Appendix B: Contacts in the Plasma Arc Industry

The following organizations are involved in plasma arc technology for waste disposal

1. **The Construction Research Center at the Georgia Institute of Technology**
   Dr. Louis J. Circeo
   Georgia Tech Research Institute
   Atlanta, GA 30332-0837
   (404) 894-2070
   A research and development center headed by Louis Circeo, a pioneer in the development of waste disposal applications for plasma arc technology.

2. **Westinghouse Plasma Corporation**
   Dan Lazzard
   Plasma Center – Waltz Mill Site
   Madison, PA 15663
   (724) 722-7052
   http://www.westinghouse-plasma.com/
   The co-developer of the only commercial plasma arc facility disposing of MSW, the 166-tpd plant in Utashinai, Japan

3. **Hitachi Metals**
   Environmental Systems Company
   +81-3-5765-4701
   http://www.hitachi-metals.co.jp/e/prod/prod07/p07_2_02.html
   The co-developer of the only commercial plasma arc facility disposing of MSW, the 166-tpd plant in Utashinai, Japan

4. **Integratead Environmental Technologies, LLC.**
   David Lamar
   1935 Butler Loop
   Richland, WA 99352
   (509) 946-5700
   http://www.inentec.com/
   The designer/engineer for the medical waste plasma unit in Honolulu, HI.

5. **The Solena Group**
   Dennis Miller, Chief Scientist
   Ronald Reagan Building and Intl Trade Center
   1300 Pennsylvania Ave.
   Washington D.C. 20004
   (202) 682-2405
   http://www.solenagroup.com/html/contact/contact.asp

6. **The Phoenix Solutions Company**
   Douglas Frame, President
   3324 Winpark Drive
   Crystal, MN 55427
   (763) 544-2721
   http://www.phoenixsolutionsco.com/main/index.php
   One of the largest manufacturer of plasma torches and process components. Their equipment is in approximately twenty ash vitrificaiton plants in Japan.

7. **SRL Plasma Ltd.**
   Rex Williams
   PO Box 119
   Narangba, Queensland
   AUSTRALIA 4504
   617-3203-3400
   http://www.srlplasma.com/srlpages/srlframe.html

8. **Plasma Environmental Technologies, Inc.**
   130 Adelaide Street West, Suite 2320
   Toronto, Ontario, CANADA M5H 3P5
   (416) 599-9979
   http://www.plasmaenvironmental.com/index.asp?counter=counter_id

9. **Resorption Canada Ltd.**
   Randy Bennett – Director of Business Development
   2610 Del Zotto Avenue
   Gloucester, Ontario
   CANADA K1T 3V7
   (613) 831-0590
   http://www.rcl-plasma.com/
   RCL designs plasma units for disposal of ash and hazardous material using off-the-shelf components.

10. **MSE Technology Applications, Inc**
    200 Technology Way
    PO Box 4087
    Butte, MT 59702
    (406) 494-7100
    contact@msw.com

11. **HI Disposal Systems**
    PO Box 1724
    Indianapolis, IN 46206
    (866) 500-1724
    http://www.hawkinsindustries.com/hawkins_0.html

12. Tetronics Limited
David Deegan
Wicklesham Farm
Faringdon, Oxon
UNITED KINGDOM SN7 7PN
+44 (0) 1367 240224
http://www.tetronics.com/homepageframe.html

13. Encore Environmental Solutions, Inc.
Gary Von Sesen, CEO
932 Heykoop Drive
Morristown, TN 37814
(423) 587-7383
http://www.encoreenvironmental.com/

14. Europlasma
contactprocess@europlasma.com
http://www.europlasma.com/gb/contact/principale.htm
Develops, builds and markets plasma torches

15. PEAT, Inc.
Marlin Springer, President
Huntsville, AL
(256) 859-3006
http://www.peat.com/frameset.html

16. Vanguard Research, Inc
10400 Easton Place Suite 450
Fairfax, VA 22030
(703) 934-6300
http://www.jdmag.wpafb.af.mil/peps.pdf
Developer of Lorton, Virginia hazardous waste facility

Appendix C: Summary of Telephone Interviews

Telephone Call Summary

Date/Time of Call: September 24, 2002; 3:30pm

Person Called: Dr. Louis Circeo
Contact Information: Center for Construction Research
Georgia Institute of Technology
Atlanta, GA 30332
(404) 894-2070

Dr. Circeo is the Director of Construction Research and a Professor of Architecture at the Georgia Institute of Technology and a leading academician in the field of plasma technology. He runs a plasma research facility at Georgia Tech and has delivered a number of papers and presentation on the use of plasma for waste disposal.

I asked him to comment specifically on the use of plasma technology for the disposal of MSW and he immediately cited the new Westinghouse/Hitachi plant in Japan. In fact, Circeo said he was the person that brought Westinghouse and Hitachi together. He said the W/H plant was the only commercial plasma facility designed to handle MSW that he was aware of. Furthermore, he felt Westinghouse was the only credible player in the business that was addressing MSW disposal. There are a number of facilities in Japan and Europe that use plasma for ash vitrification, but only the W/H plant is being designed to handle MSW.

He did not have any information capital or operating costs and referred us to Westinghouse to get that kind of information. Circeo warned me several times about the number of "fly-by-night" companies out in the marketplace who claim to have a plasma technology, but have not proven their technology in an operating facility. Again, he cited Westinghouse as the most credible company in the business.

Circeo also mentioned a resolution by the Georgia State Legislature in the spring of 2002 that encouraged/supported the use of plasma technology for waste disposal. This resolution has prompted the formation of several small companies that are pursuing plasma technology in Georgia. One of these companies, PR Power, is apparently try to develop a tire disposal facility using plasma.

Dr. Circeo promised to send us a packet of information on his research and invited us to visit his research lab at Georgia Tech if we were in Atlanta. In closing, I mentioned that R.W. Beck is about to begin a state-wide waste characterization study for the State of Georgia.

Tom Jones

Telephone Call Summary

Date/Time of Call: October 3, 2002; 2:30 pm

Person Called: David Lamar
Contact Information: Integrated Environmental Technology, LLC
1935 Butler Loop
Richland, WA 99352
(509) 946-5700

Integrated Environmental Technologies (IET") is the supplier of the core technology for the plasma arc medical waste gasification facility in Hawaii. The unit is 3-4 TPD plant accepts the Regulated Medical Waste ("RMW") in 8 gallon buckets. The bucket with the waste is fed into the plasma reactor. The reactor has graphite torches (or electrodes) in the glass melt to keep the melt in the liquid state and other torches above the melt to provide the heat to process the organic/ hydrocarbon material. Steam and oxygen are injected to complete the gasification process. The synthesis gas (240-270 BTU/SCF) is sent to an internal combustion engine after cleaning (engine mixes about 10 percent propane for stability).

The Plasma arc uses DC current generated. There is no net electrical output from the medical waste unit. IET reports that a net power output is generated at plant sizes above 25 TPD. Oxygen Demand is at 0.1 equivalence (1.0 would be sufficient oxygen to combust) and the amount of steam required depends on the feedstock. The steam is used to complete the water gas shift reaction and Bouvard reaction. For plastics, three times the required water is used; for cellulose 1.5 times is used.

Hawaii is the first IET unit to come on line (February 2001), a second facility is in Japan (10 TPD) currently finishing construction. Scale-up is anticipated to go to a 250-300 TPD per unit. However, the next step for IET is expected to be a 50 TPD unit. It is worth noting that Honolulu's RMW unit tested some RDF from H-Power and reported that it worked well.

The system uses a gravity feed, reactor is at slightly negative pressure (- 5" H2O). Top temperature is 100-1200 C minimizing potential tar formation. Tar will form during upset conditions. IET stated that an MSW unit would probably need 6-inch minus material. Main concerns would be potential damage to an electrode. The flow sheet is gasifier, quench, baghouse, acid gas removal, carbon bed and engine.

O & M electrodes are a consumable. The rate of consumption is in the range of 8-15 percent of graphite per ton of waste. The large refractory units are relined every 3 to 8 years. Smaller units are relined in the range of 1 to 3 years. Tap hole are expected to be redrilled every 2 years, but more experience is need to be sure of this estimate. The AC electrode in the bath maintains the melt and DC electrodes process the waste. IET estimates that the capital cost for 100 TPD process train is in the range of 20-23 million dollars. This does not include feed preparation. Cost data is an order of magnitude estimate.

Telephone Call Summary

Date/Time of Call:	November 5, 2002; 10:00am
Person Called:	Len Frame
Contact Information	Phoenix Solutions, Inc. 3324 Winpark Drive Crystal, MN 55427 (763) 544-2721

Phoenix Solutions, Inc. ("Phoenix") claims to be one of the largest manufactures of both transferred and non-transferred plasma torches in the world. They supply torches to firms that design and build full plasma-arc systems. Phoenix does not advocate one type of torch (i.e., transfer vs. non-transfer) over another. Their torches are copper-plated, water-cooled, and can use either air or nitrogen. Their torches are placed inside the reactor which maximizes the heat available to process the waste, but also corrodes the torches more quickly. They advocate a shorter, squatter reactor than Westinghouse, introducing the MSW in the side, rather that the top.

Phoenix estimates that a 125 TPD facility would require 3 MW of power to operate. Mr. Frame stated that unless a system using their torches and combined with a combustion turbine produced a minimum of one MW per tons of waste, it would probably not be able to compete with other methods of MSW disposal. However, this estimate is hypothetical because none of their units have actually been used with a combustion turbine.

Up to this point, Phoenix has focused on medical and hazardous waste disposal applications in countries with high landfill costs and strict environmental regulations. Phoenix has 20 operating units in place in Japan and supplied the torches for the Honolulu medical waste facility. If they received an RFP from Honolulu, they would try to find a partner who could lead the project and respond.

Telephone Call Summary

Date/Time of Call: October 15, 2002; 11:00am

Person Called: Randy Bennett
Contact Information: Resorption Canada, Ltd.
2610 Del Zotto Ave.
Gloucester, Ontario K1T 3V7
CANADA
(613) 831-0590

Resorption Canada Limited ("RCL") is a developer of Plasma Arc systems for waste disposal. They have been operating a pilot plant near Ottawa Canada for over 15 years. The pilot plant has approximately 1200 hours of operation. They use plasma torches manufactured by Phoenix Solutions, Inc of Crystal, Minnesota or Europlasma of France. RCL's pilot plant has a 150 kW torch which gives it a capacity of approximately 4 tons per day of MSW. RCI does R & D work and is in the process of developing their first commercial unit in the Far East for biomedical waste and hazardous waste.

RCL's system uses a DC torch that is a water-cooled. The electrical discharge heats a flowing gas (primarily air). The torch extends into the reactor vessel, with the hot plasma exiting the end of the torch to the desired point in the reactor. The system operates as a gasification system at high temperatures. The typical gasification reaction occurs producing a synthesis gas rich in hydrogen and carbon monoxide. The addition of steam allows a level of control on the ratio of hydrogen to carbon monoxide. They clean up the gases (still in the syngas phase) with standard hydrocarbon processing techniques. The gas can be used as a fuel gas in the proper combustion equipment. The reactor is operated at slightly negative pressure to ensure containment of the gases.

RCL indicated that a commercial system might contain modules of approximately 250 TPD each using three torches with a total of 4 MW's of power. The maximum single torch is approximately 2 MW. RCL has performed some commercial design that calls for a 500 TPD plant using two units each with 4 MWs of torches. This system would generate 30 MW gross and 17.5 MW net (using approximately 5000 Btu/pound waste). Note that at 17.5 MW net, the net output is 350 kW/ton. This is substantially less than the 550 to 600 kW net per ton that a standard mass burn WTE unit will produce. However, it correlates with the use of approximately 400 kW per ton of the torch. RCL reported that the waste does no need to be sized, if the reactor input feed port is large enough. Waste is introduced in the side of the reactor. We note that without operational experience there are mechanical issues that would need to be addressed for scale-up to a commercial size unit. The size of a 250 TPD unit would be 16 feet in diameter. Slag is tapped off the side of the reactor.

RCL claims that their breakeven tip fee (with no return on capital- debt or equity) is approximately $45/ton. They also claim that they can purchase process insurance from FM Global.

The typical advantages of Plasma gasification were stated: a) no residue to be landfilled because the ash is vitrified, b) extremely high temperatures that convert the organics to a harmless gas, and c) the compact size of the reactor. RCL's approach is to concentrate on higher value wastes in areas where MSW landfill costs are high and environmental regulations are strict.

Telephone Call Summary

Date/Time of Call:	November 13, 2002; 3:00 pm
Person Called:	Dennis Miller
Contact Information:	Ronald Regan Building and Intl. Trade Center 1300 Pennsylvania Ave. Washington D.C. 20004 (202) 682-2405

The Solena Group is a developer of projects using waste fuels, including MSW. They do not own any technology but utilize technology supplied by others to put together the technology portion of a project. One of their main thrusts is the use of plasma arc gasification of MSW to produce a synthesis gas to be used in a combined cycle operation. Their main concentration is in the European Union ("EU") primarily Italy and Spain. The EU has two attributes that encourage alternative methods of disposal of MSW. First landfill space is scarce and expensive and certain countries have placed restrictions on what can be deposited in landfills. Second the EU has set a goal for increasing percentages of power to be generated from renewable resources. According to Mr. Miller, the Italian government is offering an incentive to renewable energy projects of the equivalent of 14 cents per KWh generated above the prevailing rate for electric power. Solena also reports that they are also developing projects in Asia (e.g., Malaysia and the Philippines).

Mr. Miller stated that Solena Group's first commercial plasma system combining MSW disposal and a combustion turbine is currently under construction in Rome, Italy and is anticipated to go into operation by the end of May 2003. It utilizes the Westinghouse Plasma Torch system, a gas cleanup system to be supplied by LGL (a French company) and a Frame 6 combustion turbine supplied by General Electric in a combined cycle operation. The plant incorporates a 14 ton per hour single train reactor, and the MSW is first processed to produce an RDF which is then baled for drying and storage. The bales are broken up prior to being fed into the reactor. Depending on the final heating value of the resulting synthesis gas, the combustion turbine may need supplemental fuel. Solena reports to have developed working relationships with Stone & Webster and CM2H Hill, as well as local constructors. They intend to build modular units based on a 20 ton per hour reactor, and the associated combustion turbine. Solena Group stated that they have obtained project technology insurance from Marsh & McLennan.

Mr. Miller stated that Solena can finance projects based on turnkey contracts and that their minimum size would be a single train 20 ton per hour unit (480 tons per day). They believe that a plant of this size would produce three times as much net power as it consumed. This would be equivalent to approximately 150,000 tons per year of waste at an 85 percent capacity factor.

Telephone Call Summary

Date/Time of Call: September 22, 2002; 9:00 am

Person Called: David Deegan
Contact Information: Tetronics Limited
Wicklesham Farm
Faringdon, Oxon
United Kingdom SN7 7PN
+44 (0) 1367 240224

Tetronics is a UK company that is primarily in the business of supplying plasma systems for steel manufacturing and waste treatment. Ash vitrification is their primary waste area with over 30 units in operation. They have one liquid hazardous waste gasification unit in Italy as a demonstration project. They also have several pilot facilities in the UK (3 MW capacity) and 5-10 TPD capacity. Current systems run from 3 TPD to over 100 TPD.

Tetronics used either a graphite transferred torches or a non-transferred gas heating torches that are water-cooled and could be subject to corrosion. All are DC systems. For an MSW application they would use the graphite electrode type to a metal pool, with a conductive refractory. The waste would gasify in the heat generated by the pool and a supply of air. The graphite electrode is sacrificial being used up at a rate of 1-2 percent of the waste throughput. We had no discussion of tar formation, however, the average reactor temperature was stated to be 1800 C. MSW systems would operate at slightly negative pressures. For an ash unit power consumption is on the order of 550-600 KWe/tonne this needs to be increased by heat losses (overall efficiency is ~80-90 percent). We will be getting additional information.

There appears to be depth in experience in ash vitrification, but little experience in other types of wastes. The Company was established in 1936and has license agreements with MHI in Japan. It sells both reactors or whole systems. The gases generated in the reactor would go to combustion chamber, waste heat boiler and an air pollution control system.

Telephone Call Summary

Date/Time of Call: September 19, 2002; 9:30am

Person Called: Dan Lazzara
Contact Information: Westinghouse Plasma Corporation
Plasma Center – Waltz Mill
Madison, PA 15663
(724) 722-7052

Westinghouse is a supplier of Plasma arc technology only. It does not supply complete plants. (the equipment they supply includes reactors and torches and ends at the point where the gas and solids exit the reactor. They have been supplying their equipment for plasma arc technology for 14 years in commercial operations. Previous applications in the metal industry include the fired coupla for General Motors in Defiance, Ohio. The GM plant runs on air, using a single train with a 500-600 TPD capacity. The design is somewhat different than the design of an MSW reactor.

Current waste disposal installations in Japan: Yoshii, a 1 ton per hour (24 TPD), single unit demonstration plant owned by Hatachi and a 180 TPD unit now in start-up with two units (4 tph each). There is also a pilot plant at the Westinghouse Plasma Research Center in Madison, Pennsylvania.

The Westinghouse units are operated under slightly negative pressure and are gravity fed. The only feed restriction is the size of the opening. All of the inerts are melted and all the organics are gasified. The reactor is an updraft design, with the hot air created by the plasma injected near the bottom of the reactor. The air can reach temperatures of 8000 F. and reacts in a coke/carbon bed

MSW is not required to be pre-treated unless it cannot pass through the input port. The plasma injection point is about ½ way up the reactor. Gas velocities are low. The Plasma torches are DC-fired. However, they heat air and the air does the heating and gasification. Particluate carryover is low and NOx generation is low. The generated synthesis gas is about 150 Btu/scf, depends on heating value of the MSW. Top gas temperature is 1000-1200 C (minimizes tar formation). Energy use is 100 kwh/ton (if all ash it would be 600-900 kwh/ton). Hatachi takes the gas to a boiler and generates steam. No gas cleaning between the reactor and the boiler. Main synthesis gases are CO, H_2, CO_2 and N_2. Enriched air can be used to enhance the heating value. GE can burn the synthesis gas in a turbine, if the gas is cleaned and cold.

All liquid slag is taken off through one tap. The capital cost of the reactor system is on the order of $200/kW of thermal capacity.

Appendix D: Plasma Waste Disposal Facilities

Ash Vitrification

Facility: Fly Ash Vitrification Plant
Location: Cenon, France
Types of Waste: Fly ash from incineration of MSW (120,000 tpd) and sludge (18,000 tpy)
Capacity: 7 tpd/2,400 tonnes per year
http://www.europlasma.com

Facility: Kakogawa Plant
Location: Kakogawa, Japan
Type of Waste: Fly ash from fluidized bed incinerator
Capacity: 30 tpd/5,000 tpy

Facility: Shimonoseki Plant
Location: Shimonoseki, Japan
Type of Waste: Fly ash and bottom ash from grate incineration furnace
Capacity: 41 tpd/10,000 tpy

Facility: Imizu Plant
Location: Imizu, Japan
Type of Waste: Fly ash from fluidized bed incinerator
Capacity: 12 tpd/ 3,000 tpy

Facility: IHI Plant
Location: Kinuura, Japan
Type of Waste: Fly ash and bottom ash from 240 tpd MSW incinerator
Capacity: NA

Hazardous Waste Facilities

Facility: INERTAM-Cofal SA
Location: Morcenx, France
Type of Waste: asbestos melting unit
Capacity: 22tpd/8,000 tonnes per year
http://www.europlasma.com

Facility: Hawaii Medical Vitrification Facility
Location: Honolulu, Hawaii
Type of Waste: Medical Waste
Capacity: Four tpd (permitted capacity 1 tpd)

Facility: PEPS Facility
Location: Lorton, Virgina
Type of Waste: Agricultural Blast Media
Capacity:
http://www.jdmag.wpafb.af.mil/peps.pdf

Facility: Nufarm Ltd (herbicide manufacturer)
Location: Laverton, Victoria AUSTRALIA
Type of Waste: Liquid and gaseous hazardous wastes
Capacity: 4 tonnes per day
http://www.eidn.com.au/plasma.html

MSW Facilities

Facility: Pilot Plant
Location: Yoshii, Japan
Type of Waste: MSW
Capacity: 25 tpd

Facility: ASR/MSW Facility
Location: Utashinai, Japan
Type of Waste: Auto-shredder residue and MSW
Capacity: 166 tpd

Facility: Enel Project (now under construction)
Location: Rome, Italy
Type of Waste: Municipal and industrial wastes
Capacity: 366 tpd