Bangladesh Society & Change
Vol. VI, No. 1, January-March 2012
ISSN :1997-1052 (Print), 227-202X (Online)

Plasma Gasification for waste treatment future hope for Bangladesh

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Abstract

Plasma treatment is a technologically advanced and environmentally friendly process of disposing waste materials and converting them to commercially usable by-products. Plasma treatment, technically known as gasification / verification, is a non-incineration thermal process that uses extremely high temperatures in an oxygen starved environment to completely decompose input waste material into very simple molecules. The by-products of the process are a combustible gas and an inert slag. Furthermore, it consistently exhibits much lower environmental levels for both air emissions and slag leachate toxicity than competing technologies, e.g. incineration.

A typical plasma treatment system consists of a feed preparation subsystem, a plasma furnace and a gas cleaning system. It is mentioned here that the amount of off-gas produced by the plasma furnace, is less than a half of the amount produced by a comparable capacity incinerator. Furthermore and most importantly, due to the high operating temperatures in plasma furnace and to the following rapid quenching with water, the formation of complex molecules, such as dioxins, is prevented.

The product gas of the process is actually a clean synthesis gas, composed primarily of hydrogen, carbon monoxide and nitrogen with smaller amounts of methane, acetylene and ethylene. Starting from this point, a proposal for an integrated process design of the plasma treatment is presented in this work. The main goal of the proposed process design is to optimize the overall efficiency of the system by recovering the maximum amount of energy, which is expected to be sufficient not only to satisfy the electricity requirements of the plant but also to be available for sale.

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To this purpose, we present preliminary energy analysis of the plasma waste treatment process along with the proposed energy recovery system. The importance of a cogeneration subsystem that will recover the energy of the produced synthesis gas, which results in steam and electricity production, is demonstrated.

Keywords: *plasma, gasification, incineration, waste treatment, process design, energy recovery, energy analysis, pyrolysis, Municipal Solid Waste (MSW).*

Plasma Gasification vs. Incineration

Fundamental Differences

There is a perception in some quarters that plasma gasification is essentially incineration, since in both incineration and plasma gasification, wastes are reduced too much smaller volumes. But whereas incineration is focused on reduction of waste to ash, gasification involves conversion of waste to synthesis gas and inert slag with recovery of energy and valuable metals.

In its purest form, incineration involves burning of organics in the presence of excess oxygen, converting them to heat, particulates, and a variety of combustion gases, with all of these vented to the atmosphere. Modern incinerators seek to achieve complete combustion employing temperatures in the 1,000 to 2,000ºF range, to capture heat generated, and to manage emissions through pollution controls (Miller 2007, USST 2010). Ash is generally landfilled, with the content of ash often requiring treatment as hazardous waste.

Fundamentally different than incineration are a number of thermal conversion (sometimes referred to as thermal-chemical conversion) technologies. All of these processes employ high temperatures (1,200-2,800ºF) in combination with little or no oxygen to decompose wastes. The lack of oxygen in waste decomposition prohibits combustion and clearly separates these technologies from incineration. Many thermal conversion processes are designed to achieve maximum gasification of wastes for subsequent use as fuel or recoverable heat/power generation, while some – often referred to as pyrolysis systems – are designed for incomplete gasification for the purpose of obtaining a variety of gaseous, liquid, and solid products, including fuels, metals, and chemicals.

One form of thermal decomposition is plasma gasification. Plasma gasification employs extreme temperatures (7,200-12,600ºF) in the absence or near-absence of oxygen (USST 2010), with organics and other materials dissociated into constituent chemical elements that are then either collected (in the case of valuable metals), vitrified to produce an inert glass-like slag, or reformed into synthesis gas that can be used as an industrial feedstock or converted to energy. Burning does not occur in a plasma gasification unit, and so as with other thermal conversion processes, gasification is completely different than incineration (Table 1).

Table 1 Differences between Plasma Gasification and Incineration

Plasma Gasification	**Incineration**
Occurs in the absence or near-absence of oxygen, prohibiting combustion.	Excess air is induced to ensure complete combustion.
Gases resulting from degradation of organics are collected and used for production of various forms of energy and/or industrial chemicals.	All potential energy converted to heat.
Products of degradation largely converted to inert (non-hazardous) glass-like slag of a volume 6% to 15% of the original solids volume.	Combustion results in ash (as much as 30% of original solids volume) that must often be treated as hazardous waste.
Emissions substantially lower than those resulting from incineration.	Far greater emissions of GHG and other pollutants than with thermal gasification systems.

As described by Heberlein and Murphy (2008) “a typical plasma system for treatment of solid wastes consists of (a) the plasma reactor, with collection of the metal (if applicable) and the slag at the bottom, periodically tapped and cast into some usable form, with power supply, cooling water supplies, gas supplies and control and data acquisition equipment, (b) a secondary combustion chamber for allowing sufficient residence time at elevated temperatures to assure complete reactions and gasification of soot; this secondary combustion chamber can be fired either by a burner or by a low power non-transferred plasma torch; (c) depending on the waste, a quenching chamber (usually water quench) to avoid formation of dioxins and furans, (d) a cyclone for particulate removal, (e) a scrubber for eliminating acidic gases, (f) if necessary a hydrogen sulfide absorber, (g) high efficiency filters or precipitators for small particulate removal, (h) an activated carbon filter for removal of heavy metals and (i) finally a fan for generating sub-atmospheric pressures in the entire installation. Additionally, various forms of waste preparation and feeding systems have to be integrated with the reactor.”

Regarding the collection of metals (“a” above), IMTE AG (2007) explains that metals within the processed waste melt and flow to the bottom of the gasifier vessel where they either mix with the silicate, or if present in a large enough quantity, form a separate layer that can be collected.

Andrijavi" and Gero (2007) explain that “Plasma itself is a high temperature ionized, conductive gas, which is created within the plasma torch by the interaction of the gas within an electric arc. This interaction dissociates the gas into electrons and ions, which enables the gas to become both thermally and electrically conductive. The conductive property of the ionized gas in the arc region provides a means to transfer energy from the arc to the incoming process gas and, in turn, to the process or furnace. This state is called plasma and will exist in the immediate confines of the arc within the torch.” The most frequently used plasma gas is air; nitrogen, carbon dioxide, steam, and argon are also sometimes used (Heberlein and Murphy 2008). A plasma arc system designed primarily for the purpose of producing ethanol is the Coskata ‘Flex’ Ethanol system. This system is reported to involve plasma gasification and biological fermentation-aided syngas-to biofuels conversion to efficiently reform ethanol from various forms of biomass. Pilot scale research thus far has focused on processing of pine chips, although other forms of biomass including other kinds of wood, agricultural wastes, energy crops, construction waste, and even some kinds of municipal waste (Coskata 2009, Krebs 2009, Alter NRG 2010).

The Source Separation Issue

Incineration and plasma gasification are also sometimes criticized as practices that discourage recycling. However, in both processes, source separation prior to processing is recommended. In the case of incineration or landfilling, removal of household chemicals, medicines and medical wastes, and batteries are critical in protecting groundwater, controlling emissions, and reducing long-term risks associated with ash disposal. In the case of plasma gasification, source separation is recommended for three reasons:

1. Although metals and other inorganic materials can be effectively broken down in a plasma arc, any waste that has no net energy content requires electricity to be used in its treatment, but does not produce electricity, thereby reducing overall efficiency (Thomas 2007, USST 2010),
2. Sorting MSW to capture recyclable commodities such as paper, metals, and high-value plastics can be a more effective way to conserve energy than by burning [or gasifying] such materials and recapturing the energy produced (Tellus Institute 2008).
3. Capturing recyclables can provide a potential revenue stream for the gasification plant. High-value plastics and papers that can be readily separated are far more valuable as recyclables than as fuel (Dodge 2009).

Removal of metals from the waste stream prior to processing is important (as noted above) because large quantities can adversely impact plant efficiency. Small quantities of metals are also difficult to deal with since collection and separation of small amounts of metals following gasification may not be economical.

4. Wastes containing halogen and sulfur compounds are converted to hydrogen halides and hydrogen sulfide and pass out of the reactor with the other gases (IMTE 2007). Wastes containing high concentrations of halogen, e.g. Including most plastics, require higher temperatures and quenching of exhaust gases, and it is more difficult to obtain a saleable co-product (Heberlein and Murphy 2008).

Plasma Gasification - Inputs and Outputs

Input Capability

Virtually any material, including low-level radioactive waste under certain conditions, can be reduced using plasma gasification. Materials that can be safely and effectively treated include coal, sludge, incinerator ash, hazardous fly ash, car fluff, medical waste, pathological wastes, PCB oil pyrolysis products, ferrous chromium waste, ferro-manganese reduction compounds, titanium scrap melt, niobium recovery products, electric arc furnace dust, Portland cement manufacturing waste, paper, cardboard, plastics, fiberglass insulation and other products, asbestos, wood, glass, ceramics, rubber, tires, asphalt shingles, used roadway asphalt, oil sands, sewage sludge, harbor sludge, composite materials containing resins, linoleum, plastic piping, solvents, paints, and other carbon-containing materials including mixed solid waste. The system will also handle such materials as steel beams and rebar; copper piping; steel, aluminum, and copper wire; and even concrete, stone, bricks, although as noted earlier it makes more sense from energy, environmental, and economic perspectives to remove such materials from the waste stream prior to processing (Solena Group 2002, Thomas 2007, Dodge 2009). Plasma gasification will also handle treated wood and even contaminated soils - both a problem currently for both landfill and incineration operations.

Products

The principal product of plasma gasification is a low to medium calorific value synthesis gas composed of carbon monoxide and hydrogen. This gas can be burned to produce heat and steam, chemically scrubbed and filtered to remove impurities before conversion to various liquid fuels or industrial chemicals/polymers, or used once cleaned as a turbine or engine fuel to produce electricity. Heat energy can also be recovered via water tube heat exchangers as the hot syngas is cooled from about 2,200 to 400ºF (1,200ºC to 200ºC).

Solid wastes from plasma gasification include a vitrified, glass-like, inert slag and small volumes of other solids that come from cleaning of filters and disposal of chemicals collected in the gas scrubbing process. The volume of solid wastes is variously reported as in the range of 1/250th - 1/125th the volume of the incoming waste stream (assuming a market for all the vitrified slag and full recovery of all metals), with the volume of slag determined by the proportion of non-organics in the material being treated (Miller 2007, IMTE 2010). In contrast, two recent reports (Miller 2007, Northspan 2008, p. 3) suggest that the slag volume itself amounts to only 1/250th of the volume of processed solid waste. These low estimates do not match other studies that indicate a volume of slag, in relation to the volume of MSW treated, in the 6 to 15% (1/16th to 1/6th) range (Thomas 2007, Heberlein and Murphy 2008, Foth Infrastructure and Environment 2008); it should be noted that this is a non-trivial volume of waste that must be accounted for in project planning. While the slag material is potentially marketable, development of profitable markets is not a given and cannot be taken for granted.

The production of products other than syngas and slag is dependent upon the nature of the waste stream. For instance, source separation ahead of the plasma arc could yield various recyclable materials. In addition, metals sent through the process can be collected in molten form for subsequent processing in smelters, provided that the volume of metal is large enough to warrant separation and that the plant is configured to recapture metals. Small volumes of non-economically recoverable metals wind up as part of the vitrified slag. Chlorine and sulfur can also be collected as by-products, in the form of hydrochloric and sulfuric acids, respectively.

Emissions and Wastes

Other than the vitrified slag the plasma arc itself produces little waste. As explained on the following page and on page 9, there can be emissions that result from the plasma arc process, largely during cleaning of syngas prior to combustion in a turbine or during the combustion process itself, in converting syngas to industrial feedstocks, and from cleaning of filters and disposal of chemicals collected in the gas scrubbing process.

Performance data for plasma gasification plants, many of which are pilot operations, is often treated as proprietary. Thus, information regarding output products of gasification and problems that may be encountered is difficult to obtain. An authoritative source of gasification products data for plants worldwide is a 2009 University of California report that includes summaries of test results for plasma arc facilities that process circuit boards, medical waste, and MSW. Gasification products measured included particulate matter, NO_x, SO_x, hydrochloric acid, and trace amounts of mercury and dioxins/furans; in all cases emissions were well below applicable standards for the regions involved (see the tables below).

Table 2 EPA Environmental Technology Verification Testing (2000) of InEnTec Plasma Arc Gasification of 10 tpd of Circuit Boards, Richland, Washington

Emiss ons (mg/N-M^3@7%O2)	**Measured**	**USEPA Standard**
PM	3.3	20
HCL	6.6	40.6
NOx	74	308
SOx	-	85.7
Hg	0.0002	50
Dioxins/furans* (ng/N-m^3)**	0.000013	13

* *Dioxins and furans are compounds consisting of benzene rings, oxygen, and chlorine that are considered to be toxic or hazardous.*

** *One ng/Nm^3 is one nanogram per normal cubic meter; Normal means at standard temperature and pressure.*

Table 3 EPA Environmental Technology Verification Testing (2000) of InEnTec Plasma Arc Gasification of 10 tpd of Medical Waste, Richland, Washington

Emissions (mg/N-M^3@7%O2)	**Measured**	**USEPA Standard**
PM	<3.3	20
HCL	2.7	40.6
NOx	162	308
SOx	-	85.7
Hg	0.00067	50
Dioxins/furans (ng/N-m^3)	0.0067	13

Table 4 Results of Third-Party Demonstration Source Tests (2008-2009) of Plasco Energy Plasma Arc Gasification of 110 tpd of MSW, Ottawa, Canada

Emissions (mg/N-M^3@7%O$_2$)	**Measured**	**EC 2000/76 Standard**
PM	12.8	14
HCL	3.1	14
NOx	150	281
SOx	26	70
Hg	0.0002	14
Dioxins/furans (ng/N-m^3)	0.009245	0.14

It is important to note that the test data shown in Tables 2-4 does not represent actual emissions to air, but rather potential emissions prior to contaminant removal from the exhaust stream. Contaminant removal can be accomplished using a variety of air pollution control technologies.

The current situation regarding emissions is summarized in the 2009 University of California report as follows:

"Results from our analysis [based on independent source test reports, compliance reports from regulatory agencies, and peer-reviewed publications] indicate that pyrolysis and gasification facilities currently operating throughout the world with waste feedstocks meet each of their respective air quality emission limits with few exceptions, most meet all of the current emission limits mandated in California, the United States, the European Union, and Japan. In the case of toxic air contaminants (dioxins/furans and mercury) every process evaluated met the most stringent emission standards worldwide. Facilities with advanced environmental controls are very likely to meet regulatory requirements in California. "Information from the University of California report, in summary form, can be found in a Los Angeles County fact sheet (2009).

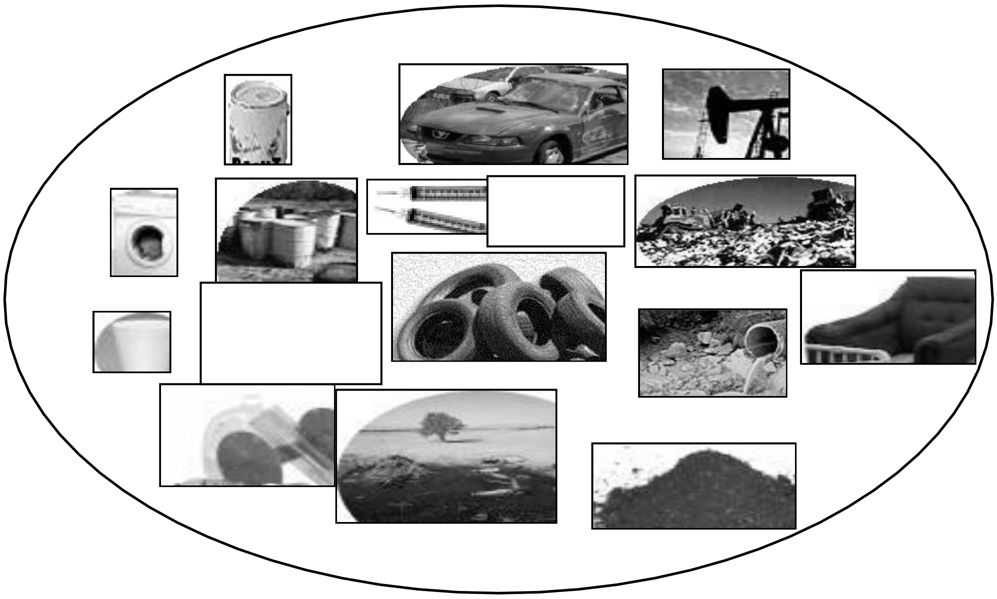
The recovered energy system

Introduction

The dream of every municipality is to recycle all of its waste into usable products, thereby completing the cycle of nature. Science teaches us that matter and energy are not destroyed - they merely change state. Waste contains significant amounts of valuable resources that were once used to produce products. Those products have lived their useful lives and have become waste, but they still contain the same matter and energy that went into their making. The Recovered Energy System recovers this matter and energy to produce other valuable products, and thereby productively manages the cycle of nature.

Recovered Energy believes that the matter and energy contained in waste is economically recoverable into valuable products. They view waste as a valuable resource and asset. They have designed a program using proven technologies combined in an advanced, safe and environmentally friendly process to dispose of waste materials, recover all the matter and energy in waste, and convert it into valuable products.

Processes any type of waste



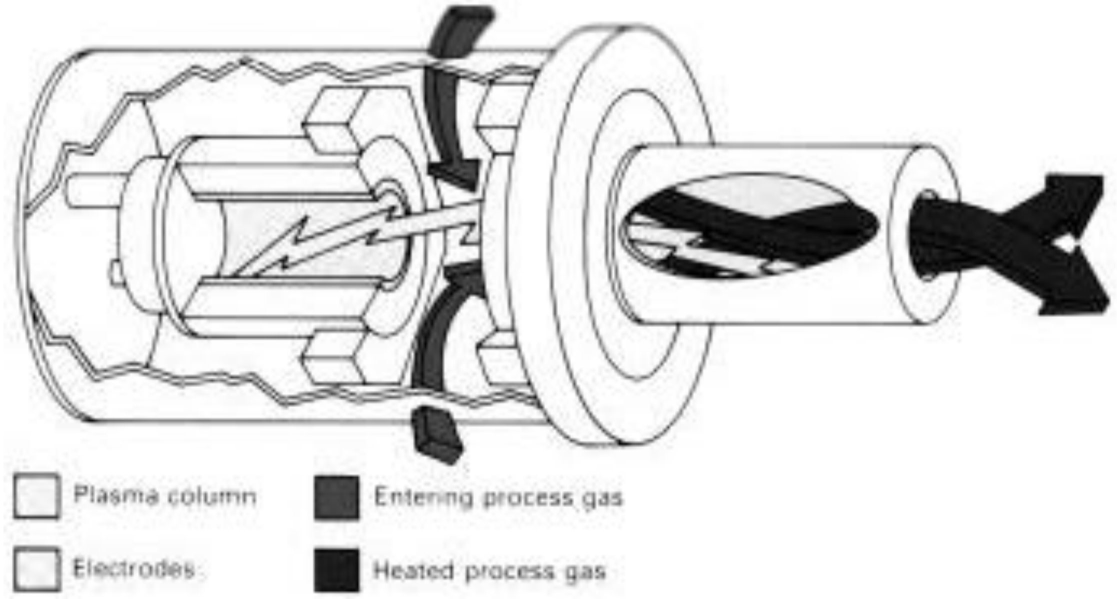
We live in a society where consumers want the latest advancements in technology and comfort. One of the unfortunate side effects of a modern society is waste. It seems that the more advanced we become the more waste we generate per capita. We are being buried in mountains of waste. At the same time society is becoming more aware and concerned about the environment. Therein lies the paradox - we want all the goods and products that modern technology can provide but we don't want the inevitable waste that results.

The Recovered Energy System can handle any type of waste in a solid, liquid, or gas state. All of the types of waste shown above can be fed either individually or mixed in any combination. The rate of input of the various wastes is controlled to keep the flow of output syngas constant. No special processing or sorting of the waste is necessary. Liquids can be injected directly into the head of the plasma torch.

Definition of plasma gasification and comparison

Plasma gasification is the gasification of matter in an oxygen-starved environment to decompose waste material into its basic molecular structure. Plasma gasification does not combust the waste as incinerators do. It converts the organic waste into a fuel gas that still contains all the chemical and heat energy from the waste. It converts the inorganic waste into an inert vitrified glass.

Plasma is considered a 4th state of matter. Electricity is fed to a torch, which has two electrodes, creating an arc. Inert gas is passed through the arc, heating the process gas to internal temperatures as high as 25,000 º F. The following diagram illustrates how the plasma torch operates.



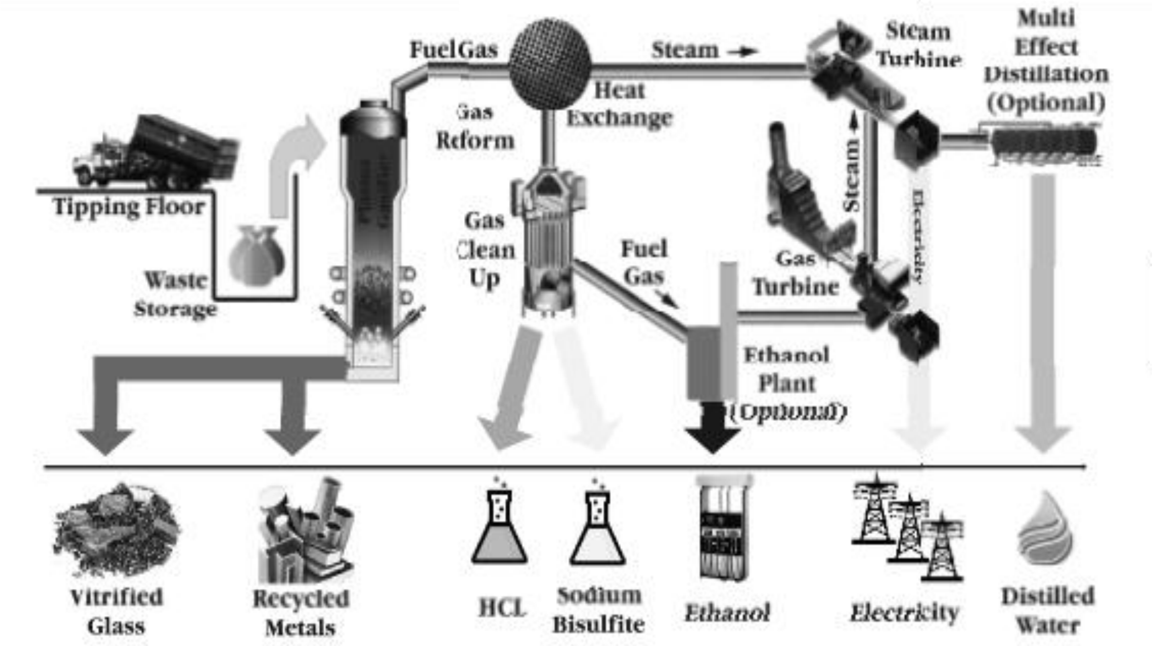
The temperature a few feet from the torch can be as high as 5,000-8000º F. Because of these high temperatures the waste is completely destroyed and broken down into its basic elemental components. There are no tars or furans. At these high temperatures all metals become molten and flow out the bottom of the reactor. Inorganics such as silica, soil, concrete, glass, gravel, etc. are vitrified into glass and flow out the bottom of the reactor. There is no ash remaining to go back to a landfill.

The plasma reactor does not discriminate between types of waste. It can process any type of waste. The only variable is the amount of energy that it takes to destroy the waste. Consequently, no sorting of waste is necessary and any type of waste, other than nuclear waste, can be processed.

The reactors are large and operate at a slightly negative pressure, meaning that the feed system is simplified because the gas does not want to escape. The gas has to be pulled from the reactor by the suction of the compressor. Each reactor can process 20 tons per hour (tph) compare to 3 tph for typical gasifiers. Because of the size and the negative pressure, the feed system can handle bundles of material up to 1 meter in size. This means that whole drums or bags of waste can be fed directly into the reactor making the system ideal for large scale production.

The gas composition coming out of a plasma gasifier is lower in trace contaminants than with any kind of incinerator or other gasifier. Because the process starts with lower emissions out of the reactor it is able to achieve significantly lower stack emissions. The gasifier doesn't care about the amount of moisture in the waste. The moisture consumes energy to vaporize and can impact the capacity and economics; however, it will not affect the process.

Process flow description



Material handling

The incoming waste is weighed in and then deposited on the tipping floor from any of the trucks currently in use that pick-up and or transfer MSW. No tedious sorting or handling is needed. The only separation that is required will be large oversized pieces or items that need special pre-processing, such as refrigerators, freezers and AC units that need the freon removed. Hazardous waste and medical waste are handled separately and not co-mingled with normal waste.

The system is designed to process waste as quickly as possible. During delivery hours the waste is delivered faster than it can be gasified. Part of the waste is stored for processing at night and on weekends and holidays. Any oversized material is shredded and then conveyed to storage.

The waste is completely cycled every 3 - 4 days. Should unscheduled shutdowns occur, the waste received from the municipality goes into the storage area which is designed to handle normal surges and continue accepting the waste. The waste is conveyed directly to the plasma reactor feed system. A hydraulic ram pushes the waste into the gasifier.

Thermal transformation

The waste is injected into the upper part of thermal transformer (also referred to as the plasma gasifier or reactor) and piles up in the body of the reactor. The plasma torches located at the bottom of the reactor generate a flame that is between 5000-8000º F.

The organic material does not burn because there is not enough oxygen. The organic matter is transformed to a gas composed primarily of carbon monoxide (CO), hydrogen (H_2) and nitrogen (N_2). This gas contains substantial energy and can be used in a variety of ways.

The hot gas rises up through the waste piled in the reactor and begins the gasification process on the material piled in the reactor. By the time the waste has reached the bottom of the reactor, the high temperature, oxygen starved environment has totally transformed all organic compounds into a gas.

The gas that exits from the top of the reactor and is made up of primarily carbon monoxide, hydrogen, water and nitrogen. Small amounts of chlorine, hydrogen sulfide, particulate, carbon dioxide and metals with boiling points less than 2280º F are contained in the gas. Because of the low oxygen atmosphere and high temperature, the base elements of the gas cannot form toxic compounds such as furans, dioxins, No_x, or sulfur dioxide in the reactor.

As the gas exits the reactor it first goes to a proprietary gas reformer and then it is cooled in a series of high temperature heat exchangers. The sensible heat is reduced to about 270º F and is used to generate high-pressure steam that is fed to a steam turbine to produce electricity.

The high temperatures from the plasma torches liquefy all inorganic materials such as metals, soil, glass, silica, etc. All matter, other than the metals, becomes vitrified or molten glass. The metal and glass flow out of the bottom of the reactor at approximately 3000º F. As the metal and glass flow from the reactor they are quenched in a water bath. The glass forms obsidian like glass fragments. The metals are then separated from the glass. There is no waste left at the end of the thermal transformation. All of the waste is recycled into metal, glass or has been converted to fuel gas.

Gas cleanup

After the fuel gas has left the heat exchanger, approximately 85% of the particulates are removed in a cyclone. A smaller percentage of the metals are also removed with the particulate. The recovered particulate and metals are then injected into the molten glass. The components of the glass are locked into the glass matrix and cannot leach out. The vitrified glass material passes EPA leachability tests.

The gas then goes through a scrubber where the hydrochloric acid (HCL) is scrubbed out to form dilute HCL water. The liquid goes through a series of membranes where the particulates and metal in the liquid are removed. The metals and particulate at this stage cannot go back into the glass and can either be sold to a metal refiner or removed to a landfill. This small amount of material is the only potential material that goes back to a landfill and represents less than a fraction of 1 percent of the waste feedstock. The clean HCL water is concentrated to 15-20% for commercial sale.

In the gas cleanup stage the temperature of the gas is further lowered and all the sensible heat is removed and used in the power generation process. The water in the gas condenses and is used to provide clean makeup water for the rest of the plant.

The gas then goes to the gas turbine (discussed in more detail later). The hydrogen sulfide (H_2S) in the gas is converted into sulfur dioxide (SO_2). The discharge from the gas turbine goes through another wet scrubber where the SO_2 is converted to sodium bisulfite.

Steam and power generation

Steam from the primary heat exchanger goes to a steam turbine where it is converted to electricity. The electricity generated with this steam source provides most of the power needed for internal power requirements. The system is capable of generating all its own internal requirements. The fuel gas goes into a gas/steam combined cycle turbine where it is used to produce electricity. All the available heat in the process is used to make electricity or steam. The discharge temperature off the gas turbine is less than 270ºF. Any low-pressure steam (small amount) not used in the process is either condensed or can be used to produce distilled water in a multi-effect distillation unit. A facility designed with electricity production can export approximately one megawatt of electricity for each ton of MSW, depending on the moisture content of the MSW.

Complete conversion of waste

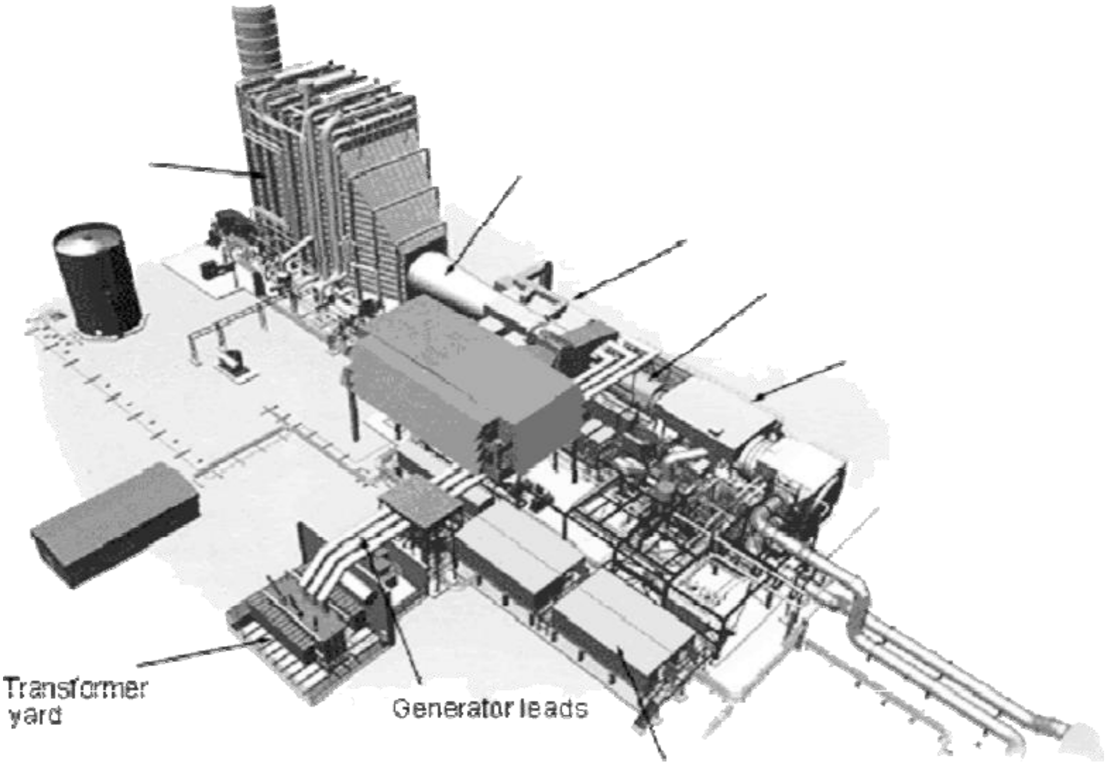
99% of all the waste that goes into the gasifier comes out either as glass, metal or fuel gas. The remaining 1% includes the particulates, chlorine, sulfur and metals in the gas. The chlorine is scrubbed out and recovered either as dilute hydrochloric acid (HCL). The HCL is concentrated to 15-20% and sold commercially. The sulfur is scrubbed out and converted into sodium bisulfite. The particulates are partially (85%) removed by a cyclone. Anything removed by the cyclone can be put back into the glass. What is not removed by the cyclone is removed either by the chlorine scrubber or the electrostatic precipitator. The particulates and metals removed by the scrubber and electrostatic precipitator cannot be put back into the process. This material is high in higher value metals and can be sold to a metal refiner. 99% of the waste is converted to usable products as a result of the gasifier. The remaining 1% is converted into usable products through the pollution control system.

Proven technologies

The gasifier system, including engineering and design, supply of the plasma torches, power supply, reactor, gasifier control system, startup and training, could be provided by a related company such as. Westinghouse Plasma Corporation who has over 25 years of experience in plasma gasification. They have supplied gasifiers to a variety of industries, including MSW and other waste products as well.

The air pollution control (APC) equipment could be supplied by such company like Turbosonic, Inc., including design and engineering, supply of the wet scrubber, sulfur removal system, electrostatic precipitator and APC instruments and controls, startup and training. Turbosonic is a leader in the design, engineering and supply of APC systems, with over 300 installations.

The gas and steam turbines, compressors, generators, transformers and other power generation equipment could be supplied by General Electric or Alstom which are industry leaders in power generation equipment in the world.



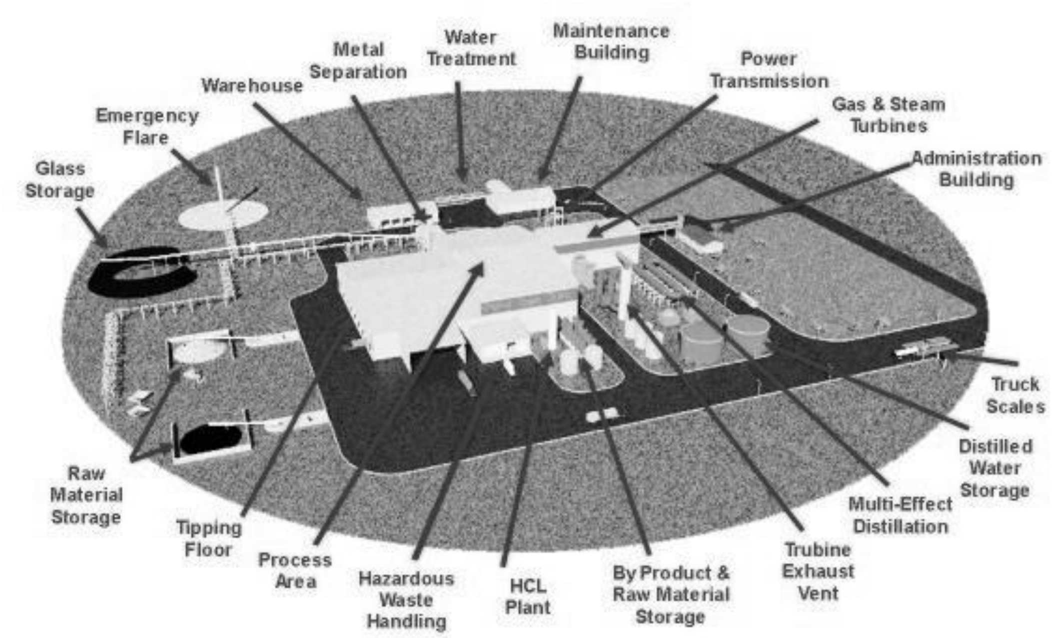
Other equipment will be supplied by well known suppliers with proven track records.

Clean, aesthetically pleasing and environmentally friendly operation

The Recovered Energy System plant does not look like a waste dump. The tipping floor is inside a building so none of the waste is visible. The air for the process is pulled through the tipping floor area so that the tipping floor maintains a negative pressure. In this way no odors are allowed to escape the building and all vapors are being processed by the system.

The entire process is enclosed inside a building to reduce noise and to keep the working area clean and tidy. The plant layout allows for the handling of a large number of trucks coming and going carrying waste, raw materials and finished products in an efficient manner. At the same time expansion is easily accommodated.

The plant rendering shown below gives a typical layout of a plant.



Health, Safety and Environmental Performance of Plasma Gasification Facilities

In investigating safety and environmental performance issues, an extensive search for information was conducted for each of the facilities listed in a recent report from the Georgia Tech Research Institute. An examination of scientific and technical literature, media reports, and other sources of information reveals no health/safety problems, and few environmental problems with plasma arc disposal systems. There are a number of years of experience in Japan and in France of using plasma arc technology to treat ash from mixed solid waste incineration. No reports of operating problems for any of these plants were found. Similarly, no reports of environmental or health/safety problems were found for plants treating materials including asbestos, tannery waste, aluminum dross, catalytic converters, medical wastes, and munitions. One plant apparently did have emissions problems; a pilot facility operated by the Allied Technologies Group in Richland, Washington, designed for treatment of hazardous wastes, was reported to have exceeded emissions limits on several occasions.

The only two plasma arc plants commercially treating mixed solid waste (MSW) in the world are those operating in Utashinai and Mihama-Mikata, Japan. The most in-depth independent examination of the performance of these plants is chronicled in a 2008 report by Juniper Consultancy Services, Ltd, in which safety, environmental, maintenance, and economic issues are addressed. For the large (300 ton per day) Utashinai plant there have been no health/safety issues with the plasma arc system through eight years of operation, and the only reported environmental problem occurred in 2007 when one or more specially coated bags used to absorb dioxins from flue gases failed; in that instance dioxin limits reportedly marginally exceeded emissions limits (but would not have exceeded US, EU, or Canadian standards). Other than that one incident, both the Utashinai and Mihama-Mikata facilities have operated well within strict compliance limits for dioxin.

Regarding the record of other emissions from the Utashinai and Mihama-Mikata facilities, there have been a few instances of emissions of HCl, NO_x, and particulates that exceeded allowable limits within Japan. Juniper evaluated emissions data against air emissions standards of the US, Canada, and the EU and concluded that emissions were generally within limits prescribed in these standards, but that emissions of particulates from the Minama-Mikata plant would not meet US and EU particulates emissions standards, and that there had been periodic problems with HCl emissions. Similarly, it was noted that NO_x emissions from the Utashinai plant appeared problematic when evaluated against Canadian, US, and EU air quality standards.

Many reports of health and safety problems with thermal gasification systems can be found in literature produced by environmental interest groups and other sources (Limerick County Council 2004, Greenaction 2006, Greenaction 2008, Ciplet 2009, Connett 2009, McKenna 2009), including reports of toxic emissions, leaks, and an explosion at a facility in Karlsruhe, Germany. It is worth noting that virtually all of these reported problems have occurred with thermal systems other than plasma arc gasification.

In a 2009 report Ciplet stated that “gasification, pyrolysis and plasma incinerators have a dismal track-record plagued by malfunctions, explosions, and shut downs.” The only such problems cited in this report for plasma gasification systems relate to an Allied Technologies Group facility in Richland, Washington that was designed to treat highly hazardous wastes including low level radioactive material; the plant, now closed, experienced emissions problems during the start-up phase. A few other problems with the operation of this facility that were cited by Ciplet relate to issues other than health and safety.

Waste concern of Bangladesh

In 1995, a national research organization was established in Bangladesh. In 2005, this organization was formed as a Social Business Enterprise (SBE). Fields of activity of this organization are:

- Solid Waste Management and Resource Recovery
- Clinical & Hazardous Waste Management
- Policy on Waste Management
- Climate Change & Clean Development Mechanism
- Industrial Pollution Control
- Organic Farming
- Ecological Sanitation
- Renewable Energy
-

City/Town	*WGR (kg/cap/day)	No. of City/Town	Total Population (2005)	Population** (2005)	TWG*** (Ton/day)		Average TWG (Ton/day)
					Dry season	Wet season	
Dhaka	0.56	1	6,116,731	6,728,404	3,767.91	5,501.14	4,634.52
Chittagong	0.48	1	2,383,725	2,622,098	1,258.61	1,837.57	1,548.09
Rajshahi	0.3	1	425,798	468,378	140.51	205.15	172.83
Khulna	0.27	1	879,422	967,365	261.19	381.34	321.26
Barisal	0.25	1	397,281	437,009	109.25	159.51	134.38
Sylhet	0.3	1	351,724	386,896	116.07	169.46	142.76
Pourashavas	0.25	298	13,831,187	15,214,306	3,803.58	5,553.22	4,678.40
Other Urban Centers	0.15	218	8,379,647	9,217,612	1,382.64	2,018.66	1,700.65
Total	**-**	**522**	**32,765,516**	**36,042,067**	**10,839.75**	**15,826.04**	**13,332.89**

The analysis of the research organization shows that the total waste generation in urban areas of Bangladesh in 2010:

*   WGR= Waste Generation Rate,

**   Including 10% increase for floating population,

*** TWG= Total Waste Generation, which increases 46% in wet season from dry season Source: 1 JICA (2004), 2 Chittagong City Corporation, 3 Field Survey, 4 Sinha (2000), 5 Field Survey, 6 Sylhet City Corporation, 7, 8 Field Survey

Average per capita urban waste generation rate is estimated as 0.41 kg/capita/day.

The survey shows that the average total waste generation in Bangladesh is 13332.89 ton/day and as stated above about the plasma arc technology; if the waste utilization system will be modified and strictly controlled, then with this amount of waste, the Government of Bangladesh easily can fulfill not only the electricity needing of the nation but a lot more. So, it is highly recommended to study this technology for the maximum treatment and reuse of waste of Bangladesh.

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