Technology Overview

Renewable Natural Gasification - RNG:

RNG is an advanced thermal conversion technology that uses an innovative and proprietary process to convert organic matter into a high-quality, renewable form of natural gas and char products. The RNG technology is designed to operate within a modular architecture that allows solution scalability from low to very high daily waste stream tonnages. Capable of processing 20-250 tons of biomass, RNG reduces your carbon footprint by turning discarded materials into a high---value form of energy with limitless applications.

PYROLYSIS+

The majority of gasification systems currently on the market use partial oxidation – heating the material in an oxygen-starved environment – to convert feedstock into a low-BTU syngas. Since the amount of air used to break down the material can vary from 25-40 percent, both the quality of the syngas and the cleanliness of the operation can vary substantially from one technology to another.

RNG uses a patented form of pyrolysis – a cleaner form of gasification that superheats feedstock without introducing outside air – to break down the material at a molecular level. Operating at temperatures that can exceed 1800 -- 2000 degrees Fahrenheit, RNG has the same effect as thermal oxidizers used to destroy pollutants.

Because the feedstock is heated indirectly, no outside flame ever touches the material as it is being converted inside the RNG system. By combusting gas instead of solid feedstock, RNG is cleaner than competing systems while still producing a high-quality form of renewable natural gas , leading us to dub the system 'pyrolysis plus'.

How It Works:

The RNG system is a two-stage process that uses high-temperature pyrolysis in addition to a proprietary catalyst and innovative gas conditioning system that eliminates oils and tars produced in the process.

Feedstock

RNG can process a variety of feedstock including:

- RDF
- Wood, sawdust, etc.
- Grasses, biocrops
- Tires
- Coal
- Non-recyclable plastics
- Auto shredder residue
- Certain industrial waste

Feedstock is preprocessed to remove any metals (ferrous and non-ferrous), inert materials (rocks, stones, bottles, etc) and dried to less than 10 percent moisture content. A grinder ensures feedstock is sized to approximately one inch.

Thermal Conversion

From the pre-processing area, the feedstock enters the thermal conversion unit on a conveyor belt. The first chamber of the unit quickly heats the material to temperatures exceeding 1800 -- 2000 degrees Fahrenheit while in the presence of a catalyst. At these high temperatures the feedstock is broken down

to its basic elements and pollutants are destroyed. The catalyst helps hydrogen and carbon atoms reform into longer chains to create desired gases. Unlike partial oxidation gasifiers, no outside air is permitted, and the absence of combustion prevents additional pollutants from being formed.

After just 90 seconds in the first Thermal Conversion Unit (TCU), roughly 60 percent of the converted gas and 40 percent of the solid material moves to the second TCU. In the second TCU the gas endures a longer residence time at a lower temperature. This extra residence time allows for fine-tuning of the chemical process. Temperatures in the second chamber vary based on feedstock but typically range between 900-1400 degrees Fahrenheit.

Waste heat from the first chamber is utilized in the second chamber, raising the efficiency of the process.

Gas moves from the second TCU to a condenser where a proprietary gas conditioning system is used to flash cool it. Cooling the gas condenses the oil vapor, tars and particulate matter into the liquid. Temperatures will drop more than 1,000 degrees in less than a second and the rapid cooling keeps toxins from reforming.

Any particulate matter that has not been removed by the condenser will be captured in the exit gas filter before the gas leaves the system. At this stage, clients can **choose** to compress and store the gas or use it in a suitable application. RNG recommends a small amount of low---pressure storage at the very least so that the gas can blend, resulting in a more homogenous mixture, needed by most applications. At this point the gas is ready to be used for a variety of applications including electricity generation or steam generation.

Liquid Tar

A positive differentiator and unique attribute of the RNG system is its ability to handle the tar production that has slowed down other systems. RNG's proprietary method of flash cooling rapidly condenses tar and other particulate matter into a liquid and removes it from the gas.

RNG's design is engineered to take advantage of every available BTU of waste energy in order to deliver a superior return on investment. The tar oil, which might be discarded with other competing processes, is converted back into a gas and fed into gas burners to provide the indirect heat to the thermal conversion chambers.

These small gas burners produce the *only* air emissions for the RNG system, similar to a natural gas boiler.

Residual Char

There will always be a small portion of material that is unable to be converted to a gaseous fuel, regardless of the feedstock and regardless of the technology employed. This solid matter is passed through the thermal conversion chambers and comes out as residual char. The amount of char produced will vary by feedstock but can be as little as four percent by weight of the feedstock going into the RNG process.

Clients using the system for resource recovery may wish to adjust the process to augment the levels of valuable components that make up the char in an effort to increase its energy value. Fine-tuning can be done with the control system that comes standard with the RNG unit. Additional information can be provided upon request to those interested in using RNG system for resource recovery.

Control System

Each RNG unit comes with an inline, gas chromatograph (GC) that continually monitors the system. The GC will collect information on parameters by taking gas samples and operating data from a

number of points every three minutes. RNG will assist in setting the controls as part of the commissioning process and the unit can adjust temperature and residence time in response to feedback from the system. Similarly, the control system will automatically shut down if it detects changes that could harm the gas quality, the RNG unit, or emissions. If the system shuts down it will notify the operator, the facility's control command, and RNG headquarters via text. Engineers from RNG can log onto the system remotely to run diagnostics and assist in troubleshooting.

Specifications

INPUTS	
Capacity	20 – 35 tpd for a single unit (preprocessed and dry)
Feedstocks	RDF, wood, sawdust, grasses, bio-crops, tires, coal, non-recyclable plastics, industrial waste, auto shredder residue
OUTPUTS	
Energy Value of Gas	600 – 800 BTU/SCF
Gas Volume	300 – 500 SCFM
Electric Output (Gross)	1 – 1.4 MW
Electric Output (Net)	800kW – 1.2 MW (plastics higher)
Char Residue	4 – 21% *
OPERATING CHARACTERISTICS	
Maximum Operating Temperature	1800˚---2,000ºF
Tar Removal	99.9%
PHYSICAL	
Size (RNG Unit Only)	30' x 30' in addition to the material handling and energy use application, which is specific to the customer.
Weight	30,000 lbs.
Modular	Yes, additions come in 35 tpd or 100 tpd configurations.
EMISSIONS	
NOX	Configured to match local requirements.
SOX	Configured to match local requirements.
CO	Configured to match local requirements.
Particulates	Configured to match local requirements.

Applications

The high quality of RNG's gas allows for a broad scope of applications. Since each project is different, the chemical composition of feedstock becomes important in determining the quality of the gas and best options for its application. Feedstock blending and/or the injection of organic liquids can boost the amount of methane in the resulting gas chemistry and is an economical option for some projects.

Generally, gas from RNG can be used in the following ways:

Thermal Applications

Using the gas from RNG for thermal applications is putting simplicity into motion. The high BTU gas can be used in an unmodified, off-the-shelf industrial boiler to heat water or create steam. Many times, this can be the most cost-effective way to use RNG's output and is an affordable solution for industrial plants ranging from plastic manufacturers to food processors.

Predicting the economic return of a project can be easily done by creating a mass and energy balance for the project.

Creating steam can take a lot of the guesswork out of the economics of potential projects. The heat rate can be determined by creating a mass and energy balance for the project. Detailed information about creating a mass and energy balance for projects can be provided upon request.

The amortized cost of the installed unit plus the cost of capital is the capacity cost. The feedstock cost will be positive if it is displacing a tip fee or if you have to pay for it. Operating and maintenance costs are a function of each specific application.

Electrical Applications

Multiple methods can be used to generate electricity with RNG gas. Some of these include:

- Combusting gas in an internal combustion engine
- Generating pressurized steam for use in a turbine to produce electricity
- Direct drive of a gas turbine
- Co---firing with natural gas in a combustion engine

RNG is able to utilize a number of feedstocks to produce a high-BTU gas that will satisfy a number of our client's needs. For others, blending feedstocks can be done to achieve the required gas specification.

For those choosing the internal combustion engine route, RNG offers a turnkey solution that provides everything from the feedstock input to the switchgear needed for linking generated electricity to the grid or a private internal Micro-grid. The design allows RNG to be one of the lowest cost thermal conversion units on the market and represents a breakthrough in biomass waste-to-energy technology.

As each application is unique, total project cost and associated returns can vary widely. RNG is available to assist developers with the process to determine the economic viability of a potential project. Additional information about our three- step process for determining project viability can be provided upon request.

Resource Recovery

The secret of turning a profit in waste to energy is in deriving the most value from the feedstock. Certain waste streams have high-value residual components that, when collected, can provide additional areas of revenue aside from the gas.

Examples of this include high concentrations of potassium from chicken litter, fixed carbon from MSW and biochar from organic biomass.

RNG allows you to fine-tune the chemical process to optimize for energy production, resource recovery or a combination thereof. Instrumentation that comes standard with each unit measures gas chemistry on a continuous basis and is able to self adjust temperature, residence time, feedstock blending ratios, etc. in order to achieve specific output targets.

Benefits:

RNG uses a superior design to create a higher quality gas. Better gas yields economic and environmental benefits, while superior design creates a modular system that can grow alongside your business.

Environmental

Biomass conversion technologies are designed to be a cleaner alternative to land-filling or incineration. As permitting standards vary by region and emerging technologies vary greatly on emissions outputs, the industry as a whole has earned an inconsistent reputation.

RNG has an excellent emissions profile and is proud to advertise its results. Due in part to the unit's superior design to burn its own gas, instead of solid fuel; to generate the high temperatures used for conversion, Tucker RNG is able to avoid producing additional harmful emissions. The absence of a direct flame in the conversion process also enables Tucker RNG to stay cleaner, thus avoiding typical backend cleanup procedures that can plague partial-oxidation systems.

The first commercial project for RNG was permitted in 60 days in a non-attainment zone in Charlotte, N.C. and this is representative how easily this system can go from concept to permit.

Modular

RNG's unique design allows clients to grow the system alongside their business. RNG's modular architecture facilitates continuous or increased operational time during scheduled or unscheduled maintenance periods, ensuring steady revenues and minimizing waste-stream storage space requirements.

Shipping and assembly complexities are also minimized with RNG's modular approach. Our original design processes 20-35 tpd, depending on feedstock, and a 100 tpd system is also in the design stage. Units can be added in 35 tpd or 100 tpd increments.

By starting small, clients can minimize risk and then add capacity with operational success. The scalable design will appeal to potential financiers weary of investing tens of millions of dollars in a large, unproven technology.