the Energy to Lead

Renewable Natural Gas Clean-up Challenges and Applications

Renewable Resource Workshop

January 13, 2011

Washington, D.C.

Brian Weeks, Gas Technology Institute

281 235 7993, brian.weeks@gastechnology.org

gti

Today's Talk

- >Who is GTI
- >What is Renewable Natural Gas (RNG)
- >Challenges for Renewable Natural Gas
- >How do we clean up RNG?
- >Recommendations and Summary

GTI at a Glance…

- Not-for-profit research, with 65+ year history
- Facilities
  - 18 acre campus near Chicago
  - 200,000 ft^2, 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

Gas Quality and RNG Clean-up

A Sustainable Gas Network Will Include Renewable Sources

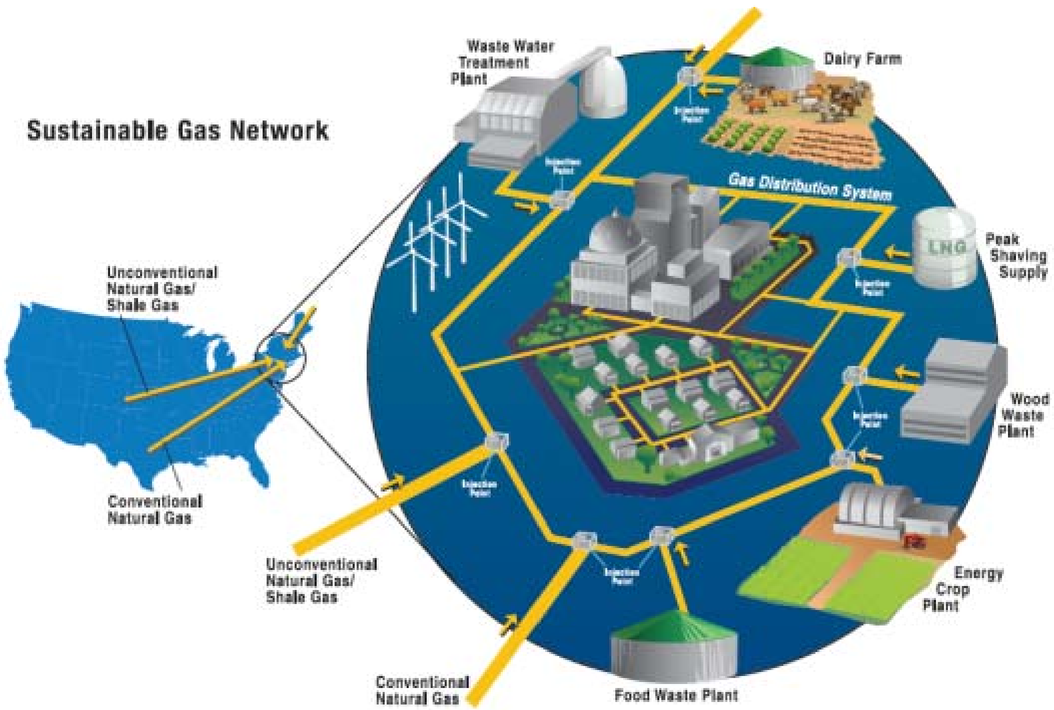
Gas Distributors increasingly asked to accept renewable gas.

Pipeline tariffs generally don't address "trace" constituents.

Existing clean-up methods are generally intended for on-site use.

Little data on impact of constituents on pipelines or end use equipment

Gas quality research also important for unconventional shale gas supplies.



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

gti

Renewable Natural Gas is…

- Methane produced from digesters
  - Animal manure (dairy cows, swine)
  - Waste water treatment facilities
- Methane from Landfills

- RNG produced from thermal chemical processes like gasification utilizing renewable feed-stocks including forest residues and agricultural wastes.

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

GTI RNG Project Examples

> Example GTI Projects:

– Gills Onions—Anaerobic digestion of agricultural waste for on-site electricity generation

– Altamont Landfill—Landfill gas (LFG) cleanup for production of liquefied natural gas (LNG) for vehicle fuel

– Ft. Lewis —Anaerobic digestion of waste water for production of hydrogen as a fuel cell vehicle fuel

– SCRA * – Landfill gas (LFG) cleanup and on-site reformation to generate hydrogen for MHE in S.C.

*Project pending final authorization

Difference between “Conventional Gas and “Renewable Natural Gas”

- Conventional gas is 95% - 98% methane (CH_4)*
  - Constituents are well understood
  - Utility and Interstate pipeline tariffs account for typical components
  - Methods for treating “raw” gas are proven and in-place
- RNG 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 can be costly

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

Existing Technologies Can and Do remove trace constituents from RNG

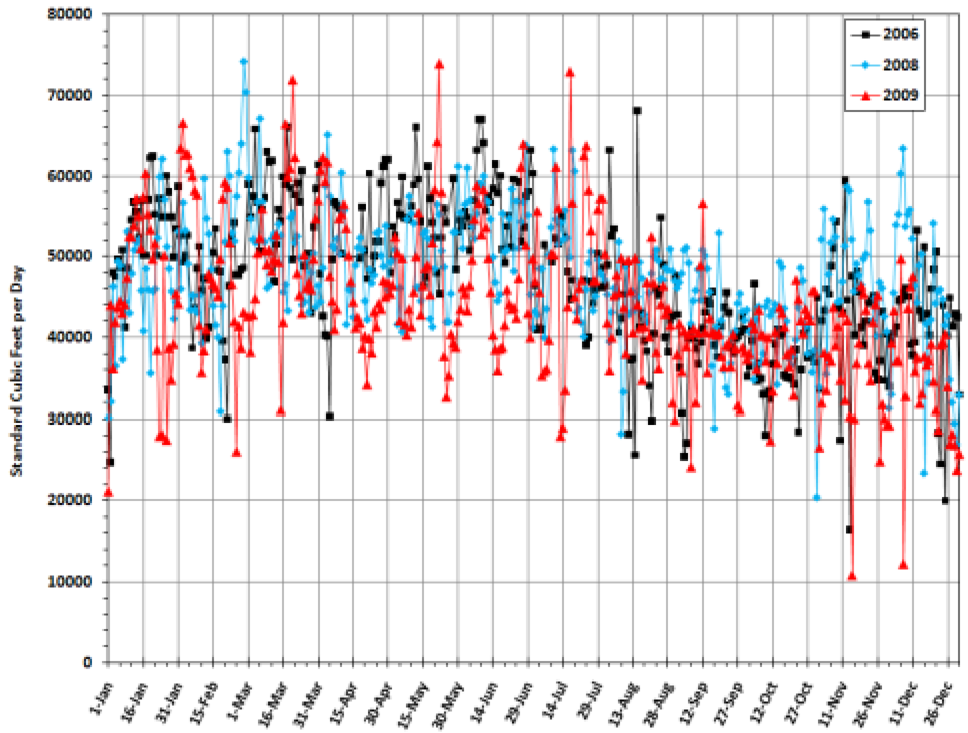
- CO_2 & O_2 found at % to ppm level concentrations. Tariff limits typical 1-2% (CO_2 & 0.2% O_2
- Sulfur Compounds (H_2S). Typical tariff is 0.25 grain/100SCF for H_2S and 1 grain/100scf total sulfur
- Inerts (N_2, He) and H_2
- Halocarbon compounds
- Volatile Organics (BTEX, aldehydes, ketones)
- Ammonia / Amines
- Siloxanes
- Mercury and Other Elementals
- Bacteria and MIC

Focus Areas for Improvement Renewable Natural Gas Utilization

- Supply Stability: Variability in composition & supply
- Impact on Infrastructure / Pipeline integrity: CO_2, water, H_2 sulfur compounds, NH_3 bacteria, etc.
- Impact on end use applications:
  - CO2, CO, H2 > flame stability, engine knock,
- Safety – Odorization & leak detection
- Contaminant Disposal – Cleanup media generally not recyclable
- Little Analysis has been performed on biogas for fuel cell applications

Supply Stability

- Volume variability introduces process configuration challenges
- Constituents can vary seasonally – or even more frequently
- Most stable supplies are dairy and swine yards



Daily WWDG Variability on a GTI ongoing project

gti

Why Treat RNG?
Impact on Pipeline Infrastructure

- Acid formation from sulfur compounds, carbonic acids, halocarbons or certain bacteria, promoting corrosion
- Deposits from contaminants
- Emissions from VOC's introduced into pipeline
- Water collection

Why Treat RNG?
Impact on End Use Applications

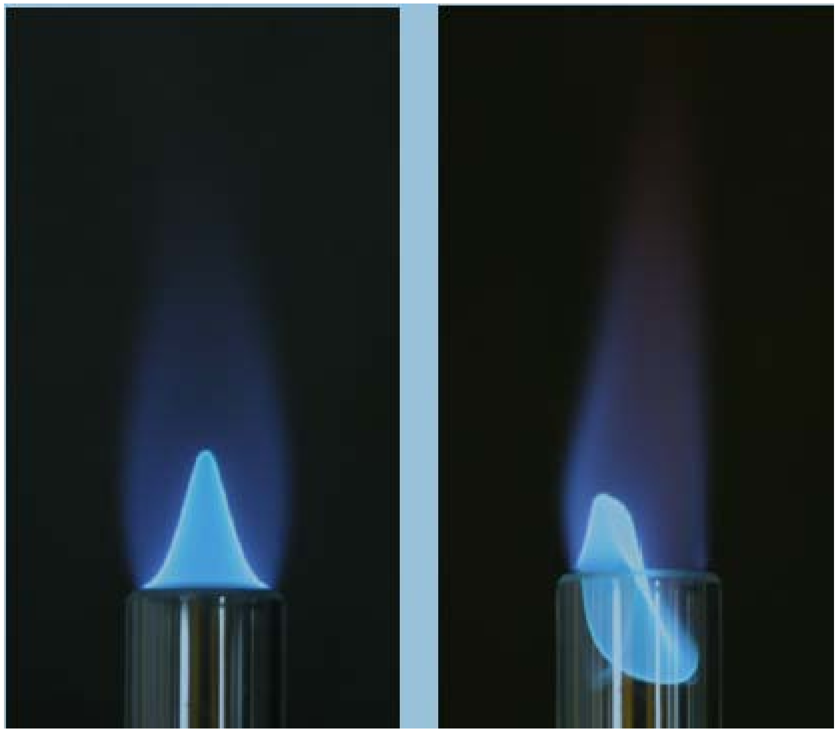
- Gas heating value / Wobbe number diminished by inerts in gas stream
- Deposits from contaminants
- Emissions from VOC’s introduced into pipeline
- NOx formation from ammonia compounds

High CO2 flame / normal gas flame

Gas with high CO_2 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

Why Treat RNG?
Impact on Fuel Cell Applications

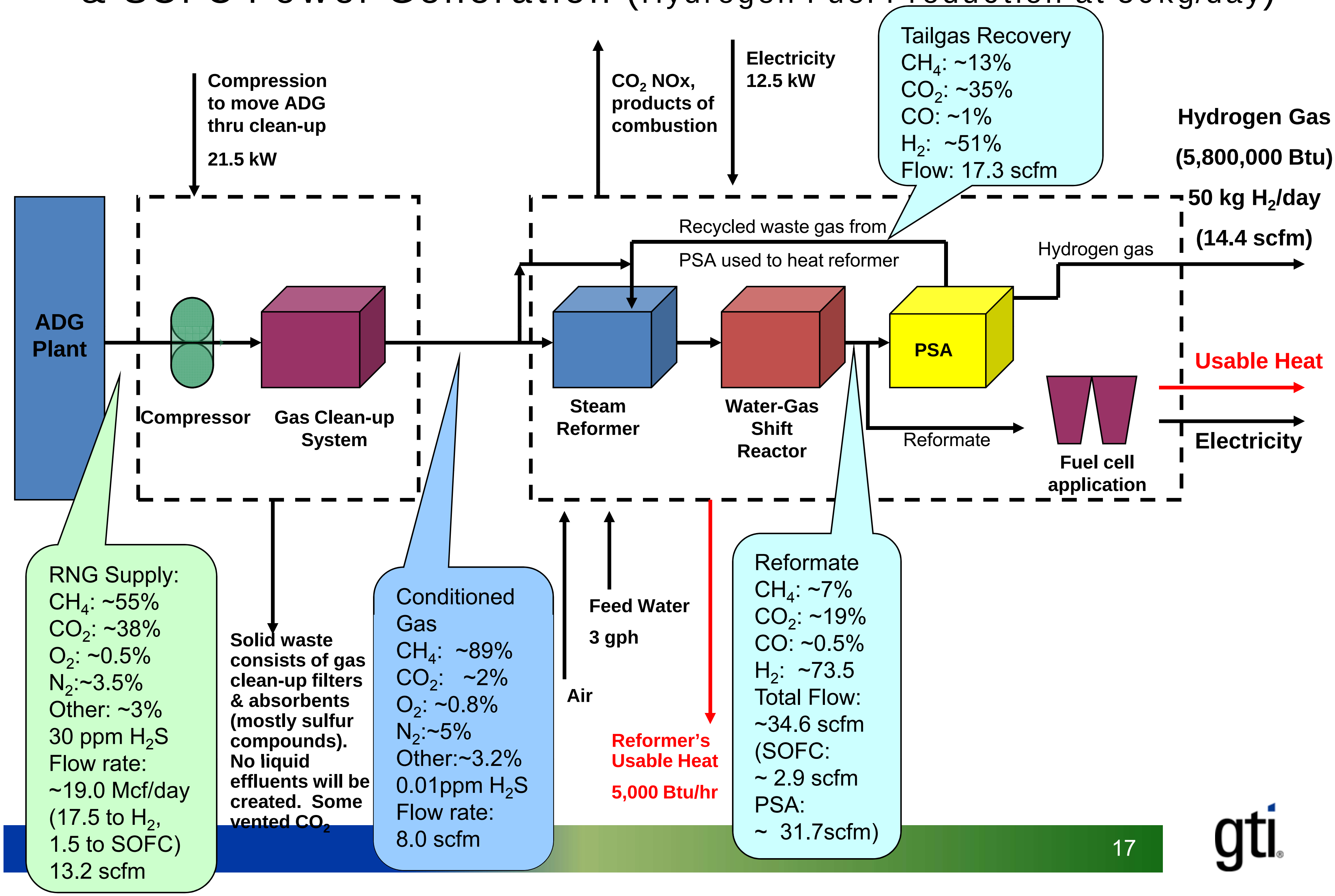
- **Impact on Reformer**
- **Impact on Fuel Cell**
  - VOC's – Coking
  - Sulfur compounds – catalyst contamination
  - Siloxanes – silica compounds can coat fuel cell component surfaces
  - Halogens (Chlorine, flourine, etc) – poison catalyst
  - Mercury and other elementals - catalyst poison and stack contaminant

gti

Now that we understand the problem, What's the solution?

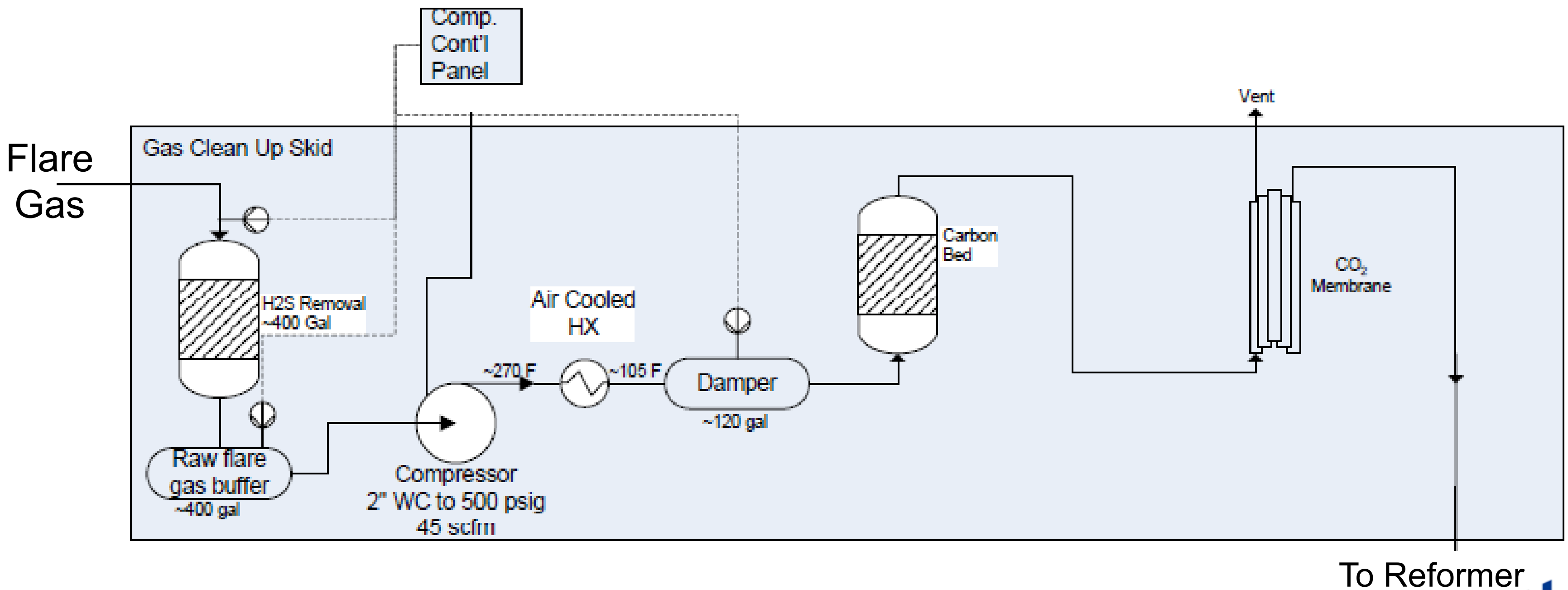
- Hydrogen generation system from RNG will consist of three key components
  - Renewable natural gas cleanup system (H_2S, CO_2, H_2O removal)
  - Biomethane reformation system (Steam-methane reformation—75-80% efficient)
  - Hydrogen Purification (remaining impurities removed including CO, CO_2,CH_4)

Illustrative Process Flow Diagram for On-site H_2 Supply System & SOFC Power Generation (Hydrogen Fuel Production at 50kg/day)



Example Gas Cleanup System for WWDG

- Configured a gas cleanup system utilizing a membrane module for CO_2 separation after H_2S removal
  - **Passive system – no moving parts, for increased reliability**
  - **Ease of operation – virtually no maintenance requirements**
  - **Ease of Installation – modular and lightweight and can be operated at wide turndown ratio**

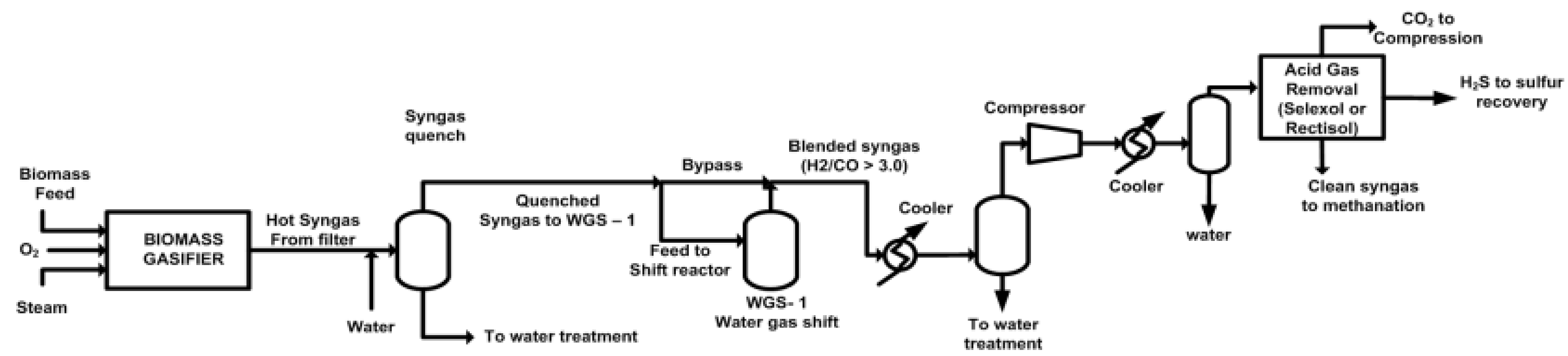


GTI's current project initiatives

- 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
- Utilities and Pipelines to take data and establish specification for their systems

gti

GTI Biomass to Renewable Bio-gas Process Simulation



SNG from Biomass: Biomass Gasifier, Water Gas Shift, & Acid Gas Removal Units

Commercial Systems Basis

- Oxygen-blown, pressurized fluidized bed gasifier (10 bar_a)
- Hydrocarbon reforming (including inherent CH_4)
- Sour water-gas shift to achieve H_2:CO >3
- Compression for commercial acid gas removal for CO_2 and S
- USDOE simulation for AGR used in process
- Two stage + trim methanation reactor
- Dehydration to achieve gas pipeline specifications

~ 70% conversion efficiency

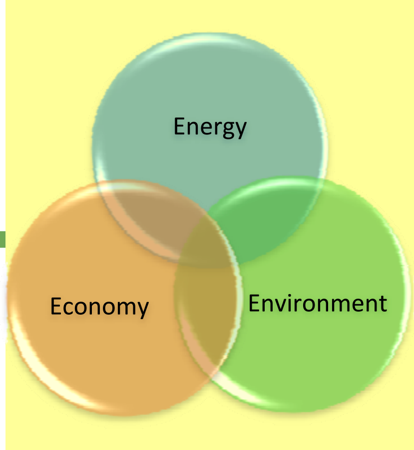
Removal of Trace Constituents
The Technology is here –need cost reduction

- Volatile Organics
  - Zeolites
  - Silica gel / adsorbents
- Sulfur compounds
  - Activated carbon
  - Zinc oxide
  - Other – biofiltering, hydro desulfurization
- Siloxanes
  - Adsorption on activated carbon bed
  - Absorption in solvents
  - Adsorption on polymorphous graphite

R&D Recommendations

- Develop resource baseline data to better understand digester gas and landfill gas production (volumetric and constituent variability and availability)
- Initiate data analysis for operation of end use equipment (including fuel cell) with various levels of contaminants found in biogas to establish operating parameters.
- Develop recycling technologies for gas clean-up techniques that can reduce O&M costs.
- Perform economic analysis on optimal end-use application for renewable natural gas; vehicle fuel, pipeline injection, electricity generation, etc.
- Build pilot gasification plant utilizing bio-feedstock

Summary



> Renewable Natural Gas

- Other than wind and solar, may be the lowest carbon renewable fuel available today
- RNG is being successfully injected into pipeline supply at over two dozen sites in the U.S.
- Additional analysis can help to reduce clean-up costs by better understanding constituent components and their potential impact on pipeline operations and consumers.
- Need to reduce costs of clean-up methods.
- Can play a major national role in reducing carbon emissions and meeting renewable goals if incentives comparable to those for other renewable energy sources are enacted

gti

Creating technology solutions with impact across the energy spectrum

Thank you for being interested in clean, reliable energy!

For more information:

Brian Weeks
Phone: 281 235-7993
brian.weeks@gastechnology.org