NATURAL GAS FOR HEAVY DUTY ENGINES

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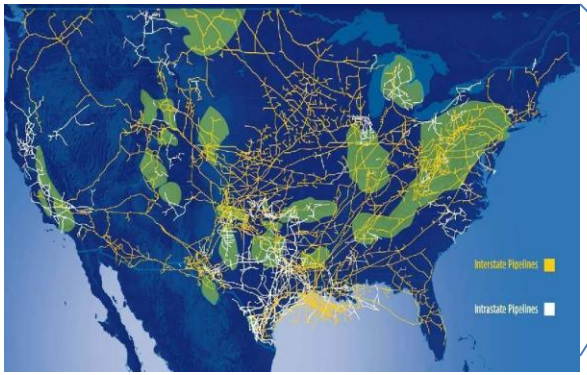
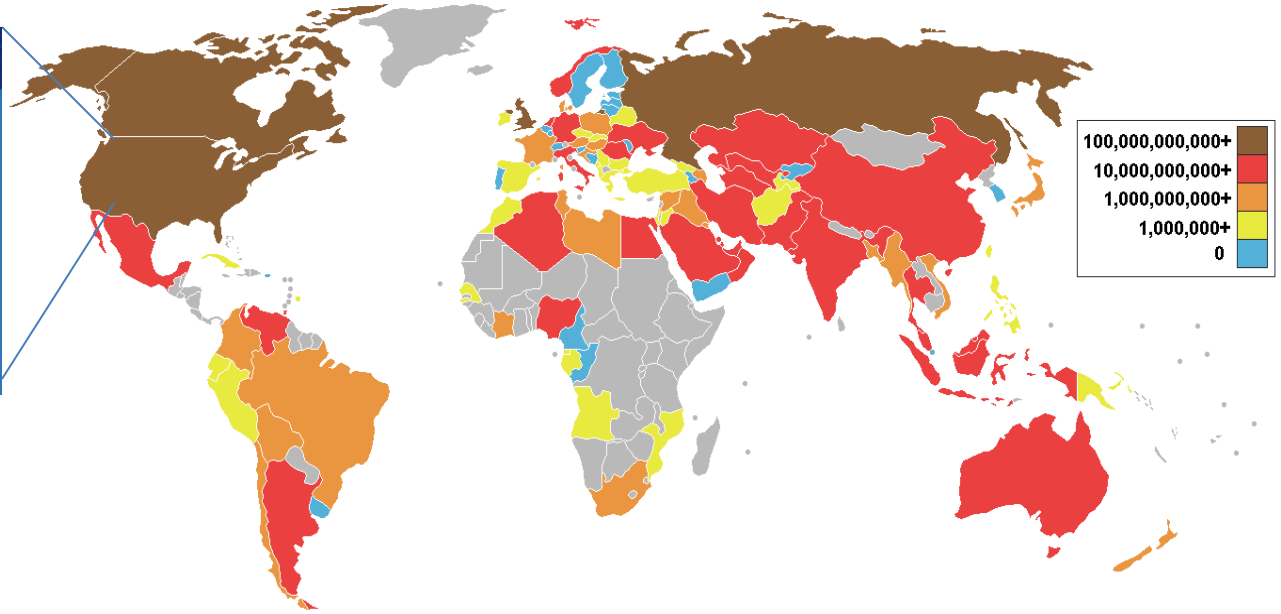
The Abundance of Supply

- Natural gas is the second largest energy resource of the U.S. Estimates are 100-200 years of natural gas production.
- The abundance of available natural gas has changed the supply/demand equilibrium to the point that natural gas makes economic sense.
- Many factors are associated with this growth: technological, geological, environmental, political, geopolitical, and economic.
- Energy independence will become one of the driving forces as well as cost.





Map of natural gas production in cubic meters per year: CIA Factbook

Natural Gas – Game Changer

ACT Research

It is no longer a question of using NG, but exactly when, where, and how much.

WALL STREET JOURNAL

U.S. NEWS | February 27, 2013, 8:50 p.m. ET

Gas Boom Projected to Grow for Decades

By: Russell Gold

U.S. DEPARTMENT OF ENERGY

Jan 2013 National Fuel Averages	
Fuel	**Price**
Gasoline	$3.29/gallon
Diesel	$4.13/gallon
Natural Gas (CNG)	$2.10/GGE

Forbes.com

BUSINESS | 12/15/2012 @ 9:24AM | 32,555 views

All Roads Lead to Natural Gas-Fueled Cars and Trucks

Ken Silverstein, Contributor:

FTR ASSOCIATES

Transport Topics

Nat Gas Could Fuel Half of Heavy Trucks by 2050, Petroleum Industry Study Says

By Eric Miller, Staff Reporter; Feb. 11 print edition of Transport Topics.

The North American market will have a measured shift to the use of natural gas as a fuel for commercial vehicles.

The Perfect Storm….

Economics

- NG Price Stability
- Availability & Infrastructure
- Commercially viable without incentives or inducements

Technology

- Natural Gas Availability & Extraction Technology
- Affordable Engine Technology for Natural Gas
- Broad range of engine platforms

Policy

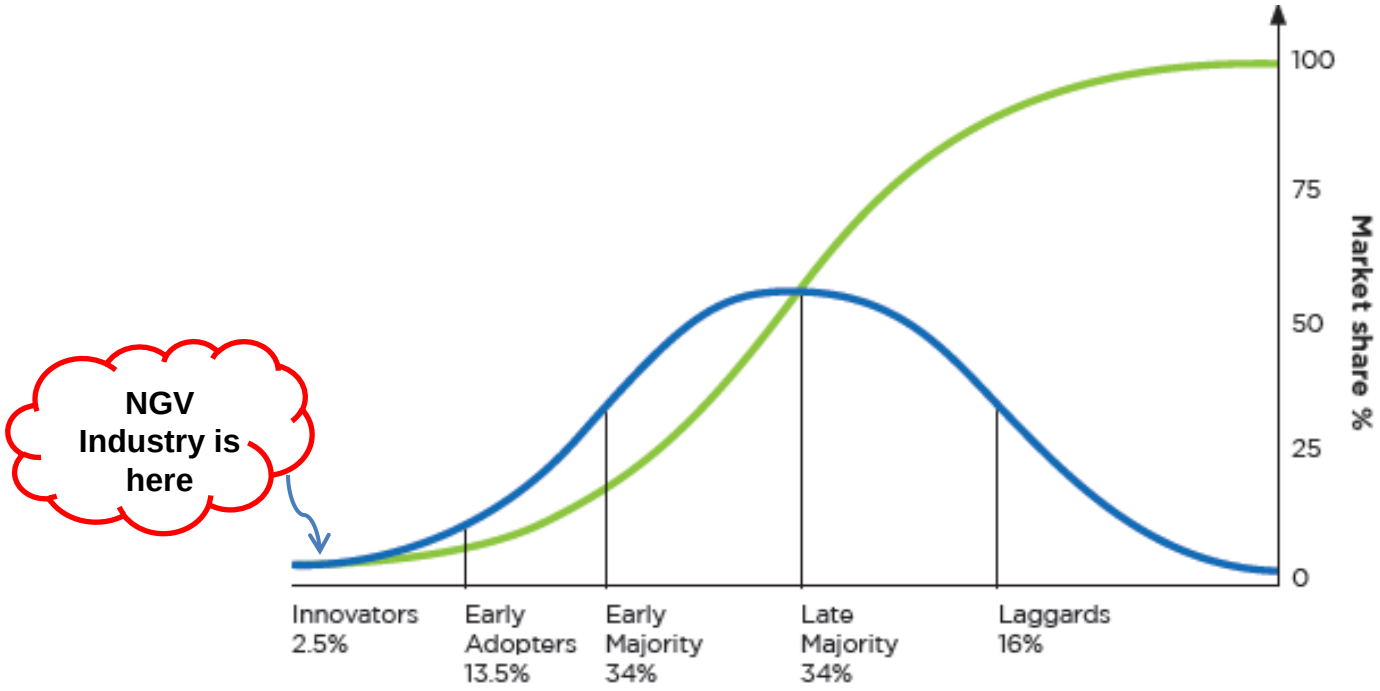
- Energy Independence
- Incentives & Mandates
- Carbon Reduction

Social Factors

- Corporate Sustainability
- Green Image
- “Made In America”

Decades of Transition

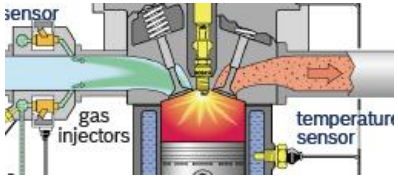
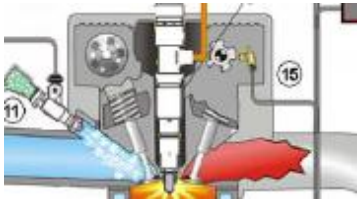
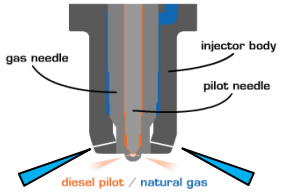
- Historically, it took 2 decades for Class 8 diesel share to reach 90% of the market in 1970 from 10% in 1950 because of infrastructure issues.
- There was no shift from diesel to turbine in the 1970's despite everyone's expectation and substantial investments by the OEMs.
- At one time, electric automobiles were 30% of the market; they are now less than 1%.
- In addition, it takes about 14 years for the entire Class 8 fleet to turn over.
- The market tends to grow in a classic "S-curve" pattern.



Transitional Issues & Obstacles

1. Proper Engine Technology
2. Fueling Infrastructure
3. Mitigation of Cost and Risk
   - Technology Costs & Payback
   - Operating costs
   - Residual Value
4. Service Infrastructure

Natural Gas Engine Technology Options

	Spark Ignited Stoichiometric	Dual Fuel	HPDI (Westport)
			
Mode of combustion	Spark igniting a homogeneous stoichiometric gas/air mixture	Diesel pilot igniting a lean gas port injected lean gas/air mixture	Diesel pilot igniting an in-cylinder injection of high pressure gas
Emission control technique	3 way catalyst (can be combined with EGR)	Lean gas/air mixture combined with small diesel injection + SCR	Lean gas/air mixture + SCR
Performance	Lower HP/Torque	Diesel-like	Diesel-like
Fuel	Dedicated Natural Gas - CNG/LNG	100% diesel at less than 30% load 5-10% diesel at 30% - 100% load CNG/LNG	< 5% diesel everywhere LNG ONLY
Fuel consumption	Worse than diesel (10-15% less)	Diesel-like	Diesel-like
Performance	Lower HP/Torque	Diesel-like	Diesel-like
Components differing from diesel version	• Modified piston • Cylinder head modified to fit spark plug • Manifold mounted gas metering/mixing device • Replaced ECU	• No changes to piston • No changes to cylinder head • Gas metering/mixing device in intake • Custom ECU 'piggy-backed' on base diesel ECU	• Modified piston • Cylinder head modified to accept Injector • Replaced/modified ECU
Best Applications	• Start/Stop • Urban • Waste/Refuse	• On-Highway	• On-Highway

Infrastructure - CNG

- Private vs. Public
- Light Duty vs. Heavy Duty
- Slow fill vs. Time fill

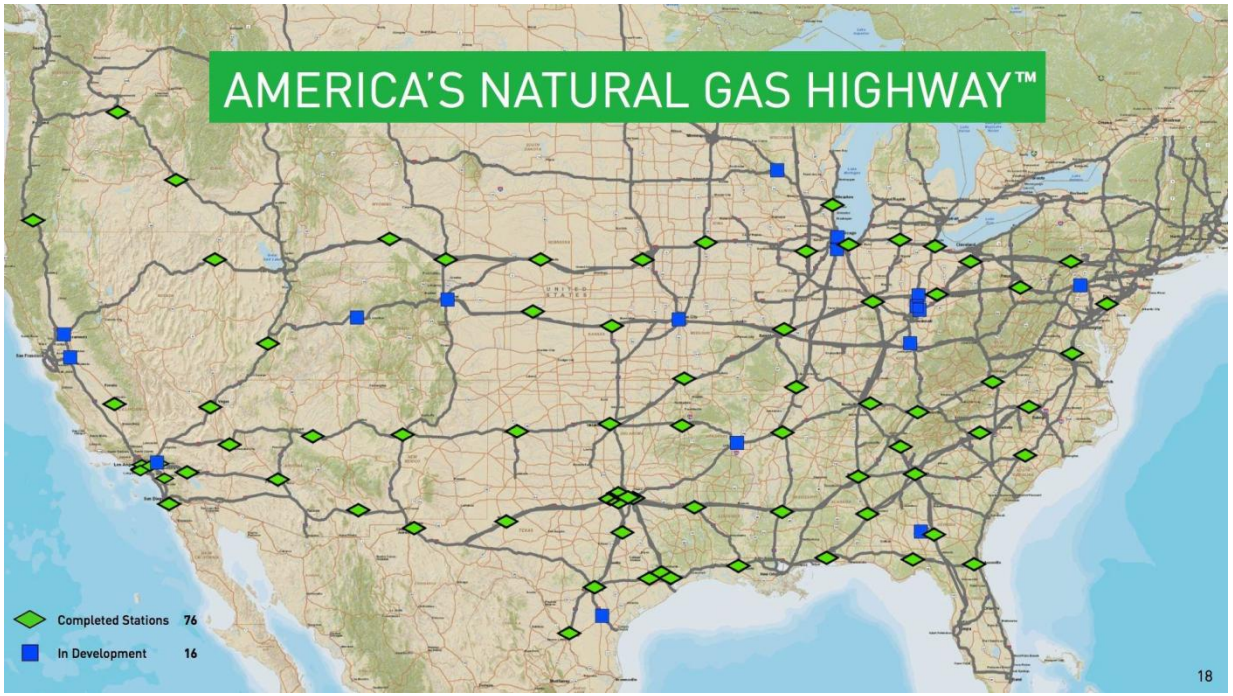
Infrastructure - LNG

- Limited availability
- Rollout contingent upon demand
- Cost & taxes

Clean Energy

Pilot TRAVEL CENTERS LLC FLYING J

TA TravelCenters of America



Mitigation of Cost and Risk

Incremental vehicle costs
- Engine costs
- Tank costs
- Life Cycle (Years)

Impact on payback
- Medium vs. Heavy Duty
- Sustainable business model

Maintenance costs

Residuals

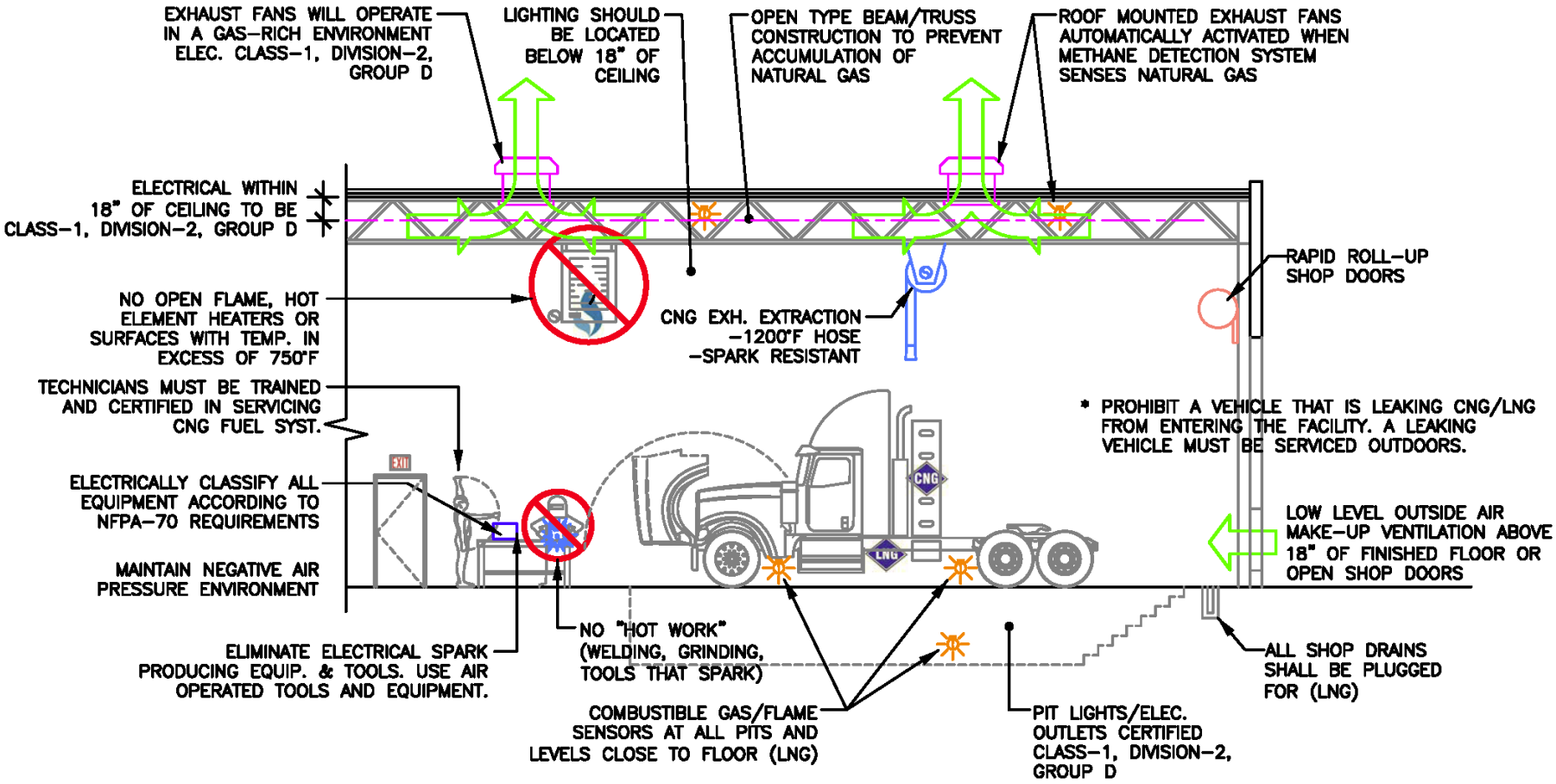
Service Infrastructure

All maintenance shops where CNG & LNG powered vehicles are serviced must be modified:

- To detect leaks
- Have sensors, alarms, and comprehensive ventilation systems
- Be fitted with special heating and electrical fixtures to prevent ignition of gases.

Safe working conditions and practices must be established and enforced.

CNG/LNG Service Requirements



CNG/LNG SERVICE BAY GUIDELINE - TRACTOR

Facilities Modifications

Facility Guidelines
for
Compressed Natural Gas (CNG)
Liquid Natural Gas (LNG)
Powered Vehicles

THIS GUIDELINE IS DEDICATED TO THE HARD WORKING TECHNICIANS OF NORTH AMERICA WHO KEEP THE TRANSPORTATION INDUSTRY ROLLING!

This guideline is intended to be a reference for a dealership to follow for facility design when evaluating, planning, designing or retrofitting a service department to maintain CNG and LNG powered vehicles. This guideline is not to be considered a specification or a replacement for your federal, state, local codes, Authority Having Jurisdiction (AHJ), Fire Marshal and other site specific requirements. National Fire Protection Association (NFPA) and Building Codes may be updated from time to time and will override this guideline.

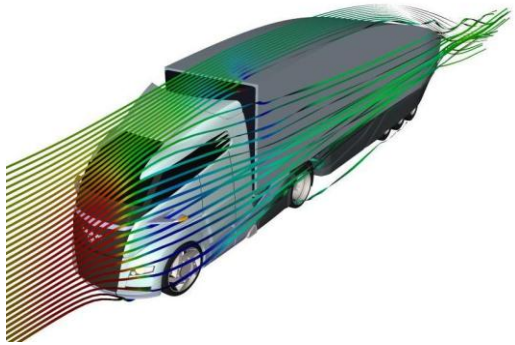
Considerations & Opportunities

TAIL WINDS

- Fuel savings per mile
- Operation cost reduction
- Long term price gap between diesel and NG
- Energy independence
- Regulations / Compliance
- Sustainability (Green Marketing)
- Budget planning on more stable fuel prices
- 80% part commonality to current diesel engines
- Least CO^2 of fossil fuels

HEAD WINDS

- Cost of technology (upfront cost of new NG product)
- Payback period drawback for some segments
- Reliability / Durability
- Maintenance & Facilities Modification cost
- Infrastructure
- Technician knowledge and ability



QUESTIONS??