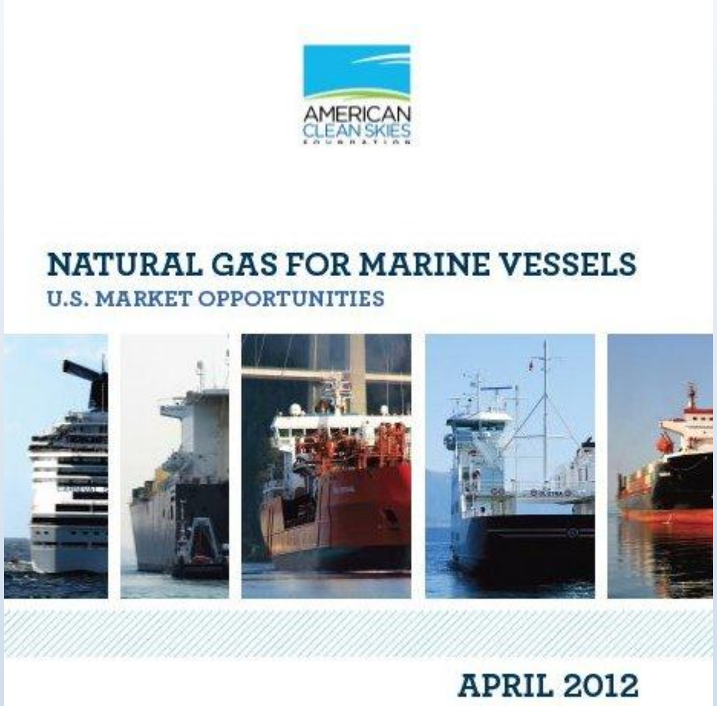
Emission Control Areas

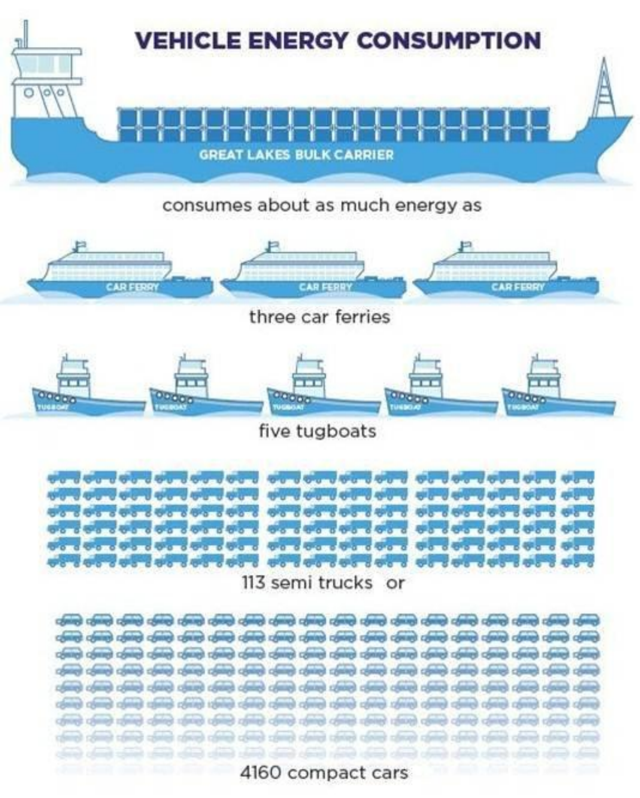


Marine is Last Major User of Resid in US



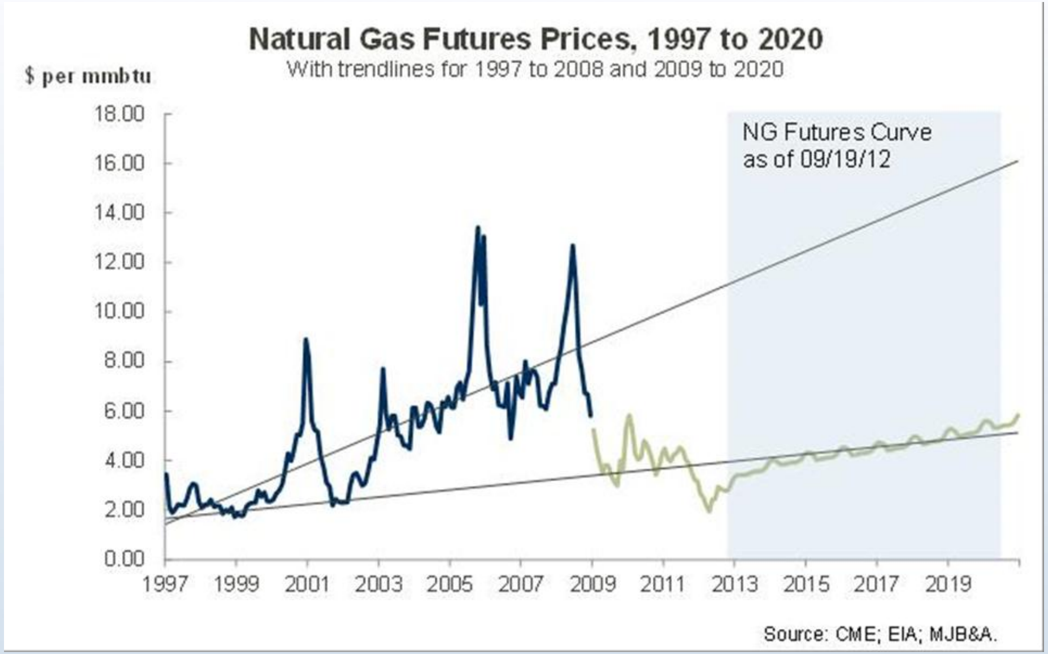
Fuel Consumption (and Cost) Matters





LNG Fuel Costs

- **US shale gas has dramatically reduced NG price volatility and shifted long-term commodity price trend**
- **LNG prices driven by commodity price plus potentially significant processing and transport costs**



MOST ANALYSTS PREDICT LONG-TERM LNG PRICE ~$1/DEG LESS THAN RESIDUAL, ~$2/DEG LESS THAN DISTILLATE

Marine LNG Obstacles

- **High CAPEX** for vessel conversion
- Lack of **Price Transparency** for LNG fuel
- Long take-off requirements for **LNG Contracts**
- Limited **LNG Fueling Infrastructure**

CONVERSION OF MARINE VESSELS TO LNG INVOLVES MAJOR UNCERTAINTY & RISK – "FIRST MOVER DISADVANTAGE"

LNG Conversion Cost and Pay-back

Order of Magnitude Costs to Convert Typical Marine Vessels to LNG Operation

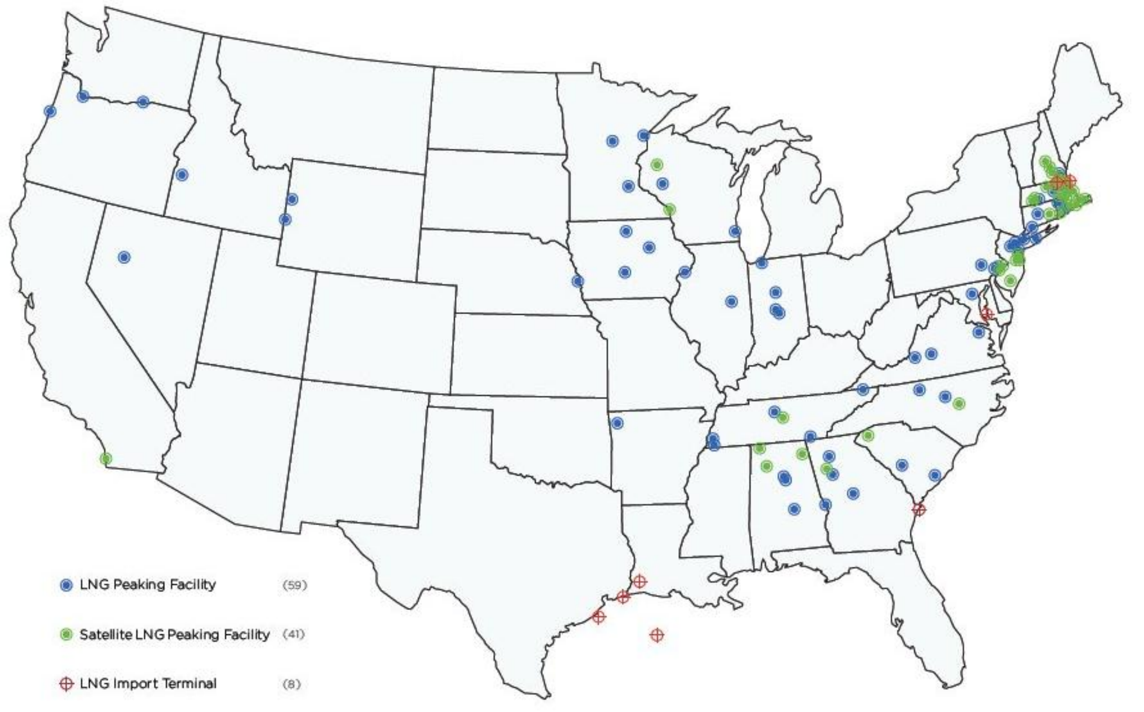
Type	Size (tons)	Engines	Engine Cost	Fuel System Cost	TOTAL CONVERSION COST
Tug	150	2 x 1500 HP	$1.2 million	$6.0 million	$7.2 million
Ferry	1000	2 x 3000 HP	$1.8 million	$9.0 million	$10.8 million
Great Lakes Bulk Carrier	19000	2 x 5000 HP	$4.0 million	$20 million	$24 million

Fuel Usage of Model Vessels

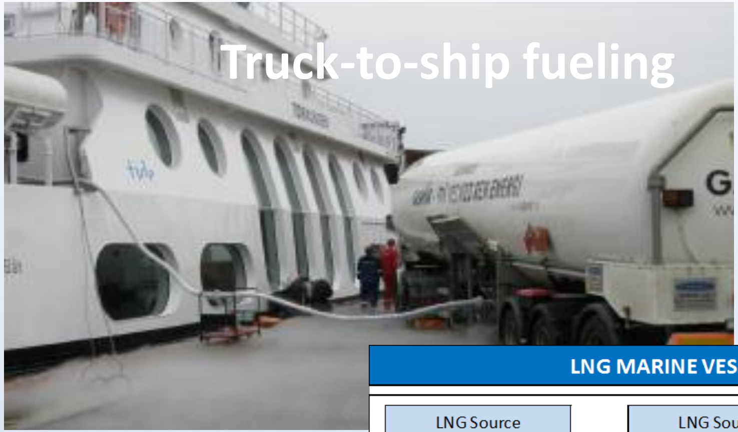
Type	Fuel	Annual Demand (gal)	Annual Equivalent LNG Demand (gal)	Annual Energy Demand (Therm)	Present Value 10-year Fuel Savings (7% Discount Rate)	Net Present Value of the Project
Tug	Distillate	424,000	768,221	583,848	$6.9 million	-$0.28 million
Ferry	Distillate	678,400	1,229,154	934,157	$11.1 million	$0.27 million
Great Lakes Bulk Carrier	Residual	2,080,064	4,097,179	3,113,856	$20.6 million	-$3.4 million

Where is the LNG?

- **Current US infrastructure is focused on getting NG into the pipeline grid**
  - ✓ **Import terminals**
  - ✓ **Small-scale production (peaking)**
  - ✓ **Satellite storage (peaking)**
- **Gulf Coast, NE Atlantic Coast, Mid-west**

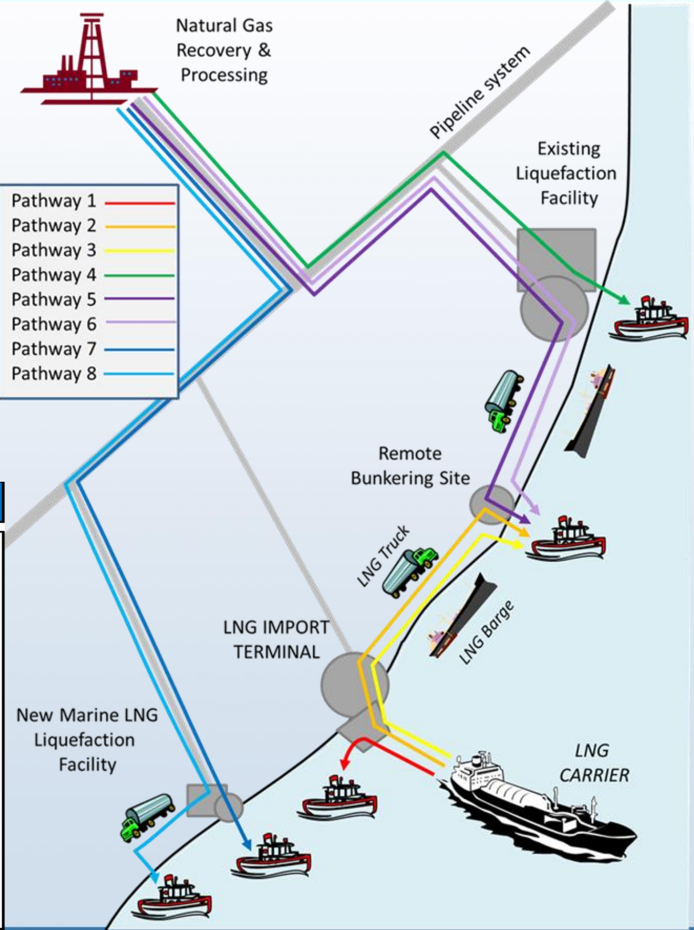


LNG Marine Bunkering



LNG MARINE VESSEL BUNKERING PATHWAYS

LNG Source	LNG Source	Bunkering Location & Method	
IMPORTED	Large Scale (centralized)	At import site	*Pathway 1*
		Distributed with storage	*Pathway 2*
		Distributed without storage	*Pathway 3*
US PRODUCED	Existing liquefaction or satellite storage facility	At production site	*Pathway 4*
		Distributed with storage	*Pathway 5*
		Distributed without storage	*Pathway 6*
	New marine LNG liquefaction facility	At production site	*Pathway 7*
		At remote site	*Pathway 8*



Summary Takeaways

- **Significant potential for greater use of LNG as a marine propulsion fuel in US and world-wide**
- **Interest is driven by opportunity for cost savings and environmental regulation**
- **LNG conversion entails significant uncertainties and financial risk – primarily due to lack of infrastructure and lack of LNG price transparency**
- **Speculative risk from potential for cheaper crude, development of GTL fuels (methanol?), Tier 5 emissions regulations (to include methane regulation)**