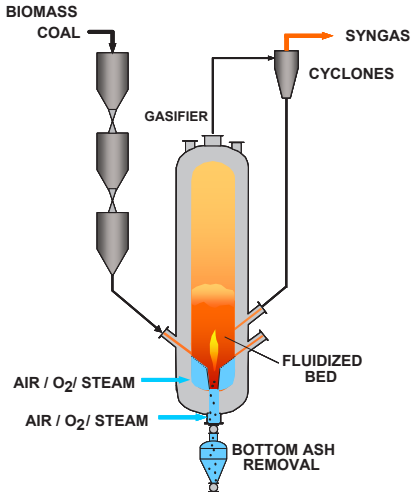
SunGas RENEWABLES

GASIFICATION TECHNOLOGY OVERVIEW

SunGas is accessing biomass conversion, gas quality, clean-up, and processing know how and technologies from GTI.

gti®



The GTI gasification technology has been developed and tested with over 25 different feedstocks from around the world including various forms of biomass.

SunGas Biomass Gasification

- **Bubbling fluidized bed gasifier developed for multiple feedstocks**
- **Applications for power, chemicals, and fuels have been tested**
- **Downstream gas conditioning developed to provide high-purity syngas**
- **Woody biomass feedstock commercial reference in operation since 2006 for combined heat and power with over 90% efficiency**
- **Integrated biorefinery configuration demonstrated wood to gasoline production over 1,000 hours of operation producing 10,000 gallons of gasoline**
- **Commercial systems have been designed for Fischer-Tropsch diesel and Renewable Natural Gas production**

The GTI gasification process is based on a single-stage fluidized bed for production of low-to-medium heating value synthesis gas or 'syngas' from a variety of feedstocks. Two versions of the process were developed more or less in parallel, with the U-GAS® technology developed for gasification of all ranks of coal and the RENUGAS® technology for gasification of highly reactive fuels such as peat, biomass, pulp mill residues and wastes. Through this development process it was determined that a single gasifier design could be used for all of these fuels, including mixtures such as biomass and coal. GTI's gasification process is an excellent technology for market applications requiring fuel gas or synthesis gas to produce or co-produce process heat, hydrogen, any gaseous or liquid biofuels.

In the GTI gasification process, fuel is dried to the extent required for handling purposes and conveyed into the gasifier from a lock hopper system. Within the fluidized bed, the fuel reacts with steam and air or oxygen at a temperature of 840 °C to 1100 °C (1550 °F to 2000 °F). The temperature for gasification depends on the type of fuel used and is controlled to maintain high carbon conversion and non-slagging conditions for the ash. The GTI process accomplishes four important functions in a single-stage fluidized bed gasifier. It decakes, devolatilizes, and gasifies fuel, and if necessary, agglomerates and separates ash from the reacting char. The operating pressure of the gasifier depends on the end use for the syngas and may vary from 3 to 30 bar (40 to 435 psia) or more. After cleaning, the product gas can be used as industrial fuel gas for process heating, synthesis gas for production of ammonia, hydrogen or liquids, and for power generation via IGCC or fuel cells.

Fuel is gasified rapidly within the fluidized bed and produces a gaseous mixture of hydrogen, carbon monoxide, carbon dioxide, water vapor and methane, in addition to hydrogen sulfide and other trace impurities.

Reactant gases, including steam, air and/or oxygen are introduced into the gasifier in two areas: 1) through a distribution grid at the bottom of the bed, and 2) through an ash discharge port at the center of the distribution grid. In both agglomerating and non-agglomerating operating modes, ash is removed by gravity from the fluidized bed and discharged into a lock hopper system for depressurization and disposal. In both operating modes, the gasifier maintains a low level of carbon in the bottom ash discharge stream, making overall carbon conversion of 95% or higher possible. Cold gas efficiencies of over 80% can be achieved.

Fines elutriated from the fluidized bed are typically separated from the product syngas by up to three stages of external cyclone separators, one or two of which may return the fines to the fluidized bed for increased carbon conversion. The product syngas is essentially free of tars and oils due to the temperature and residence time of the gases in the fluidized bed, simplifying downstream heat recovery and gas cleaning operations.

When used to gasify biomass or highly reactive wastes, an inert material such as sand, limestone or dolomite is used to maintain the fluidized bed. In this case, most of the ash from the fuel leaves the fluidized bed with the product syngas, with the bottom ash discharge serving primarily to discharge tramp material entering with the biomass or waste feed.

Due to its dry feeding system (as opposed to slurry or paste feeding), non-slagging operation and increased gas and solids residence times compared to entrained bed gasification technology, the GTI gasification process is capable of handling a wide range of fuels with a broad range of fuel properties (Tables 1 and 2).

TABLE 1. Fuel Flexibility Range of Feedstock Properties

Feedstock Property	Tested Range
Moisture Content, %	1 – 41
Volatile Matter, %	3 – 69
Fixed Carbon, %	6 – 83
Sulfur, %	0.2 - 4.6
Free Swelling Index (FSI)	0 – 8
Ash Content, %	0 – 41
Ash Softening Temp, T1, °C / °F	1045 – 1370 / 1915 – 2700+
Heating Value, HHV, kJ/kg / Btu/lb	12770 – 31600 / 5490– 13590

The GTI Flex Fluel Test Facility, Des Plaines, IL

TABLE 2. Feedstocks Processed in the GTI Gasification Process

Bituminous Coals

- Western Kentucky No. 9 , Providence (washed and run-of-mine)
- Western Kentucky No. 9 and 11, Camp
- Illinois No. 6, Peabody No. 10 and Crown III
- Pittsburgh No. 8, Champion and Ireland
- Australian, Bayswater No. 2, Sydney Basin
- Polish, Silesia
- French, Merlebach (run-of-mine)
- Utah (run-of-mine)
- Colombian
- Chinese, Shen Fu
- Indian, North Karanpura Coal Field (washed and run-of-mine)

Low Rank Coals

- Montana Rosebud, Colstrip
- Wyoming, Big Horn
- North Dakota, Freedom
- Saskatchewan Lignite, Shand

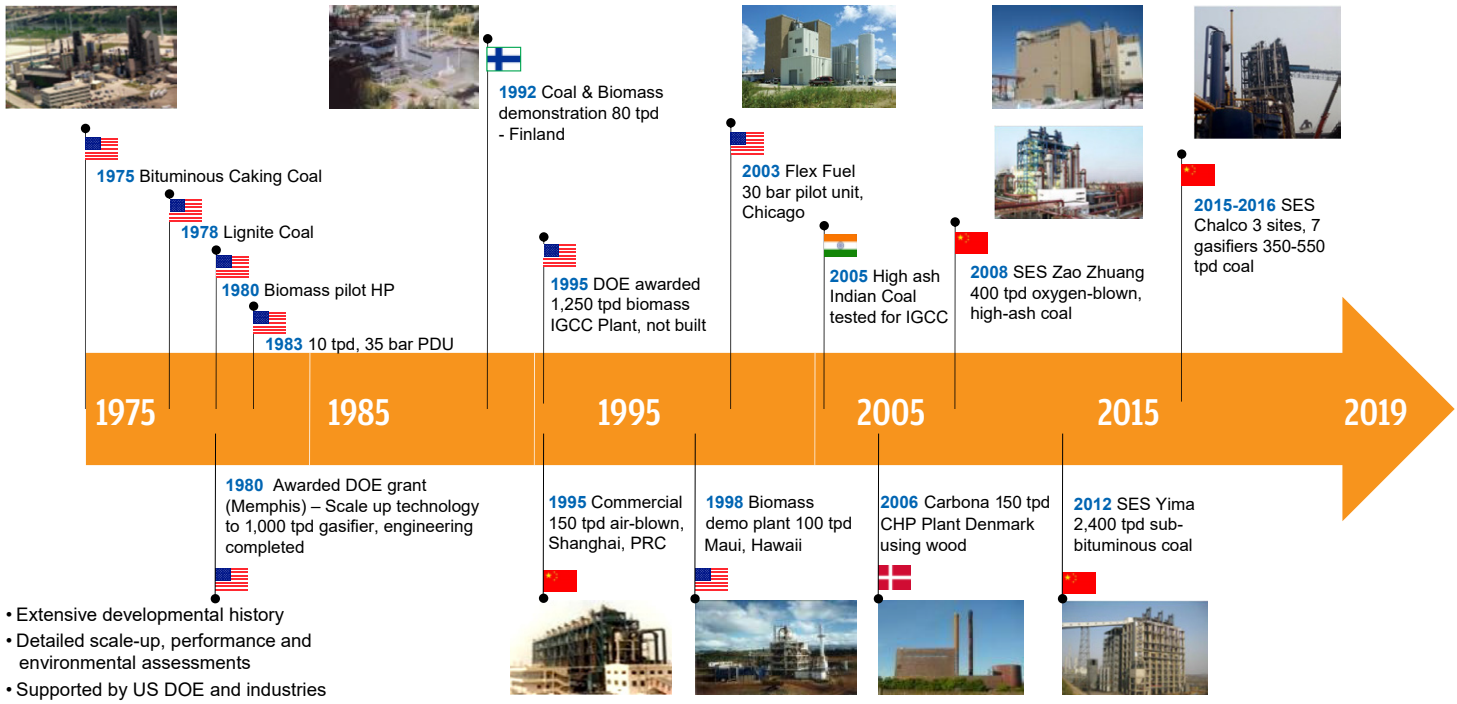
Coke, Char, Peat, Wastes

- Metallurgical coke, U.S. 'Bethlehem', Polish, and Chinese
- Western Kentucky No. 9 coal char
- Illinois No. 6 coal char
- Finnish Peat, Viidansuo and Savaloneva
- Automobile Shredder Residue

Biomass

- Hard wood and soft wood chips
- Forest Residue
- Waste wood and paper mill waste
- Bark
- Willow
- Straw
- Pelletized alfalfa stems
- Pelletized U.S. waste wood
- Bagasse
- RDF Pellets
- Oil Palm

GTI Fluidized Bed Gasifier Development



GTI Gasification Process Development History

Early development testing was conducted at near atmospheric pressure with low-volatile coal chars and metallurgical coke in a 24 ton/day pilot plant built in 1974. With support from the U.S. natural gas industry together with the U.S. Department of Energy (DOE) and its predecessor agencies, the process development was extended to encompass pressurized operation at 60 psia with caking bituminous coals from 1977 through 1980. During this time, over 125 air, enriched-air, and oxygen-blown test campaigns were conducted in the GTI Pilot Plant, with more than 3,000 tons of a wide variety of coals processed in over 11,000 hours of operation. In 1983, a 5 ton/day, 300 psia process development unit (PDU) was designed and built, with modifications in 1985 bringing the operating pressure up to 510 psia. A total of 39 air, enriched-air and oxygen blown test campaigns were conducted in the PDU at pressures ranging from 115 to 465 psia. Over 80 tons of bituminous, subbituminous and lignite coals were processed in 2000 hours of pressurized operations, including in-situ desulfurization testing with limestone injection to the fluidized bed.

In 1989, the GTI gasification technology was licensed to Tampella Power Inc., who built a multi-fuel pressurized pilot plant in Tampere, Finland to further develop and demonstrate the technology for air-blown IGCC power generation with coal and biomass. This fully integrated plant included all gasification island components from fuel preparation through waste heat recovery and hot gas clean-up. Gas generated in the plant was combusted in a heat recovery boiler producing district heat for the city of Tampere. The facility processed up to 42 tons/day of coal and 60 tons/day of biomass at pressures up to 435 psia. The plant logged 3,800 hours of operation with 5,900 tons of fuel processed in 26 test runs. The tested fuels include coal (Polish, Colombian, coke, German lignite) and biomass (wood, paper mill wood waste, forest residue, willow, straw, alfalfa) and mixtures of coal and biomass. At the end of demonstration tests the plant was decommissioned and is no longer operated.

In the early 1990's, GTI developed a commercial-scale gasification project in China based on the U-GAS technology, a coal-fueled variant of the GTI gasification process. Located in a coal-based chemicals production complex in the Wujin Chemical Industry Area southwest of Shanghai, the plant includes eight parallel, low-pressure, air-blown gasification trains producing fuel gas from Chinese Shen Fu bituminous coal. The fuel gas was used to fire an existing battery of coke ovens, freeing up the higher heating value coke oven gas for blending into town gas. Each train of gasifiers processes about 150 tons per day of coal and produces 500,000 Nm3/day of fuel gas. Commercial operation started in 1995 and by 2001, the plant had logged over 77,000 hours of gasifier operation, processed over 220,000 metric tons of coal, and produced over 1 billion Nm3 of fuel gas for commercial use. This plant was mothballed due to a lack of demand for the town gas and has since been demolished.

Thousands of hours of testing and over a decade of reference commercial operations provide technical confidence in the GTI-developed direct bubbling fluidized bed gasifier.

Technology developed over 40 years to handle waste biomass materials from agricultural residues to wood wastes to refuse-derived fuel.

FOR MORE INFORMATION

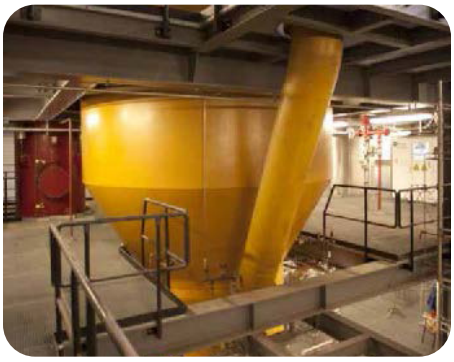
Robert Rigdon
CEO
rrigdon@sungasrenewables.com
+1 281.841.5717

David LaMont
Senior Vice President,
Business Operations
dlamont@sungasrenewables.com
+1 847.636.9780

Dan LeFevers
Vice President of Business
Development
dlefevers@sungasrenewables.com
+1 443.758.5129

Commercial Deployment Projects

Woody Biomass



The GTI gasification technology was deployed in a biomass application in Skive, Denmark in 2008 and the plant is still operational today providing 12 MWth of district heating and 6 MW of electric power using wood pellets as the fuel. At the Skive gasification project in Denmark, GTI's bubbling fluidized bed (BFB) gasifier is used to produce gas from wood-based biomass. This gas is then cleaned catalytically and used in IC engines in a combined heat and power (CHP) application. The heat is consumed in the local district heating network and the electricity is sold to the grid.

Deployments in Asia

Hai Hua

On October 22, 2006, Synthesis Energy Systems Inc. (Gasifier Licensee for coal) signed a co-operative joint venture contract with Shandong Hai Hua Coal & Chemical Company Ltd. (Hai Hua) for the development, construction and operation of an approximately $25 million syngas production plant utilizing U-GAS® technology in Zaozhuang City, Shandong Province in China, as well as a contract for the purchase and sale of syngas and other gasification byproducts (ash, elemental sulfur, hydrogen and argon). The plant is designed to produce approximately 28,000 standard cubic meters per hour of gross syngas. Construction of the plant was completed in the third quarter of 2007 and the plant is now in commercial operation.

YIMA

In April 2009, SES finalized a joint-venture agreement with Yima Coal Industry Group Co., Ltd. (YIMA), a company partially owned by the Chinese government, for the construction of an approximately $250 million integrated coal-to-methanol plant in Henan Province, China. The total cost represents the estimated capital expenditures for both the gasification and methanol portions of the plant. The Yima plant is a 2 operating + 1 spare U-GAS® gasifier configuration. It processes low-grade coal to produce 300,000 tons of refined methanol per year. The plant was commissioned in December 2012.