

Plasma Arc Gasification
of
Municipal Solid Waste

Louis J. Circeo, Ph.D.

Principal Research Scientist

Director, Plasma Applications Research Program



Electro-Optical Systems Laboratory

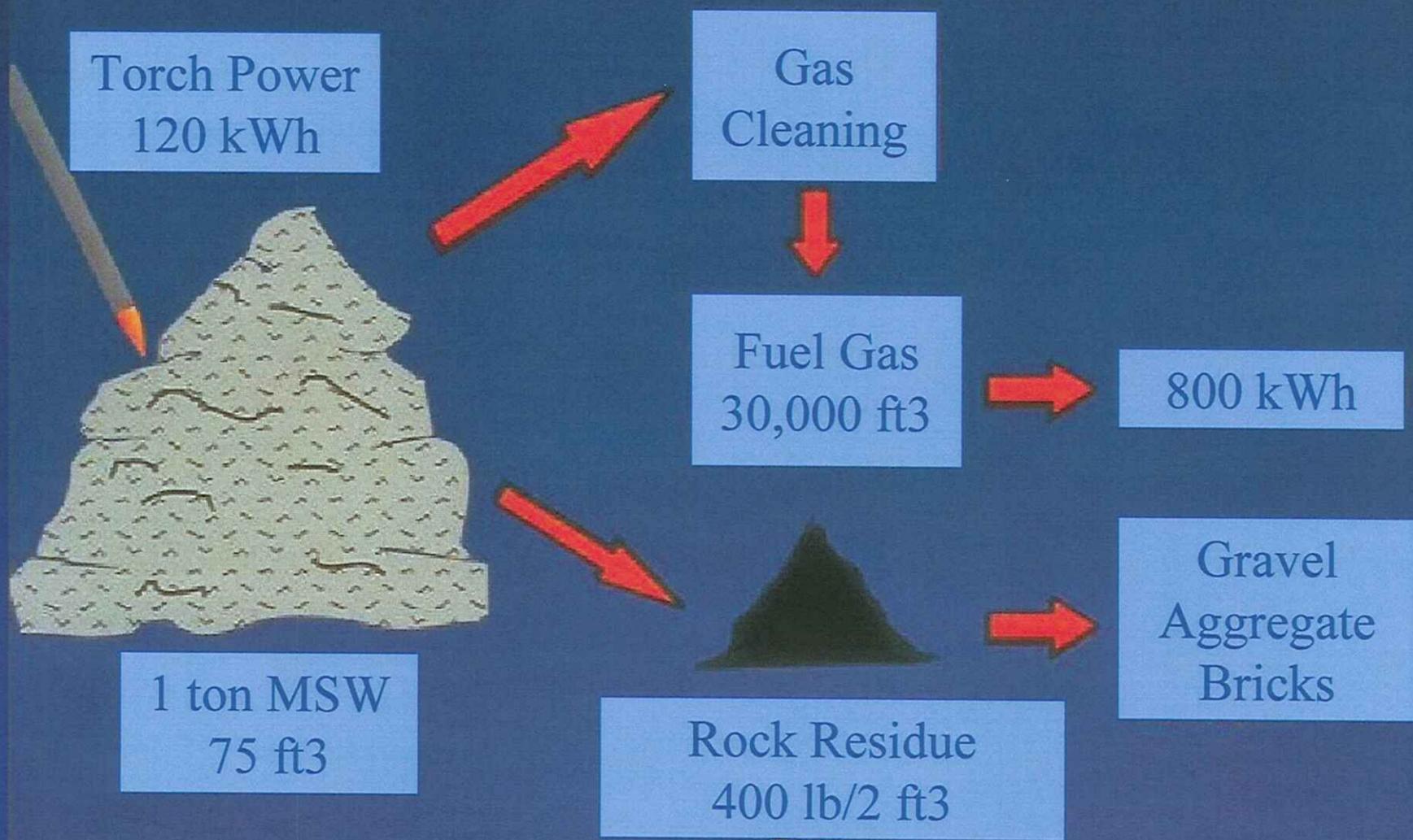
Characteristics of Plasma Arc Technology

- Temperatures 4,000°C to over 7,000°C
- Torch power levels from 100kW to 200 MW produce high energy densities (up to 100 MW/m³)
- Torch operates with most gases
 - Air most common
- A pyrolysis and/or gasification process
 - Not an incineration process
- Permits in-situ operation in subterranean boreholes

Plasma arc technology is ideally suited for waste treatment

- Hazardous & toxic compounds broken down to elemental constituents by high temperatures
 - Acid gases readily neutralized
- Organic materials
 - Gasified or melted
 - Converted to fuel gases (H_2 & CO)
 - Acid gases readily neutralized
- Residual materials (inorganics, heavy metals, etc.) immobilized in a rock-like vitrified mass which is highly resistant to leaching

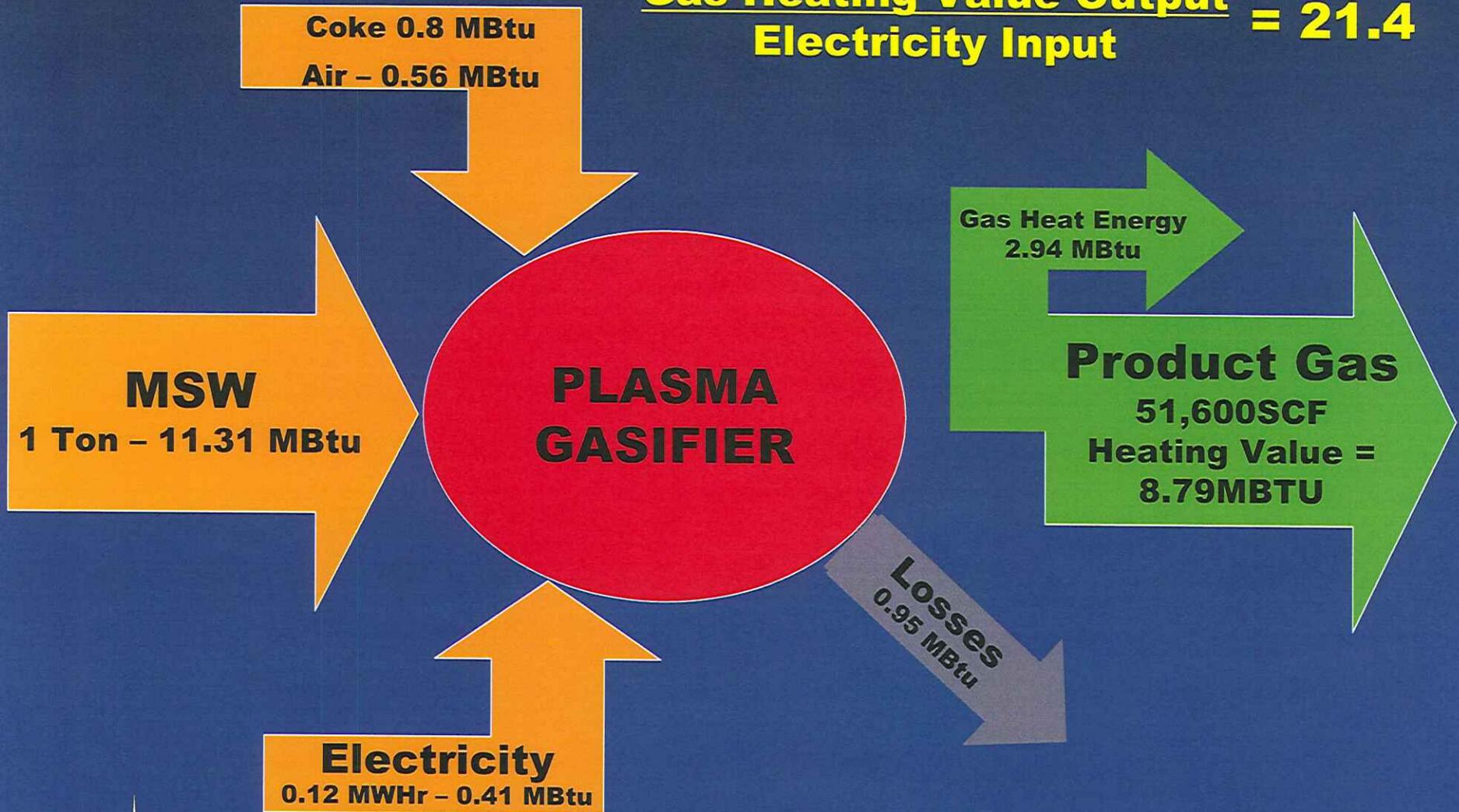
Pyrolysis of MSW



Plasma Gasification of MSW

Notional Heat Balance

$$\frac{\text{Gas Heating Value Output}}{\text{Electricity Input}} = 21.4$$



Municipal Solid Waste (MSW) – to – Electricity Thermal Process Comparisons

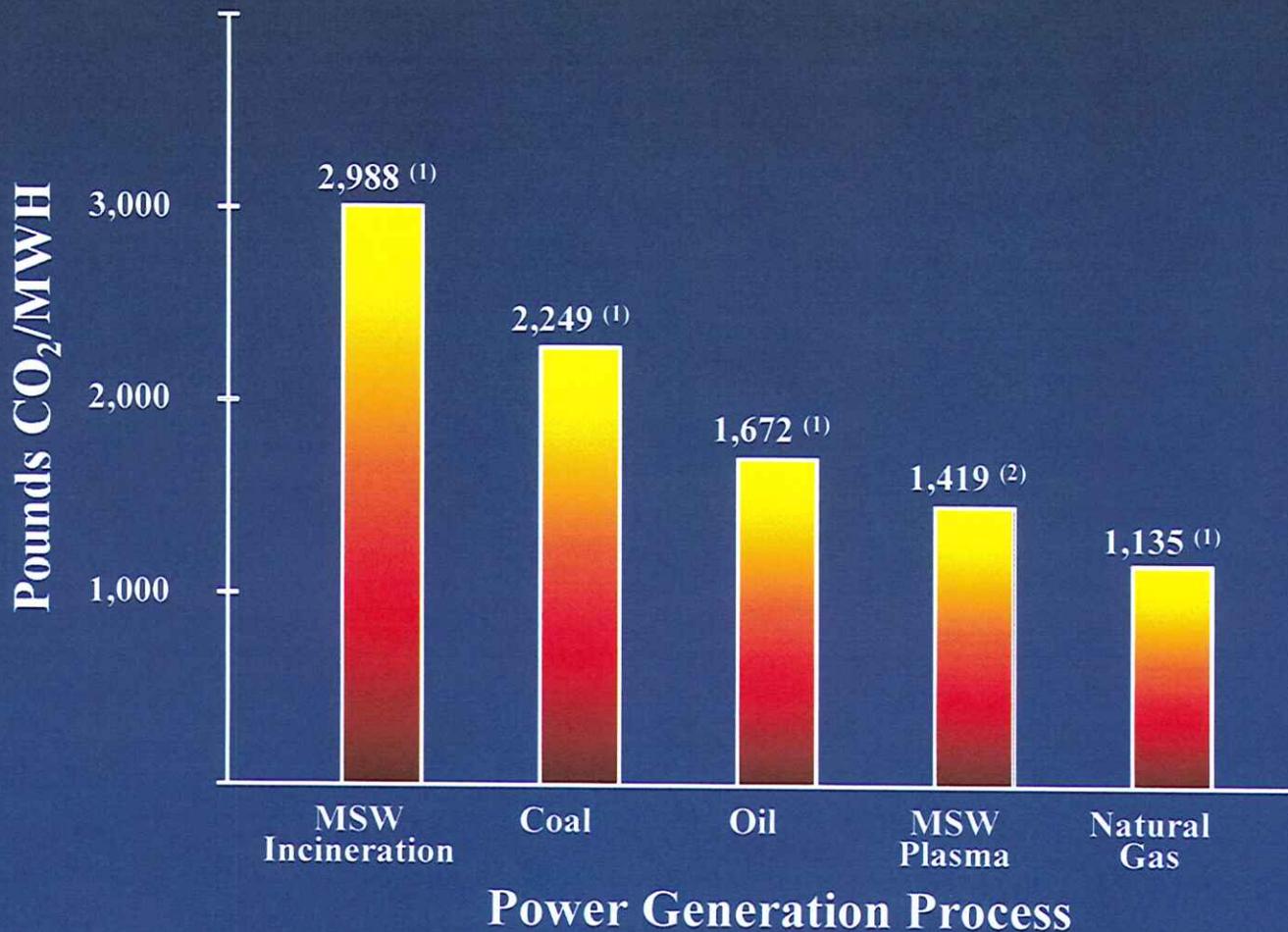
<u>Process</u> ⁽¹⁾	<u>Net Electricity to Grid</u> <u>(kWh/ton MSW)</u> ⁽²⁾	<u>Plasma Advantage</u>
• Plasma Arc Gasification	816	-
• Conventional Gasification - Fixed/Fluidized Bed Technologies	685	20%
• Pyrolysis & Gasification - Thermoselect Technology	685	20%
• Pyrolysis - Mitsui R21 Technology	571	40%
• Incineration - Mass Burn Technology	544	50%

(1) 300 – 3,600 TPD of MSW

(2) Steam Turbine Power Generation

Reference: EFW Technology Overview, The Regional Municipality of Halton, Submitted by Genivar, URS, Ramboll, Jacques Whitford & Deloitte, Ontario, Canada, May 30, 2007

Pounds of CO₂ Emissions per MWH of Electricity Produced



- (1) EPA Document: www.epa.gov/cleanenergy/emissions.htm
(2) Complete Conversion of Carbon to CO₂; MSW Material & Heat Balance, Westinghouse Plasma Corp.

Ultimate MSW Disposal System Requirements

- Accept all solid and liquid wastes
 - No preprocessing
 - Can include hazardous/toxic materials, medical wastes, asbestos, tires, etc.
- Closed loop system
 - No direct gaseous emissions to the atmosphere
 - No landfill requirements
- Total waste reclamation
 - Recover fuel value of wastes
 - Produce salable residues (e.g., metals and aggregates)

Commercial Project

Plasma Gasification of MSW in Japan

- Commissioned in 2002 at Mihama-Mikata, Japan by Hitachi Metals, LTD
- Gasifies 24 TPD of MSW & 4 TPD of Wastewater Treatment Plant Sludge
- Produces steam and hot water for local industries



The Plasma Direct Melting Reactor (PDMR) at Mihama-Mikata, Japan converts unprocessed MSW and WWTP Sludge to fuel gas, sand-size aggregate, and mixed metal nodules

Commercial Project

Plasma Gasification of MSW in Japan

- Commissioned in 2002 at Utashinai, Japan by Hitachi Metals, LTD
- Original Design – gasification of 170 TPD of MSW and Automobile Shredder Residue (ASR)
- Current Design – Gasification of approximately 300 TPD of MSW
- Generates up to 7.9 MW of electricity with ~ 4.3 MW to grid



The Plasma Direct Melting Reactor (PDMR) at Utashinai, Japan converts unprocessed MSW and ASR to electricity, sand-size aggregate, and mixed metal nodules

Planned St. Lucie County, FL GEOPLASMA Project

- 3,000 TPD of MSW from County and landfill
- 6 gasifier units @ 500 TPD each
 - Up to 6 plasma torches per cupola
 - Power levels of 1.2 to 2.4 MW per torch
- Energy Production
 - ~160 MW electricity with net of ~120 MW to grid
 - power for ~98,000 households
 - Steam sold to local industries
- Rock-like vitrified residue salable as construction aggregate

TRASH VAPORIZATION

1. Waste is conveyed from the storage area up to the entry into the plasma cupola and enters the cupola via an air lock chamber.

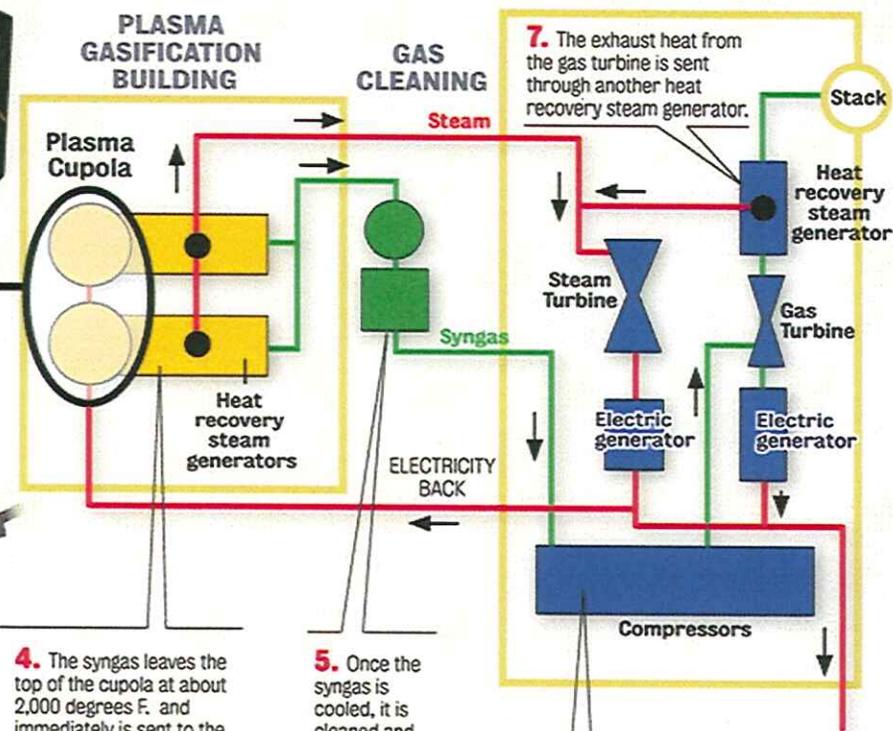
2. The extremely hot (10,000 degrees F) plasma torches at the bottom of the cupola convert the waste into either a fuel gas or a liquid slag.

3. The process is oxygen-deprived (meaning there is no combustion) and it creates a synthetic fuel gas called syngas. The syngas leaves the cupola at the top while...

3 cont. the slag runs out the bottom into a pool of water. The slag is converted into granular pieces that are completely inert and can be used as aggregate (a crushed stone product that is used for constructing foundations, roads, etc.) or shaped into paving bricks or other construction materials.



PROPOSED WASTE PLASMA PLANT



4. The syngas leaves the top of the cupola at about 2,000 degrees F, and immediately is sent to the heat recovery boiler, which reduces the temperature of the syngas to about 400 degrees F while making steam that is sent to the power plant building to produce electrical energy in a steam turbine-driven electric generator.

5. Once the syngas is cooled, it is cleaned and scrubbed to remove contaminants. The syngas is now ready to be used in the power plant.

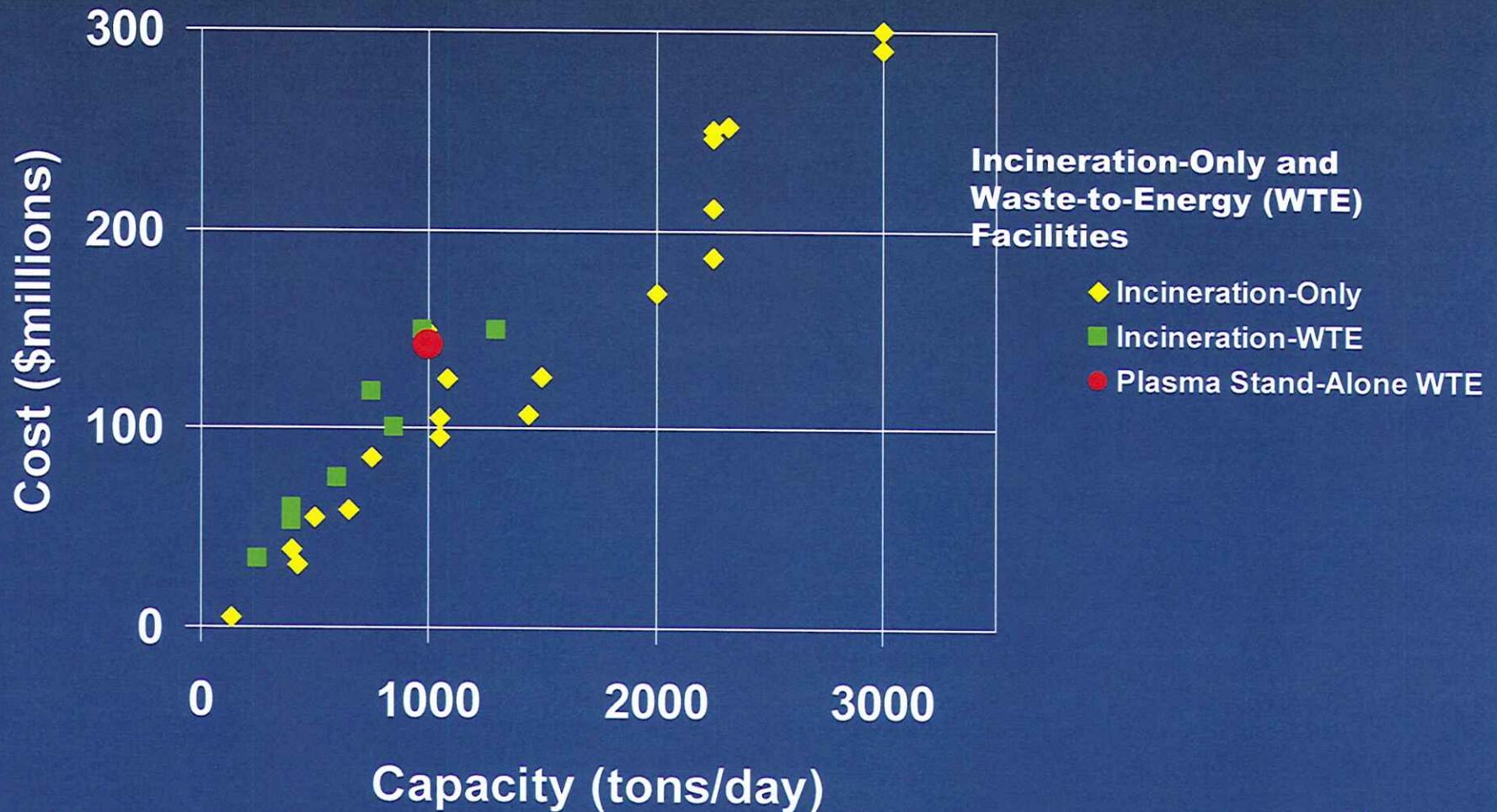
6. Compressors pull the syngas from the plasma cupola through the heat recovery boilers and the gas cleaning equipment and compress the gas for use in a gas turbine. After the syngas goes through the gas turbine and goes through the electric generator to produce electricity, it is able to be sold to a utility grid.

7. The exhaust heat from the gas turbine is sent through another heat recovery steam generator.

Edelman

KWENCY NORMAN • Staff

Capital Costs: Incineration vs Plasma Gasification Facilities



Summary and Conclusions

- Plasma processing of MSW has unique treatment capabilities unequaled by existing technologies
- It may be more cost-effective to take MSW to a plasma facility for energy production than to dump it in a landfill
- Plasma processing of MSW in the U.S. could:
 - Significantly reduce the MSW disposal problem
 - Significantly alleviate the energy crisis
 - Reduce the need for landfills

Westinghouse Plasma Projects Under Development

Geoplasma's St. Lucie WTE Project

When completed, Geoplasma's WTE plant in Florida will be the largest plasma gasification facility in the world, and will use WPC plasma gasification technology. Located on an existing landfill site, it will process up to 3,000 tons-per-day of MSW and producing 120 MW of electricity. The first phase will process 1,500 tons-per-day and produce 60 MW or enough electricity to power 60,000 homes.

The only other output from the facility will be an inert slag which can be used for aggregate in road construction.

Alter Nrg has formed a strategic joint venture, Geoplasma, with Jacoby Energy Development Inc (Jacoby) whereby they become the exclusive marketer of the WPC plasma gasification technology for use in WTE applications, in Canada and the United States.

NRG Energy's Coal Retrofit Projects

- NRG Energy Corporation (NRG) is the largest independent power producer in USA (US\$ 10 billion market cap). (NRG has exclusive access to WPC plasma technology)
- NRG has identified numerous plants that are coming up to the end of their permitting life (over 350 power plants)

NRG's Somerset, Massachusetts coal-fired power plant will be the world's first plasma gasification retrofit to use WPC plasma gasification technology.

- Produce 120 MW electricity in Massachusetts
- Their current permit expires in 2009
- Only a one year process for facility

"Power generation with Plasma Gasification reduces emissions far below conventional coal plants." – NRG Energy

Sun Energy WTE Project, New Orleans

Sun Energy is intending to build a large WTE facility in New Orleans that will use WPC plasma gasification technology to convert 2,500 tpd of garbage to 138 MW of power. The company has acquired a site located in the industrial sector of eastern New Orleans and is near completion of its environmental permit applications.

"We think it's a good technology, the actual process is really pretty good" said Karen Wimpelberg, board president of the Alliance for Affordable Energy, a consumer-focused group that has taken a close look at the gasification process (Source: The Times Picayune, October 14, 2007)

Coronal WTE Project, International Falls, Minnesota

The Koochiching County, International Falls project will use approximately 150 tpd of municipal solid waste to produce a syngas which will be directed to the kilns at a neighboring paper mill, reducing the mill's usage of natural gas. The WPC plasma gasification process will convert the MSW to syngas and a glass slag material which could be sold as a building aggregate, greatly reducing the amount of garbage Koochiching County and neighboring counties send to landfills. Coronal, the consulting and development firm for the project is currently coordinating a feasibility study to be completed as the first step in the project permitting process. Upon completion of the feasibility study, project permitting will begin mid-year 2008.

"I've studied this for a couple of years here and I'm very, very much in favor of this happening," said Kluess (Steve Kluess, Laurentian Resource and Conservation Development, US Department of Agriculture) "I can see the potential nationwide, North America wide for that matter, 20 or 30 years from now, as more and more facilities go off line and tipping fees go up, you'll see that this will be the way that municipal solid waste will be disposed of and taken care of in this country." (Sources: Minnesota Public Radio - July 31, 2006)

Green Power Systems, WTE project, Tallahassee, Florida

Renewable Fuels of Tallahassee LLC, a subsidiary of Jacksonville-based Green Power Systems LLC will install a system in Tallahassee to convert municipal solid waste into clean energy, including electricity. Financing for the project will be provided through a \$182 million funding agreement with the Controlsud International Group, based in Luxembourg, which is composed of more than 70 companies. The deal was announced Monday (November 5, 2007) by Gov. Charlie Crist, who led a delegation of more than 200 business and government leaders on a trade mission to Brazil.

Renewable Fuels will install a WPC designed plasma gasification system that uses WPC plasma torches to convert landfill waste into syngas, which can be injected into a combustion turbine for the production of electricity. It is anticipated that the project will generate sufficient power to supply 22,000 homes and produce ethanol. (Source: Tampa Bay Business Journal, November 6, 2007)

Fuel Frontiers, Inc. (FFI), Muhlenberg County CTL Project, Kentucky

Fuel Frontiers, Inc. (FFI), through its parent corporation Nuclear Solutions, Inc., has contracted with Westinghouse Plasma Corporation (WPC) for the WPC Plasma Gasifier to be designed and incorporated in the FFI Muhlenberg County, Kentucky CTL (Coal-to-Liquid) Diesel Fuel Production Plant. The plant will operate at coal feedstock levels of 400 to 450 tons per day, producing in the range of 72 million gallons per year of ultra-clean diesel fuel. FFI has Letters of Intent from Phoenix Coal Corporation for plant locations for the CTL Ultra-Clean Synthetic Diesel production facility close to Phoenix Coal producing areas. At the same time, FFI has Letters of intent with Phoenix Coal for coal supply. FFI plans to work with Stone & Webster Ltd of Milton Keynes, England to do the design integration of the WPC Plasma Gasifier and the Fischer Tropsch system and to design the gas cleanup system and balance of plant systems.

Stone & Webster Ltd, in concert with WPC, will assist FFI in selecting the Fischer Tropsch system supplier. Stone & Webster Ltd and its parent corporation, Shaw Stone & Webster, will assist FFI in selecting the best plant site for the Diesel Fuel Production Plant. FFI anticipates plant startup in year 2010.

Environmentally Responsible

OVERALL EMISSIONS RATE REDUCTIONS

Hg (Mercury)

95% REDUCTION

NO_x (Nitrogen Oxide)

60% REDUCTION

SO₂ (Sulfur Dioxide)

> 95% REDUCTION

CO₂ (Carbon)

CAPTURE COMPATIBLE

Plasma gasification technology offers an environmentally responsible solution for older power plants and works with numerous feedstocks including: solid biomass, coal, construction and demolition waste. Feedstocks such as biomass can be co-gasified with coal in retrofitted plants, reducing non-renewable resource use.