



the Energy to Lead

Renewable Biogas for Pipelines

Renewable Resource Workshop

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Today's Talk

- > **Who is GTI**
- > **The Gas Delivery Network**
- > **What is Biogas**
- > **Why do we need to treat biogas**
- > **Biogas benefits**

GTI at a Glance...

- > Not-for-profit research, with 65+ year history
- > Facilities
 - 18 acre campus near Chicago
 - 200,000 ft², 28 specialized labs
- > \$60 + million in revenue
- > Staff of 250
- > A growing business
- > Commercial partners take our technologies to market



Offices
& Labs

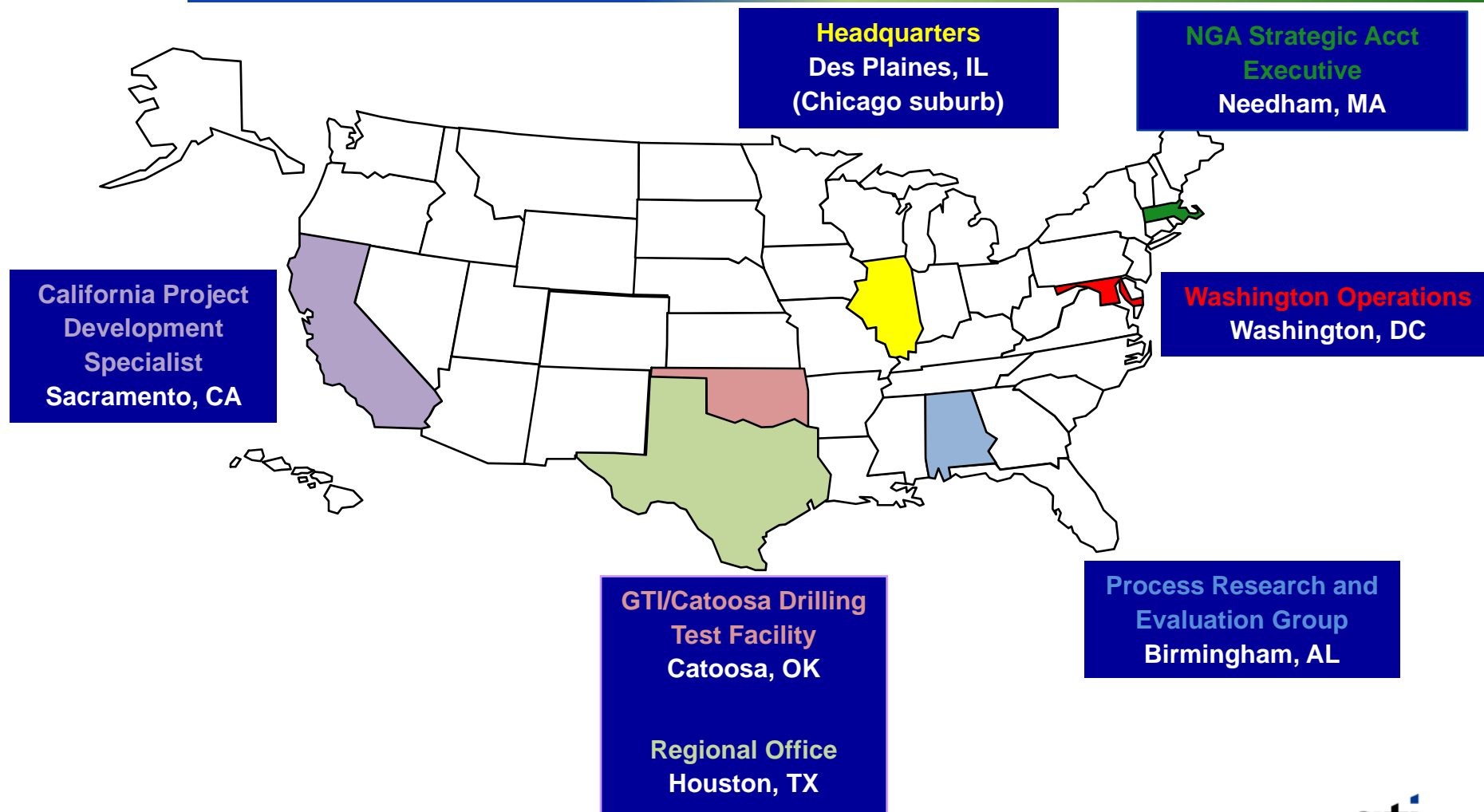


Flex-Fuel
Test
Facility



Energy & Environmental Technology Center

Locations



Addressing Key Energy Industry Issues Across the Value Chain



Supply

Expanding the supply of affordable energy



Delivery

Ensuring a safe and reliable energy delivery infrastructure

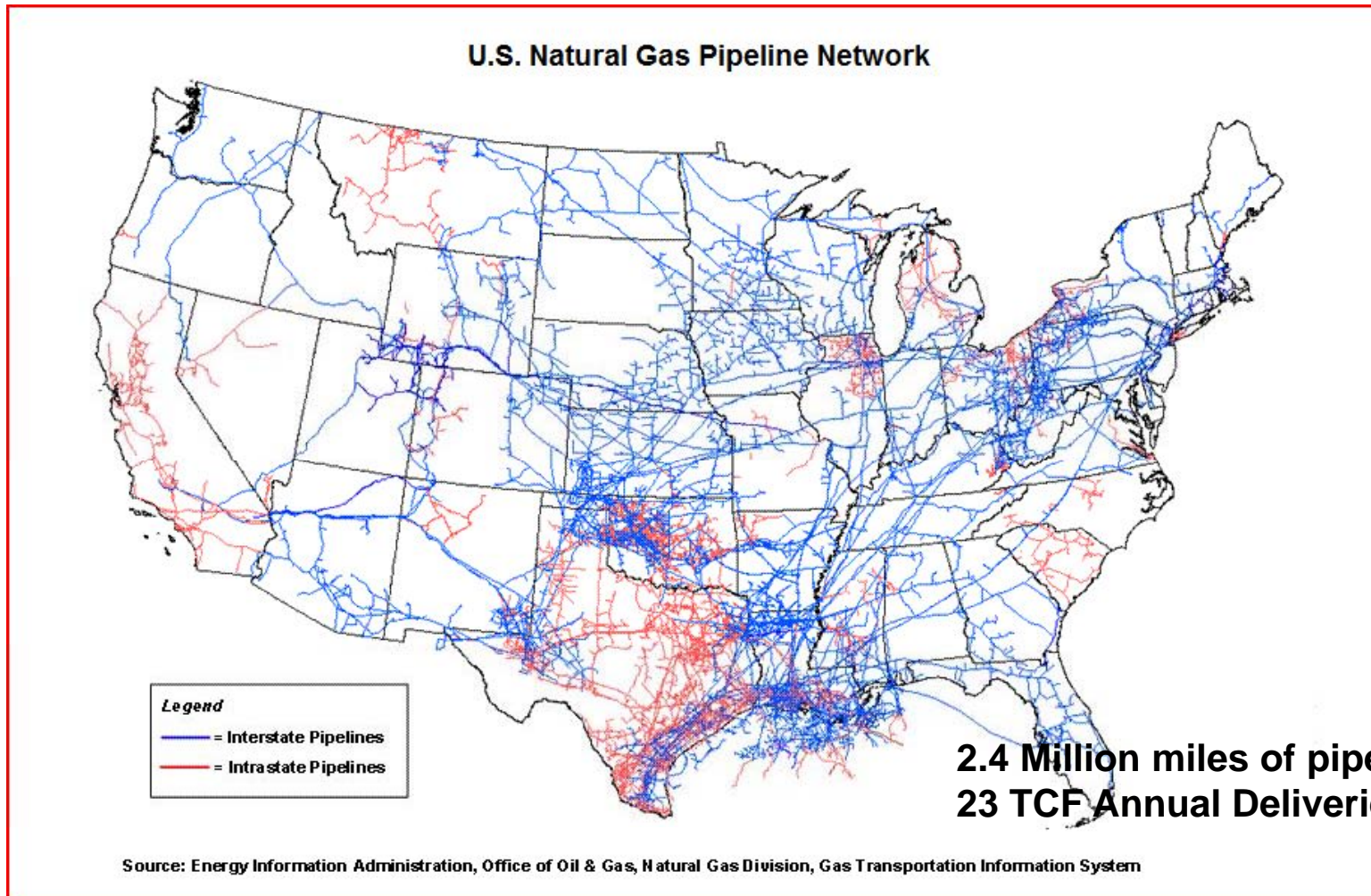


End Use

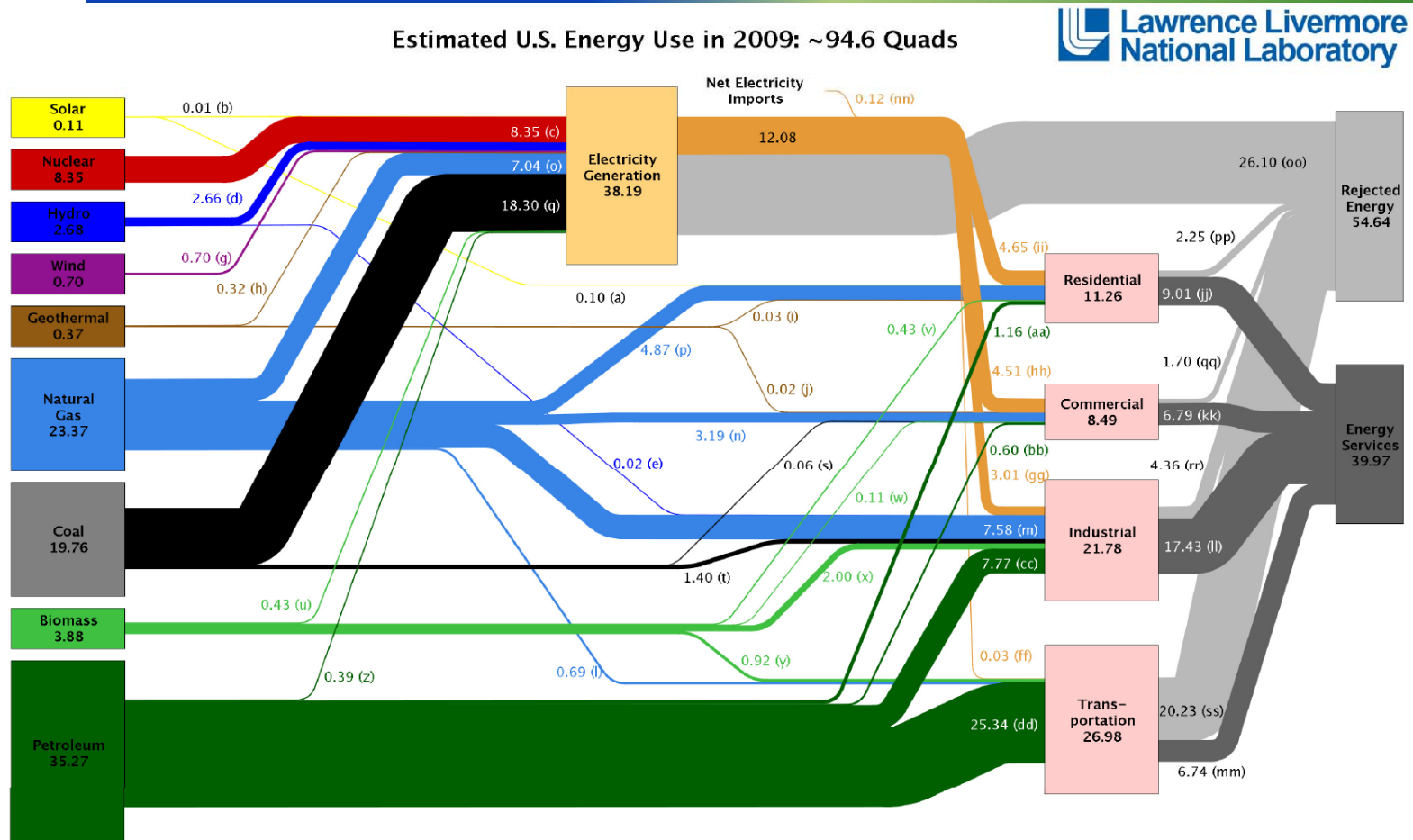
Promoting the efficient use of energy resources

Reducing carbon emissions to the environment

The U.S. Natural Gas Pipeline Network

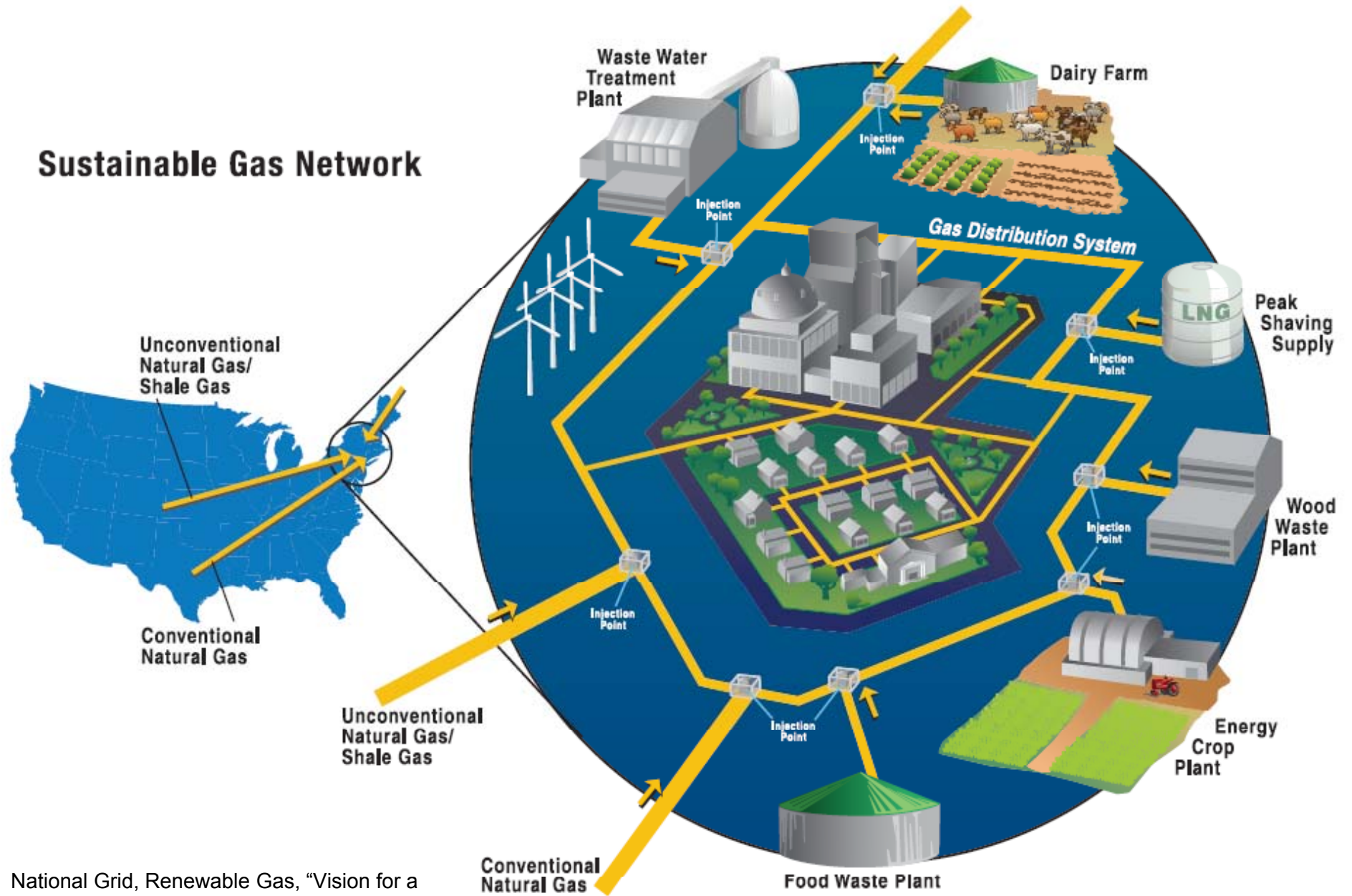


U.S. Energy Use Profile 2009



Source: LLNL 2010. Data is based on DOE/EIA-0384(2009), August 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Sustainable Gas Network



National Grid, Renewable Gas, "Vision for a sustainable gas network", 2010

Renewable Biogas is...

- > Methane produced from digesters
 - Animal manure (dairy cows, swine)
 - Waste water treatment facilities
- > Methane from Landfills
- > Bio-gas produced from thermal chemical processes like gasification utilizing renewable feed-stocks including forest residues and agricultural wastes.



RENEWABLE BIO-GAS CAN BE CLEANED-UP AND PLACED IN THE NATURAL GAS PIPELINE SYSTEM

Difference between “Conventional Gas and “Biogas”

- > Conventional gas is 95% - 98% methane (CH₄)*
 - Constituents are well understood
 - Utility and Interstate pipeline tariffs account for typical components
 - Methods for treating “raw” gas are proven and in-place
- > Biogas is also 95% - 98% methane*
 - Constituents are not as well understood
 - Utility and Interstate pipeline tariffs don’t typically address all components
 - Methods for treating “raw” biogas are still being analyzed

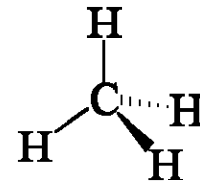
*Post clean-up. Methane percentage could be lower in some cases

Renewable Biogas Issues

- > Environment: CO, HCN, NH₃, phosphine, bacteria
- > End use:
 - CO₂, CO, H₂ > flame stability, engine knock,
- > Infrastructure / Pipeline integrity: CO₂, water, H₂ sulfur compounds, NH₃ bacteria, etc.
 - Siloxanes: silica formation
 - Emissions
- > Little analysis has been done on renewable biogas impact on fuel cells (early project results are just now coming in).

Major Hydrocarbon Constituents

- > Methane, ethane, propane, butanes, pentanes, hexanes, etc.
- > Found at % to ppm levels
- > Necessary for calculating gas heating value, specific gravity, and Wobbe Index
- > Specific hydrocarbon concentrations are not regulated
- > A typical tariff limit for BTU content is 950-1050 BTU/SCF (gross or HHV, dry)



Carbon Dioxide and Oxygen

- > Found at % to ppm level concentrations
- > CO₂ is naturally occurring
 - In the presence of water will form carbonic acid
 - Promotes corrosion if H₂S and O₂ are present
- > O₂ is not naturally occurring,
 - Usually present due to leaks, or otherwise artificially introduced
 - Supports colonies of sulfate reducing bacteria
- > Typical tariff limits are 1-2%v (CO₂) and 0.2%v (O₂)



High CO₂ flame / normal gas flame



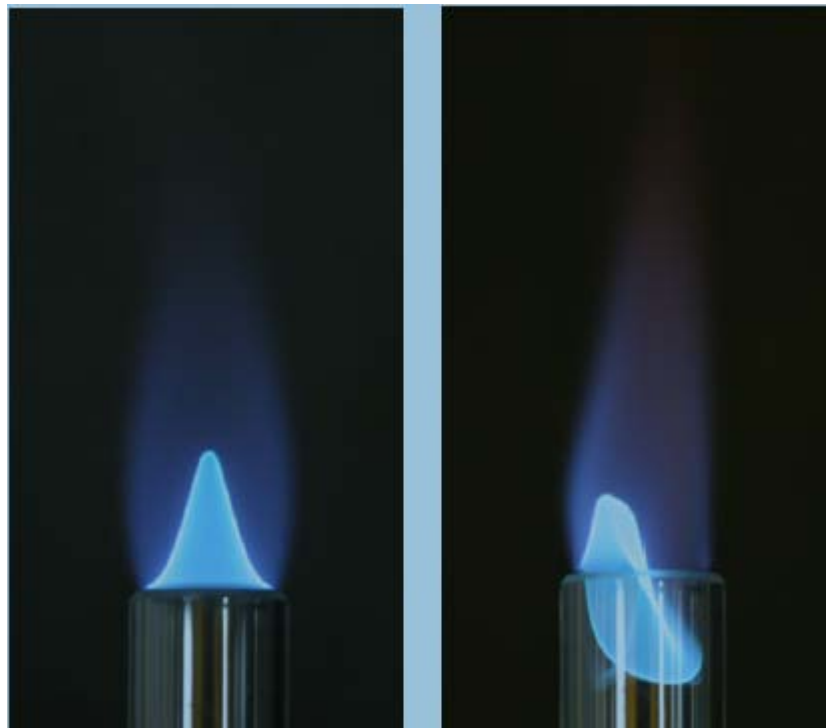
Gas with high CO₂ content



Pipeline quality natural gas

Amell, A. (2007). Influence of altitude on the height of blue cone in a premixed flame. *Applied Thermal Engineering*, 27 (2-3), 408-412.

Normal gas flame / High H₂/CO flame



H. Levinsky, KEMA, University of Groningen,
The Netherlands

Other Non-hydrocarbons (H₂, He, N₂)

- > N₂ is found at % to ppm level concentrations
- > H₂ and He can be found depending on the source environment and geology
- > Inerts are regulated because they affect the BTU value of the gas
- > A typical tariff limit for total non-hydrocarbons (H₂, He, N₂, CO₂, O₂) is 2-3 % by volume

Sulfur Compounds

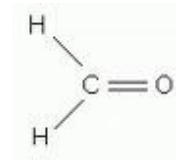
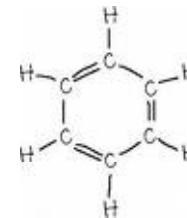
- > H₂S and other sulfur species found at ppm levels
- > Artificially added as an odorant to natural gas
- > In the presence of water, sulfur compounds can form corrosive acids, especially if O₂ is present
- > A typical tariff limit is 0.25 grain/100SCF for H₂S and 1 grain/100SCF for total sulfur

Halocarbon Compounds

- > Chlorinated hydrocarbons found at ppm levels in processed landfill gas, usually absent in natural gas
- > In the presence of water halogenated compounds can form corrosive acids, especially if O_2 is present
- > No natural gas tariffs exist for halocarbons

Volatile Organics

- > BTEX, aldehydes, ketones, VOCs and SVOCs on EPA target lists
- > EPA definition of a volatile organic:
 - Organic compounds with vapor pressure $> 10^{-1}$ Torr at SATP
- > Found at ppm levels
- > No natural gas tariffs exist

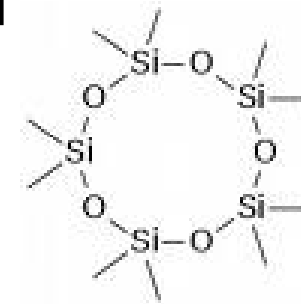


Ammonia and Amines

- > Not naturally found in natural gas but may be present due to gas processing efforts
- > Likely found in digester gas
- > Potential NO_x formation for end use applications
- > No natural gas tariff

Siloxanes

- > Found at ppm levels in raw and processed landfill gas, not typically found in natural gas
- > As silicon-containing waste streams are digested, silicon converts to siloxane compounds that volatilize and become entrained in the biogas, silicon dioxide is formed during combustion
- > One value under consideration for biogas is 0.4 mg Si / m³
- > Engine manufacturers may drive this value lower



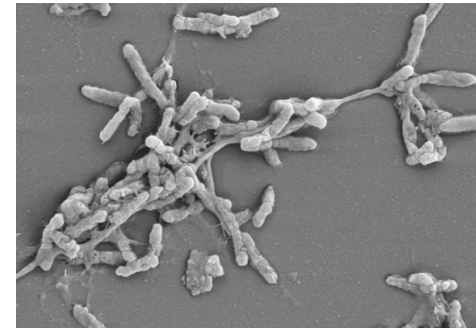
Mercury and Other Elementals

- > Found at trace levels in natural gas and processed landfill gas
- > Concentration depends on the source environment and geology
- > Other elements of concern are As and Sb
- > Metals may cause toxicological, environmental, and operational problems
- > A typical tariff statement is “gas delivered shall be free from any detectable mercury”



Bacteria and MIC

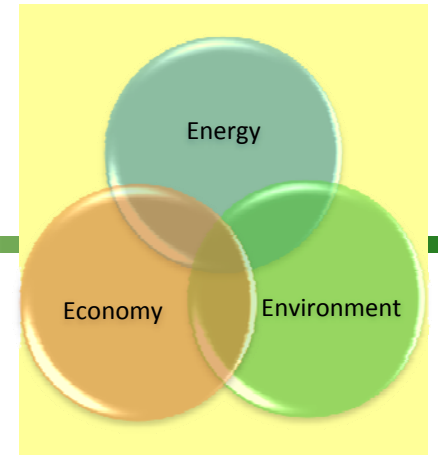
- > Found in natural gas and processed landfill gas
- > Some species produce acidic by-products which leads to microbially-induced corrosion (MIC)
- > Natural gas can contain 10^6 counts per 100 SCF, biomethane has similar numbers
- > Some LDCs want MIC testing done to validate the supply
- > No tariffs exist



GTI current project goals

- > Develop baseline for expected levels of various constituents in landfills
- > Analyze clean-up techniques (membrane, reactants, and PSA).
- > Future work:
 - Develop understanding of impact each constituent has on pipeline operations and end use applications
 - Provide data to gas utilities
- > GTI will not recommend pipeline quality specifications – up to each utility / pipeline

Summary



> Renewable Bio-gas

- Other than wind and solar, may be the lowest carbon renewable fuel available today
- Is referenced in a 2009 CARB report, which determined that bio-gas is the lowest carbon transportation fuel available
- Needs additional analysis to understand constituent components and their potential impact on pipeline operations and consumers.
- Needs additional analysis on clean-up methods.
- Can have a major national role in reducing carbon emissions and meeting renewable goals if incentives comparable to those for other renewable energy sources are enacted



**Creating
technology solutions
with **impact****

▼
**across the
energy spectrum**

*Thank you for being interested
in clean, reliable energy!*

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