

the Energy to Lead

Hydrogen Delivery in the Natural Gas Pipeline Network

DOE'S HYDROGEN ENERGY STORAGE
FOR GRID AND TRANSPORTATION
SERVICES WORKSHOP

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Topics for Today

- > GTI Introduction
- > Natural Gas Infrastructure is Undergoing Changes
- > Questions that have been addressed
- > Two Scenarios
- > Unanswered Questions
- > CEC's Mobile Hydrogen Station

Company Overview

ESTABLISHED 1941

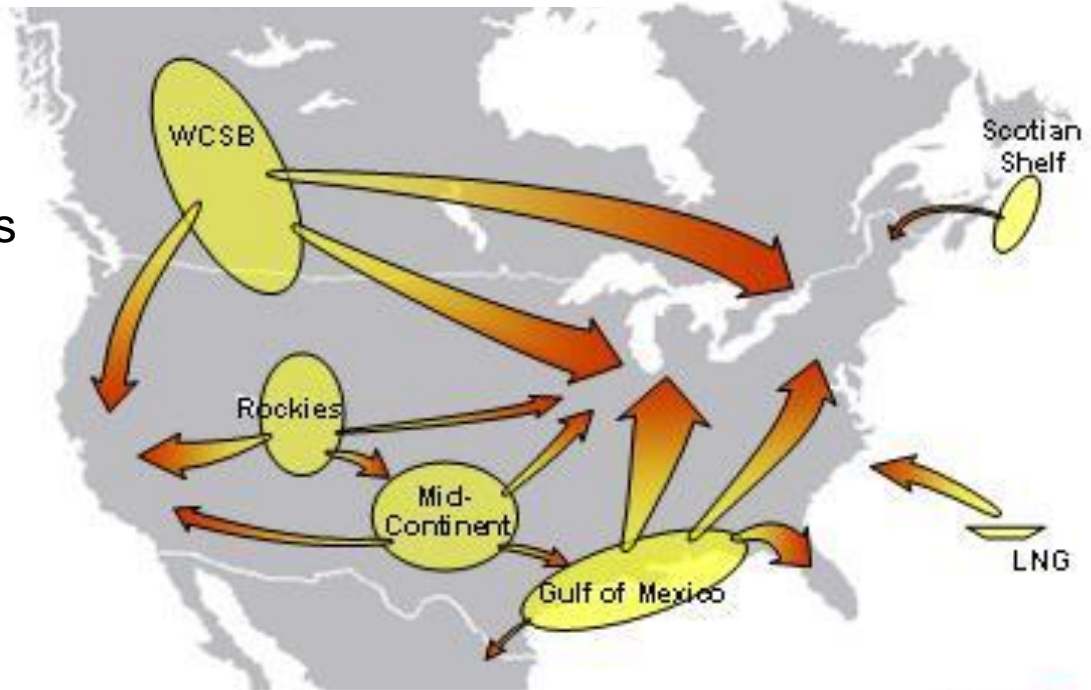
- > Independent, not-for-profit company established by natural gas industry
- > Providing natural gas research, development and technology deployment services to industry and government clients
- > Performing contract research, program management, consulting, and training
- > Facilities
 - 18 acre campus near Chicago
 - 200,000 ft² with 28 labs
- > Staff of 250
- > Wellhead to the burner tip including energy conversion technologies



The Natural Gas Pipeline Grid

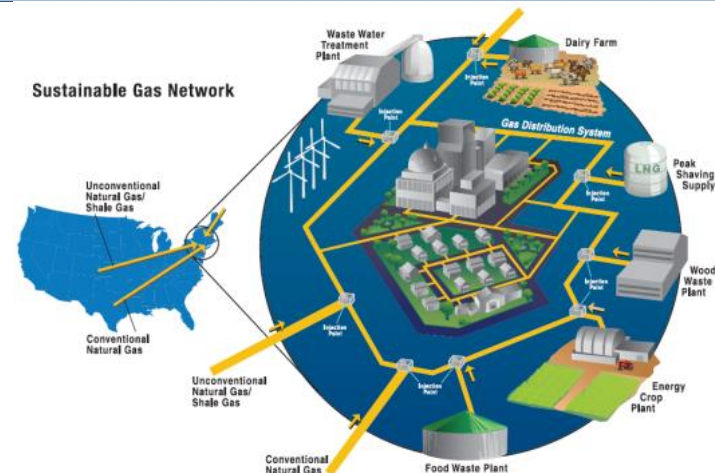
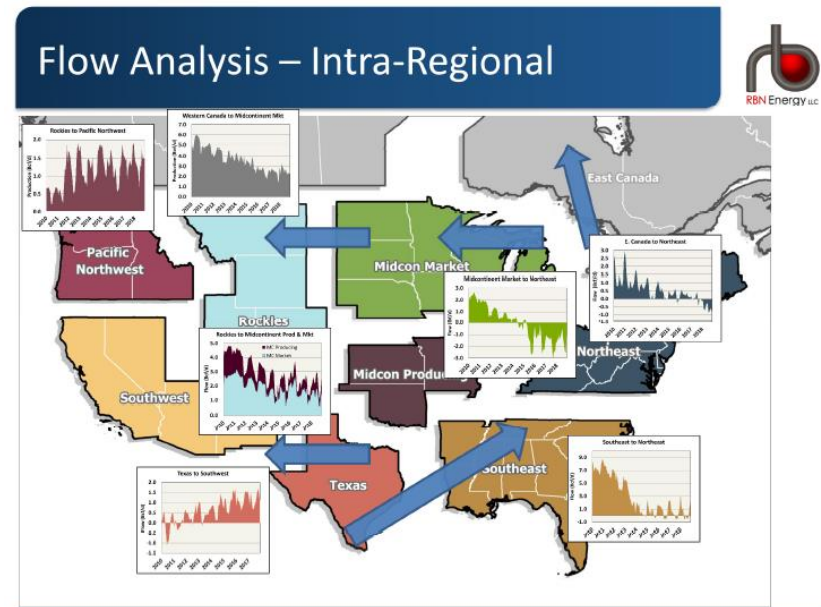
The U.S. Natural Gas Supply Network (past 30 years)

- > Transmission Pipelines
 - \$6-10 billion per year
 - Over 10 million hp of installed compression capacity
- > Local Distribution Pipelines
 - \$12 billion year
 - > \$8.2 billion repair/replace
 - > \$4.0 billion new construction
- > Natural Gas **STORAGE**
 - Substantial volumes of stored **CNG, LNG**



The U.S. Natural Gas Supply Network (next 5 years)

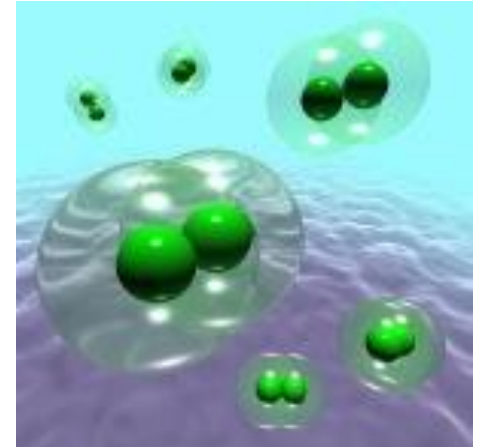
- > Northeast gas production will increase by 10.5 Bcfd to 18 Bcfd over next five years
- > Extensive gas gathering and 80 new NGL plants to be built
- > Increased CAPEX for pipeline integrity upgrades
- > Relieve northeast capacity constraints
- > Respond to increased demand from NGV's
- > Gas utilities with broadened supply portfolio



Introducing Hydrogen into the Network

Hydrogen in a Pipeline Network: Preliminary Assessment

- > Are “Lifecycle” and Social Benefits of Hydrogen Injection Supportable
- > Can Safety be Maintained
- > Is Gas Leakage Manageable
- > Are There Adverse Impacts on Material Durability
- > Can Pipeline Integrity be Maintained
- > What is the End Use Impact of Hydrogen Injection?
- > What are the Economics?



Source Documents: NREL, “Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues”, Melaina, Antonia, and Penev, March, 2013

GTI, “Review Studies of Hydrogen Use in Natural Gas Distribution Systems”, Zhou, Ersoy, October, 2010

End Use Impact from Hydrogen Blending: Two Scenarios

Scenario 1

Hydrogen is injected in a Natural Gas Pipeline, delivered a known distance and then separated from the gas stream via PSA or other separation technology. Hydrogen is then used in a fuel cell.

Scenario 2

Hydrogen is injected in a Natural Gas Pipeline network for blending and resale to conventional or dedicated applications as natural gas with a “renewable” component. Blended methane/hydrogen mix is used as combustion fuel.

Scenario I Challenges

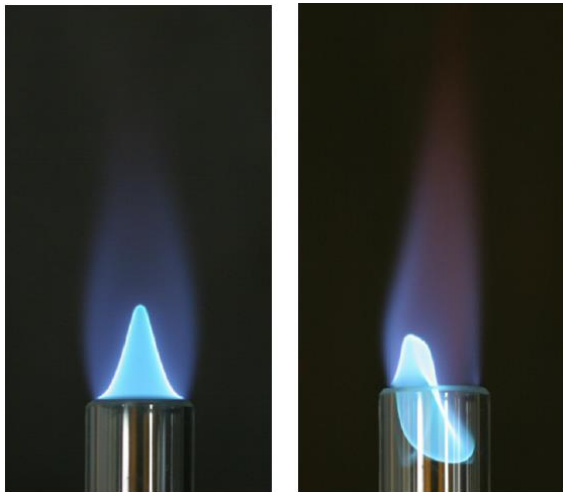
Separation of Hydrogen from NatGas Blend

- > Separation costs are high (report estimates \$2 - \$7 per kg for volumes 100 – 1000 kg/day)
 - Lower costs achievable at pressure-drop points (city gate stations).
 - Isolating a section of pipeline to maintain relatively high concentration of H₂ is difficult.
- > Maintaining significant blends requires a lot of hydrogen.
 - To attain 20% blend Hydrogen to Methane for mid-size utility (Dallas): 205,000 kg/day
 - To attain 20% blend Hydrogen to Methane for long-haul transmission line (Tennessee Gas Pipeline): 1.8M kg/day

Scenario I | Challenges

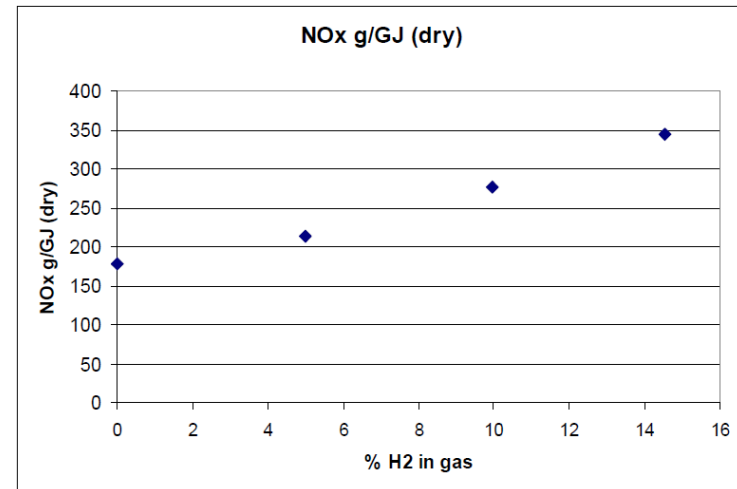
Natural Gas / Hydrogen Blend

- > Adding Hydrogen to the gas supply can impact end-use equipment operations and emissions.



Normal flame

H₂ blended



NO_x in a Gas Engine

5% H₂ content increases NO_x by 10%

Questions to be Addressed

- > **Transportation and Hydrogen Separation**
 - What blending percentage is realistic?
 - Are composites or new materials feasible for dedicated hydrogen blend pipelines
 - Can sections of the natural gas pipeline network be isolated for hydrogen blending and delivery?
 - Can separation technologies be improved to handle low hydrogen concentrations economically?

- > **What is the net emissions and energy efficiency impact of hydrogen blends?**
 - GHG reduction vs potential NOx increases
 - Efficiency losses / gains in gas combustion equipment

- > **What impact do hydrogen blends have on end-use equipment?**
 - Natural Gas Vehicles and HHP Natural Gas Engines
 - Residential, Commercial, and Industrial appliances and equipment.

Now, for something completely different...

> PON 13-607

- Mobile Hydrogen Refueler
- GTI, US Hybrid, and Hydrogen Frontiers

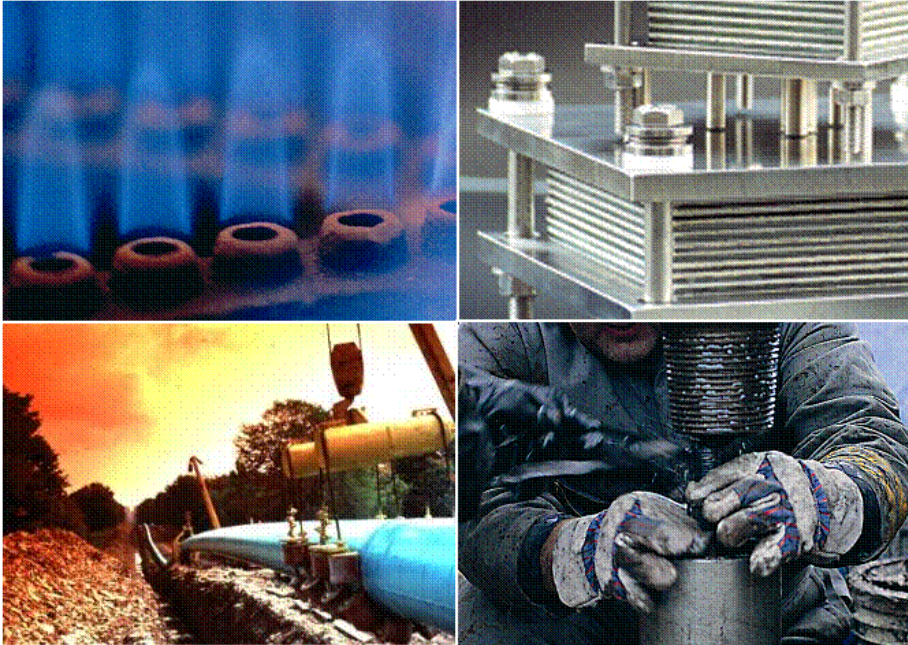


GTI's Fuel Mule
Built for & Operated by
Ultimate CNG



Mobile Hydrogen Refueler
Concept Drawing

Thank You for Your Interest in Clean, Reliable Energy



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