Renewable Natural Gas Clean-up Challenges and Applications

Renewable Resource Workshop

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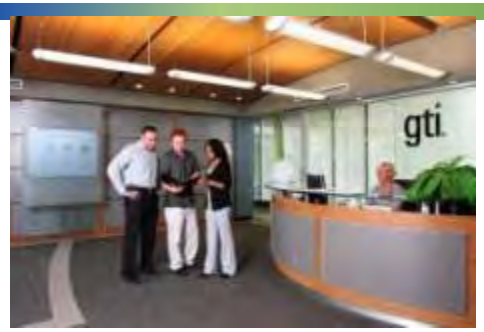
Today's Talk

- 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 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

Gas Quality and RNG Clean-up

A Sustainable Gas Network Will Include Renewable Sources

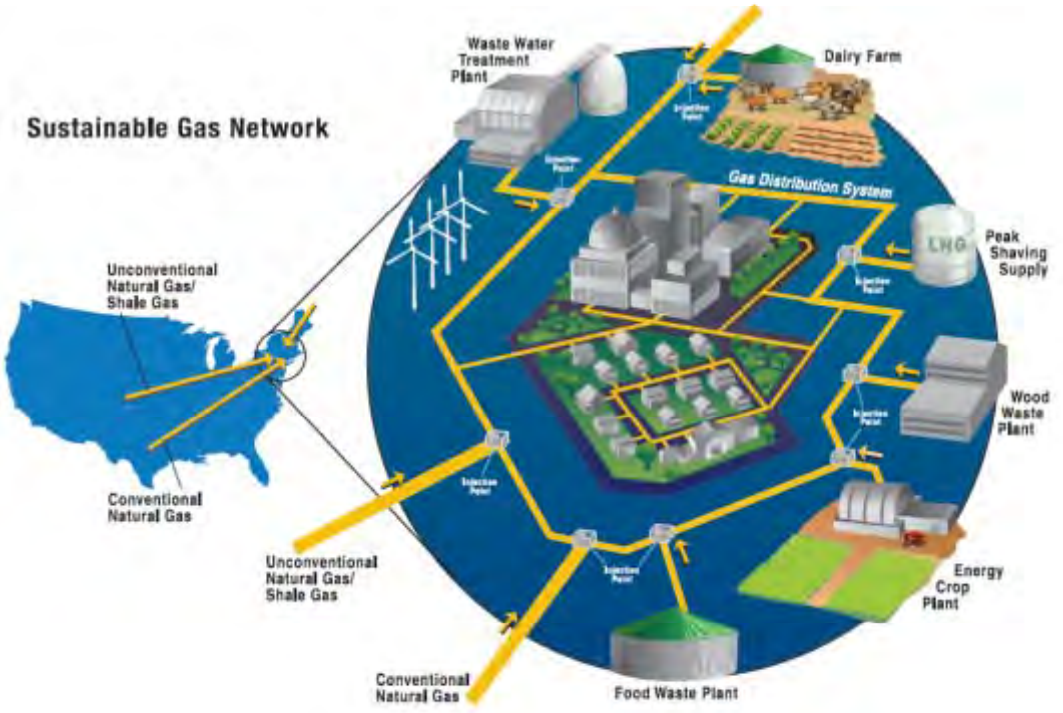
Gas Distributors increasingly asked to accept renewable gas.

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

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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

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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

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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

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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

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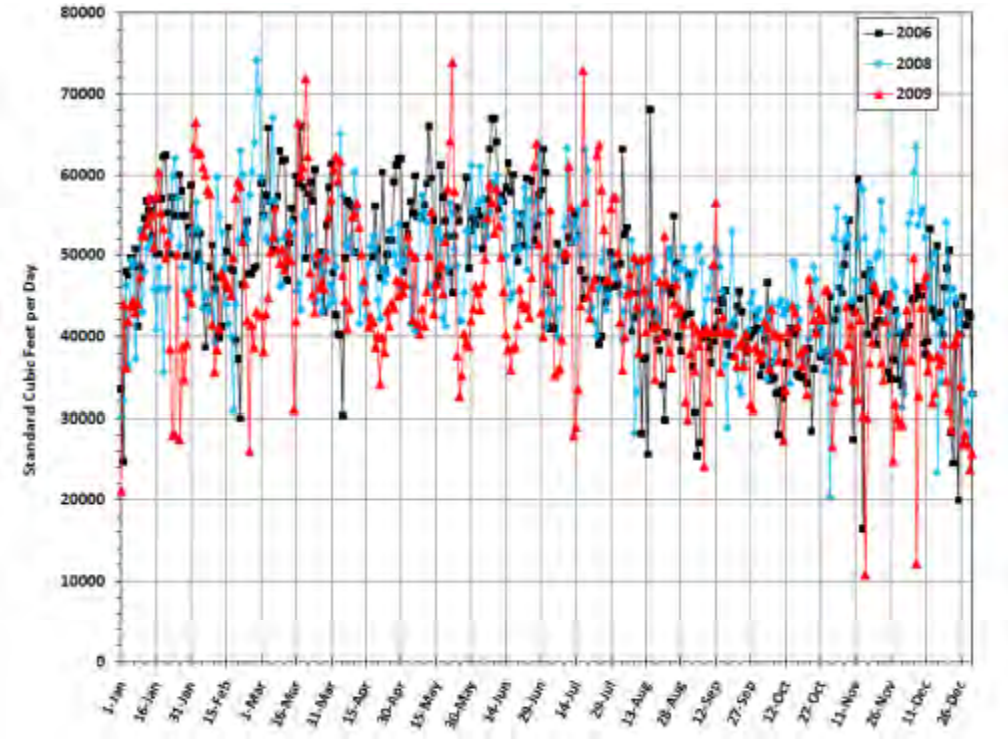
Supply Stability

- 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

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

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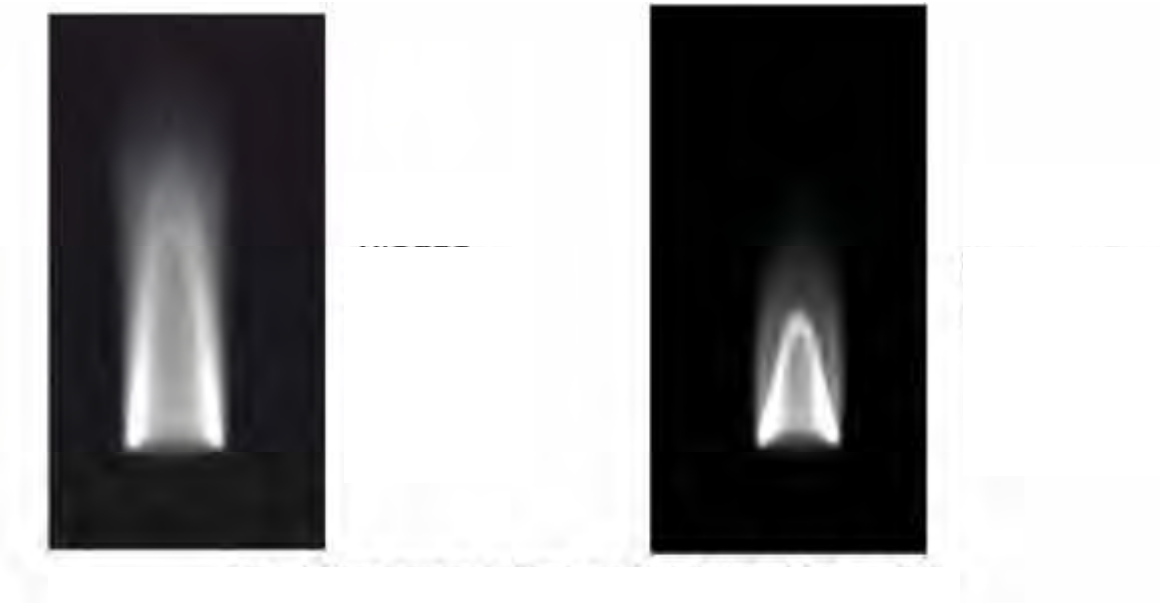
Why Treat RNG?
Impact on End Use Applications

- 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

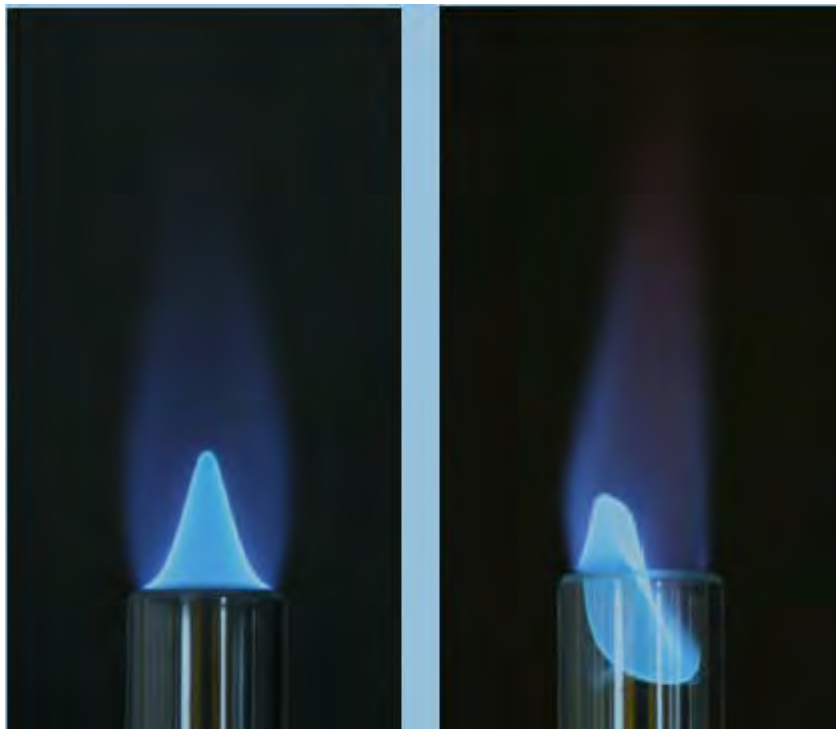


Gas with high CO_2 content

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

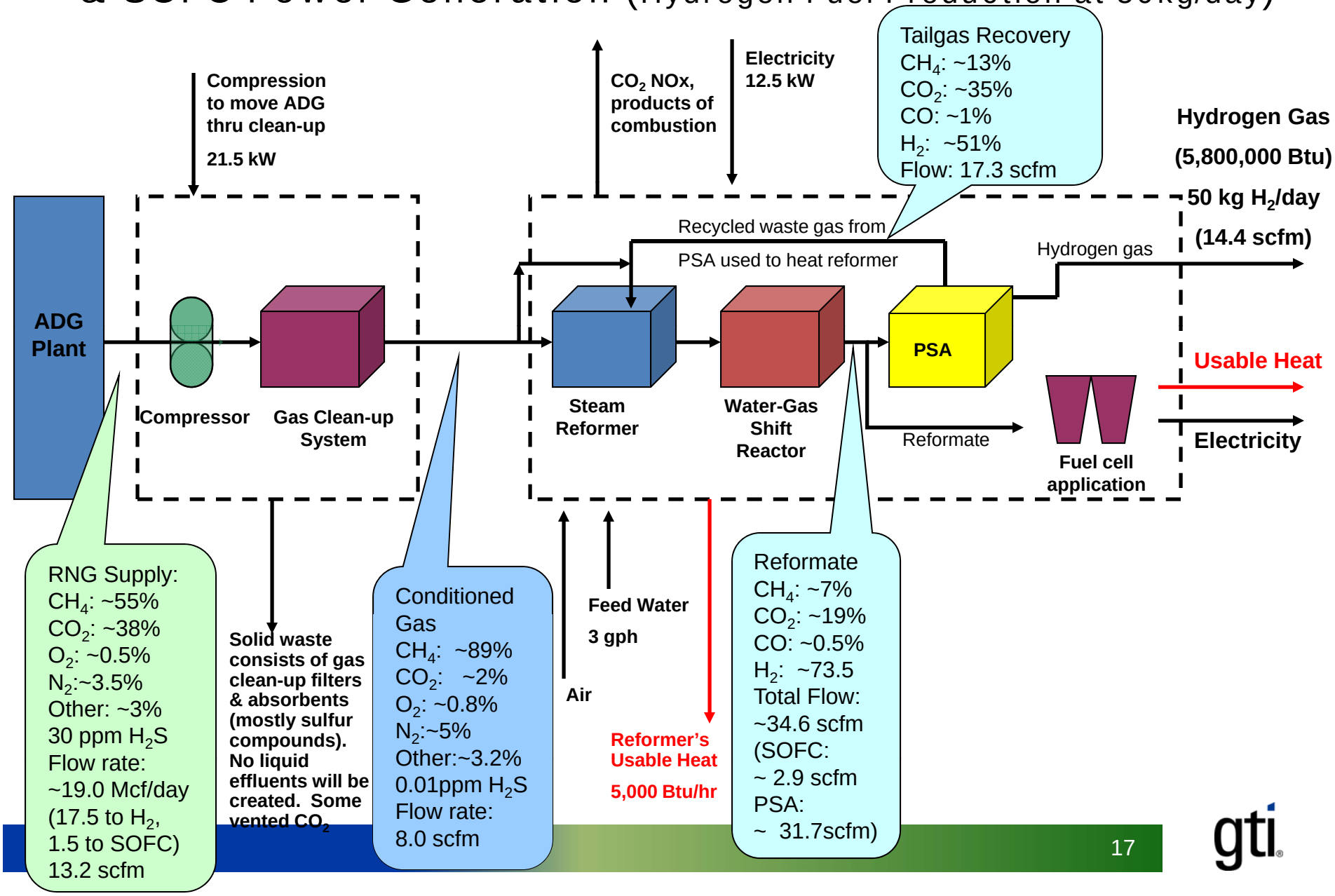
Why Treat RNG?
Impact on Fuel Cell Applications

- **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

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

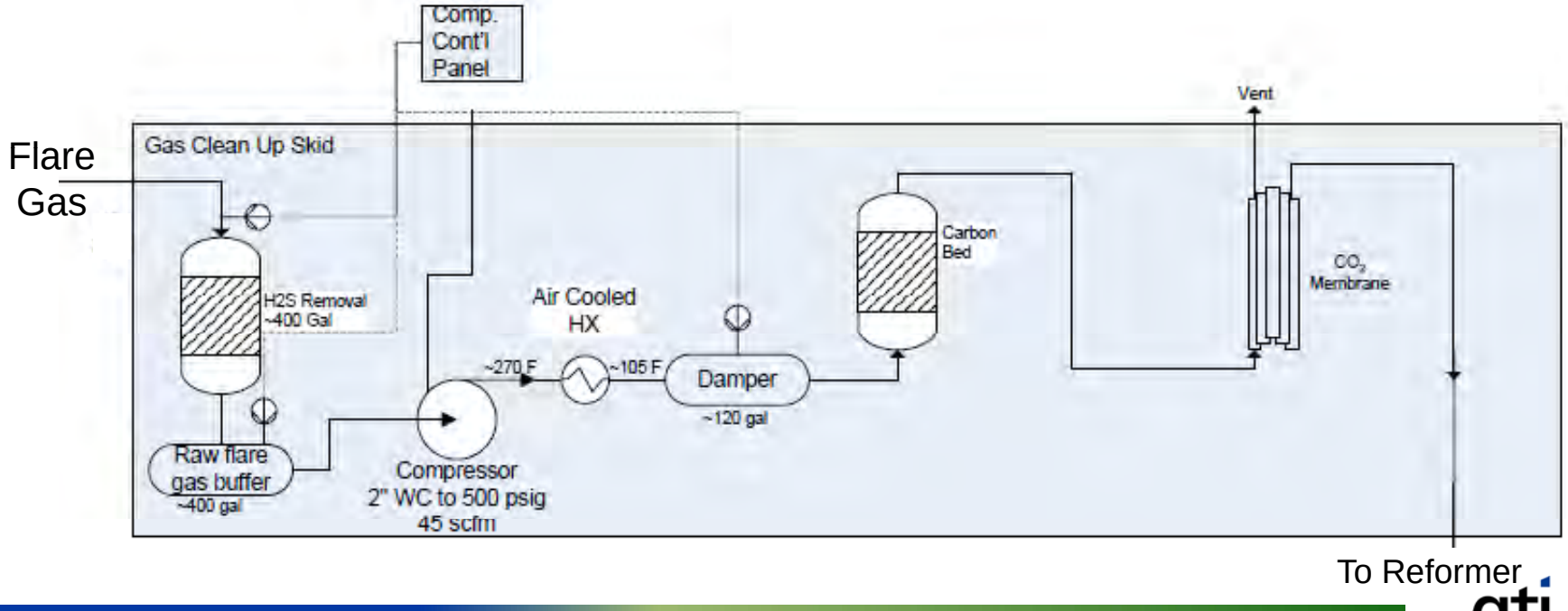
- Hydrogen generation system from RNG will consist of three key components
  - Renewable natural gas cleanup system (H_2S, CO_2, H_2O removal)
  - Biomethane reformation system (Steam-methane reformation—75-80% efficient)
  - Hydrogen Purification (remaining impurities removed including CO, CO_2,CH_4)

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

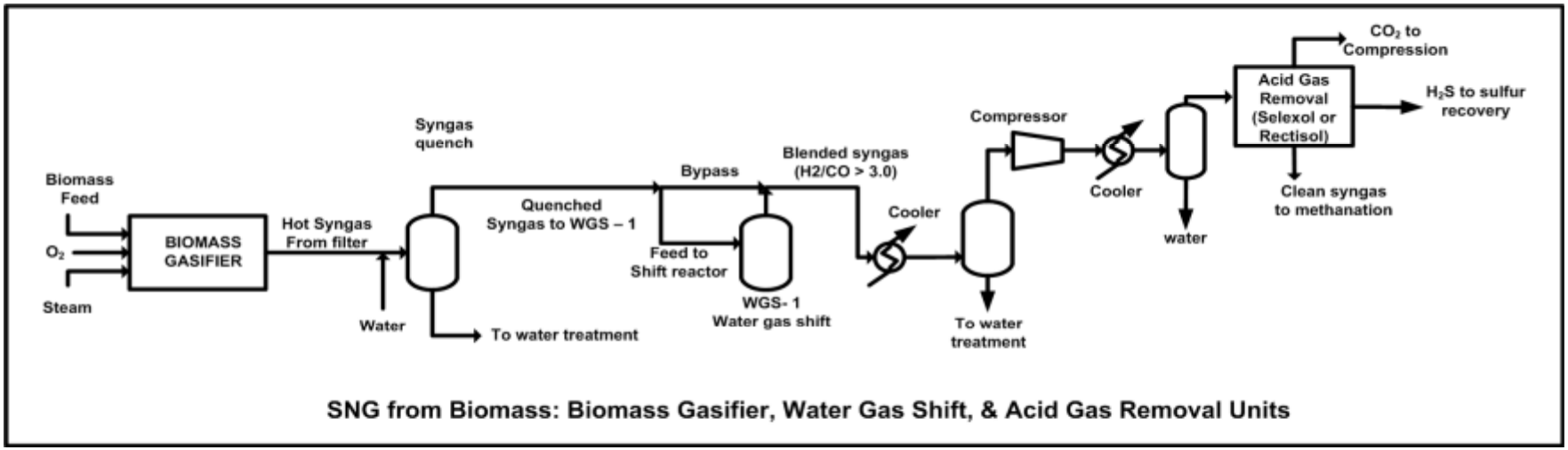
- Configured a gas cleanup system utilizing a membrane module for CO_2 separation after H_2S removal
  - **Passive system – no moving parts, for increased reliability**
  - **Ease of operation – virtually no maintenance requirements**
  - **Ease of Installation – modular and lightweight and can be operated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

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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

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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

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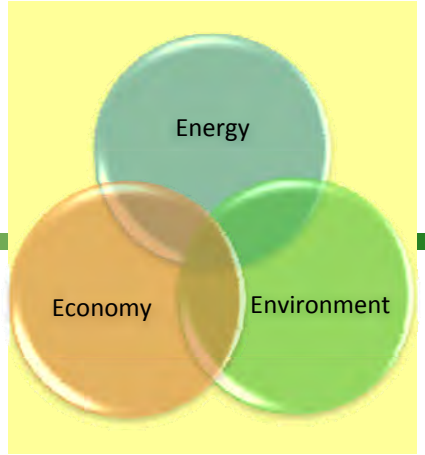
Summary



> 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

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Creating technology solutions with impact across the energy spectrum

Thank you for being interested in clean, reliable energy!

For more information:

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