GTI Gasification and Gas Processing R&D Program
Research, deployment and training for the Natural Gas Industry and energy markets

> 65 years, 1000+ patents, 500 products
> 18 acre campus, 200,000 ft² of lab and office space
> 50 years of Gasification R&D

1700 S. Mount Prospect Road. Des Plaines, IL 60018
**Goals**

> Increase the use of coal and biomass through the development, evaluation and commercialization of new gasification technologies.

> Develop and evaluate new technologies to clean/treat syngas for various end use applications.

> Integrate advanced gasification-based technologies with end-use technologies for production of power, fuels, and chemicals.

*Increasing Energy Supply with Advanced Processes to Convert Coal and Biomass to Power, Fuels, and Chemicals.*
Gasification and Gas Process R&D Expertise

> Advanced gasification systems

> Gas cleanup systems for sour gas and syngas

> Integration of syngas production and conversion

> Process simulation and techno-economic evaluations
GTI Energy Development Center
1951-1996

Scale-up and Investment History of GTI Gasification Technology

- **HP Biomass**
- **LP Coal**
- **HP Coal**

**Capacity, Tons/day**
- UGAS Pilot and PDU - Chicago (1970), 24 tons/day
- RENUGAS Chicago (1980), 8 tons/day
- Shanghai (1990), 10 tons/day
- Flex-Fuel (2000), 150 tons/day
- Skive, Denmark (2010), 400 tons/day

**Total Investments, US$ Millions**
- 0 (1970)
- 10 (1980)
- 40 (1990)
- 20 (2000)
- 40 (2005)
- 165 (2010)

**Locations**
- Skive, Denmark
- Shanghai, China
- Hai Hua, China
- Maui, Hawaii
- Finland
- Chicago
- Flex-Fuel
- UGAS Pilot and PDU - Chicago
Gasifier Projects

80 ton per day Gasification Pilot Plant in Tampere, Finland using biomass & coal

100 ton per day Bioenergy Demo Plant in Hawaii using bagasse

1000 ton per day U-GAS® Industrial fuel gas in Shanghai, China using coal

165 ton per day CHP Plant in Skive, Denmark using wood
GTI’s Flex-Fuel Test Facility: A Technology Development and Systems Integration Platform

- Flexible fuel capability
- Operational flexibility
- Plug and play systems integration and testing
Flex-Fuel Test Facility Overview

Features
- Coal - 10 tpd w/air; 20 tpd w/oxygen
- Biomass - 24 tpd w/air; 40 tpd w/oxygen
- Gasification Pressure to 28 atm
- Multi-contaminant Syngas Cleanup
- On-line Syngas Analysis Systems

Process Evaluations
- Hydrogen Production
- SNG Production
- CO₂ Capture Technologies
- Syngas-to-Liquids Production
- Advanced Power Conversion Systems
- Advanced Oxygen Production Systems
- Industrial Syngas End-Use

Commercial Operator Training
## GTI Projects Relevance to FutureGen

### FutureGen Gasification Technology and Systems Integration R&D

<table>
<thead>
<tr>
<th>Oxidant</th>
<th>Coal</th>
<th>Conversion</th>
<th>Gas Cleanup</th>
<th>CO₂ Separation</th>
<th>Co-Products</th>
<th>Power</th>
</tr>
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<tbody>
<tr>
<td>Gasification Systems</td>
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</tr>
<tr>
<td>Advanced Oxygen Separation</td>
<td>Advanced Coal Feeding</td>
<td>Advanced Coal Conversion</td>
<td>Advanced Gas Cleanup</td>
<td>Advanced CO₂ Separation</td>
<td>Other Technologies</td>
<td>Advanced Electricity Generation</td>
</tr>
</tbody>
</table>

- **Catalytic gasification for SNG**
- **Fluidized bed gasifier**
- **Advanced Compact Gasifier**

- **Siemens Novel Gas Cleaning**
- **UCSRP-HP Multicontaminant**

- **Morphysorb**
- **Membranes**

- **Fischer-Tropsch Liquids**
- **Hydrogen Membranes**

- **Coal-Based Hybrid Solid Oxide Fuel Cell**
Objectives of Selected Gasification and Gas Processing Projects

GASIFICATION

> bluegas® Catalytic Gasification (GreatPoint Energy): Produce low-cost substitute natural gas (SNG) from coal via catalytic gasification.

> Advanced Compact Gasifier (Pratt & Whitney Rocketdyne, GTI, DOE): Convert all ranks of coal to power and fuels at high efficiency and economy with an advanced entrained gasifier.*

> IGCC for India (USAID, Nexant): Support design of U-GAS® solution for advanced power production in India.

SYNGAS PROCESSING

> Novel Gas Cleaning Process (Siemens Power Generation, DOE): Remove hot syngas contaminants to ultra-clean levels for high-efficiency IGCC (fuel cell) and chemicals applications.*

> UCSRP-HP Multi-contaminant Process (DOE, ICCI): Develop a new, inexpensive process to remove and recover multiple contaminants in coal-derived syngas.*

*Projects with DOE participation
Objectives of Selected Gasification and Gas Processing Projects (2)

SYNGAS PROCESSING (cont’d)

> Acid Gas Treatment Pilot Plant (IL DCEO, GTI): Efficiently capture sulfur and CO₂ from syngas for acid gas and carbon management.

> Engineered Catalyst for In-Situ Elimination of Tar (DOE-EERE, GTI): Create a lower-cost, high-performing catalyst for tar reductions in biomass gasifiers.

> Hydrogen Production from Biomass Gasification (Xcel): Demonstrate membranes for H₂ separation from biomass-derived syngas.

SYNGAS CONVERSION

> Coal-Derived High-Hydrogen Content Fischer-Tropsch Liquids (Headwaters, GTI, DOE): Produce Fischer-Tropsch liquids from coal using iron-based catalysts.*


*Projects with DOE participation*
Acid Gas Treatment Pilot Plant

Value: Sulfur and CO₂ capture for low emissions and carbon management

> Sponsor: State of Illinois DCEO, GTI

> Scope
- Refurbish and Reconfigure the Acid Gas Treatment Pilot Plant for syngas application
- Integrate with FFTF for sulfur and CO₂ removal evaluation on syngas

> Status
- Equipment installed at FFTF in 2006
Ultra-Clean Syngas Process

Value: Syngas contaminant removal for high-efficiency IGCC (fuel cell) and methanol plants.

- Particulate < 0.1 ppmw
- Total S (H₂S, COS) ~ 1 to 5 ppmv
- Halide (HCl) ~ 1 to 5 ppmv

H₂S : 35 ppmv (9.3 lb/hr)
HCl : 250 ppmv (74 lb/hr)
Part. : 10,000 ppmw (1600 lb/hr)

Particulate < 0.1 ppmw
Total S (H₂S, COS) ~ 20 ppbv
Halide (HCl) ~ 10 ppbv
Hg ~ 50 to 70% removal (at 570°F)

Project Team: GTI, Siemens Power Generation, DOE-NETL
UCSRP Multi-Contaminant Process


- ‘Warm gas’ (>260°F) removal of multiple contaminants - sulfur, ammonia, HCl, mercury, other trace metals.
- Solvent with high temperature stability and high sulfur solubility.
- Sulfur removed as pure liquid product.
- Integrated loop to remove multiple other contaminants.

Project Team: GTI, University of California, ConocoPhillips, DOE-NETL, ICCI
bluegas® Catalytic Gasification

**Value:** Production of low-cost substitute natural gas (SNG) from coal.

- Sponsor: GreatPoint Energy

- **Scope**
  - Evaluate catalytic gasification for production of SNG from two potential fuels
  - Laboratory tests followed by pilot-scale tests in Flex-Fuel Test Facility

- **Schedule**
  - 18+ month program, started Jan 06
Pratt & Whitney Rocketdyne (PWR) Compact Gasification System

**Value:** High-efficiency, low-cost advanced gasifier to convert all coals to power and fuels.

Component Development & Pilot Plant

2004 - 2009

Pilot Plant Gasifier & Test Facility

Commercial Demonstrations (400 & 3000 TPD Gasifiers)

2007 - 2010

15% to 20% Lower End Product Cost from Improved Efficiency, Cost and Availability
## Gasifier Comparison

<table>
<thead>
<tr>
<th></th>
<th>GE Gasifier</th>
<th>Shell Gasifier</th>
<th>Conoco Phillips Gasifier</th>
<th>Transport Gasifier</th>
<th>PWR Gasifier</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital Cost</strong></td>
<td>Base</td>
<td>&gt;Base</td>
<td>Base</td>
<td>Base</td>
<td>&lt;50%</td>
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<tr>
<td><strong>Availability</strong></td>
<td>0.90</td>
<td>0.85 †</td>
<td>0.82 †</td>
<td>?</td>
<td>0.99</td>
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<tr>
<td><strong>Cold Gas Efficiency</strong></td>
<td>0.77</td>
<td>0.83</td>
<td>0.83</td>
<td>0.75</td>
<td>0.85</td>
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<tr>
<td><strong>Fuel Flexibility</strong></td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
<td>Poor</td>
<td>Good</td>
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<tr>
<td><strong>Product Flexibility</strong></td>
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<td>Fair</td>
<td>Fair</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

*Based on public domain reports through DOE NETL and Gasification Technologies Council*
Fischer-Tropsch Process Development Unit

Value: Coal-to-liquids from Illinois basin coal.


Participants: Headwaters, GTI, Nexant, Argonne National Laboratory, DOE National Energy Technology Laboratory, Department of Defense/Air Force

Scope:
- Design and build pilot-scale PDU to integrate with Flex-Fuel Test Facility - use existing gasifier, gas cleaning and conditioning systems to pre-treat the syngas
- Produce F-T liquids and wax for downstream refining and evaluation (5-10 bpd) (DOE and DOD/AF to evaluate)
  - Compare medium- and high-alpha catalysts
  - Compare slurry and fluidized bed operations
  - Test with syngas from various coals
- Train operating staff
Fischer Tropsch PDU Simplified Flow Diagram - Syngas Feed from FFTF
Conceptual Plan for Expanded Gasification Test Facility

- Oxygen supply
- SulfaTreat
- Morphysorb
- Rocketdyne Gasifier
- Labs & Offices
- SOFC Slipstream Stack
- Fischer-Tropsch PDU
Advantages of GTI Location

> Fast-track by integrating with existing facilities
> Existing gasifier for long-duration operation
> Flexibility in handling different fuels with air or oxygen as oxidant
> Existing gas cleaning and conditioning systems
> Facility already permitted
> Experienced scientists, engineers, and operators