Liquefied Natural Gas (LNG) Yard Hostler Demonstration and Commercialization Project

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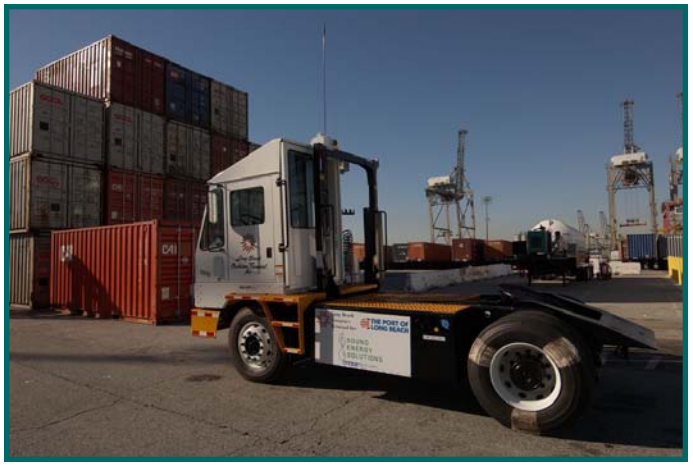
LONG BEACH

Project Team

- Port of Long Beach
- Sound Energy Solutions
- WestStart-CALSTART
- Long Beach Container Terminal, Inc.
- United States Environmental Protection Agency
  - Awarded $75,000 to project
- Total project cost: approximately $1 million

Project Goals

- Assess performance and emissions of LNG yard hostlers
  - Fuel Economy
  - Operator Acceptance
  - Service and Maintenance
  - Compare relative emissions to diesel yard hostlers
  - Business Case



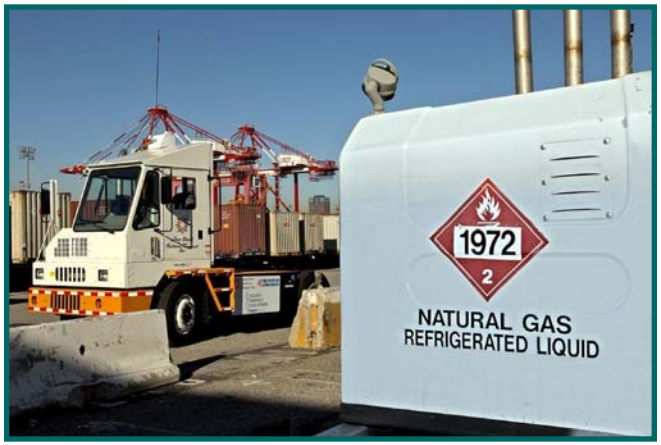
Test Program Overview

- Performance and emissions testing on 3 LNG yard hostlers
- Baseline comparison group: Eight diesel yard hostlers
- In-use testing conducted over 8 months (June 2006 – January 2007)
- Training provided to LBCT staff
- Temporary LNG refueling infrastructure
  - 3,450 gallon ORCA™ parked in “fixed” location
- Fuel economy data collected daily
- Drivers and mechanics surveyed
- Emissions testing and analysis performed by UCR CE-CERT

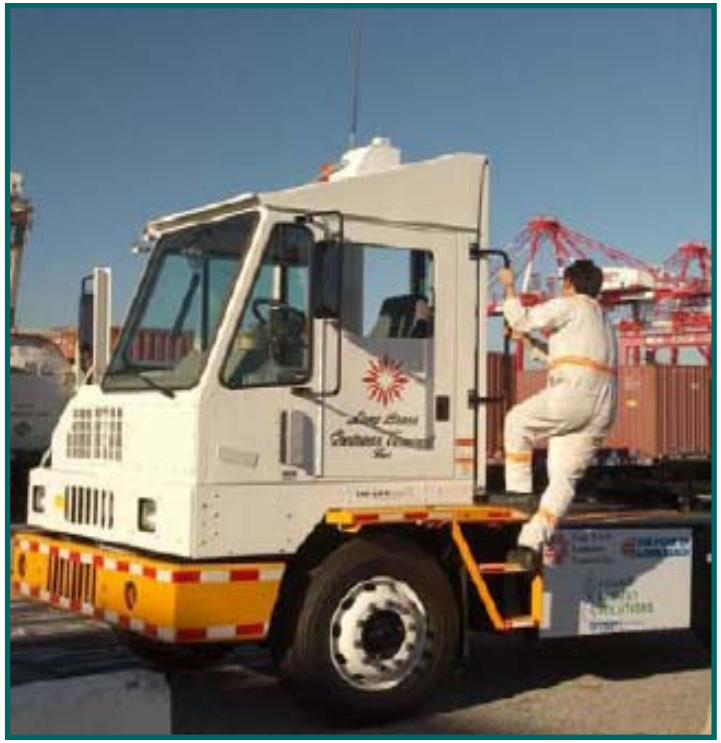
Fuel Economy

- Energy content of LNG < diesel, for direct comparison LNG gallons converted to diesel gallon equivalents (DGE)
- Average Fuel Economy
  - 8 diesel yard hostlers: 1.7 diesel gal/hr
  - 3 LNG yard hostlers: 3.8 LNG gal/hr

    = 2.2 DGE/hr
- Conclusions
  - LNG yard hostlers use about 30% more DGE than diesel yard hostlers
  - Expected with heavy-duty spark-ignited engine vs. compression-ignited diesel engine



Operator Acceptance



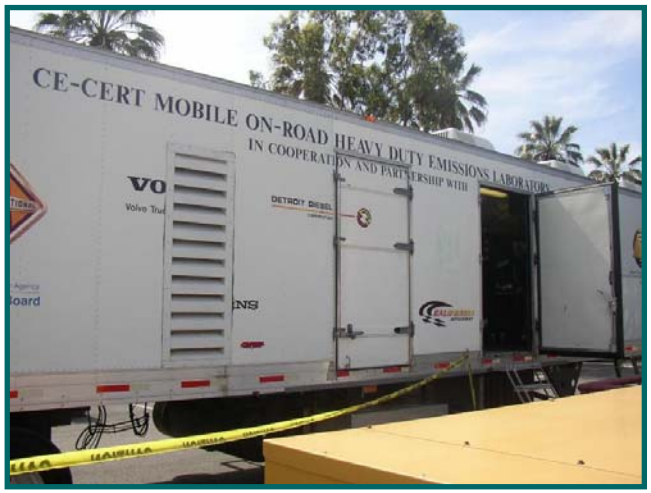
- 97% felt LNG yard hostlers performed same or better than traditional diesel yard tractors
- 67% of drivers rated LNG yard hostlers superior in general
- Only Cab entry and exit frequently rated “worse” than diesel yard hostlers
- Some cited slow acceleration, vehicle “hesitation” and problems with shifting

Maintainability and Serviceability

- 100% of mechanics rated LNG yard hostlers “acceptable”
- Routine maintenance performed several times during performance testing period
- Noted LNG pressure regulation and leaking problems during early phase of demonstration
  - Westport Innovations upgraded on-vehicle LNG fueling system to address problems

Emissions Testing

- Compared emissions between LNG and diesel yard hostlers
  - 2005 LNG on-road engine
  - Tier 1 diesel off-road engine (2)
  - Tier 2 diesel off-road engine
  - 2005 diesel on-road engine
- Steady-state emissions testing on heavy-duty chasis-dynamometer
- Followed CARB's yard hostlers emissions testing protocol
- Emissions Testing performed by UCR CE-CERT



Emissions Testing Results

- By agreement, PM emissions were not tested
- Lowest NOx emissions produced by 2005 on-road diesel yard hostler
- NOx emissions from LNG yard hostler approximately 21% higher than 2005 on-road diesel yard hostler
  - Possible explanation: LNG engine running “lean” at higher loads - higher engine temperature and higher NOx emissions

Engine Year/Model	Fuel Type	NOx (g/whp-hr)*
2005 ISB 5.9L	Diesel	2.94
2005 C-Gas 8.3L	LNG	3.57

*Values shown in units of grams per wheel-horsepower-hour

Comparison with Earlier Study

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- CARB, POLA, and PMSA conducted study of yard hostlers in 2006
- Diesel, liquefied petroleum gas (LPG or propane), and LNG-fueled yard hostlers
- NOx emissions from LNG yard hostler higher compared to diesel yard hostler in POLA study
- NOx emissions slightly lower (approximately 18%) in this study compared to POLA study

Engine Year/Model	Fuel Type	POLB Study		POLA Study	
		NOx	PM	NOx	PM
2004 ISB 5.9L	Diesel	---	---	2.47	0.10
2005 ISB 5.9L	Diesel	2.94	0.10	---	---
2005 C-Gas 8.3L	LNG	3.57	---	4.36	0.008

*Values shown in units of grams per wheel-horsepower-hour (g/whp-hr)

Business Case Assessment

- LNG yard hostlers not currently offered as standard commercial product
- New diesel yard hostler typically $65K-$80K
- Assuming avg. base cost of $80K, incremental cost for LNG yard hostler approximately $40K (50% of base cost) = $120K
- Life cycle cost analysis: diesel and LNG yard hostler approximately equal over 10-year life
- LNG fueling infrastructure costs (est. $700k per station) and 2010 emissions regulation compliance not considered
- Permitting process for LNG fueling infrastructure can vary
- Demand unlikely without financial or regulatory incentives

Recommendations

- Measure LNG vs. diesel yard hostler emissions using yard hostlers with current engines that meet (or exceed) heavy-duty emissions standards
- Evaluate in-use performance of new LNG yard hostlers
- Update business case analysis with actual costs for new LNG yard hostlers
- Optimize refueling procedures for LNG yard hostler fleets
- Consider port-based incentives to address incremental costs of LNG yard hostlers and capital costs of LNG refueling infrastructure

Next Steps

- Emissions testing on:
  - 2007 on-road diesel engine yard hostler
  - diesel engine yard hostlers converted to operate on LNG fuel
- Develop standard yard hostler duty cycle, available late summer

Thank you!

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