



8310 S. Valley Hwy; STE 285
Englewood, CO 80112
Phone: (303) 867-4247 · Fax: (844) 270-1821
www.TCGEnergy.com

TCG Global Gasification System

Overview

TCG Global LLC (TCG) designs, builds, sells, owns, and operates gasification plants capable of converting any carbon-containing feedstock such as biomass, coal, petroleum coke, or municipal solid waste into synthesis gas (Syngas), consisting primarily of hydrogen (H) and carbon monoxide (CO). The Syngas produced by this gasification process is a clean, dry, flexible fuel which can be (1) burned to create heat and electricity, (2) passed through any of several different catalysts to produce fluids such as alcohols and transportation fuels, including clean burning diesel, or (3) used to supply pure hydrogen gas for multiple applications.

The TCG technology was created and developed by Mr. Marcus Wiley, a registered professional engineer with 40 years of experience in mine engineering and management. He was also the co-owner of multiple bore-hole mining and gasification process patents, including all patent-protected technology utilized by TCG.

A short video introduction to TCG technology can be found at: <https://tcgenenergy.com/about/media/>

TCG Gasification Process

Gasification is accomplished with heat, pressure, and the injection of ionized water. The basic chemical reaction used in gasification is $C + H_2O = CO + H_2$. This process begins in an externally and internally heated, oxygen-starved environment (known as the pyrolysis chamber), which drives off moisture and volatile gases contained in the feedstock. Pyrolysis produces carbon char and ash that moves

into a separate, externally heated gasification reactor, which converts the solid carbon molecule into a gaseous state. Next, the injection of ionized water in a process known as steam reformation creates a water shift reaction to produce Syngas. The hot Syngas is water quenched and cleansed of its impurities in a proprietary, ionized water treatment system, thus delivering a clean, dry Syngas with minimal liquid discharge from the plant operation.

It is important to note that the TCG process is not a typical gasification process, which requires the injection of oxygen for the reaction: $2C + O_2 + H_2O = CO + H_2 + CO_2$, nor is it heated by internal feedstock combustion which is represented by $C + O_2 = CO_2$. Conventional gasification plants produce high amounts of carbon dioxide in their internal combustion processes. The externally heated and internally heated recycle systems of the TCG process actually reduces CO₂ through the following reaction: $CO_2 + C = 2CO$, and does not utilize internal combustion in the process.

Very Low Emissions Footprint

The TCG Global technology focuses on the prevention of harmful pollution from carbon utilization, rather than removing pollution resulting from conventional combustion. Since the feedstock is heated internally and externally, no feedstock combustion by-products are released into the atmosphere, nor are they present in the Syngas produced. All feedstock is processed in an enclosed and sealed reactor allowing contaminants to be efficiently captured and disposed of in



ash collectors or through water scrubbing processes. Pollutants such as sulfur, arsenic, and mercury typically present in many feedstocks are not released into the atmosphere in this process design, as they would be in a combustion-centric process.

TCG gasification features a unique, low emissions footprint:

- Syngas is clean and cool as it exits the gasification process.
- The gasifier fully utilizes or recycles the process water such that the facility has a near zero liquid discharge, which liquid discharge levels vary depending on how much moisture is present in the inlet feedstock.
- When the gasifier utilizes its own Syngas output to fire the burner, the resulting emissions are lower in NOx and CO2 than when burning natural gas.
- The gasifier can capture and recycle flue gas, including carbon dioxide (CO2), from the external burners, to provide exterior heating for the reactor.
- Ash recovered from the system can be further processed to recover elements contained in the ash, and/or the ash can be used in production of cement or used as a fertilizer. A portion of the ash can be recovered as a bio-char and used as a soil amendment, which provides for carbon capture and sequestration in addition to improved crop performance.

Unique Design

The TCG gasifier design is unique in many respects:

- Flexible feedstock. Feedstock with high or low moisture content can be utilized. Virtually any type of coal can be utilized, including low rank coals, coal high in moisture and other impurities, or a blended fuel including other organics along with coal. Biomass, municipal solid waste, and tire-derived fuel can also be used for waste-to-energy projects.
- No pulverization or slurry injection is necessary.
- If make-up water is required (used to derive oxygen and hydrogen for the plant), it can contain some impurities e.g. discharge water from other manufacturing facilities or water from any municipal or well source.
- Separation and injection of oxygen is not required.
- Utilizes an injection of ionized or singlet oxygen molecules (O) to enhance the chemical reaction.
- Flexible production of various mixes of gases. Demonstrated delivery of a higher hydrogen ratio than other commercial gasifiers. It's also capable of varying the production of hydrogen depending upon the desired hydrogen to carbon monoxide ratio.
- Various process and support systems in modular design, shop fabricated. Able to be constructed offsite, disassembled, and delivered via over-the-road trucks to any remote location.
- No ceramic refractory brick is required, thus reducing cost, maintenance requirements, and downtime.

Economic Advantages

A TCG gasification plant can provide an attractive risk-adjusted return on investment due to its superiority of design:

- Designed for high conversion efficiency from feedstock to Syngas, but in commercial-scale, real-world testing, ***efficiencies exceeding 89%*** have been documented by Department of Energy funded research. Additionally, TCG's design has a 16%-20% production advantage when producing syngas, as compared to other internally-fired gasifiers.
- A large air separation unit (ASU) for oxygen is not required.
- Minimal requirements for crushing or drying of the feedstock.
- Additional water pre-treatment requirement is not required, since water treatment and recycling is an integral part of the process itself.
- Additional Syngas cleanup equipment for combustion biproducts is not required since syngas cleanup is an integral part of the process.
- Most all system components are designed for over-the-road and standard shipping container legal load shipments. Off-site construction and re-assembly on-site ensures that site-driven labor availability will not impede rapid implementation.
- Gasification system only, has a relatively small footprint of less than 250' x 250',
- TCG plants can be put into operation on a compressed schedule and can be operational in 12 - 24 months – typically half the time required by competing solutions.

Implementation Options

The TCG gasification process can use virtually any carbon-based material such as coal, crop and forest waste (biomass), other waste products such as petroleum coke from refineries, old tires (TDF), or municipal solid waste (MSW) as a feedstock. The design capacity for one TCG installed plant utilizes 500 tons per day of dry feedstock; plants using high moisture content feedstocks, such as biomass, have a higher design capacity. Depending on the moisture content of the feedstock, additional water may be added to provide the source of oxygen and hydrogen needed for the reaction.

With high quality coal as the feedstock, one 500 ton-per-day plant has the following range of output capabilities:

1. Generate up to 55 megawatts of electricity or
2. Produce up to 25,000 gallons of liquid fuel daily or
3. Produce up to 100,000 gallons of mixed alcohols daily or
4. Deliver 30 million standard cubic feet of hydrogen and CO, or
5. Supply a combination of electricity and fuel products depending on the customer's needs.

Multiple TCG plants can be combined for a higher capacity at a lower cost and construction lead time of a single, large conventional gasification plant.

Environmental Impact and benefits

The TCG Technology focuses on the prevention of harmful pollution from carbon utilization rather than addressing pollution as an aftermath of combustion. The TCG GLOBAL Gasifier has proven its ability to be flexible in the production of various mixes of gases. It has produced more hydrogen than other commercial gasifiers, with syngas levels up to 86% hydrogen, but is also capable of varying the production of hydrogen depending upon the desired hydrogen to carbon monoxide ratio.

Ash is recovered from the system's filter press in a semi-solid form. This ash can be further processed to recover elements contained in the ash, and can be used in production of cement, used as a fertilizer, or placed in a land fill - all of which provide for permanent carbon dioxide capture and sequestration. A portion of the ash can be recovered as a bio-char and used as a soil amendment, which provides for carbon dioxide capture and sequestration in addition to improved crop performance.

4-year Track Record as a Demonstrated Technology

A reference plant based on TCG technology was manufactured to handle in excess of 175 tons per day of coal or petroleum coke and was put into commercial operation in 2007 in Denver. The plant was moved to The University of Toledo, proving the portability features of the plant, which was dismantled, shipped, and placed back into operation in less than 90 days. Since its startup in May of 2008, the Toledo plant has demonstrated the ability to produce high quality, clean Syngas from a variety of coal, petroleum coke, and biomass feedstocks. In December 2009, a US Department of Energy (DOE) grant of nearly \$20 million was awarded to the Toledo facility. This grant is intended to demonstrate the capability for conversion of biomass to diesel using the TCG gasification technology to make Syngas for reaction with a catalyst to produce liquid fuels.

Patent Protection

The TCG gasification process integrates several individual technologies to convert carbon-containing feedstock to Syngas. The patents and pending patents underlying the gasification technology are owned by Thermo Technologies, LLC and licensed to Thermo Conversions, LLC, with which TCG Global has an agreement to develop, own, and operate gasification plants. TCG's technology relies on seven individual U.S. patents totaling over 800 claims, and it is also protected by a South Africa patent covering the identical technologies and set of claims.

Links and References:

- [1] Additional information on TCG Global, LLC can be found on our website: www.tcgenergy.com
- [2] Additional information on gasification: www.gasification.org

Comparison of various technologies and reports on the implementation of Thermo Technologies process

- [3] Western Governor's Report – Assessment of Bio-alcohol Fuel Production Technologies, and Gridley Bio-fuels Project Report: <https://www.osti.gov/servlets/purl/1324758>
- [4] Additional information on bio char: <http://www.biochar-international.org/biochar>
- [5] Coal Without Carbon report (page 26): https://www.catf.us/resource/coal-without-carbon/coal_without_carbon/