

# METHANE POWER



**Canadian  
Green Energy Technology**  
- CGET -



2018

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# Canadian Green Energy Technology



Methane Power Overview



# Thermo Chemical

- Pyrolysis - 200-600°C, no added O<sub>2</sub> or oil products
- Combustion - 2000 °C, ample O<sub>2</sub> ,CO<sub>2</sub> + H<sub>2</sub>O
- Gasification - 600-1000 °C, limited O<sub>2</sub>, producer or syngas
- As feedstock is reduced to char and ash, the air flow is increased to burn off the char (highest points in

PC Temp profile SC-T and PC-T) and NO<sub>x</sub> and SO<sub>2</sub> emissions fall to near baseline levels

**STAGE 1**



*Waste Loaded afterburn chamber heating up.*

**STAGE 2**



*Waste begins to gasify and fume travels into high resolution afterburn chamber.*

**STAGE 3**



*Towards end of burn cycle the waste mass and ash reach 1,000° C. Ash is bleached white by heat.*

# Waste To Energy Technology

This technology known as the CatOx Gasification

Unit

Has been successfully tested and approved

by the United States Environmental Protection

Agency

**report number EPA/600/R-08/127**

# Waste To Energy Technology Application

- Municipal Solid Waste
- Power Generation
- Forestry waste
- Environmental Cleanup
- Damaged crops
- Hazardous Waste Disposal

# Waste To Energy Technology

Generation Units are:

Green Energy

&

Carbon Neutral

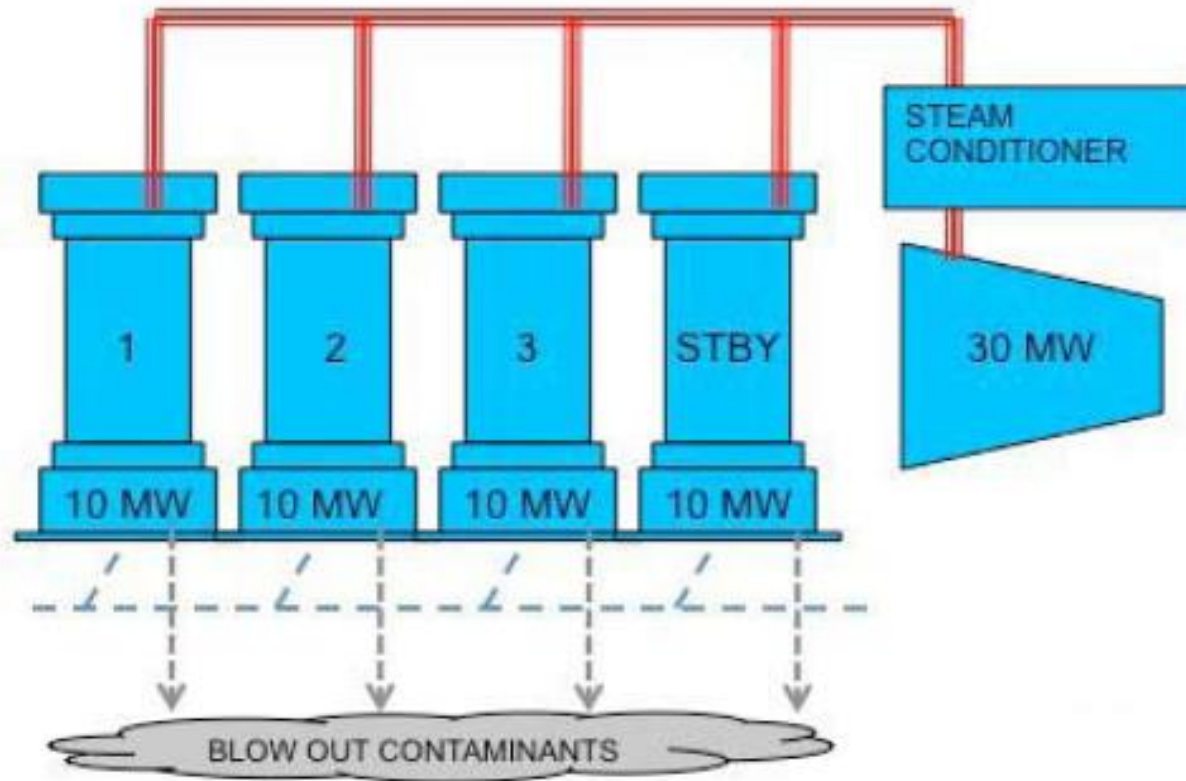
# Summary

Turnkey solution for waste disposal

Customized to meet municipal needs

Scalable for future expansion

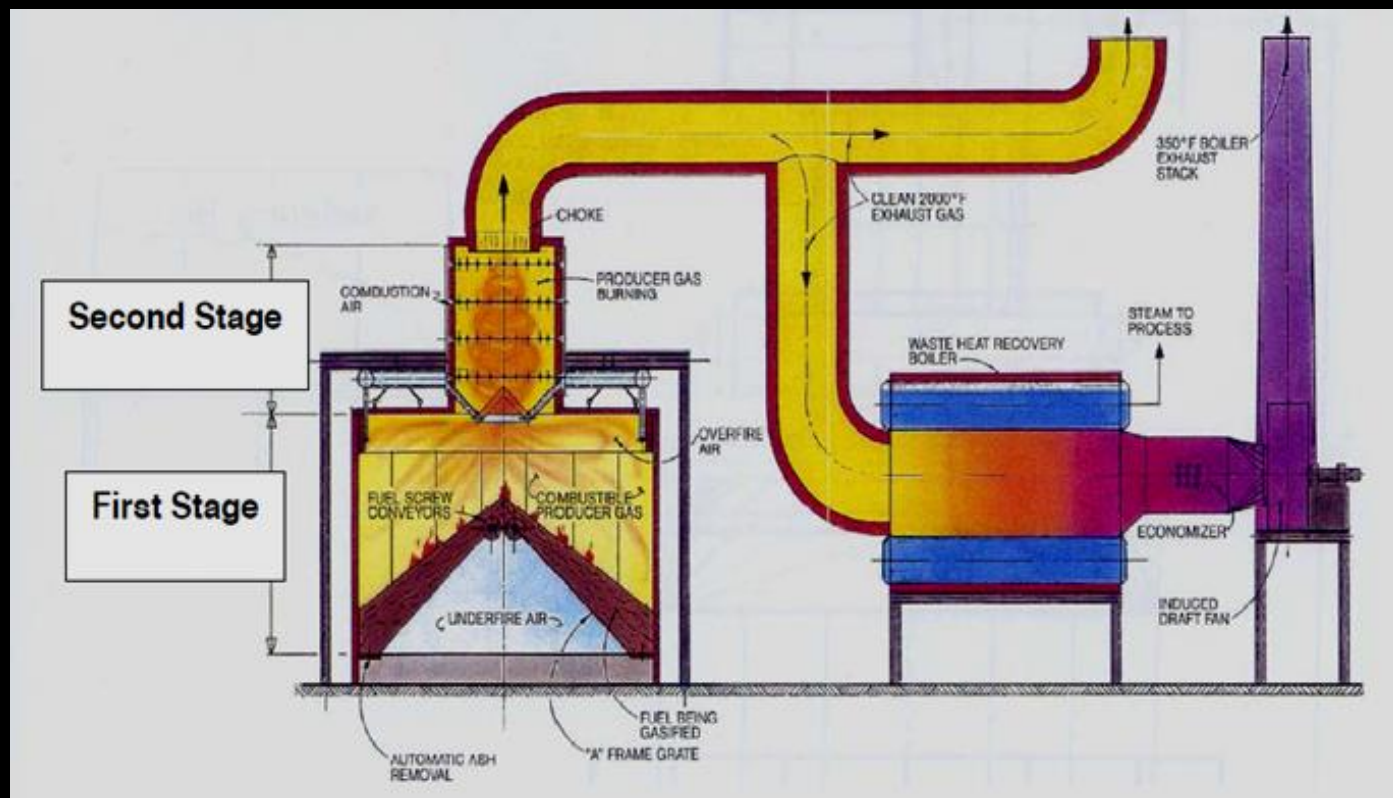
RE-USABLE H<sub>2</sub>O





## CURRENT ISSUES WITH MUNICIPAL SOLID WASTE

Central to the demand for waste-to-energy (WTE) technologies are the increasing difficulties experienced by municipalities to find new landfill sites for MSW. With thousands of tons of MSW being generated on a daily basis from households and commercial establishments, municipalities are either forced into increasing the size of existing landfills or developing new landfill sites far from their own jurisdictions. This is an ongoing concern for municipal officials and society who are actively seeking alternatives to landfills for MSW disposal. At the macro-economic level, a large number of countries are seeking to reduce their dependence on imported fossil fuels and their exposure to rising global prices for fossil fuels such as those experienced in 2008. MSW is viewed as a source of domestic renewable energy that can curtail the demand for these imported fuels.



## OPERATING PRINCIPLE

### First Stage

Gentle updraft gasification generates combustible producer gas at controlled temperatures

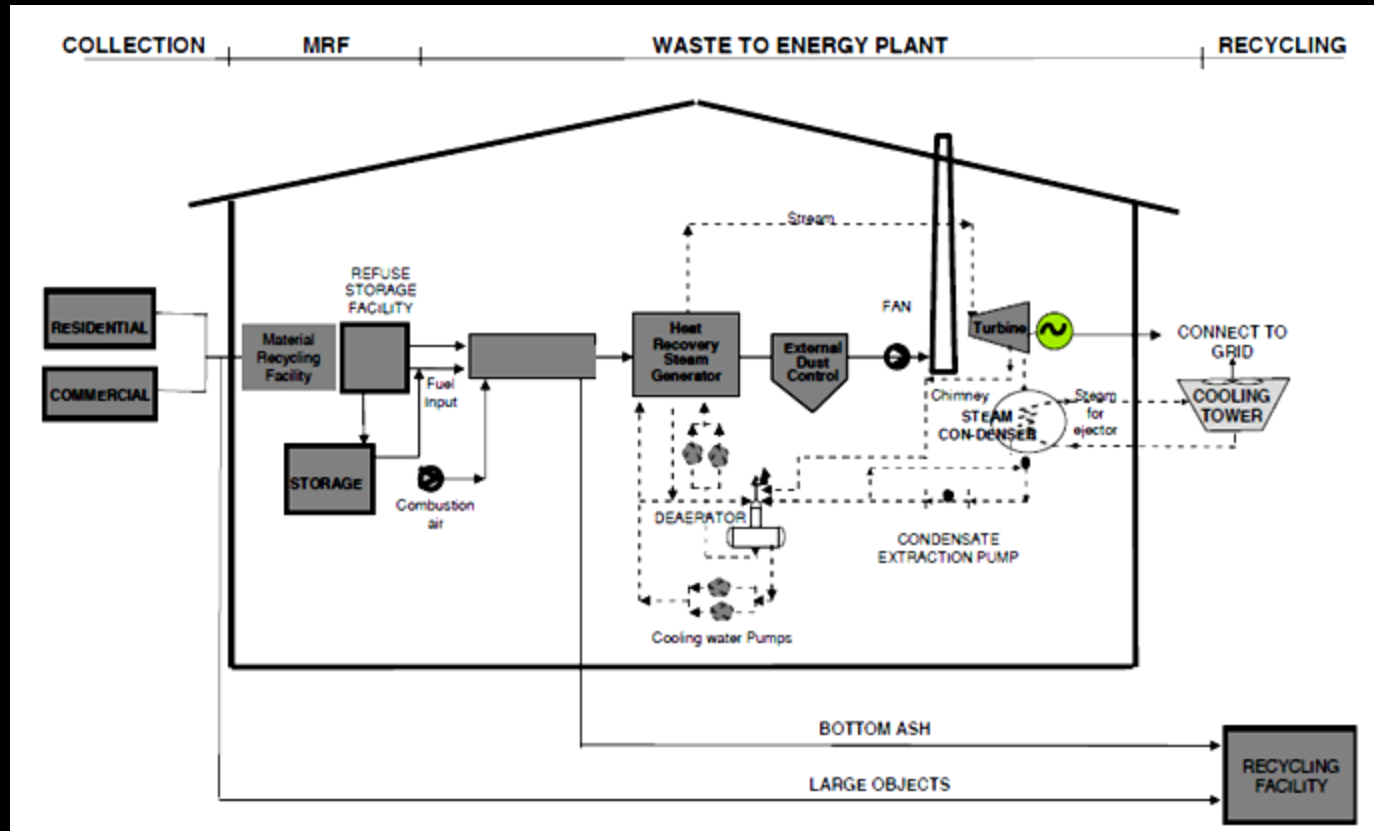
### Second Stage

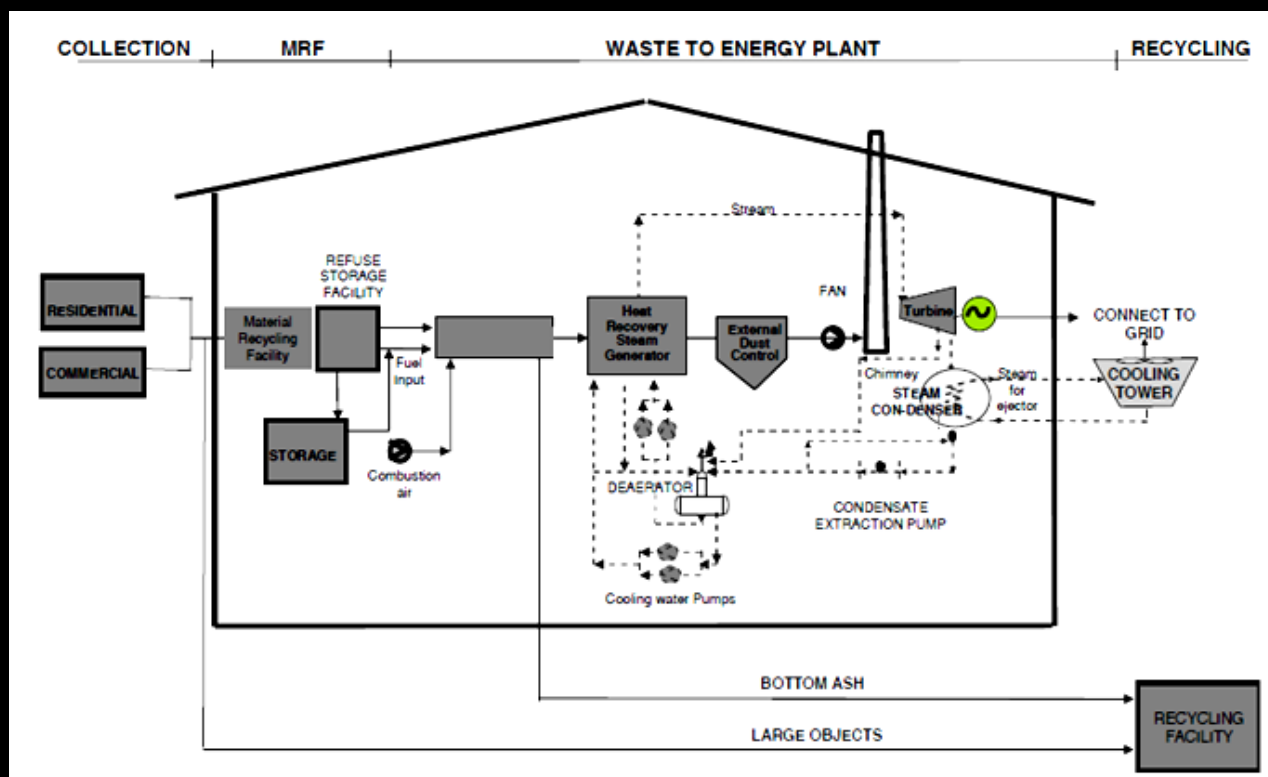
Vigorous cyclonic combustion of first stage producer gas with minimum excess air, produces high temperature, clean products of combustion.

## SPECIAL FEATURES

<b>Feed:</b>	Robust dual screw conveyors or dual hydraulic rams.
<b>Grate:</b>	Large, stainless steel. Low heat-release rate. A-frame grate.
<b>Ash Removal:</b>	Reciprocating, wedge-type unloaders on either side of grate bottom (easily removed for servicing).

Incineration is the most common method deployed to convert MSW into energy; it is a one-step high temperature highly oxidizing environment with almost continuous and costly external fuel support. Emissions of a mass burn incinerator are dioxins, furans, PCBs, NO<sub>x</sub>, potentially unburned tar and volatile organic carbons that produce obnoxious odors and smoke that can create health issues in the community. To meet stringent emission standards, many of these plants are outfitted with extensive pollution controls.





A refractory lined duct retains the products of combustion through a one-second residence time to ensure complete combustion before the hot products of combustion enter the heat recovery steam generator (HSRG);

A heat recovery steam generator recovers the 1010 C products of combustion.  
This could be a waste heat boiler to produce steam;

The first stage producer gas (consisting of water vapour, volatiles, carbon monoxide, carbon dioxide, nitrogen and methane) rises up into the second stage. Overfire air admitted at the top of the first stage, burns some of the first stage "producer gas" so that the temperature of all the first stage producer gas is raised above the ignition temperature of that particular gas mixture before the gas enters the second stage.

*Second  
Stage*

*First  
Stage*





The second stage, located immediately above the first stage, contains an outer vortex of downward spiraling, combustion air, inside which is an inner vortex of, upward spiraling, burning first stage producer gas. The primary combustion air is admitted at the inlet to the second stage combustion chamber through a "flame holder". The flame holder acts similar to wire gauze in the centre of a Bunsen burner, only in reverse. The flame holder with primary combustion air blowing from it, is surrounded by preheated, combustible, first stage producer gas rising upwards. Primary combustion air ignites the producer gas and combustion is initiated.

Secondary combustion air is admitted through a number of tangential openings (called "tuyères") in the walls of the second stage combustion chamber. With the top of the second stage combustion chamber fitted with a choke, the injected secondary combustion air is forced to complete the combustion process and then spiral down the walls towards the flame holder at the inlet to the second stage.

Encountering the flame holder, and the rich mixture of burning first stage gases swirling around it, the secondary combustion air reverses axial direction, moves radially inwards and then spirals upwards. This mixes with and completes the combustion of first stage producer gas. The flaming gases burn in an intense, upward spiraling, inner vortex surrounded by a sheath of downward spiraling secondary combustion air.

The flame holder also acts as a barrier to prevent the second stage inner vortex from extending down into the first stage. Without the flame holder, a tornado-like funnel would reach down into the first stage and draw first stage particulate up into the second stage.

The actual quantity of first stage particulate carried up into the second stage is minimized by the centrifugal action imparted to it by the tangentially injected, high velocity, overfire air. Any particulate, which does reach the second stage, encounters the vigorously rotating inner and outer vortices of the "double vortex" combustion chamber. This particulate is then thrown outward against the combustion chamber wall. It then falls back, down into the first stage by gravity.

There is a choke at the top of the second stage. In combination with the tangential injection of the secondary combustion air, a downward spiraling, outer vortex is established consisting of secondary combustion air surrounding an upward spiraling, inner vortex of burning producer gas. This stage of combustion ensures almost complete oxidation of producer gas formed in the previous stage, harnessing the maximum energy from the exothermic reaction to ensure the system meets the effluent gas discharge specifications.

Dioxins form when chlorine atoms from natural biomass, PVC (polyvinyl chloride) and plastics dislodge hydrogen atoms along the cellulose molecule and take their place. In the furnace of a typical utility boiler, MSW burns on a grate at the bottom of the "black" (from a radiation perspective) waterwall-lined furnace. The intermediate products of combustion of the MSW waft from the grate through the "black" waterwall-lined cavernous furnace of the boiler. As they do so, their temperature drops drastically due to radiant heat transfer to the waterwalls, according to:

$$\frac{T_{\text{gas}} - T_{\text{wall}}}{\text{Boiler Waterwall}}$$

The result is the "locked in" replacement of the hydrogen atoms with the chlorine atoms on the intermediate products of combustion that eventually rise to the boiler stack.

## Environmental Benefits

- Conversion of non-reusable waste into combustible gases for electricity generation and economic benefits;
- Utilization of MSW to reduce the use of fossil fuels for heating and generating electricity;
- Elimination of the need for new landfills or expansion of existing landfills to accommodate municipal solid waste streams from urban areas;
- Reduces the risk of soil and groundwater contamination and spreading disease from landfills;
- Reduction of environmental pollution to rivers, land and air in jurisdictions where there is a lack of regulated waste disposal and restrictions on the open burning of waste;
- Improvement of urban and rural environmental quality;
- Reduction in the use of fossil fuels and concomitant production of GHG from trucks delivering MSW to distant landfill sites;
- Reduction in the use of fossil fuels and concomitant production of GHG from equipment operating at landfill sites;
- Reduction of GHG emissions from landfills; and
- Creation of employment opportunities (as many as 80 persons per 100 million BTU units).



### GENERAL CONDITIONS & SCOPE OF SUPPLY

- AVAILABLE IN 10 MW INCREMENTS FOR LARGE SYSTEMS PACKAGES TO 30 MW
- ALSO AVAILABLE IN 500 KW SMALL SYSTEMS PACKAGES

**INCLUDES:** BOILERS, FUEL AND WATER TRAINS, STEAM EXCHANGER, TURBINE GENERATORS, CONTROLS AND INSTRUMENTATION, SKID MOUNTED, INSTALLATION AND TRAINING,

**WARRANTY:** 2 YEARS

**NOT INCLUDED:** FUEL STORAGE AND TREATMENT, ELECTRICAL CONNECTION TO THE GRID, SERVICE CONTRACT OR SPARE PARTS

GENERALIZED CONTRACT TO CUSTOMER ACCEPTANCE:

- 10 MW UNITS APPROX. 18 MONTHS
- 500 KW UNITS APPROX. 9 MONTHS

## The Methane Opportunity

Methane is emitted from a variety of natural and man-made sources, including landfills, natural gas and petroleum systems, agricultural activities, coal mining, stationary and mobile combustion, wastewater treatment, and certain industrial processes. "Wet" Methane is natural gas that surges to the surface accompanied by a soup of Hydrocarbons including propane, butane and ethane. Methane is of little value (\$14 per bbl) versus propane (\$50 per bbl) and butane (\$90 per bbl). In some applications, Methane can be given away as associated gases. Methane value is trending towards sub \$0.03 per standard cubic foot. The opportunity is to turn this of little value gas into valuable energy or power with as little processing or transport as possible.

## Methane as a "Greenhouse Gas"

Methane, the primary component of natural gas, accounts for 16 percent of all global greenhouse-gas emissions. Methane is 23 times more effective at trapping heat in the atmosphere as carbon dioxide. This makes low value, methane-emissions reductions most important in mitigating global warming in the near term. The USA (the Obama administration), the World Bank and the United Nations have publically targeted Methane and Combustion Particulate Reduction as their primary focus for environmental investment.

In addition, capturing low value and abundant methane emissions and using it as a clean, low cost energy source, versus Oil, Natural Gas and Coal will also increase domestic power energy security, enhance economic growth; and improve local air quality, public and industrial safety.

## Stranded “Wet” Methane

Most by-product or associated gas, “Wet” Methane is considered “Stranded” when the location or gas volume does not warrant the cost of storage and transport. To store and transport methane it must be cooled to -113 degrees Celsius (-171 degrees Fahrenheit) or pressurized to 50 atmospheres, both of which require large amounts processing and energy and can be dangerous and flammable. Historically, this Methane is usually permanently capped or flared off (burned). There is now an economic opportunity to use stranded or low flow or “Wet” methane sources as to generate power, transporting the methane to electrical energy and therefore to users and paying customers.

## Stranded Methane converted to Power

In Mexico, methane from a landfill produces 10 mega watts, enough power to light over 15,000 homes. In China, methane from a coalmine is fueling a power plant producing 120 megawatts of electricity. By 2015, China, methane based power production is estimated to deliver annual reductions in harmful emissions of up to 50 million metric tons and generate over 5000 megawatts of power. These numbers can now be dramatically improved.

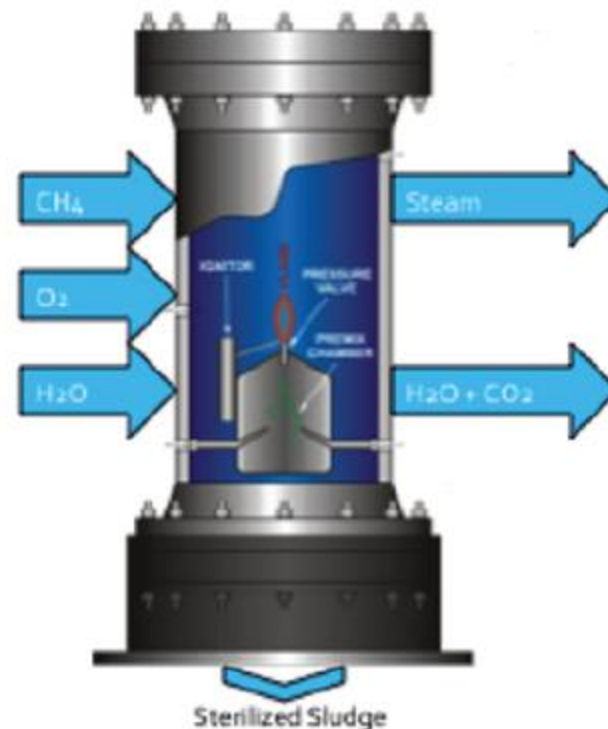
## The Solution

This Equipment which is Patented will provide solutions which can then safely and effectively convert, normally stranded methane, into a valuable and transportable power source, via the simple combust methane to generate steam to steam, and to then generate electric power via turbine, but, without the level of gas and feed water treatment or the emission management required of traditional airborne combustion vessels and their traditional steam boilers and turbines.

Contrary to other processes and products, MP is highly scalable and can be configured to convert most low to high flow rates of methane, methane specifications of heat and chemical content and most remote locations of methane availability to usable on or off grid power.

## Immersed Combustion Technology

- Ingenious alternate boiler design with NO tubes, NO combustion chamber
- Patented igniter starts combustion
- Imbedded sensors monitor the flame, pressure, temperature, gas flow and interlocks.
- Advanced Controls ensure combustion and emissions performance via a stoichiometric burn
- The system can go from cold to operational in less than five minutes.





## Estimated Cost of One (1) MegaWatt Hour, Greenfield Construction Turn-Key Basis

Source: Energy Information Administration, DOE, @2010 Basis

Construction Type	Capital Cost (\$)	O & M Cost (\$)	Variable Cost (\$)	Trans Investment (\$)	TOTAL COST (\$)
<b>Methane</b>	5.2	3.8	23	3.7	35.7
Advanced Coal	92.7	9.2	33.1	1.2	136.2
Advanced LNG	34.6	3.9	49.6	1.2	89.3
Wind	83.9	9.6	0	3.5	97
Solar	194.6	12.1	0	4	210.7
Geothermal	79.3	11.9	9.5	1	101.7
Biomass	55.3	13.7	42.3	1.3	112.5
Hydro	74.5	3.8	6.3	1.9	86.4

Compared to other electric power generating sources, to produce 1 mega watt--hour, the solution, "all in cost" for fuel, capital and operations is approximately \$35. This cost compared to coal at \$136, LNG at \$89, Solar at \$210 and Hydro at \$86 makes MP a new low cost threshold to methane reduction combined with power generation.

Normal, Coal Mine Methane (CMM) and Stranded Gas Well Methane are very suitable. For small CH<sub>4</sub> sources, can be packaged and skid mounted for autonomous operation, generating 50 kW to 30000 kW in common product module increments. For large sources, units can be deployed in banks and cycled, feeding a common steam turbine generator which uses minimally treated or "dirty" methane and can use re--cycled water, with less stringent chemical treatment than boiler tube based systems. Therefore for remote applications such as a coalmine, oil and gas drilling site, waste management site or a remote area needing power or clean water production.

A unique ICSG (immersed combustion steam generator) without air combustion chamber supporting a direct in water burn of fuel and oxygen. The energy transfer is near 100% with combustion gases trapped in the steam and precipitated minerals separated either via steam blowback cycle or supported in the evaporation cycle.

This can be scaled from either a 250 kW version or from a 10 MW version. Simplified Methane, O<sub>2</sub> and H<sub>2</sub>O feed trains and ICSG combustion management are supported by an advanced control system to ensure safe and continuous operation. The 250 kW version is small and highly transportable, matched with a standard micro steam turbine.

3-megawatt ICSG Boiler



The system includes the ICSG units, a turbine, an electric generator, water and fuel utility trains and the appropriate advanced controls and management. Typically equipment pricing is \$1.25 MIL USD per Megawatt (installation services and personnel support extra).

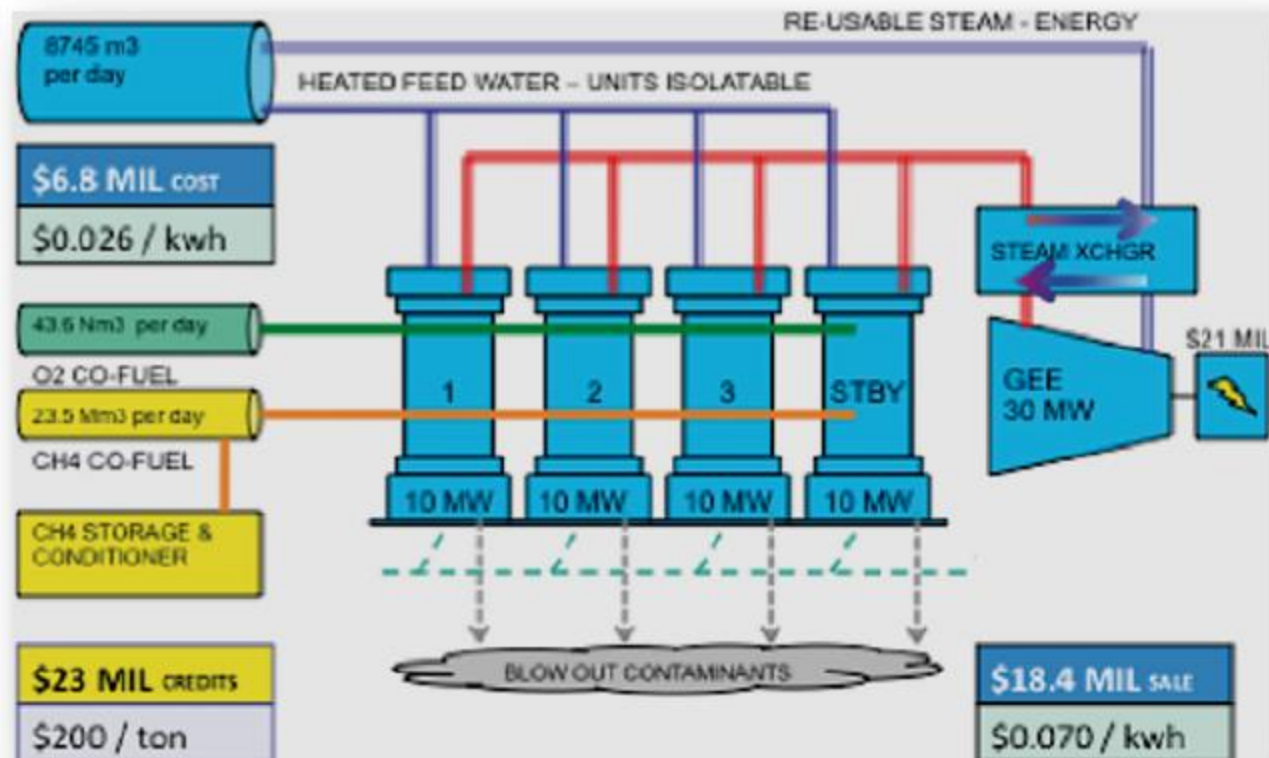
Aquacendia Effect



Immersed Combustion

## Scope of Supply

The standard 10 MW version, would be arranged in banks of 4 ICSG steam units, one standby, three operational, that feed a common steam turbine header and using common H<sub>2</sub>O and fuel supply chains / utilities. In this orientation, the steam header would feed a single 30--mega watt GE Energy turbine. This simplified process design supports necessary prime power reliability using low cost cycling of the steam units for maintenance.





## **A** Customer Supply -- Fuels and H2O

1. Methane Specification must be a minimum of 90% CH<sub>4</sub> and other HC, minimal S<sub>2</sub>, CO<sub>2</sub> and inert (N<sub>2</sub>) under a constant pressure of at least 350 psig. O<sub>2</sub> is pure gas delivered to site and under pressure.
2. H<sub>2</sub>O Specification, clean with low turbidity

## **B** Fuel Trains

1. One common fuel train for each CH<sub>4</sub> and O<sub>2</sub> with isolation and control to each of the 4 individual ICSG units. Supplied with the boilers.

## **C** IMCS Boilers

1. Dimensionally, the 10--megawatt steam unit is approximately 1000 lbs with H<sub>2</sub>O, 8--feet tall by 3--foot radius.

#### **D** METHANE Side Header and Heat Exchanger

1. Methane Boilers will feed a common steam header, isolated by each boiler. The steam header will feed a common steam heat exchanger with the evaporated H<sub>2</sub>O fed back to the boilers to retain as much as possible heat generated. Temperature 550 Deg F and 350 psig.
2. Turbine side will feed the GEE unit as required by the manufacturer and under GEE control and instrumentation.
3. One boiler unit will be held in active standby cycled into the operation on a daily basis to allow for steam blowback to eliminate any residual minerals in the system and periodic maintenance.

#### **E** Controls and Instrumentation

1. Manage the total process from the fuels and H<sub>2</sub>O storage sources to the heat exchanger.
2. Manage the safety interlocks and maintenance cycles as required by the steam generation units.

#### **F** GEE Steam Turbine & Power Generator – per GEE specifications

#### **G** Customer to Supply Power Management and Grid Connection – define 50 or 60 Hz

# Generalized Milestones from Order to Installation to Customer Turnover

Estimate: 540 days from Finalized Order Commitment and Initial Payment

Milestone	DAYS TO COMPLETE	TOTAL PROJECT DAYS
ORDER COMMITMENT (initial payment)		
SPECIFICATION REVIEW AND CUSTOMER ACCEPTANCE	30 days	30
SYSTEM SUPPLY AND PRODUCTION (2 <sup>nd</sup> payment)		390
Build and Test (CH4 Side)	120 days	
GEE Steam Turbine Build and Test	360 days	
Customer Acceptance	15 days	
SHIPMENT TO SITE (3 <sup>rd</sup> payment)	TBD	
INSTALLATION & CUSTOMER SITE PREPERATION & TRAINING	15 days	405
SITE DELIVERY, ASSEMBLY AND CHECKOUT (4 <sup>th</sup> payment)	90 days	495
TURNOVER & OPERATIONAL CHECKOUT	30 days	525
FINAL CUSTOMER ACCEPTANCE (final payment)	15 days	540

## Operating System Personnel and Training

The GEE Turbine unit is a traditional steam boiler power system and will require personnel trained in the safe and reliable operation of pressure equipment and electrical generation equipment. It will require operational supervision on a 24 / 7 basis.

## Maintenance and Service Contract

GEE will offer "separate" service agreements to ensure reliable and continuous operation of the equipment to meet its specification and performance results. Customer maintenance personnel will be trained in the daily requirements of each until an understanding of circumstances requiring specialized support plus a list of on-site spare parts to be on hand as field replaceable units.

# Economics

Using stranded or low cost methane as its primary fuel, O<sub>2</sub> as an accelerant and H<sub>2</sub>O as the transport between steam and the heat exchanger prior to the GEE turbine. Since it requires NO air combustion chamber or boiler tubes and feedstock management, as you would see in other steam designs the steam side is very simple in construction and efficient in operation. As can be seen following, the cost per Kilowatt is \$0.034 including capital cost, water and fuel operating cost (not including methane cost as in this model it is a waste gas and therefore worthless).

## ECONOMICS

### Waste Methane at NO COST to OPERATION

Capital Cost per kWh:	\$0.011
Op Cost per kWh (O <sub>2</sub> and no cost CH <sub>4</sub> ):	\$0.023
Total Cost per kWh:	\$0.034
Profit per kilowatt hour @Revenue of \$0.07 kWh	\$0.036

For a 1--megawatt project, capital inclusive:	\$313,000 profit margin per operating year plus up to \$400,000 in carbon credits
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## Competitors

There are multiple solutions appearing to take advantage of the stranded methane opportunity, especially the CMM marketplace. All combust and generate heat as the methane conversion to a transportable gas for a LNG pipeline is not cost viable. Methane Heat generator, provide industrial steam via an air combustion chamber and water boiler. This solution requires large volume methane access with consistent specification plus costly methane and water feedstock treatment and in most cases, post combustion emissions filtering and control.

Caterpillar has recently introduced a \$2.5 Million per mega watt, power generator set using CMM or stranded methane as the feedstock to a modified diesel engine. This engine requires major "Wet" methane treatment to standardize the gas composition specification, scrub harmful contents (CO<sub>2</sub>, Sulphur, Nitrogen, etc.), add costly post combustion emissions filters, provide frequent unit maintenance and therefore is typically designated as a standby power plant.

## EXAMPLES OF OPPORTUNITY

ECONOMICS Feedstock Costs with CH<sub>4</sub> at \$0.03 scf and Power Revenue at \$0.07 per kWh

Power (kW)	CH <sub>4</sub> (scf)	O <sub>2</sub> (scf)	H <sub>2</sub> O (bbls)	Revenue (\$USD)	Profit (\$USD)
	\$0.03/scf	\$.01 /scf	\$2.50/bbl	@\$0.07/kWh	
35 kW	1000 scf/day	1860 scf/day	2 bbls	\$21,700	\$5150
250kW	7000 scf/day	13020 scf/day	14 bbls	\$152,000	\$36,000
1000 kW	30000scf/day	55800 scf/day	58 bbls	\$650,000	\$155,000
10 MW	300k scf/day	558k scf/day	580 bbls	\$6.5 MIL	\$1.54 MIL
30 MW	875k scf/day	1627k scf/day	1690 bbls	\$19 MIL	\$4.5 MIL
150MW	4.25m scf/day	7.9m scf/day	8200 bbls	\$92 MIL	\$21.9 MIL