

CNG – Present Status and Future Challenges

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Natural Gas Transportation

CNG

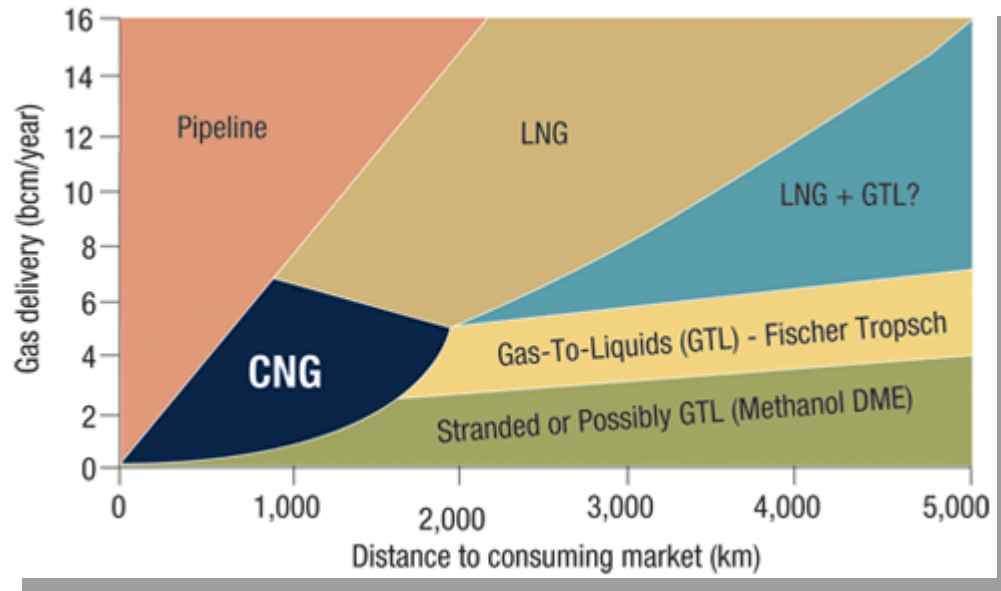
CNG Vessels

CNG Transport:
CAPEX
optimization

Case Studies

Conclusions

- Current
 - 70% via pipeline
 - 30% as LNG
- Economics



Globalization of Gas Trade

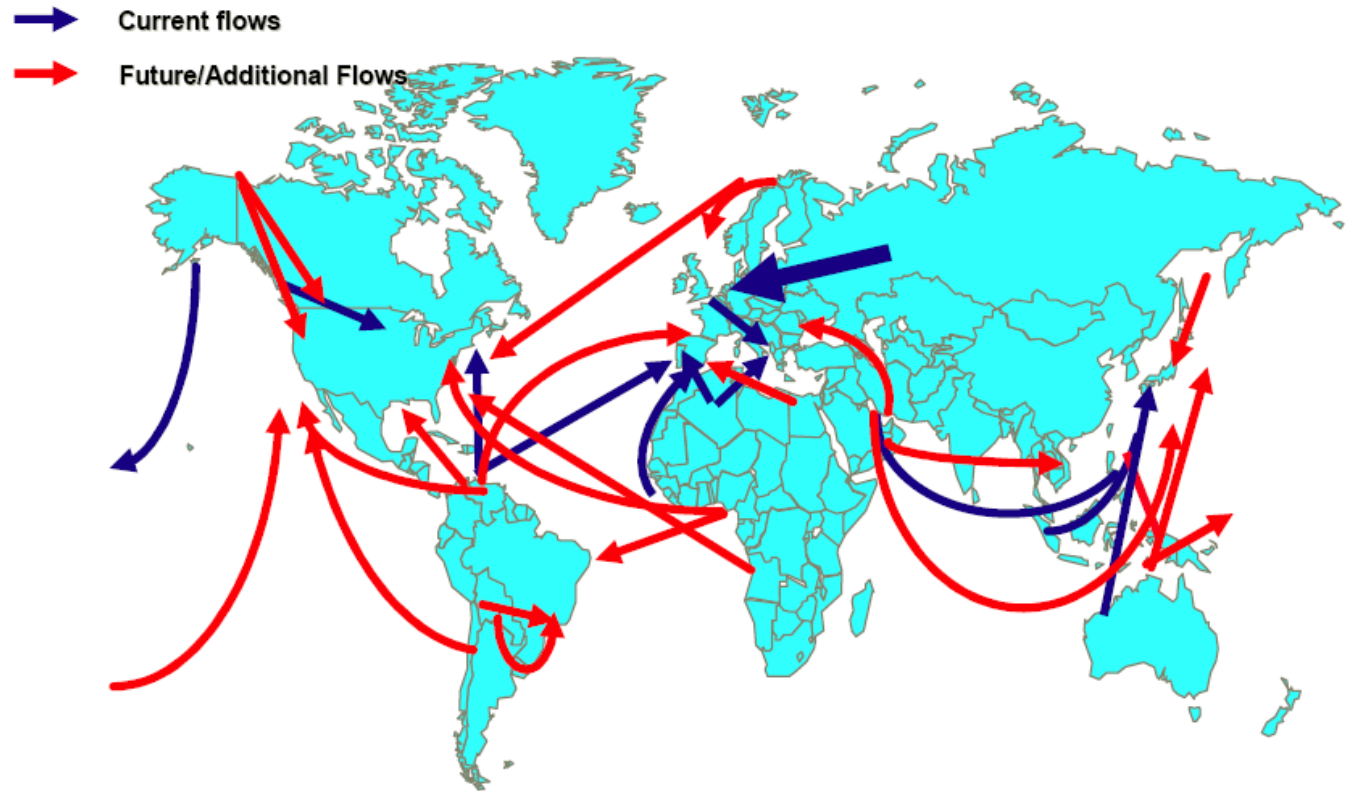
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Source: International Energy Agency

Potential CNG Markets

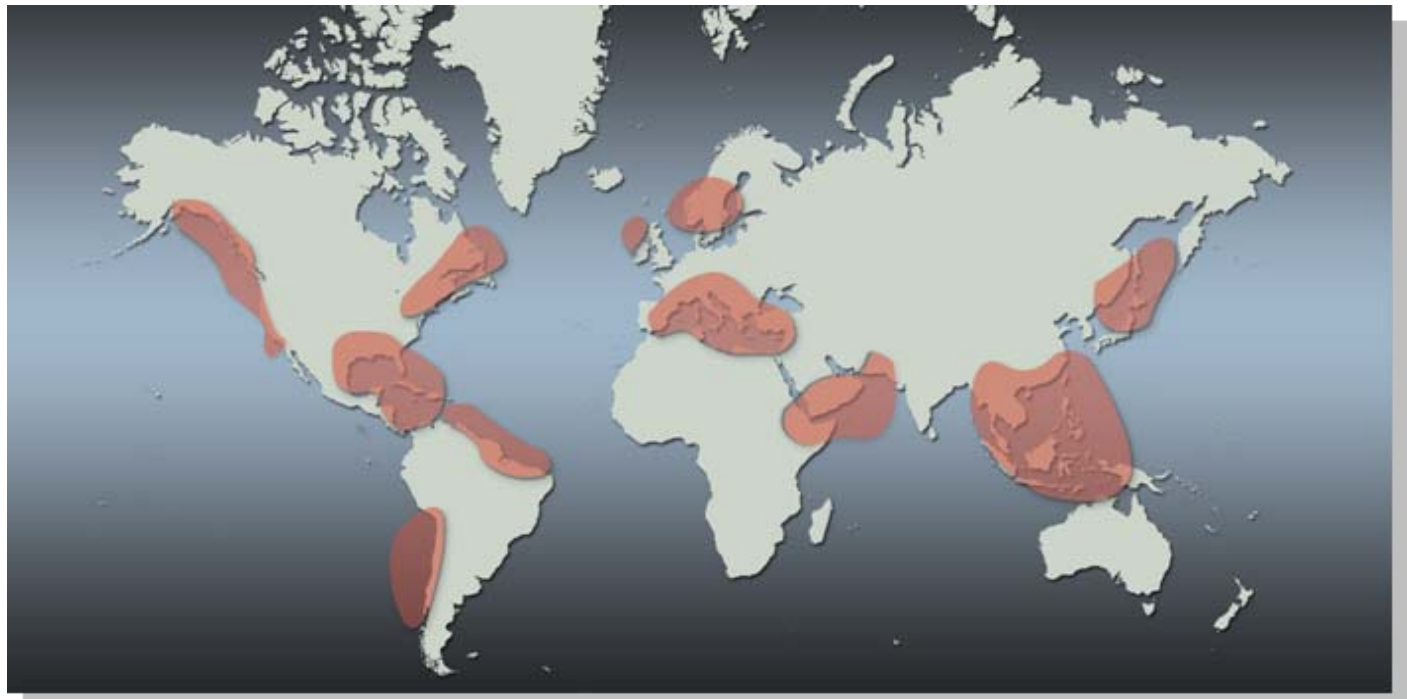
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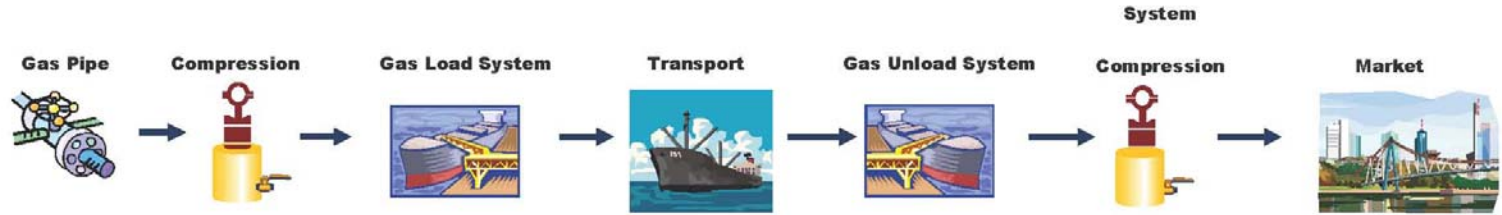
Conclusions



CNG vs. LNG Marine Transport

CNG

CNG



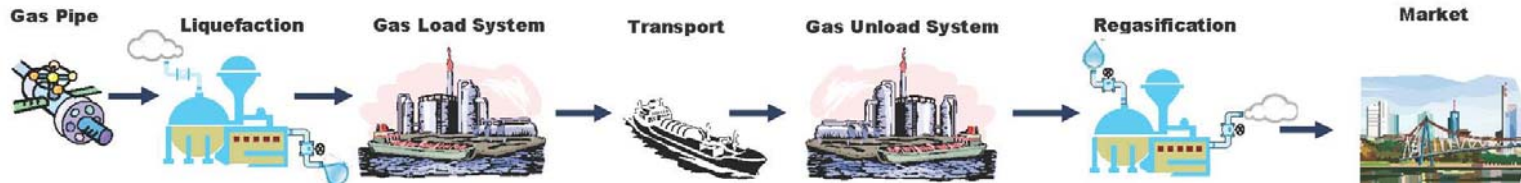
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LNG



Loading and Offloading Terminals for LNG and CNG

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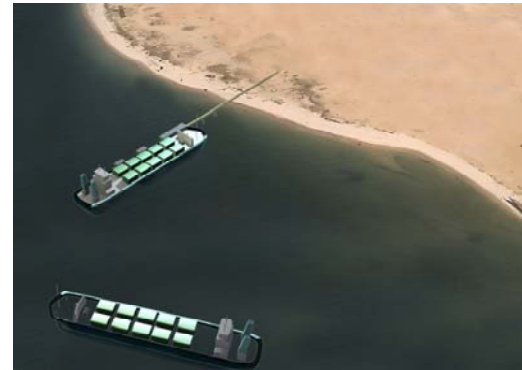
Case Studies

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LNG



CNG





At Source



At Destination

CNG vs. LNG

	CNG		LNG	
CNG				
CNG Vessels	Processing	Compressed gas <math><1:300</math> (Possibly chilled)	gas \rightarrow liquid \rightarrow gas (1:600)	
CNG Transport: CAPEX optimization	Loading	Dehydrate, compress	Treat, liquefy, store	
Case Studies	Terminals	Jetty or buoy	Jetty or regas offshore	
Conclusions	Ships	Simple – like bulk-carrier	Sophisticated, efficient	
	Receiving	Decompress (& heat) – utilize energy released	Store, regasify	

Marine CNG History

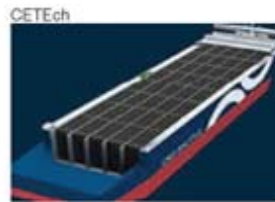
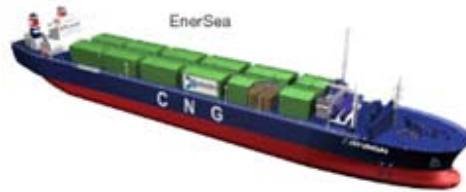
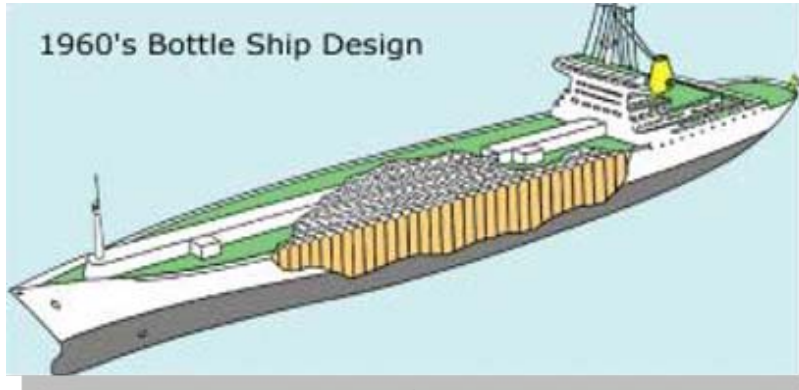
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ABS, DNV Approval

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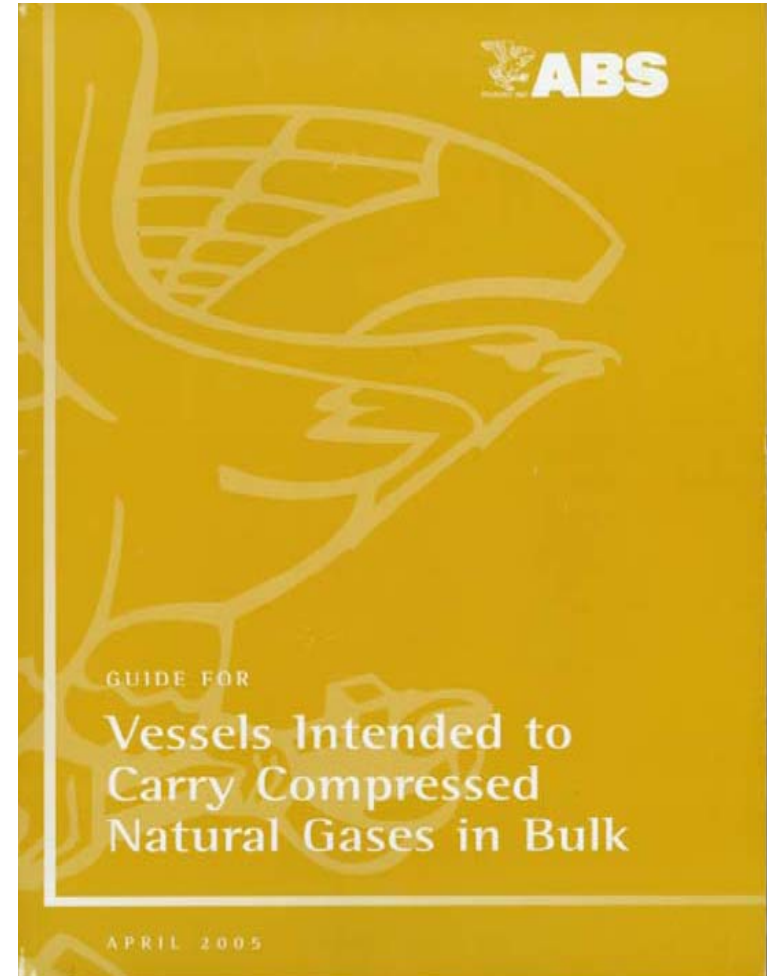
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- EnerSea (steel, vertical pipes, 130 bar, -29°C)
- SeaNG (Coselle 275 bar)
- Knutsen (steel, vertical pipes, 250 bar)
- CETech: (steel, horizontal pipes, 200-250 bar)
- TransCanada (wrapped steel liner)
- Trans Ocean Gas (composite)



CNG Vessels Trivia

CNG		Articulated Tug Barge 	Ship 
CNG Vessels			
CNG Transport: CAPEX optimization	Volume	0.7-2 MMcm (25-75 MMscf)	8-29 MMcm (300-1000 MMscf)
Case Studies	Loading unloading rates	0.3-2 MMcm/day (10-75 MMscf/day)	2-14 MMcm/day (75-500 MMscf/day)
Conclusions	Distance	100-1000 km (50-500 nautical miles)	250-5000 km (135-2700 nautical miles)
	Speed	<25 km/hr (<14 knots)	<33 km/hr (<18 knots)
	Estimated cost	\$15-35 million	\$150-350 million

CNG Technologies: Coselles (Compression only)

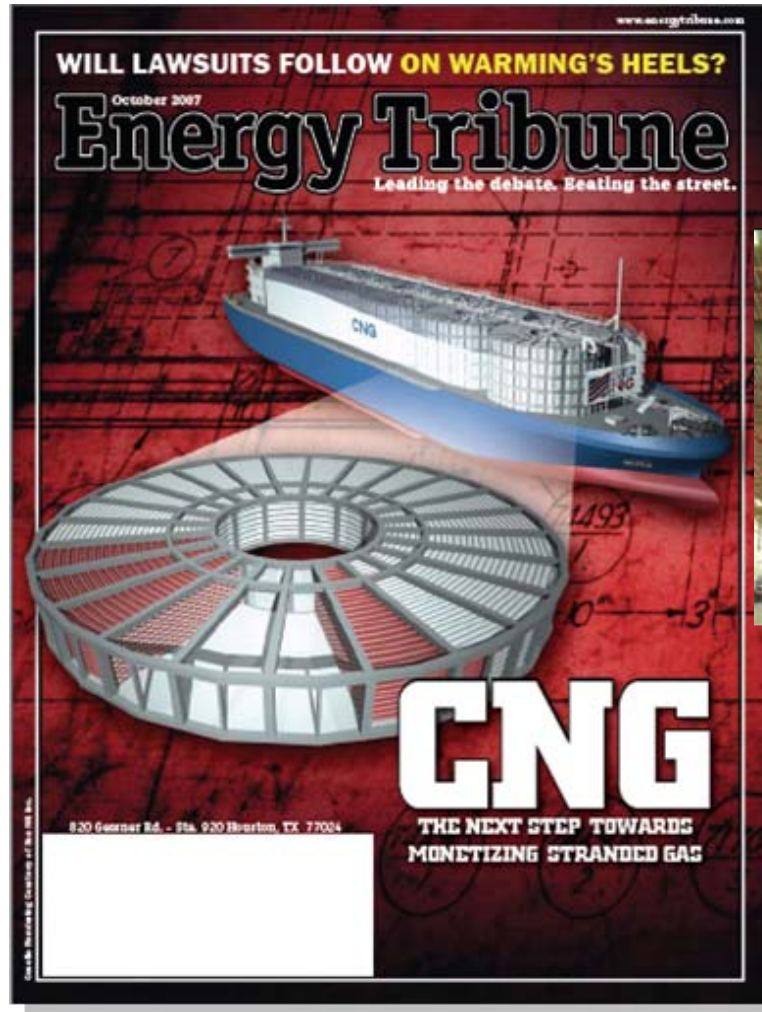
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CNG Technologies: Compression and Chilling

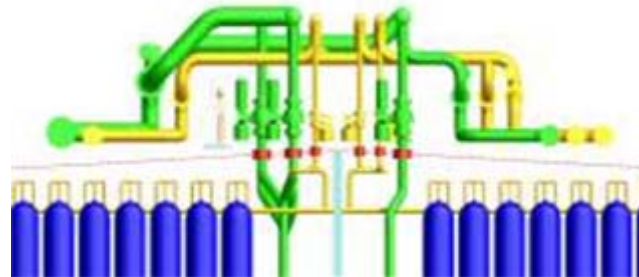
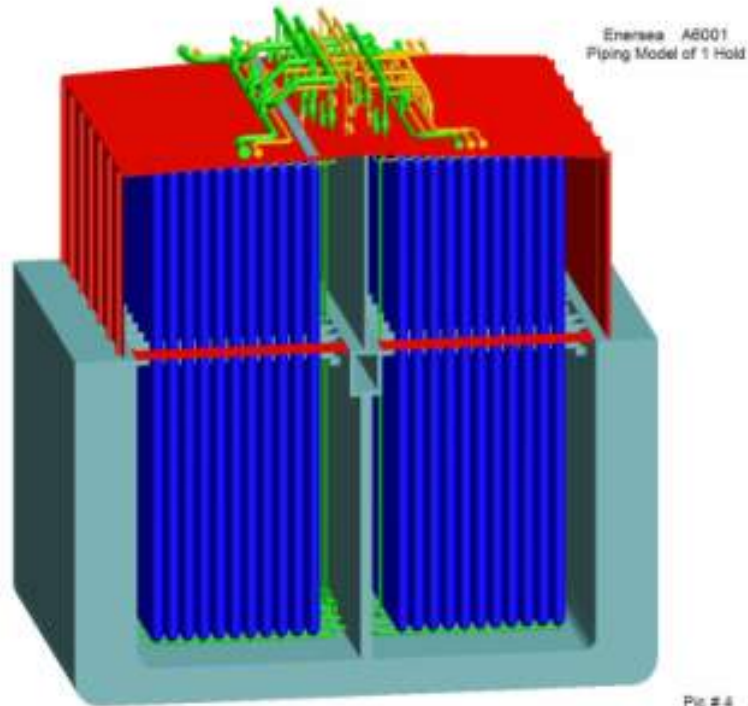
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Why Compression and Chilling?

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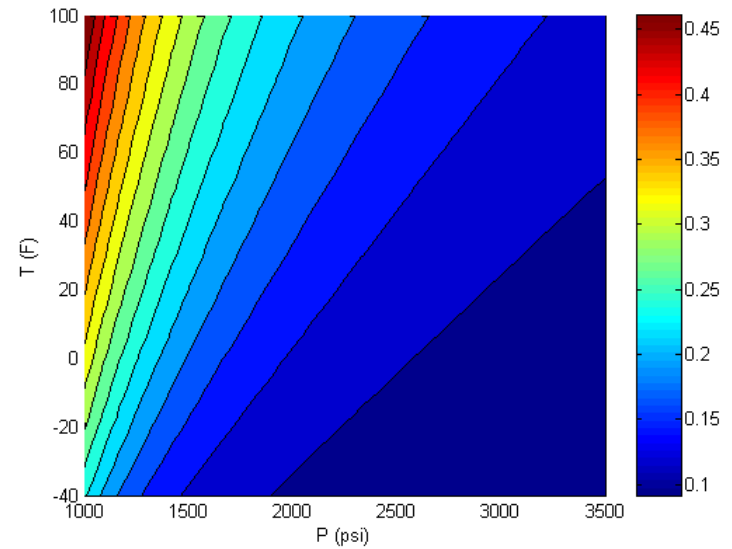
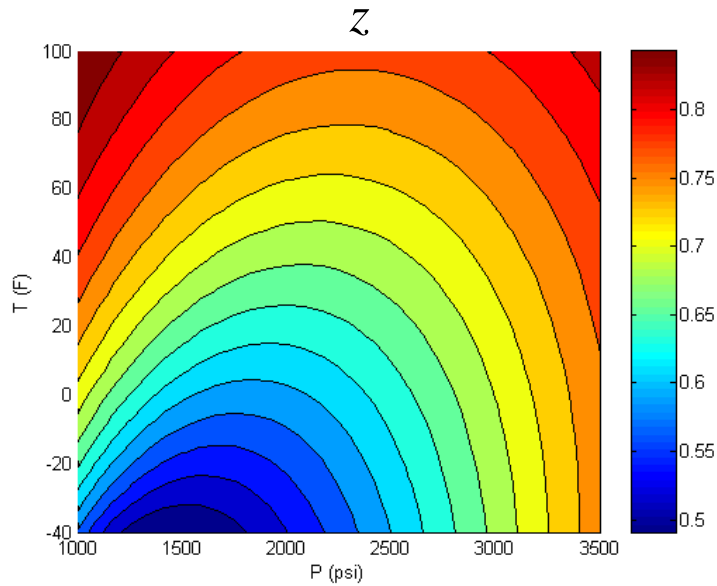
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$$V \sim \frac{zT}{P}$$



Loading and Offloading

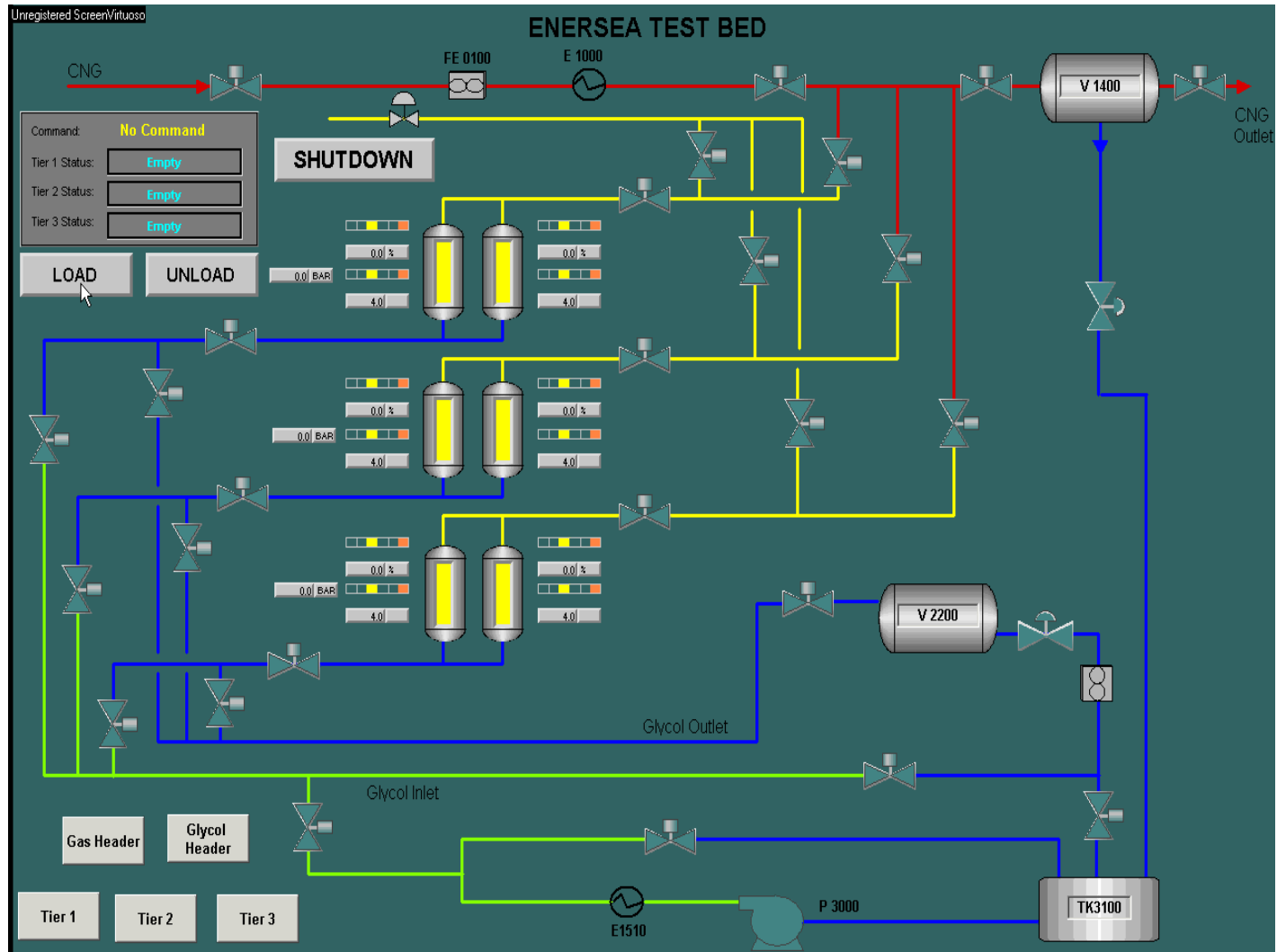
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Natural Gas Transport: Fixed Cost

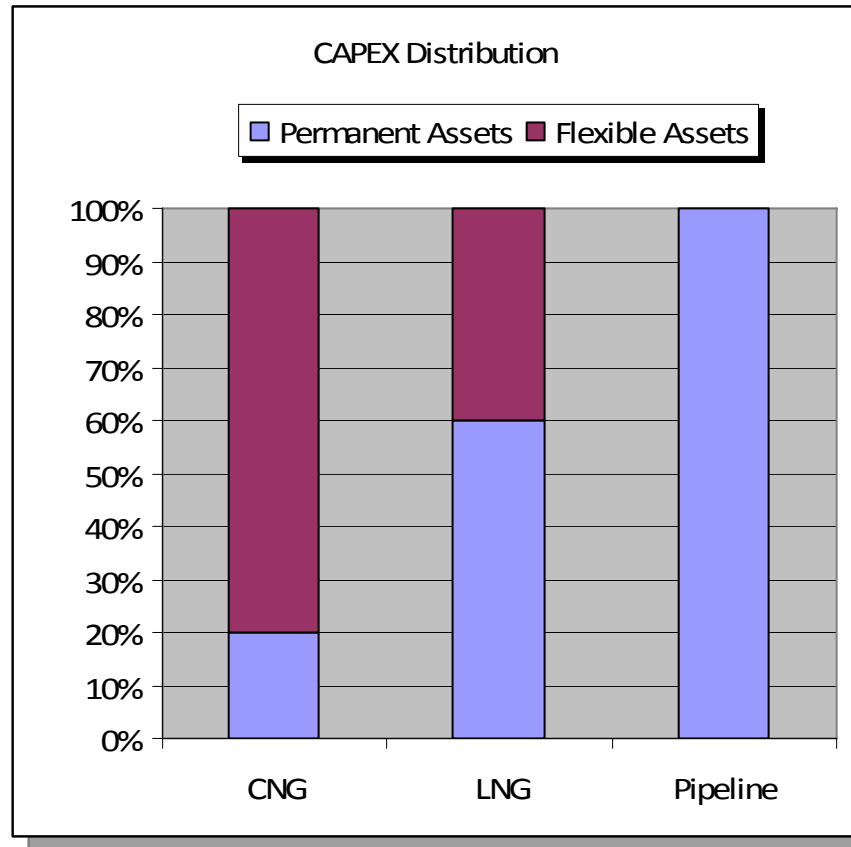
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CNG Distribution Patterns: Logistics Matter!

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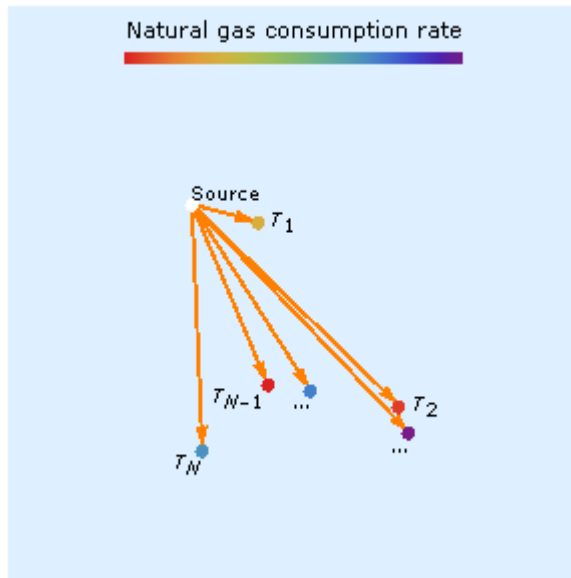
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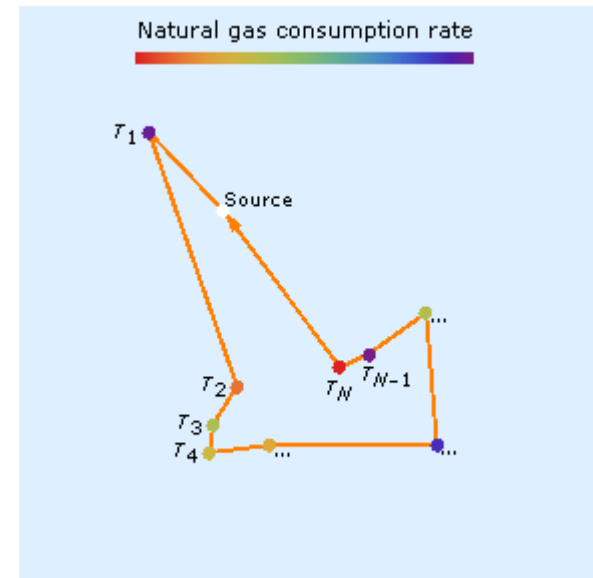
Case Studies

Conclusions

- Hub-and-Spoke



- Milk-Run



CNG Distribution

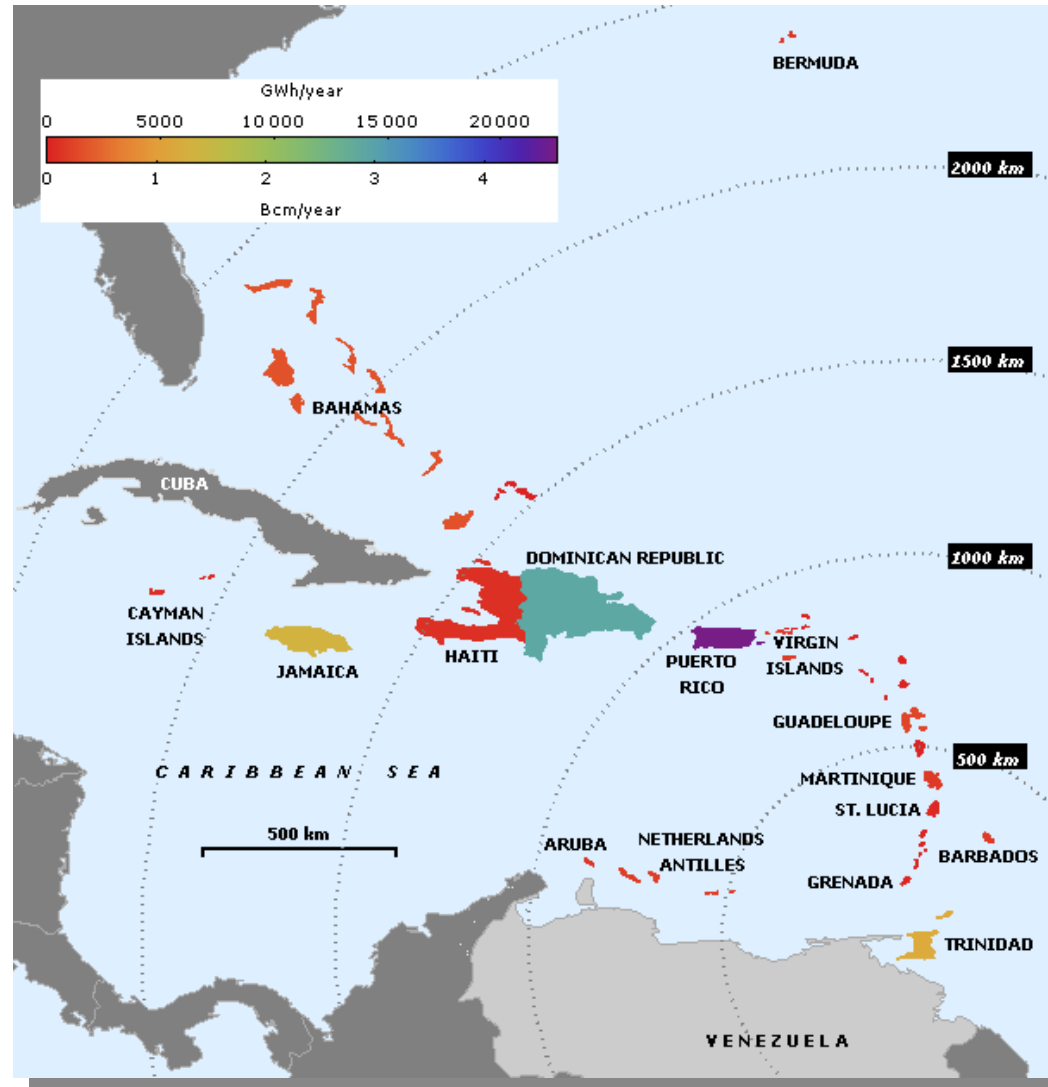
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CNG Fleet Size Bounds

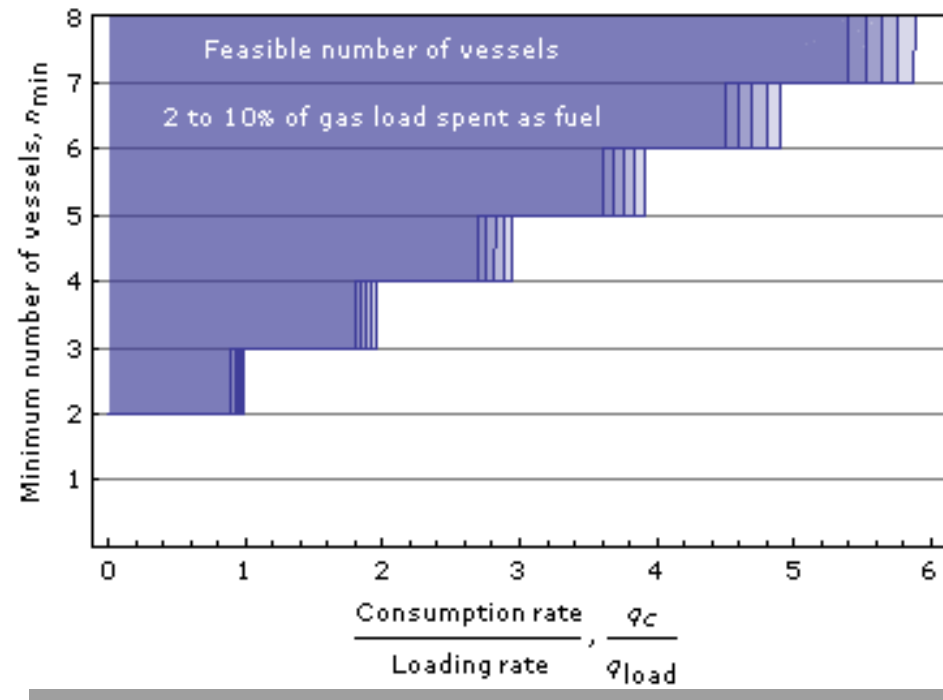
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CNG Distribution in the Caribbean

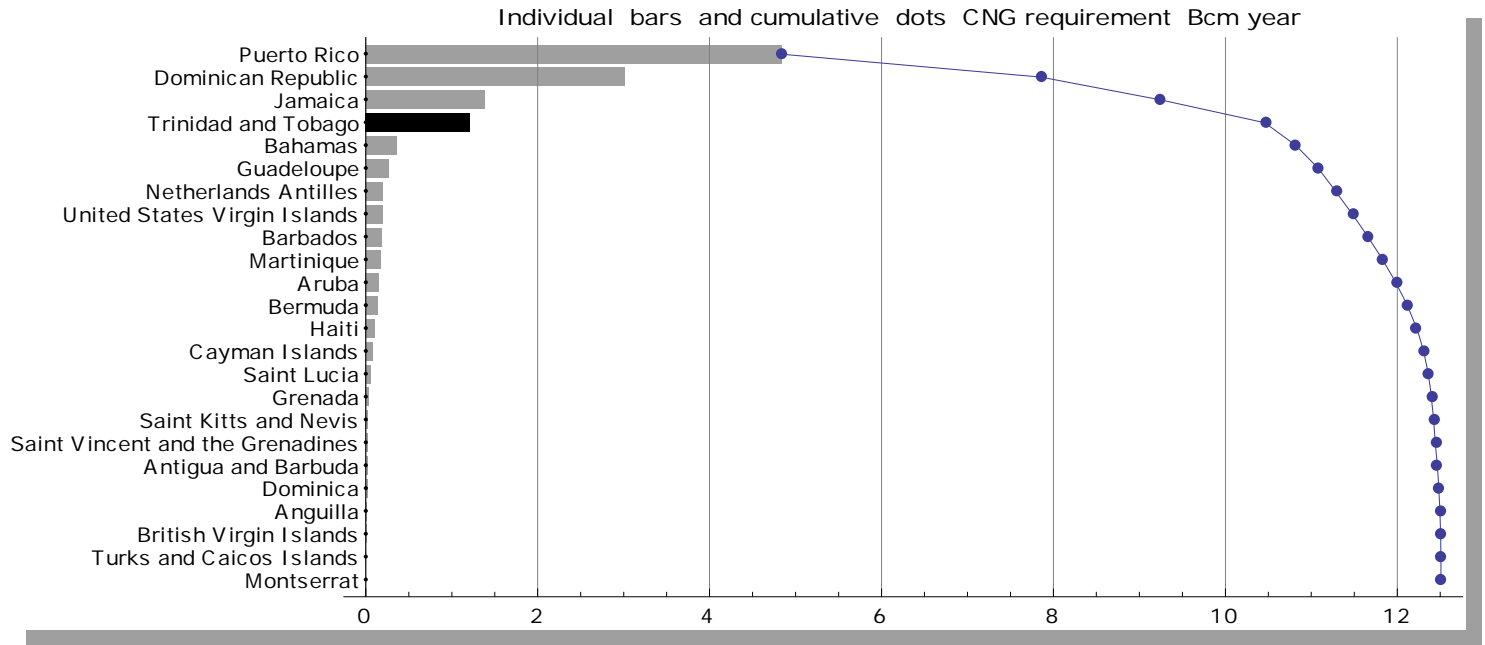
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CNG Distribution in the Caribbean: The Big 4

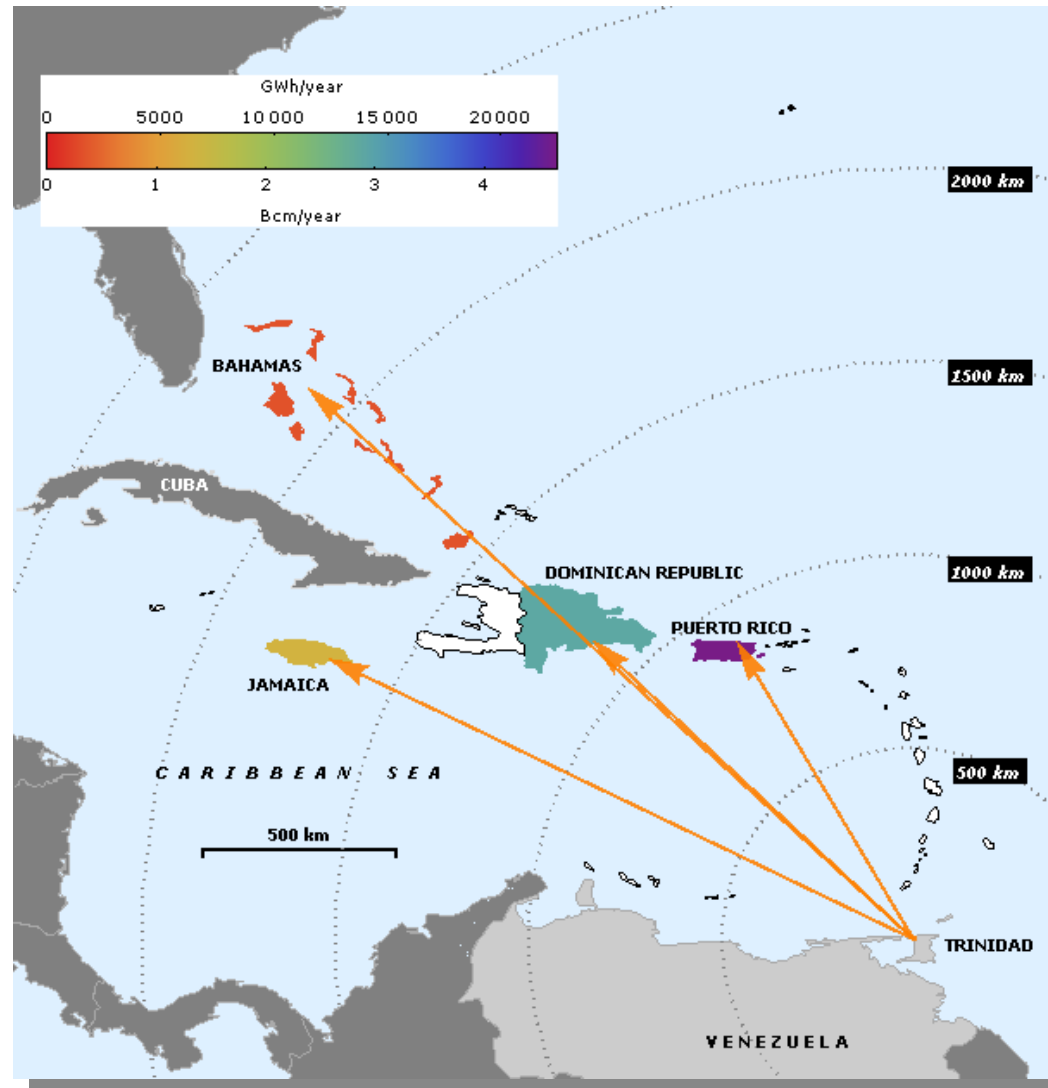
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CNG to the Big 4: Fleet Capacity

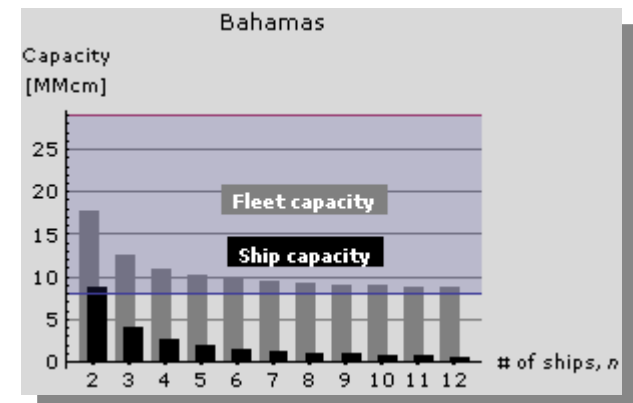
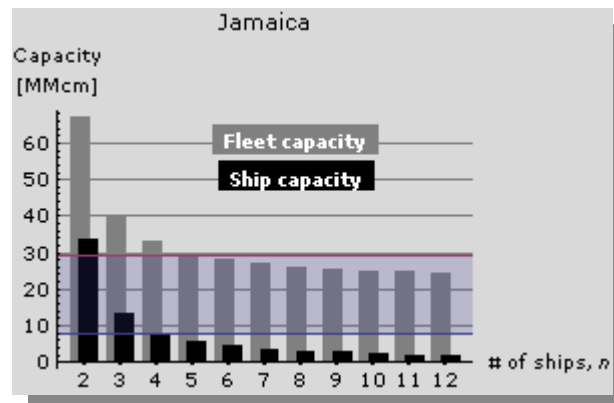
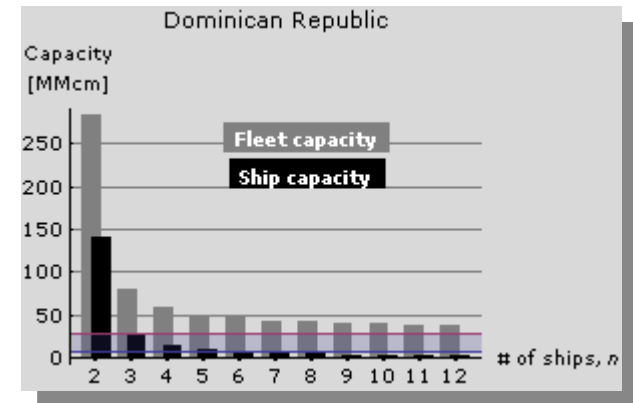
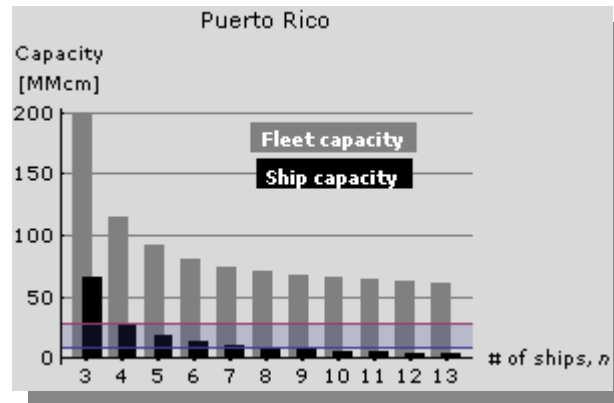
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CNG to the Big 4: Travel Time

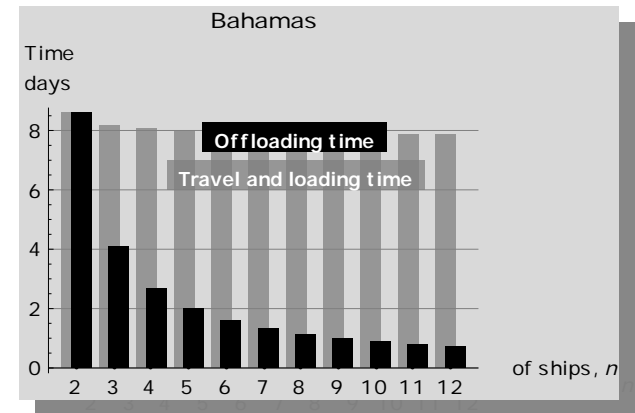
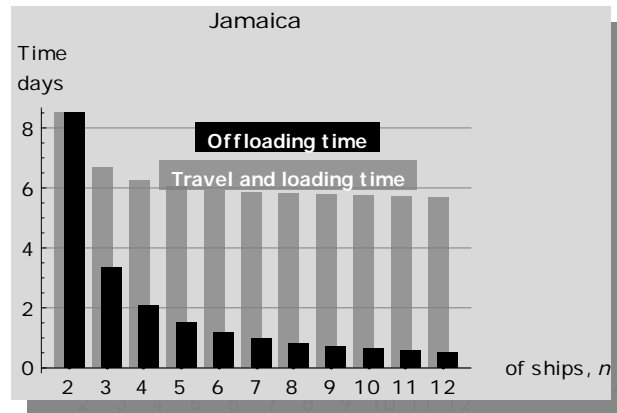
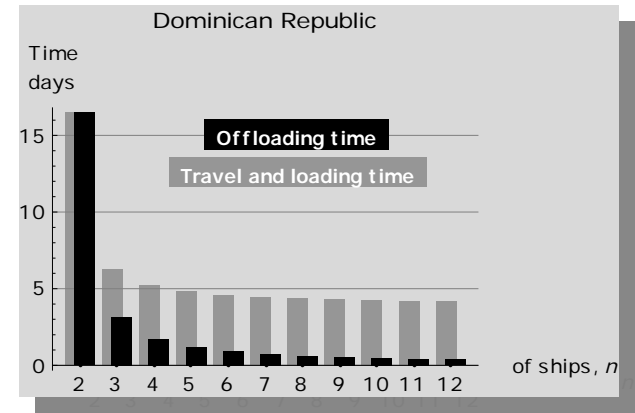
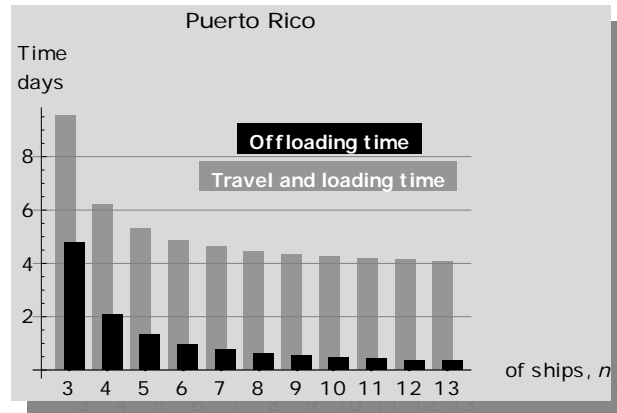
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CNG Distribution in the Caribbean: The Small Ones

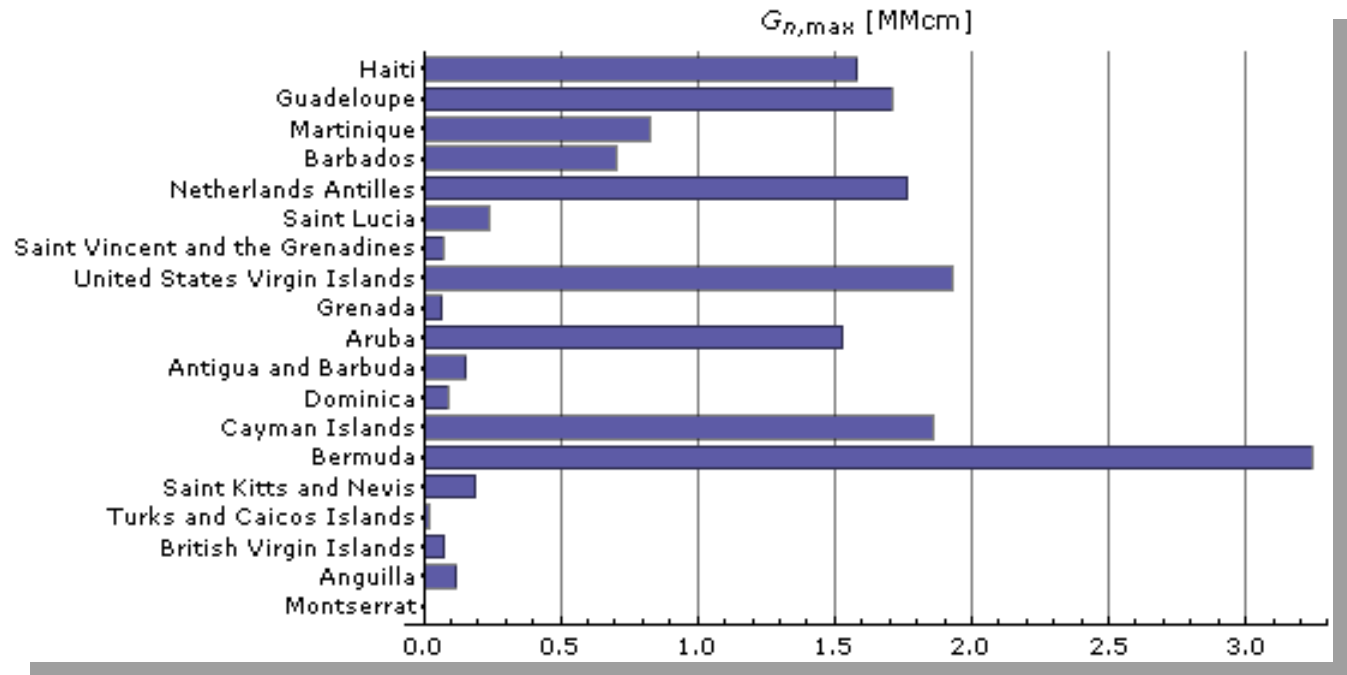
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CNG to the Small Ones: Itinerary

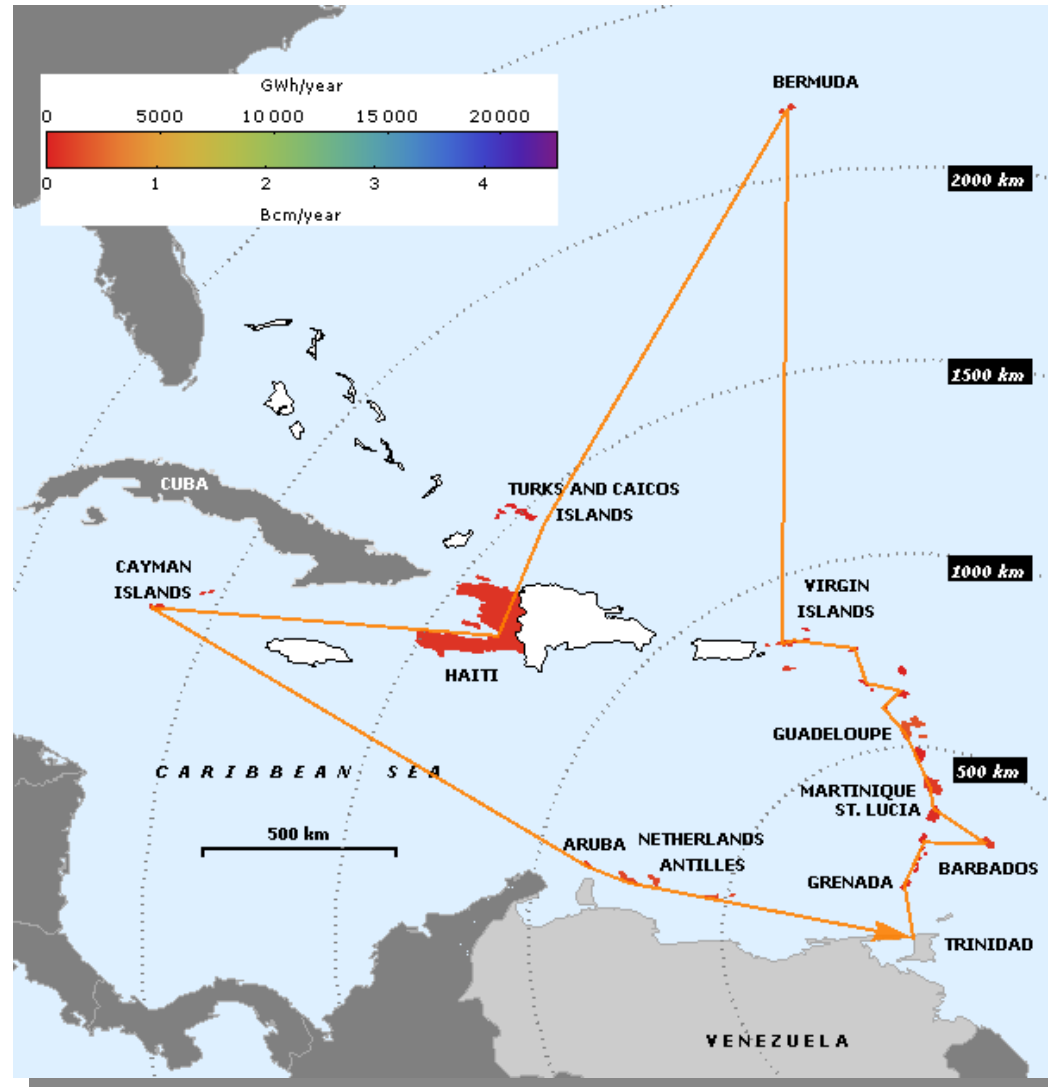
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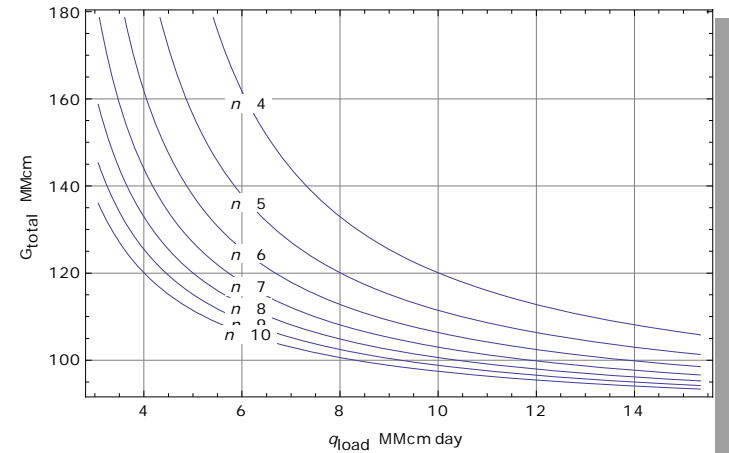
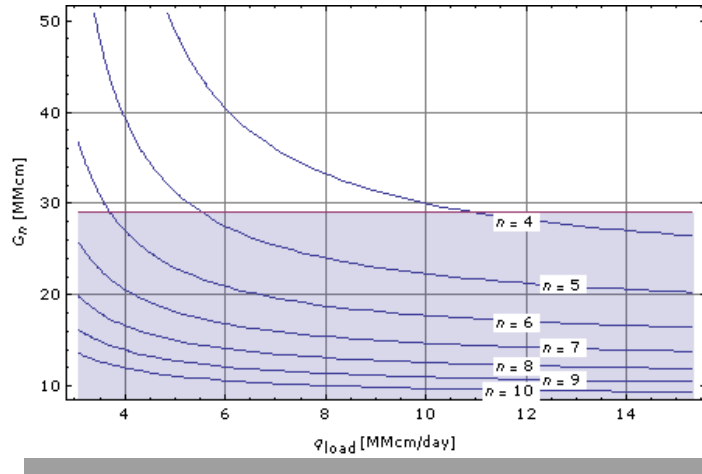


CNG to the Small Ones: Fleet Capacity

CNG

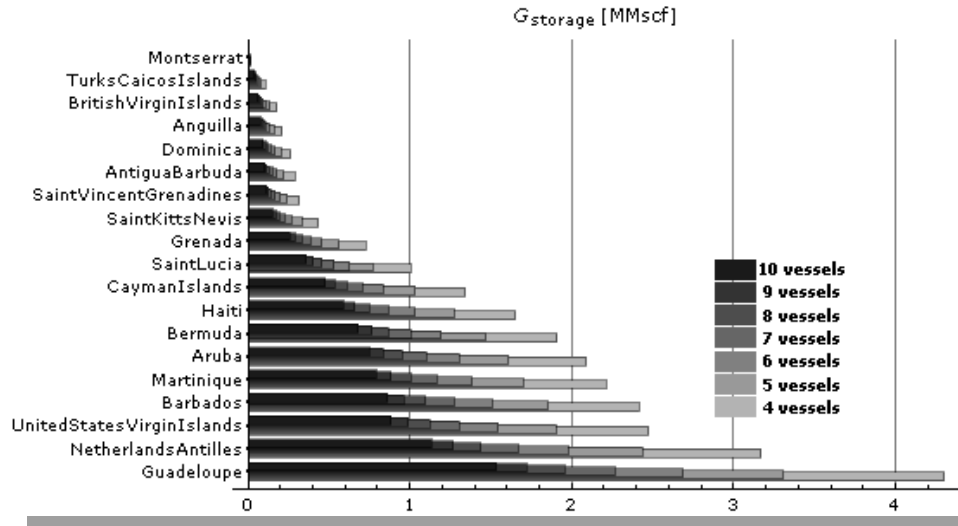
CNG Vessels

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CNG to the Small Ones: Reduced Itinerary

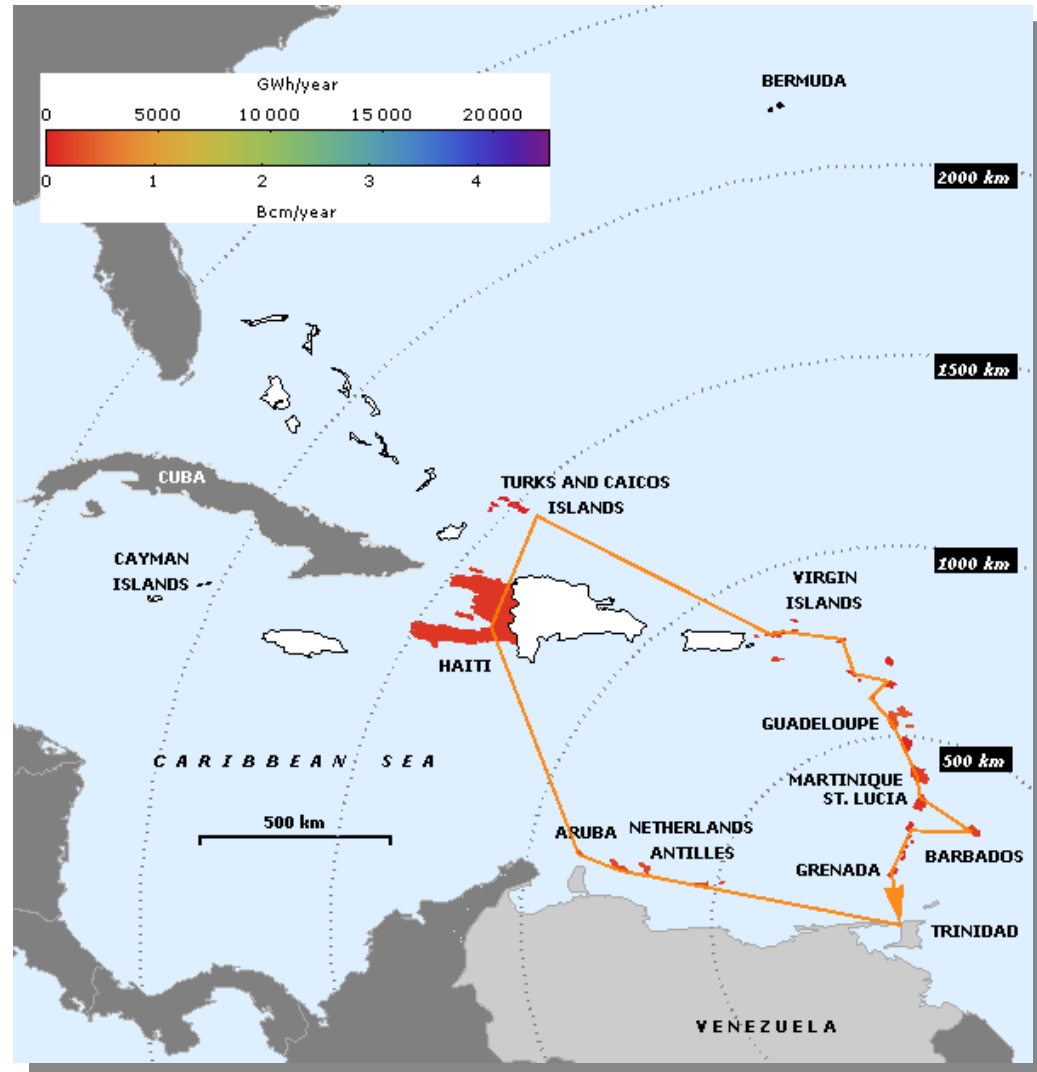
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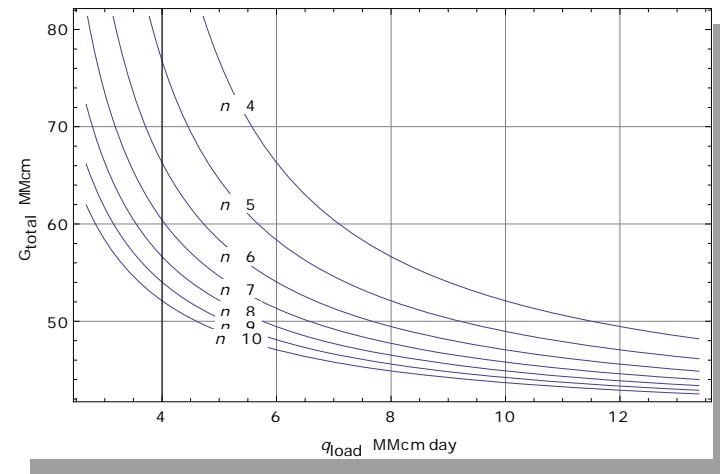
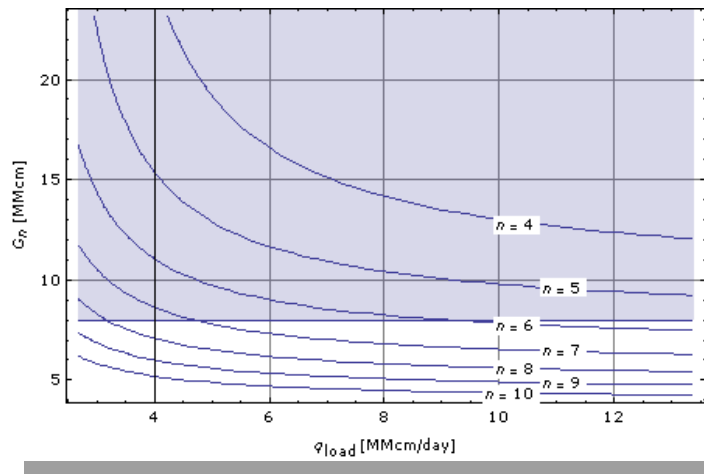


CNG to the Small Ones: Fleet Capacity for Reduced Itinerary

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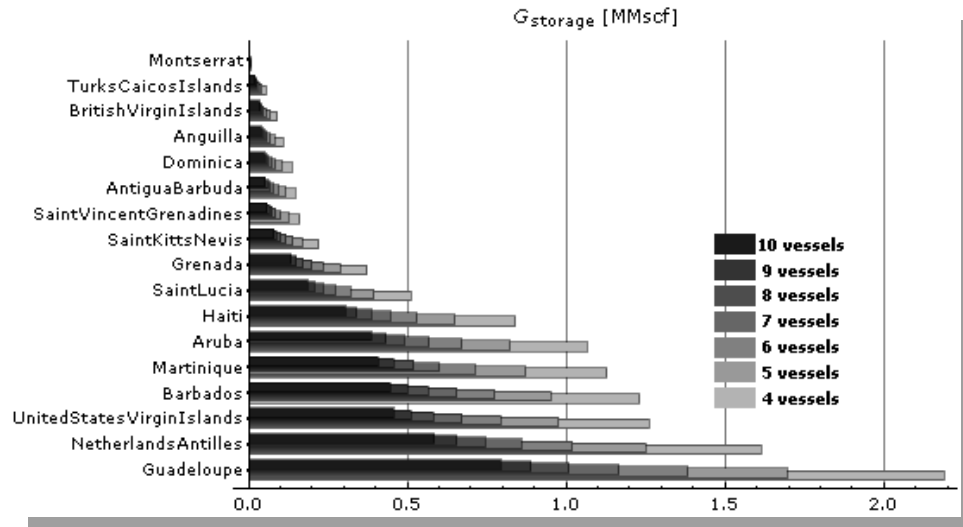
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CNG

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- CNG ready for prime time
 - Room for further improvement
- CNG complements LNG
 - Several potential markets worldwide
- Logistics and fleet optimization important