Aitkin County Economic Development & Forestry

# AITKIN COUNTY PLASMA GASIFICATION STUDY

**Does it make sense to move forward with a full feasibility analysis?**

April 2008

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This report was prepared by the Northspan Group, Inc.
a private non-profit business and community development corporation located in Duluth.

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# I. EXECUTIVE SUMMARY

"Does it make sense to move forward with a full feasibility analysis?"

Disposal of municipal solid waste, auto fluff, hazardous materials and medical wastes (feedstock) have become increasingly expensive and challenging for communities. Aitkin County is considering options for a Plasma Energy Park, with a Plasma Gasification facility anchored by several complimentary businesses providing the aforementioned feedstock to curb the disposal concerns, along with creating jobs, helping the environment and other advantages. (See Appendix, Map C)

Plasma Gasification has been in use since the late 1800s in the metal industry, expanding into the chemical industry in the 1900s. NASA Space program chose Plasma Gasification for simulating the extreme heat of reentry into earth's atmosphere. Since then small prototype processes have been tested. Today, Plasma Gasification technology is again expanding to diversify feedstocks; with Plasco Energy Group, with the first North American facility in Ottawa, Canada accepting municipal solid waste in 2007. Plasma torches heated up to 20,000°C gasify feedstock. The byproducts include steam, electricity, syngas and rock wool. Very little is remaining of the feedstock once gasified.

When considering the possibility of a facility, it is imperative to understand the merits and limitations. Gathered through supporters and opposers alike, the underlying fact is the information on the impacts – economic, environmental, and others - of operating a plant are uncertain and/or proprietary to the owners at this time. Existing pilot facilities in Japan and Spain own the rights to testing information, and are not required to publically announce results. Thus, public information is limited and regulatory agencies are working to accommodate pilot testing through careful monitoring.

Two types of Plasma Gasification torches predominant today are Westinghouse (Alter Nrg) and Plasco.

To illustrate, Canada allowed Plasco, a private company to move forward with their project in Ottawa, without having an environmental assessment completed upfront. For two years the pilot plant will be allowed to operate with testing and reporting required. They are carefully and continuously monitoring the emissions of $CO_2$, $NO_x$, $SO_x$, heavy metals and particulate pollutions. Plasco also has a research facility in Castellgali, Spain which operates at only five tons/day which was used to modify the Ottawa pilot project design. Because Canadian government provided some financing of the project, and because of it's stature of being a "pilot plant", emission results are publically posted for this facility.

As we assess this technology and the opportunity for Aitkin County, we need to look at whether or not the benefits outweigh the limitations when considering a Plasma Gasification. Coronal, LLC, a developer of Plasma Gasification facilities promoting Westinghouse technology, considers the following:

Benefits:

- Syngas is more homogeneous and cleaner burning fuel than Municipal Solid Waste (MSW)
- Unwanted organic compounds or trace contaminants is minimized

- No direct air emission points
- Syngas produced in the conversion of feedstock is lower than the volume of flue gases formed by MSW
- Pre-cleaning of syngas is possible
- Slag recovery can produce multiple products for reuse

Barriers:

- Lack of regulations needed for permits
- Financial Risk
- Technical Risk
- Economics

In this report, we are presenting information gathered from interviews, websites, newspaper articles, and reports by the developers of the technology. The technology is not new, although, it has changed over the years of research and development. Proven impacts are not clear, although developers of facilities do have some information available, and are moving forward with "pilot" plants in North America and in other parts of the world in cooperation with regulators.

Projects under consideration in the United States include St. Lucie, Florida, International Falls, Minnesota, Tallahassee, Florida, Sacramento, California, and many around the world.

This project was initiated through a group of Blandin Foundation leaders and community members. Blandin Foundation provided funding for this report.

Aitkin County has the challenge of deciding whether or not to pursue significant funding for a more comprehensive feasibility analysis of constructing a plasma gasification facility as the anchor and support resource for a new Energy Park. Such a facility could address solid waste management needs and provide an economic development tool to support and leverage other private investment jobs. This assessment has provided a more detailed level of understanding about the technology, current events and limitations.

We are recommending that Aitkin County take the time to further assess the findings of three major North American projects that are either operating, under construction or have major feasibility studies underway. Some additional preliminary work can be continued, but the environmental and economic operating questions will have more answers and could streamline the next steps for Aitkin. That decision remains with the committee and its partners.

## II. WHAT IS PLASMA GASIFICATION?

### A. Plasma Gasification

Plasma Technology was created and used in the metal industry during the late 1800s to provide extremely high heat. During the 1900s, plasma heaters were employed in the chemical industry to manufacture acetylene fuel from natural gas. This application continues to be the largest (150 megawatt) plasma heated industrial plant in the world, located in the Chemische Were Huls plant, Marl, Germany.

Plasma Arch heaters regained attention in the early 1960s, when the United States NASA Space program selected the technology for simulating and recreating the extreme high heat of reentry into the earth's dense atmosphere encountered by spacecraft from orbit. Using a water-cooled copper electrode, a 50 megawatt plasma arc heater converted electricity into heat to test the reentry heat shield material at NASA.

Small-scale prototype plasma heated processes were built and tested during the 1970s, with larger industrial plants built and commissioned during the 1980s. Today, plasma technology is being used successfully in industrial plants worldwide for different applications ranging from chemical industry, metallurgical industry to the waste / environment industry.

### B. Plasma Gasification Versus Incineration

Gasification is NOT incineration as the side-by-side comparison of plasma gasification and incineration below demonstrates (as published on the website of the Plasco Energy Group). While Plasco is focused on the production of syngas, other companies (BRI Energy, Fuel Frontiers, and others) are focused on the fermentation of cooled syngas into biofuels (like ethanol).

| Plasma Gasification | Incineration |
|---|---|
| No air emissions during syngas production | Air emissions can include high levels of green house gases, other air pollutants and dioxins and furans |
| No smoke stack* | Requires high volume smoke stack |
| Solids reduced 150:1 to inert slag that has commercial value | 30% of solids remain as ash that is solid waste and potentially hazardous solid waste |
| Occurs in an oxygen starved converter vessel | Excess air is added to the incinerator |
| Plasma Generator provides all the energy required for the process | Supplementary fossil fuel is required to sustain the process |
| Decomposition of waste into energy-rich fuel | Burning: all energy converted to heat |

In plasma gasification the waste input is pyrolysed by the high temperature into its constituent elements: H2, O2, C, N2 etc. The converter conditions are controlled so that prior to exit, the elements reform into the desired syngas that is rich in CO and H2. The materials that can not be converted into syngas, such as metal, glass, rock and concrete are vitrified to produce an inert slag. The slag is 1/250th of the volume of the processed solid waste.

In incineration, excess O2 is added to the input waste so that at low temperature it burns. The result is heat and an exhaust of CO2, H2O and other products of combustion or partial combustion. As much as 30% of the processed solid waste remains as ash. This ash is a solid waste and could be categorized as hazardous solid waste. (http://biowaste.blogspot.com/2007/01/plasma-gasification-and-incineration.html)

Plasma arc gasification is a waste treatment technology that uses high electrical energy and high temperature created by an electrical arc gasifier. This arc breaks down waste primarily into elemental gas and solid waste (slag), in a device called a plasma converter. The process has been intended to be a net generator of electricity, depending upon composition input wastes, and to reduce the volumes of waste to being sent to landfill sites. (Wikipedia.com definition)

### C. Gasification Processes

Four types of gasifier processes are currently available for commercial use: counter-current fixed bed, co-current fixed bed, fluidized bed and entrained flow. New technology considered is the high temperature conversion of waste reactors.

The *counter-current fixed bed* ("up draft") gasifier consists of a fixed bed of carbonaceous fuel (e.g. coal or biomass) through which the "gasification agent" (steam, oxygen and/or air) flows in counter-current configuration. The ash is either removed dry or as a slag. The slagging gasifiers require a higher ratio of steam and oxygen to carbon in order to reach temperatures higher than the ash fusion temperature. The nature of the gasifier means that the fuel must have high mechanical strength and must be non-caking so that it will form a permeable bed, although recent developments have reduced these restrictions to some extent. The throughput for this type of gasifier is relatively low. Thermal efficiency is high as the gas exit temperatures are relatively low. However, this means that tar and methane production is significant at typical operation temperatures, so product gas must be extensively cleaned before use or recycled to the reactor.

The *co-current fixed bed* ("down draft") gasifier is similar to the counter-current type, but the gasification agent gas flows in co-current configuration with the fuel (downwards, hence the name "down draft gasifier"). Heat needs to be added to the upper part of the bed, either by combusting small amounts of the fuel or from external heat sources. The produced gas leaves the gasifier at a high temperature, and most of this heat is often transferred to the gasification agent added in the top of the bed, resulting in an energy efficiency on level with the counter-current type. Since all tars must pass through a hot bed of char in this configuration, tar levels are much lower than the counter-current type.

In the *fluidized bed gasifier*, the fuel is *fluidized* in oxygen and steam or air. The ash is removed dry or as heavy agglomerates that defluidizes. The temperatures are relatively low in dry ash gasifiers, so the fuel must be highly reactive; low-grade coals are particularly suitable. The agglomerating gasifiers have slightly higher temperatures, and are suitable for higher rank coals. Fuel throughput is higher than for the fixed bed, but not as high as for the entrained flow gasifier. The conversion efficiency can be rather low due to elutriation of carbonaceous material. Recycle or subsequent combustion of solids can be used to increase conversion. Fluidized bed gasifiers are most useful for fuels that form highly corrosive ash that would damage the walls of slagging gasifiers. Biomass fuels generally contain high levels of corrosive ash.

In the *entrained flow gasifier* a dry pulverized solid, an atomized liquid fuel or a fuel slurry is gasified with oxygen (much less frequent: air) in co-current flow. The gasification reactions take place in a dense cloud of very fine particles. Most coals are suitable for this type of gasifier because of the high operating temperatures and because the coal particles are well separated from one another. The high temperatures and pressures also mean that a higher throughput can be achieved; however thermal efficiency is somewhat lower as the gas must be cooled before it can be cleaned with existing technology. The high temperatures also mean that tar and methane are not present in the product gas; however the oxygen requirement is higher than for the other types of gasifiers. All entrained flow gasifiers remove the major part of the ash as a slag as the operating temperature is well above the ash fusion temperature. A smaller fraction of the ash is produced either as a very fine dry fly ash or as black colored fly ash slurry. Some fuels, in particular certain types of biomasses, can form slag that is corrosive for ceramic inner walls that serve to protect the gasifier outer wall. However some entrained bed type of gasifiers do not possess a ceramic inner wall but have an inner water or steam cooled wall covered with partially solidified slag. These types of gasifiers do not suffer from corrosive slags. Some fuels have ashes with very high ash fusion temperatures. In this case mostly limestone is mixed with the fuel prior to gasification. Addition of a little limestone will usually suffice for the lowering the fusion temperatures. The fuel particles must be much smaller than for other types of gasifiers. This means the fuel must be pulverized, which requires somewhat more energy than for the other types of gasifiers. By far the most energy consumption related to entrained bed gasification is not the milling of the fuel but the production of oxygen used for the gasification.

### D. High Temperature Conversion of Waste (HTCW)

High Temperature Conversion of Waste (HTCW) reactor, one of many proposed gasification processes which are still to be proven in real life installments.

Several gasification processes for thermal treatment of waste are under development as an alternative to incineration.

Waste gasification has several principal advantages over incineration:

- The necessary extensive flue gas cleaning may be performed on the syngas instead of the much larger volume of flue gas after combustion.
- Electric power may be generated in engines and gas turbines, which are much cheaper and more efficient than the steam cycle used in incineration. Even fuel cells may potentially be used, but these have rather severe requirements regarding the purity of the gas.
- Chemical processing of the syngas may produce other synthetic fuels instead of electricity.
- Some gasification processes treat ash containing heavy metals at very high temperatures so that it is released in a glassy and chemically stable form.

A major challenge for waste gasification technologies is to reach an acceptable (positive) gross electric efficiency. The high efficiency of converting syngas to electric power is counteracted by significant power consumption in the waste preprocessing, production of large amounts of pure oxygen (which is often used as gasification agent), and gas cleaning. Another challenge becoming apparent when implementing the processes in real life is to obtain long service intervals in the plants, so that it is not necessary to close down the plant every few months for cleaning the reactor.

Several waste gasification processes have been proposed, but few have yet been built and tested, and only a handful have been implemented as plants processing real waste, and always in combination with fossil fuels.

One plant (in Chiba, Japan using the Thermoselect process) has been processing industrial waste since year 2000, but has yet not documented positive net energy production from the process. (http://en.wikipedia.org/wiki/Gasification)

## III. FEEDSTOCK

A White Paper titled, *The Commercial Viability of Plasma Arc Technology*, by the Solena Group states waste streams that were successfully treated and disposed of by plasma arc technologies since the 1980's at test facilities (Pittsburgh Plasma Center, North Carolina pilot testing facility) include, but are not limited to:

- Municipal Solid Waste
- Automobile Tires
- Waste coal
- Coal
- Sludges
- Hazardous fly ash
- Incinerator ash
- Steel scrap
- Car fluff
- Hospital Medical waste
- Pyrolysis of PCB oil
- Pathological wastes
- Ferrous Chromium containing waste
- Portland Cement Manufacture waste
- Contaminated soils and fines
- Electric Arc Furnace dust
- Titanium scrap melt
- Asbestos containing material
- Niobium recovery
- Glass waste
- Ceramic waste
- Harbor sludges
- Natural gas for acetylene production
- Solvents
- Paints
- Low level radioactive waste
- Ferro-manganese reduction
- Contaminated landfill material
- Mixed source waste (combination of different waste source with MSW, ash, coal, tires, etc.

The data collected during testing is considered proprietary and confidential business information. Solena works with a consortium of Global Plasma Systems Group, Westinghouse Plasma Corp and Stone & Webster, along with a long list of developers, engineers, and others. They are a project developer of plasma technology.

## IV. FACILITIES – FEEDSTOCK: MUNICIPAL SOLID WASTE (MSW)

Two primary plasma gasification technology developers stand out: Plasco Energy Group and Alter Nrg (Westinghouse).

### A. Plasco Energy Group:

Ottawa, Canada and Castellgali, Spain are home to facilities by Plasco Energy Group, a privately held Canadian company. Plasco will build, own and operate facilities using feedstock of municipal solid waste, institutional wastes, commercial and industrial wastes or a combination of any/all. They have patented the equipment and process. Plasco Energy Group websites claim no odor emissions, a small amount of waste is stored indoors, noise levels are low, ultra low atmospheric emissions from engine exhaust with no other emissions or effluent, and only clean water. The physical size of the plant can be small, and the opportunity to build in 100-ton "modules" is available. Exteriors of facilities can match the aesthetics of the surrounding area, making their processing plants less noticeable, and adaptable to many types of environments. They have been in development and trial for 20 years; previous names include Resorption Canada LTD – RCL Plasma Ltd.

1. **Ottawa, Canada**

The Ottawa, Canada demonstration plant processed its first municipal solid waste in February 2008. Its capacity is 225 tons per day of MSW, with start up processing 75 – 85 tons per day. For every ton of MSW, 1400 kilowatt hours of power, enough to power one house for two months, is produced. Also, 150 kilograms of black glass, "slag" is produced, which can then be reused for concrete and other applications. Only 1 kilogram per ton cannot be used or recycled and needs to be landfilled.

The Canadian government did not require an environmental assessment; however, strict monitoring regulations are in place. The Environmental Registry for Ontario, EBR Registry Number RA05E0021 states "the EAA regulation also exempts Plasco's proposed short term demonstration project from the requirements of the EAA.

The Environmental Protection Agency (EPA) regulation exempts the demonstration project from the hearing requirements under the EPA and imposes additional site specific requirements, including air emission limits, monitoring protocols, third party inspector reports, cease emission procedures and mandatory consultation sessions." Also, "Plasco will be required to meet and/or exceed ministry standards as outlined in Guideline A-7 Combustion and Air Pollution Control Requirements for New Municipal Waste Incinerators and in Air Pollutions – Local Air Quality Ontario Regulation 416/05." The demonstration plant will be allowed to operate up to two years without a full environmental assessment.

Canadians are safeguarded by a guarantee from the Plasco Energy Group. For eighteen months to two years, the demonstration plant has committed to meeting and exceeding the environmental reporting requirements. At that time, if the group has not complied with environmental requirements, they will remove the entire facility, returning the site to the original condition.

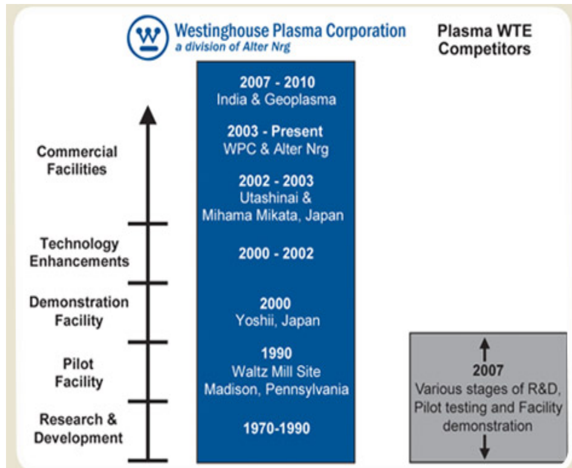
The city of Ottawa donated the 1.4 hectares (6 acres) on the closed Nepean Landfill site for the project. Permitting was completed by the city, and the need for a "Permit to Take Water" will not be required according to the proposal, "Plasco Energy Recovery Demonstration Project" (Nov. 2005). The City of Ottawa created an operating budget line item of $600,000 (2007), calculated at Canadian $40.00 per ton for tipping fees; which is similar to what they are currently paying for Waste Management, Inc. services.

The demonstration project will receive between 75 and 85 tons per day of solid, non-hazardous municipal solid waste and will produce about 5.2 MW of electricity. To power the plant, 1MW will be used. Hydro Ottawa has agreed to buy all power produced during the operation of the facility at the market price at the time of purchase.

Continuous testing of nitrogen oxides, hydrochloric acid, sulphur dioxide and other organic matters will be required of the facility. The Plasco facility also must ensure that stack tests are conducted on particulate matter, mercury, cadmium, lead, dioxins and furans. (EPA, Ontario Regulation 254/06 Plasco Demonstration Project)

The facility, cost construction is approximately $27 million. In order to fund the project in Ottawa, Plasco Energy Group received 30% from Sustainable Development Technologies Canada (up to $9.5 million), approximately 20% from other federal / provincial funding ($4.5 million) and $8.1 million from Plasco. It is unknown where the remaining balance of $4.9 million came from.

Plasco Energy Group will be generating revenues from fixed tipping fees projected at CND $40.00 per ton for up to 20 years. They will also produce income from generating electricity sales, carbon credits, selling of aggregate, sulfur and salt.




If successful, Plasco has agreed with the City of Ottawa, and upon a final decision from the City Council, to construct a 225 ton per day facility, producing about 12 MW of electricity.

According to the Plasco Energy Group Corporate Summary Presentation, November 2007, expected air emissions from engine exhaust or flare are:

| Item | Current Ontario Limit | Limits Agreed to by Plasco Energy for Demonstration Project | Expected Performance at Demonstration and Commercial Facilities | Units |
|---|---|---|---|---|
| HCl | 18 | 13 | 1 | ppmv |
| Nitrogen oxides | 110 | 110 | 20 | ppmv |
| SO2 | 21 | 14 | 4 | ppmv |
| Organic Matter | 100 | 75 | 25 | ppmv |
| Particulate Matter | 17 | 12 | 2.5 | mg/Rm3 |
| Mercury | 20 | 20 | 0.5 | ug/Rm3 |
| Cadmium | 14 | 14 | 1 | ug/Rm3 |
| Lead | 142 | 142 | 12 | ug/Rm3 |
| Dioxins and Furans | 80 | 40 | 0 | pg/Rm3 |

*ppmv = parts per million (volume based)*
*1 mg/Rm3= 0.001 gram per cubic meter of exhaust*
*1 ug/Rm3= 0.000001 gram per cubic meter of exhaust*
*1 pg/Rm3= 0.000000000001 gram per cubic meter of exhaust*

### 2. Castellgali, Spain

Castellgali, Spain is a 5 ton per day research facility which has been in operation since 2004. Lessons learned from this facility have become the solutions for the facility in Canada. A partnership with Barcelona's Hera Holdings, Spain's second largest waste management company guarantees MSW. Hera Holdings is considering owning and operating a 200-ton per day, MSW facility utilizing the Plasco Energy Group technology.

Lessons learned at the Castellgali, Spain facility are proprietary, and are not accessible by the public, as per the Plasco Energy Group Project Description, November 2005; however it states that the experience at the Spain facility indicates that "a commercially viable plant can be made profitable and that the business case for electricity generation is viable".

Also according to the above referenced project description, this caption states one of the uncertainties:

"In normal operation, the Plasco process dissociates waste to the atomic level – dioxins and furans are absent at the exit from the converter. During equipment or process malfunctions, dioxins may be formed (mainly in the gas quality control suite) until the equipment is shutdown, or until the process is re-stabilized. During these short and infrequent transition periods, the facility may produce 1-30 picogram/Nm3 of dioxins and furans."

## B. Alter Nrg / Westinghouse

Alter Nrg is the parent company of Westinghouse Plasma (WPC) technology. With over 40 years of experience in design and application of plasma technology, Alter Nrg has engineered advanced plasma technology solutions by:

- Conversion of garbage into clean energy
- Hazardous Waste destruction
- Retrofit old coal-fired power plants
- Advancing metallurgical applications
- Liquid fuels and electricity production
- Intense heat for industrial application
- Ferrous and non-ferrous metal and sulfur creation
- Spent catalyst recovery.

WPC's competitive strength comes from its plasma technology which was developed over a period greater than 30 years and with an estimated $100 million in Westinghouse R&D funding. The WPC technology was initially developed in collaboration with NASA for use in the Apollo space program to simulate space vehicle re-entry conditions of over 5,500°C (10,000°F).

Since the 1980s, the WPC technology has proven itself in various applications over several years in industrial facilities owned or operated by companies such as Alcan, General Motors and Hitachi Metals.

WPC's torches have proven to be robust and reliable even in the most rigorous and demanding applications. WPC's plasma technology and research facility, in Madison Pennsylvania, has completed approximately 100 pilot tests on a multitude of feedstocks. Since 2002, Hitachi Metals [Japan] has been operating two waste-to-energy facilities that use WPC's technology. In North America, WPC plasma technology has been selected by numerous projects that are currently under development to convert household waste into energy. (Westinghouse Plasma Corporation brochure, 2008)

Westinghouse Plasma technology is the "leader in the industry" according to ENR magazine [Engineering News – Record magazine] (Changing Economics Improve Plasma Technology's Outlook, 12-05-2007).

Partners of Alter Nrg include GeoPlasma LLC, Energy Systems Group, Green Power Systems and others. They have 72-ton per day hazardous waste disposal facilities under construction in Pune and Nagpur, India; expected operational in first quarter of 2008. Other projects upcoming are in Istanbul, Turkey (operational in 2009); St. Lucie, Florida (operational in 2009); Sacramento, California; Tallahassee, Florida and International Falls, Minnesota. Most of these are in Feasibility Assessment Phase.

Alter Nrg has identified up to 320 retrofit opportunities (coal to MSW) in North America alone. Over twenty MSW designated "qualified leads" are currently in process with Alter Nrg, ordering an average of two gasifiers per facility. Some thirty countries have 55 potential projects currently in the works with Alter Nrg. Projects proposed have not been identified in the existing information found. (www.alternrg.com, accessed March 2008)

### 1. Utashinai, Japan

Utashinai, Japan has a capacity of 200-300 tons per day of municipal solid waste gasification and auto shredder residue. The facility has been in operation since 2002 as a test pilot facility. Careful monitoring has allowed the growth to larger production. The plant was designed for 200 tons per day of Auto Fluff or 300 tons per day MSW, or a combination of the two applications. The facility is using 4 megawatts of electricity internally and is selling 3.9 megawatts net to output. At optimized capacity, it is noted, that up to 7 to 12 megawatts can be generated. Public information on environmental studies, permitting, and additional research completed by the facility is limited.

### 2. St. Lucie, Florida

The St. Lucie, Florida project is a $450 million municipal solid waste plasma arc facility utilizing eight plasma arc cupolas, operating at approximately 10,000 degrees. The largest waste to energy facility in the world, it will be a 100,000 square foot facility on a 331-acre site. Proposed project reports claim it will be able to gasify 3,000 tons per day of municipal solid wastes; starting up at 1,000 tons. They will also be mining and gasifying the existing landfill wastes in the mixture. GeoPlasma, Inc., the developer of the project has projected it will take approximately eighteen years to reclaim the landfill site, or empty the landfill.

At full capacity, the facility will be producing 120 megawatts of electricity; enough to provide service to some 40,000 residences. They are also generating 80,000 pounds of steam, of which a neighboring facility is purchasing. Some 600 tons of slag materials will also be produced that can be used for aggregate in road construction. In the article County to Vaporize Trash – Poof! September 09, 2006, www.wired.com, the claim states: "The facility will operate on about a third of the power it generates." The article also says that "No byproduct will go unused, according to Geoplasma."

A Development Agreement was executed on April 10, 2007. GeoPlasma will design, permit, finance, construct, own and operate the facility in St. Lucie. Industrial development revenue bonds – tax-exempt and taxable – will be utilized in the financing. The State of Florida has not issued any permits, nor has the city. Approximately $150 million in county tax revenue during the first 20 years of operation is expected.

### 3. International Falls, Minnesota

International Falls, Minnesota received an award in late 2007 to complete a feasibility study of an Alter nrg / Westinghouse plasma gasification facility. The project steering committee has begun gathering information for the study, with an expected completion date in late 2008. This will be the first "public" facility, and determination of proprietary information is currently under negotiation.

The feasibility study will:

- Evaluate a preliminary technical design of the components for a waste-to-energy facility
- Evaluate the economic performance (capital, revenues, expenses) associated with a waste-to-energy facility in its multiple configurations
- Evaluate the potential creation of economic development that could occur with a waste-to-energy facility
- Plan the operations & maintenance schedule as it relates to the components of a waste-to-energy facility
- Sample the emissions developed from the northern Minnesota waste stream once exposed to the plasma torch
- Determine the caloric and British thermal unit (btu) value of a sample of northern Minnesota waste
- Determine the appropriate mixture of feedstock to optimize the performance of the waste-to-energy facility
- Evaluate the conversion of the syngas to ethanol or biodiesel
- Model revenue streams and expenses associated with the expenses, capital and depreciation
- Examine what permits are associated with a project of this type
- Identify insurance requirements for a waste-to-energy facility

Coronal is the developer involved with the International Falls project. They have provided presentations to many groups including the United States government departments. They are utilizing feedstock consisting of municipal solid wastes.

Area counties that are considered in the municipal solid waste equation for the International Falls assessment include all of the surrounding counties, and in one report Aitkin County is also included. The facility is looking at 100 ton / day of MSW, which would have to include additional counties for adequate feedstock. (See Appendix, Map B)

An annual operating income is projected at $1.9 million through tipping fees, electric generation and sale of rock wool.

#### 4. Sacramento, California

Sacramento, California has approved (February 2008) a study of Plasma Gasification to be spearheaded by the U.S. Science and Technology Research Institute. They are utilizing Westinghouse Plasma technology only, and have not offered to open up the technology to other groups. Other communities in California are also looking at the option of plasma gasification. Internet news releases have been consulted with no additional information on the proposed study.

## V. OUTPUTS

Known outputs of plasma arc facilities range from electricity, to steam, to molten slag. The output is generally dependent upon the feedstock. Most facilities producing any form of output want to utilize the opportunity as an additional income generator. In the example in Ottawa, Canada (as per the Plasco Energy Group, Corporate Summary Presentation, November 2007):

| What Becomes of The Waste? | |
|---|---|
| Per Tonne | Type |
| 1400kWh | Energy (kWh) |
| 55 days | Energy (household use) |
| 150 kg | Vitrified Slag |
| 5 kg | Sulphur |
| 1.3 kg | Heavy Metals and Particulate |
| 5 – 10 kg | Salt |
| 300 L | Clean Water |

## VI. ENVIRONMENTALLY RESPONSIBLE

"In contrast to conventional thermal treatment technologies, plasma gasification is environmentally responsible because it generates non-hazardous residual byproducts, has fewer emissions and generates more energy per tonne of waste.

Plasma gasification facilities also have a smaller environmental footprint than conventional waste disposal options including landfills, incineration and non-plasma gasification.

The decomposition of waste in landfills produces methane gas, a greenhouse gas that contributes to climate change. Methane is estimated to have a global warming effect 23 times greater than carbon dioxide. According to Environment Canada, emissions from Canadian landfills are equivalent to approximately 5.5 million cars on the road. Gasification, which produces carbon dioxide instead of methane, has a smaller impact on the greenhouse effect than emissions from landfills."

(http://www.baumpub.com/cep/features_details.php?feature_id=327, Canadian Environmental Protection, May/June 2007 publication)

In March 2007, the U.S. EPA also identified plasma gasification technology as "a viable solution to convert waste to energy without emitting harmful chemicals such as dioxin, furan and mercury."

**A. Limitations and Benefits**

In this section, we have taken bits from many studies, reports and websites focusing on the environmental area.

1) Green Action and Global Alliance for Incinerator Alternatives (GAIA) posted two reports in March 2008. In each report, claims against plasma, gasification, pyrolisis and catalytic cracking technologies question the manufacturers and owner/operators of proposed facilities, focusing on St. Lucie County and Tallahassee, Florida projects. In the report Burning Issues in Waste Disposal, 2008, authors of the presentation state that facilities have not been proven safe environmentally. They are clear to point out that the Green Power Systems website has stated misleading information regarding the process and lack of needing a stack for emissions.

2) The Plasma Arc Technology for Municipal Solid Waste: A Proven Technology or Incinerator in Disguise? March 10, 2008 paper states claims such as:

- "These projects [St. Lucie County] and the claims of the companies [Alter Nrg, Green Power Systems, others] involved have not received adequate scrutiny by government agencies." Page 2
- "Without a doubt – the synthetic gas ("syngas") would contain toxic chemicals." Page 3
- "This combustion process is the incineration that results in emissions of toxic and criteria pollutants into the air. These emissions will include dioxins and furans, highly toxic chemicals linked to a wide range of profound illnesses including cancer, reproductive, developmental and immunological diseases." Page 4
- "Dick Basford, Senior Vice President of Green Power Systems, admits they have no information on emissions and emissions levels, and have no final design of the plant: "The emissions and their levels are yet to be determined since the final design of the plant is not completed" (email from Dick Basford to Doctor Ron Saff, February 6, 2008." Page 4
- "Plasma arc facilities…require considerable amounts of electrical energy to operate." Page 5
- "…the plasma-arc incinerator in Utashinai, Japan often suffers from operational problems, and one of the two lines is often down for maintenance. (Cyranoski, David, One Man's Trash…, Nature, Volume 444, November 16, 2006, http://www.nature.com/nature/journal/v444/n7117/full/444262a.html . Browsed February 27, 2008). Page 6
- "Far from being sources of renewable energy, incinerators and landfills emit harmful pollutants into the air, soil and water, waste more energy than they generate, and contribute to climate change." Page 9

3) Oilweek.com, August 18, 2007, viewed January 31, 2008, says "Garbage gasification is not a new concept, but a full-scale gasification plant has yet to be built anywhere in North America. Some cities, including Toronto, have rejected the idea as too dangerous, too unreliable or too costly."

- "The byproducts include ash and, depending on the plant's emission controls, greenhouse gases and other particles that can be hazardous to human health."

4) Westinghouse Plasma Corporations' brochure states their plasma torch systems are "proven in metallurgical and waste-to-energy commercial application." There are no proven environmental assessments/studies available for public review, however.

5) "One technology which potentially can use various types of waste, produce electricity and hydrogen without emitting dioxin, furan and mercury, is plasma arc technology. Municipalities can install a plasma arc facility which will eliminate landfilling." – U.S. Environmental Protection Agency (EPA)

6) Plasma Arc Treatment of Municipal and Hazardous Wastes, Catherine Bodurow, USEPA/OPPTS/PPT/RAD, Louis J. Circeo, Kevin C. Caravati, Robert C. Martin, Michael S. Smith Georgia Institute of Technology – Georgia institute of Technology – Georgia Tech Research Institute:

- "At volumes of approximately 1,000 tons per day, costs for PDMR (Plasma Direct Melting Processor) processing of MSW are about the same as for traditional incineration technology. However, plasma processing offers several significant advantages over incineration, including:
    - Ability to process a wide variety of solid and liquid MSW with little or no preprocessing;
    - Ability to process several MSW streams which are normally not acceptable for incineration;
    - Ability to process medical wastes and household hazardous wastes;
    - Production of salable by-product materials including recyclable metals and aggregate;
    - Elimination of requirements for landfilling of fly or bottom ash;
    - Elimination of wastewater discharges.

PDMR gasification of MSW would provide a highly efficient and cost effective alternative to conventional Waste to energy incineration. Collocation of a PDMR gasification facility with an existing coal or oil fired power plant could significantly reduce the capital and operating cost of the gasification facility while reducing the consumption of fossil fuels and reducing emissions and residues."

7) A Plasma Gasification Developer, Position Paper on Technical and Environmental Matters, January 18, 2007, Coronal presents us with the Environmental benefits [of plasma gasification]:

"Conversion technologies have a number of environmental benefits.

- Conversion technologies often incorporate pre-processing subsystems to produce a more homogeneous feedstock. This provides the opportunity to recover chlorine-containing plastic (as a recyclable), which could otherwise contribute to the formation of organic compounds or trace contaminants.
- Syngas produced by thermal conversion technologies is a much more homogeneous and cleaner burning fuel than MSW.
- Conversion technology processes occur in a reducing environment, so that formation of unwanted organic compounds or trace contaminants is precluded or minimized.
- Conversion technologies are closed pressurized systems such that there are no direct air emission points. Contaminants are removed from the syngas and/or from the flue gases before being exhausted from a stack.

- The volume of syngas produced in the conversion of the feedstock is considerably lower than the volume of the flue gases formed by WTE facilities. Smaller gas volumes are easier and less costly to treat.
- Pre-cleaning of syngas is possible, thus reducing the potential for corrosion in power generation equipment and reducing overall air emissions. Sulphur compounds can be removed by commercially available equipment and recovered as marketable sulphur or gypsum.
- Methane emissions from landfills are significant even with energy recovery. Using a conversion technology to convert the carbon content of the MSW to combustible syngas, instead of allowing it to degrade in a landfill to methane, eliminates this environmental impact.
- The inert, glassy slag recovered from high-temperature gasification is similar to that produced from steel mills and coal-fired power plants. It can be used for making roofing tiles, sandblasting grit or asphalt filler, bricks or pavers, tiles, or rock wool."

"Barriers that appear to restrain further development of conversion technologies include:

- Lack of regulations needed for permits (as in California)
- Financial risk
- Technical risk
- Economics (overall $/on processing cost versus tipping fees for existing disposal solutions)
- Reluctance of cities and counties to take on environmental groups or to commit to the public education required for successful siting and permitting."

"Landfill issues and increasing tipping fees are motivating cities and counties to look for alternatives in their waste management."

8) RECAP Renewable Energy Clean Air Project, Coronal developers presenting in regards to International Falls, Minnesota

"EPA tests have shown that this material [molten slag by product] is non-leachable. The slag can be further processed into road aggregate, bricks, pavers, and similar construction material."

"Environmental benefits: potential to completely negate the need for landfills; increase recycling; reduce mercury going into landfills, air, water, and soil; reduce methane generation, a greenhouse gas produced by existing landfills; the high temperature of the process eliminates the nasty compounds associated with the lower temperatures of various methods of incineration; and the utilizing of green credits, and green energy sources for other businesses consuming the energy or steam from this facility."

Municipal Solid Waste facilities in Japan have met Koyoto standards as stated by Alter Nrg and Westinghouse. Reports claim Koyoto standards are well above United State standards for emissions.

9) As provided in the Plasco Energy Recovery Demonstration Project: Project Description, November 2005 study:

- "Greenhouse gas (GHG) emissions and other controlled emissions from the Plasco facility will be substantially less than GHG and other emissions from landfilled waste
- The Plasco facility will convert the waste to electricity both rapidly and efficiently
- The solid residual (slag) from the process is non-leachable
- The electricity produced displaces dirty electricity from coal or fossil fuels
- The physical appearance of the Plasco facility is better than the appearance of the landfill

- Additional traffic will be kept to a minimum due to the location of the site
- Drawing of fresh water (ground water) will be minimized as process water will be cleaned and reused onsite as much as possible, resulting in minimal impact on the aquifer
- The project will showcase home-grown technology and demonstrate to the public that waste and energy problems can be solved in a way that is economically sustainable, and environmentally safe."

The time to complete a fully developed project is projected at approximately 18 – 28 months, on average. Alter Nrg developed the "100-tpd module" to reduce the construction timelines. They also claim facilities become an asset to the community because the construction can be aesthetical to the area. Noise levels are minimal; making a commercial plant located in an urban area a possibility.

10) Coronal: <u>A Plasma Gasification Developer position paper</u> lists the following environmental benefits:

- Syngas is more homogeneous and cleaner burning fuel than MSW
- Unwanted organic compounds or trace contaminants is minimized
- No direct air emission points
- Syngas produced in the conversion of feedstock is lower than the volume of flue gases formed by MSW
- Pre-cleaning of syngas is possible
- Slag recovery can produce multiple products for reuse

Barriers include:

- Lack of regulations needed for permits
- Financial Risk
- Technical Risk
- Economics

11) In the article <u>County to Vaporize Trash – Poof!</u>, September 09, 2006, www.wired.com, Louis Circeo, Director of Georgia Tech's plasma research division said of the St. Lucie County, Florida project: "We are going to put emissions out, but the emissions are much lower than virtually any other process, especially a combustion process in an incinerator." Both plants operating in Japan are producing far less pollution than [Koyoto] regulations require, and the standards are more stringent than in the U.S.

## VII. PERMITTING

The Ottawa, Canada facility, although not needing an Environmental Assessment, was required to obtain Certificates of Approval for air and waste management. After the demonstration facility has been in operation for eighteen months to two years, a full Environmental Assessment is required.

The state of Florida permitting required for the St. Lucie County facility is not clear at this time. Further investigation is required.

For the state of Minnesota, at the minimum, permits will be needed from the Minnesota Pollution Control Agency, Department of Natural Resources, Environmental Protection Agency, City/County permits, and others. Because this type of facility has never been permitted in the United States, it is difficult to know what all of the requirements will be.

From the Minnesota Pollution Control Agency MPCA Position on Waste-to-Energy, November 14, 2006, "MPCA supports Waste to Energy as an important part of the Waste Management System, with the understanding that each facility must satisfy the requirements of environmental review and the permitting process."

## VIII. MUNICIPAL SOLID WASTE

Aitkin produces 7300 tons of MSW annually, with surrounding counties generating 4,200 to 16,200 tons each. In the U.S. and Canada = 320 million tons of MSW is annually collected (nacleanenergy.com).

Coronal, a developer of plasma gasification facilities utilizing Westinghouse Plasma technology, is proposing the facility in International Falls, Minnesota. According to the RECAP documents by Coronal, there are only 15 years of landfill capacity remaining and there are only three landfills currently operating in northern Minnesota.

Recent U.S. legislation is dictating MSW landfill use regulations become much more restrictive. In addition, many communities (city/county) are closing landfills, thus the waste management teams are forced to transfer MSW longer distances to alternative sites. The transportation and tipping fees are rising, across the country, forcing communities to strategize about waste management and new technologies.

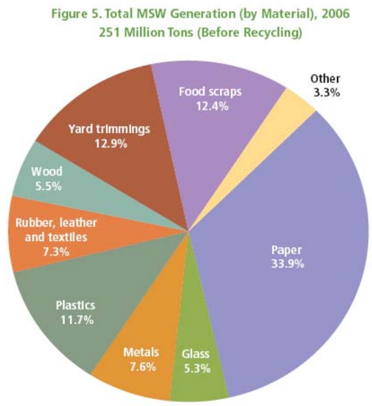
Landfills produce hazardous gases and pollute the air, land and waters – some have labs to collect the hazardous toxins, especially methane, however only having a capacity of "maybe 50%" collection, not enough according to environmentalists. Plasma gasification supporters claim emissions are "greatly less than landfills."

Feedstock looked at for International Falls project is municipal solid wastes; it is proposed to gasify 100 tons/day of MSW. Counties surrounding the site would need to be included in the MSW feedstock numbers. At a minimum Koochiching County must include the adjacent counties or consider transporting MSW from further areas. Even with adjoining counties, there is an estimated 85 tons per day being produced, which still does not meet the capacity proposed. Aitkin County is an "adjoining" county within the International Falls study area. (See Appendix, Map B)

### A. 2006 Total U.S. Waste Generation – 251 Million Tons (before recycling)

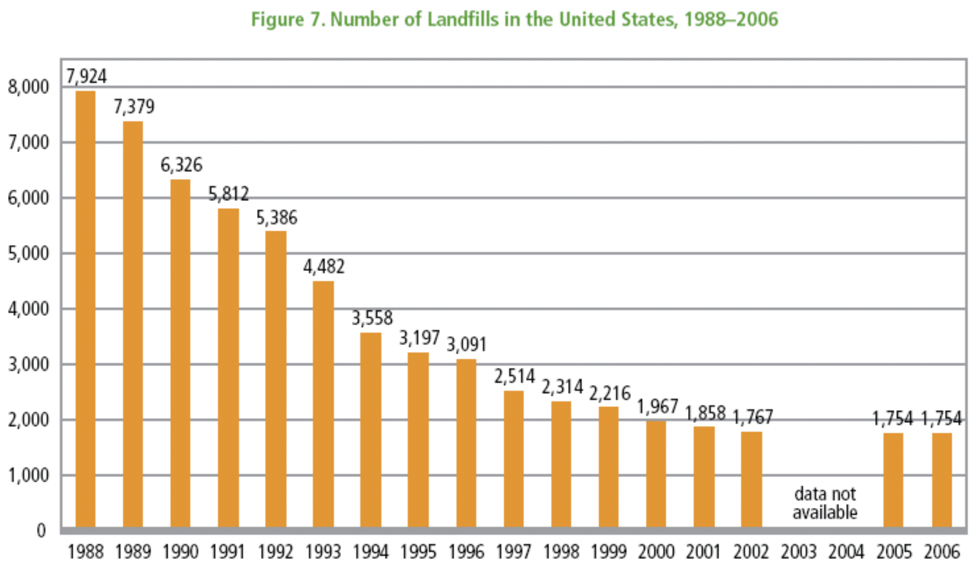
Two hundred fifty-one million tons of waste generated in the United States annually takes up a large amount of space. This pie chart depicts the percentage by which different materials contribute to the municipal solid waste stream.

The breakdown is as follows:




Paper: 33.9%
Yard Trimmings: 12.9%
Food Scraps: 12.4%
Plastics: 11.7%
Metals: 7.6%
Rubber, Leather, and Textiles: 7.3%
Glass: 5.3%
Wood: 5.5%
Other: 3.3%

Source: http://www.epa.gov/garbage/facts-text.htm#chart1



The number of landfill sites has significantly decreased since 1988; however the amount of rubbish put into landfills has increased, as shown in the U.S. E.P.A charts presented.

Plasma gasification can help to reduce the number of landfill sites, and work to reclaim lands currently used. The current technology has the capability to mine existing (full) landfills and accept new municipal solid wastes for their systems. Thus, by reducing the number of landfill sites, the methane and other hazardous toxins currently emitted into the air, land, and waters will also be reduced.

## IX. COSTS

Determining the size of a gasification project has great impact on the cost of completing a project. Developers of projects are not apt to give out details of the expenses for constructing and purchasing the technology. Announcements of Plasco Energy Group and Alter Nrg have included some estimates of constructing facilities.

Estimates for the Ottawa, Canada facility, an 85-ton, municipal solid waste facility is $27 million. Plasco Energy Group received assistance through the Sustainable Development Technology Group (30%), federal/provincial funding of approximately 20% and the balance as the investment by the group.

St. Lucie, Florida plasma gasification facility will boast eight gasifiers. The estimated cost of this 3,000-ton, municipal solid waste per day compound is $425 million. It has not been publically announced where all of the financing will come from.

## X. AITKIN COUNTY

A group of like-minded business, county, and community people in Aitkin, MN came together because of the Blandin Leadership Development Program. Community members were invited to participate in a leadership program that goes further than just training. Participants were asked to choose project they can work on, bring it back to their respective communities, and utilize the lessons they learn in order to develop the "stir" that is needed to create change in communities. Aitkin / Blandin Alumni determined they would create a business energy park. The anchor business proposed is a Plasma Gasification Facility.

A committee consisting of Ross Wagner, Aitkin County Economic Development & Forest Industry Coordinator; Felicia Finsterwalder Forder; William (Bill) R. Forder, Forder Engineering Consultant – Mechanical Engineer; J. Mark Wedel, Aitkin County District 1 Commissioner; and Thomas Eberhardt, President and CEO American Peat Technology, LLC was formed. They began by introducing themselves to plasma gasification facility developers, such as Coronal. With identifying new prospects for constructing a plasma gasification facility, it became obvious that additional information was needed to determine whether to complete a full feasibility assessment. A private, 501c 3 nonprofit organization, *Aitkin Business Energy Park*, is currently being formed to coordinate and oversee site operations.

The committee requested a planning grant from the Blandin Foundation. They were awarded funds to look into the feasibility of a plasma gasification facility. After an RFP was sent, approved and awarded, the Northspan Group was hired to:

- Gather and compile information on current studies and any available information on existing and similar projects (i.e. feasibility analysis, project specifications, review of International Falls and Florida projects, etc.)

- Create a comparison of the merits and limitations of creating a Plasma Gasification Project in Aitkin

- Ascertain the infrastructure needs / costs that may be associated with project based on similar facilities

- Calculate financing, based on models that may be needed to complete the project. List of potential funding resources that may be available for a feasibility analysis

- Present organizational structure possibilities

- Identify the steps needed to continue with the feasibility assessment upon determination to proceed

- Upon determination by the committee members to move forward with a project, infrastructure needs/cost estimates, financing and resources, and organizational structures will be complete. We will also identify the "next steps" to continue with the feasibility assessment.

## XI. AITKIN CONCEPT: PROJECT OVERVIEW

By Blandin Leadership Committee Members

"The concept of the Aitkin Plasma Energy Park is to create an Industrial Park setting featuring a Plasma Gasification Plant as the centerpiece. Utilizing Plasma Gasification technology to convert municipal and other solid waste to energy creates opportunities for other businesses that utilize by-products such and steam heat, primary products such as electricity and or syngas as well as provide an outlet for other businesses to dispose of waste products in an environmentally safe and cost effective manner. A direct by-product, rock wool, creates opportunities for spin off businesses to manufacture and market rock wool. (See Appendix, Map D)

Plasma Gasification of waste and converting it to energy is a new concept using proven technology. The first such plant in North America came on-line in July/August 2007 in Ottawa, Canada. The owners of this plant are operating two similar facilities in Spain and four similar plants are operating in Japan. International Falls, MN is currently completing a feasibility study for Plasma Gasification Plant in that community.

The Aitkin Plasma Energy Park is proposed for section 23 of Spencer Township. This location has a number of attributes including a facility byproducts user in close proximity. The proposed location for the energy park has a peat manufacturing facility in operation that is a high user of propane gas in drying and processing peat into pellets. The location has access to rail and all weather roads. All-important feedstock, municipal solid waste, is also available as local waste hauler, Garrison Disposal, is already hauling 100 tons/day from the general area to a landfill in Elk River, MN. A Plasma Gasification plant would need a minimum of 100 tons of solid waste per day to be economically feasible. (See Appendix, Map C)

In addition to the peat processing plant, preliminary discussions have been held with other companies that would either utilize byproducts from the Plasma Plant or utilize the plants ability to gasify waste. Great River Energy has discussed purchasing and distributing generated electricity. An auto recycling company has expressed interest in locating in the Energy Park to use the plant to dispose of the "auto fluff". Other businesses that have been contacted are a bio-refinery start up and a wood pellet manufacturer.

A group of individuals are in the process of forming a 501-(c)3, public non-profit corporation to own/operate the Plasma plant and to possibly operate the Energy Park. Aitkin County would be asked to help provide infrastructure for the Energy Park. Infrastructure at a minimum would include a rail spur, all weather road from Co. Rd 56 to 350th Ave to Hwy 47 and land. In addition, sewer and water service needs to be addressed.

# XII. CONCLUSION AND RECOMMENDATIONS

## A. Major Findings Summary

Two primary leaders of plasma gasification technology are – Westinghouse (Alter Nrg) and Plasco Energy Group

Feedstock can be a combination of a large variety of materials, including municipal solid waste, auto fluff, hazardous materials, and others

Because the technology is so new in North America, the permitting process is unknown. Also, the only plant in operation (Ottawa, Canada) is a pilot facility with ongoing emission testing required, however, an environmental assessment was not required at this time

By products include molten slag, rock wool, electricity, and steam, dependent upon the feedstock and mixtures; all with the ability to be sold for profit

Minnesota is among the leaders of the U.S. in supporting use of municipal solid waste in waste to energy facilities by proposed strategies to reach by 2011. This includes other efforts, such as increasing composting, recycling, and resource recovery.

Costs to construct a plasma gasification facility are varied dependent upon the brand, and primarily due to size.

## B. Conclusion

Plasma Gasification of municipal solid waste is still new technology; emerging into the North American ideals of resolving landfill issues, reducing emissions of highly toxic (methane) gases, and providing an alternative to traditional methods of handling wastes. Areas across the country are interested in the possibility of facilities in or near their locations in order to eliminate the need for additional trucks on the roads, reducing shipping costs for MSW and eliminating the landfill use.

Consideration of siting concerns include proximity to communities, the economic impacts, who the users of the facility will be, what is the social and environmental issues, what values do the community have, and what are the legal mandates. To determine permitting requirements, consulting federal and state regulatory agencies, local planning and zoning, building permitting, along with air emissions, solid waste storage, water pollution discharge and possible hauling permits may be necessary. Additional considerations of developing a facility include timing, location, infrastructure, and effects to the surrounding region.

Income may be generated through tipping fees, sale of steam and/or electricity, production and sale of the slag/aggregate materials. The "break even" for producing enough energy to support the plan and have excess for sale is dependent upon the type of facility and the feedstocks.

Feedstock can include a great variety of materials, with municipal solid waste being the focus of this study. Additional income may be generated by the variety of feedstock, such as including a hazardous materials gasifier potentially could bring additional dollars into the project as the disposal of said materials is costly. With the addition of certification for handling specialized material, i.e. medical wastes, fees collected continue to rise.

Environment, economic and social impacts are yet to be determined in the United States. Opposers of this technology claim it will reduce recycling efforts, continue to pollute the air, land and waters, and will only create a newer problem for the environment. Costs and use of energy to operate these facilities is a major concern of groups fighting against plasma gasification.

### C. Recommendations

Before deciding to proceed with a full feasibility analysis, the Aitkin Blandin Leadership Group should thoroughly review the merits and limitations of developing a Plasma Gasification Facility as outlined in this report, and await the results of:

- Coronal / International Falls Feasibility Assessment,
- St. Lucie, Florida permitting and project approval, and
- Further outcomes of environmental testing for the Ottawa, Canada facility.

The Northspan Group remains available upon determination to proceed to ascertain the infrastructure needs, calculate financing and list potential funding resources for a feasibility analysis, and present options for organizational structures.

## XIII. REFERENCES


Alter Nrg. (February 2008). *A Leading Provider of Green Energy Solutions, Corporate Presentation*.

Associated Press. (September 2006). *County to Vaporize Trash – Poof!* Retrieved January 31, 2008 from the Internet: http://www.wired.com/print/techbiz/media/news/2006/09/71757

Bodurow, Catherine USEP, Circeo, Louis J.; Caravati, Kevin C.; Smith, Michael S., Georgia Institute of Technology. (2005). *Plasma Arc Treatment of Municipal and Hazardous Wastes.* Retrieved February 19, 2008 from the Internet: http://www.epa.gov/ord/scienceforum/2005/pdfs/oeiposter/Bodurow_OEI30.pdf

Coronal. (2007). RECAP Renewable Energy Clean Air Project, International Falls, Minnesota.

Coronal. (January 18, 2007). A Plasma Gasification Developer, Position Paper of Technical and Environmental Matters.

Environmental Protection Act. (June 9, 2006) *Ontario Regulation 254/06 Plasco Demonstration Project.* Retrieved February 27, 2008 from the Internet: http://www.ebr.gov.on.ca

Environmental Registry. (June 14, 2006). *Regulation Decision Notice: EBR Registry Number: RA05E0021.* Retrieved February 27, 2008 from the Internet: http://www.ebr.gov.on.ca

Greenaction for Health and Environmental Justice and Global Alliance for Incinerator Alternatives (GAIA). (April 2006). *Incinerators in Disguise: Case Studies of Gasification, Pyrolysis, and Plasma in Europe, Asia and the United States.* Retrieved January 31, 2008 from the Internet: http://www.no-burn.org

Greenaction for Health and Environmental Justice and Global Alliance for Incinerator Alternatives (GAIA). (2008). *Burning Issues in Waste Disposal: Incinerators in Disguise.* Retrieved March 2008 from the Internet: http://www.no-burn.org

Greenaction for Health and Environmental Justice and Global Alliance for Incinerator Alternatives (GAIA). (March 10, 2008). *Plasma Arc Technology for Municipal Solid Waste: A Proven Technology or Incinerator in Disguise?* Retrieved March 2008 from the Internet: http://www.no-burn.org

Minnesota Pollution Control Agency. (November 14, 2006). *MPCA Position on Waste-to-Energy*. Retrieved February 19, 2008, from the Internet: http://www.pca.state.mn.us/publications/reports/solidwaste-wastetoenergy.pdf

Plasco Energy Group. (November 2007). *Corporate Summary Presentation*

Plasco Energy Group. (November 2005). *Plasco Energy Recovery Demonstration Project.*

Solena Group. *The Commercial Viability of Plasma Arc Technology*. Retrieved February 2, 2008, from the Internet: http://www.solenagroup.com/html/images/plasma.pdf

The Canadian Press. (August 18, 2007). *It sounds good, but turning garbage to energy has downsides, critics say*. Retrieved January 31, 2008 from the Internet: http://www.oilweek.com/news.asp?ID=10882

Wikipedia (many authors). (revised 2008) Plasma Arc Gasification. Retrieved January 2008 from the Internet: http://en.wikipedia.org/wiki/Plasma_arc_gasification

## XIV. APPENDIX

A. Coronal: Potential MSW Feedstock per County

B. Minnesota Counties, MSW Annual Tonnage

C. Aitkin Plasma Gasification Proposed Site

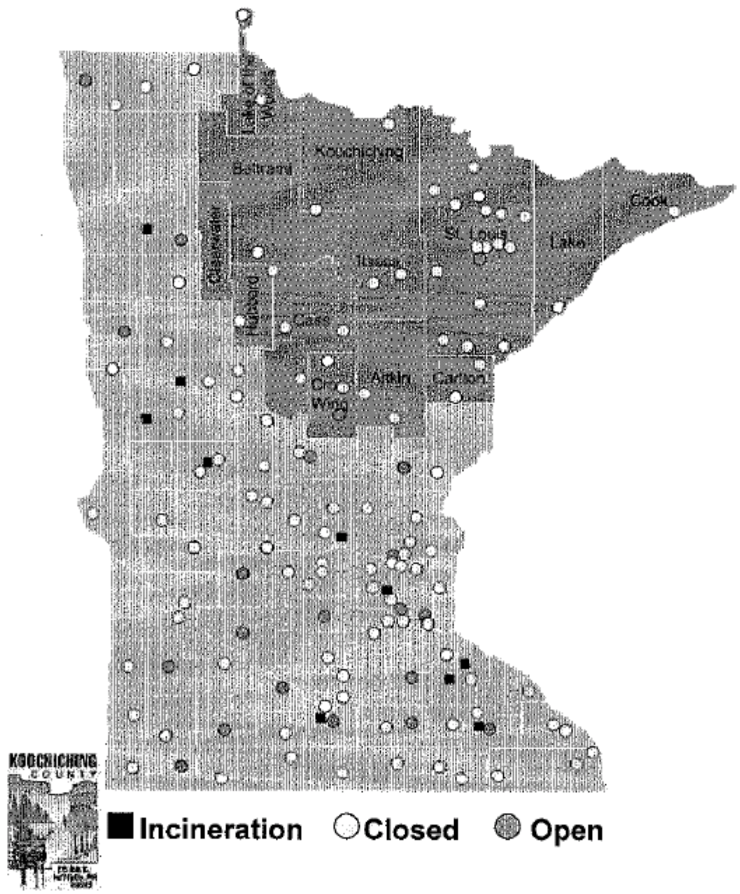
D. Aitkin Plasma Aitkin Facility Layout

RECAP

Renewable Energy Clean Air Project

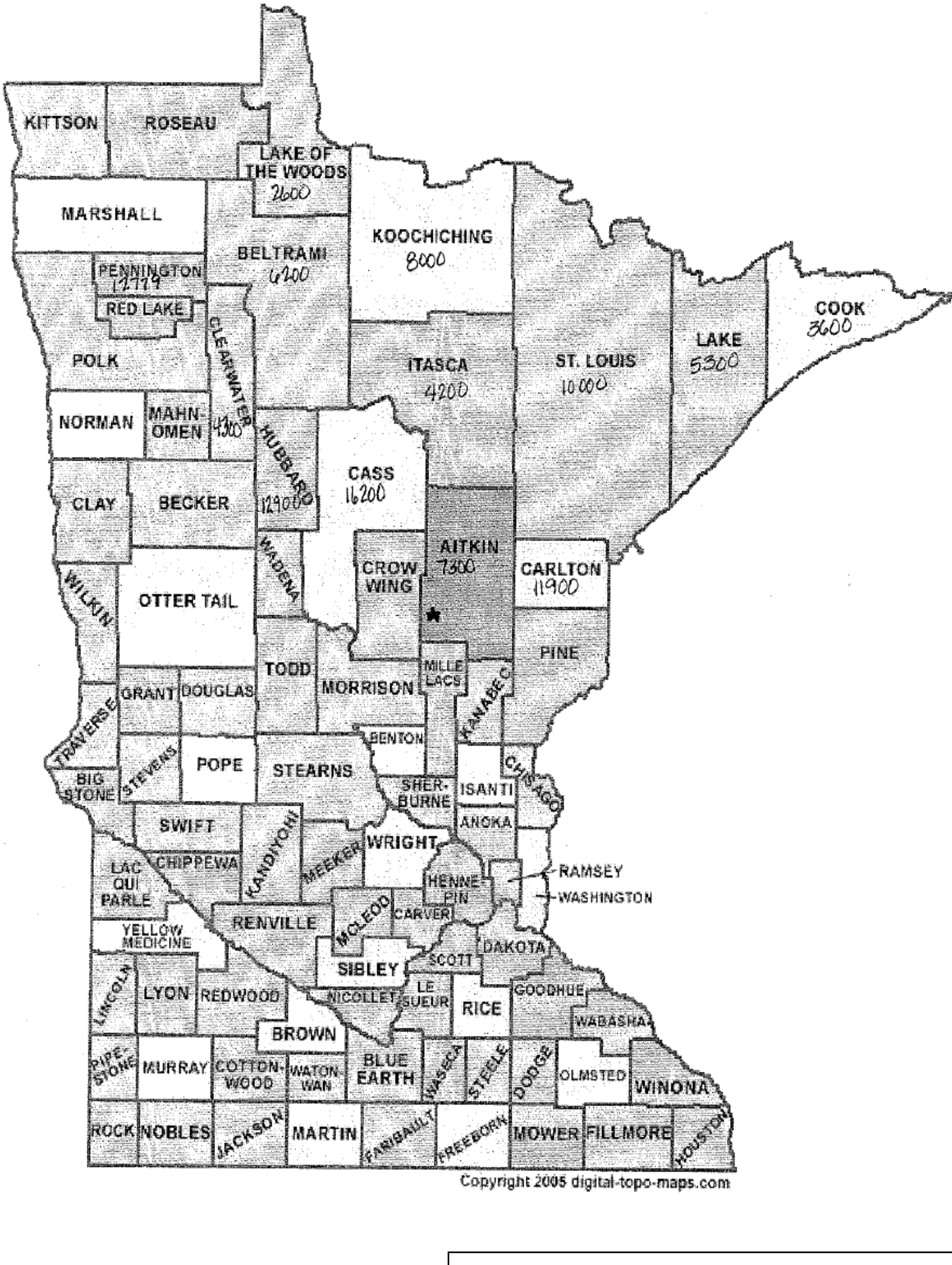
Coronal

# Potential Municipal Solid Waste Feedstock

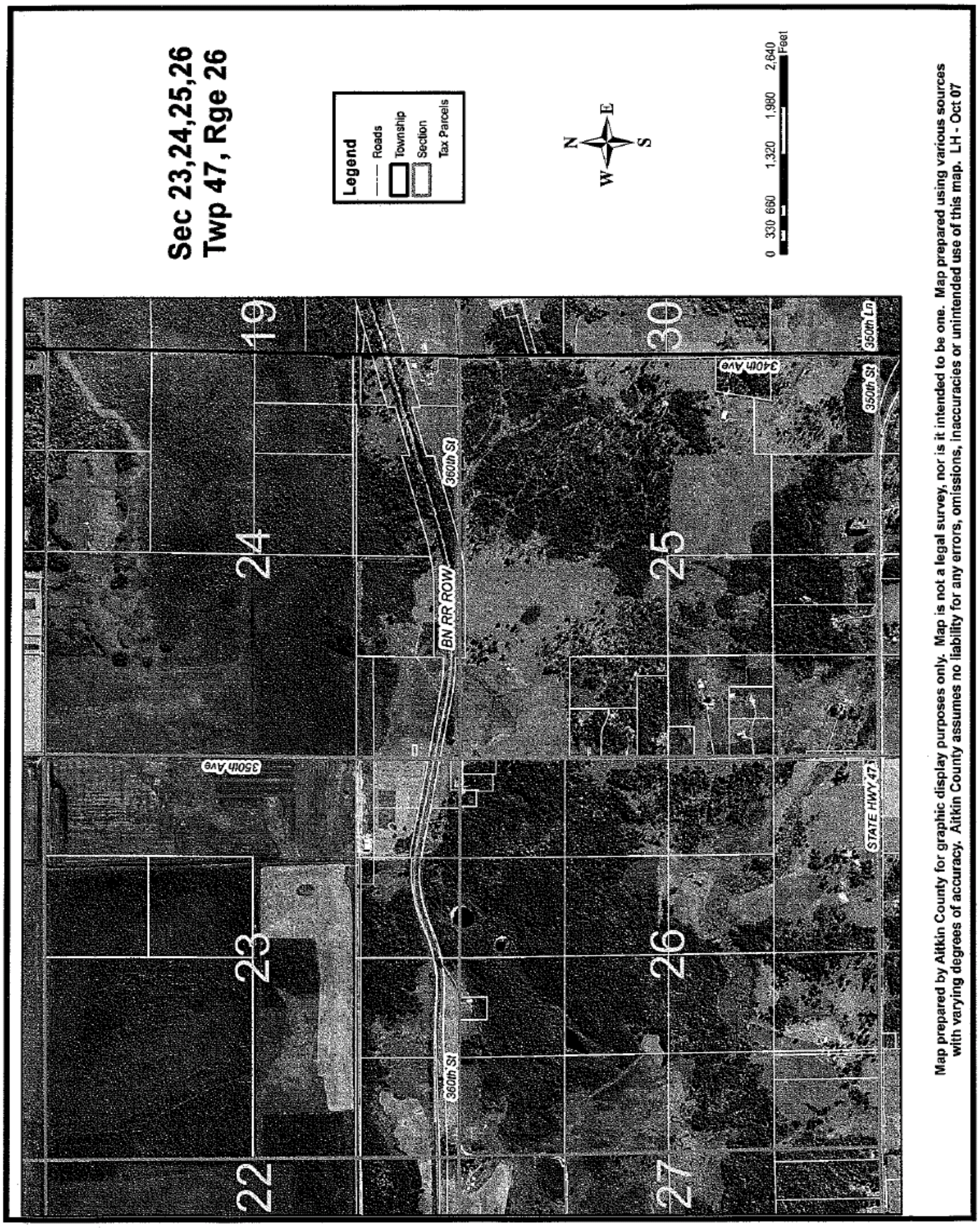



| County | Tonnage | Recycle | Expire |
|---|---|---|---|
| Aitkin | 7,300.00 | 37.7% | |
| Beltrami* | 6,200.00 | 27.8% | 2010 |
| Carlton | 11,900.00 | 38.4% | |
| Cass | 16,200.00 | 44.5% | 2010 |
| Clearwater | 4,300.00 | 28.0% | 2008 |
| Cook | 3,600.00 | 38.9% | |
| Hubbard | 12,900.00 | 43.7% | 2006 |
| Itasca* | 4,200.00 | 39.4% | 2010 |
| Koochiching | 8,000.00 | 31.8% | 2010 |
| Lake | 5,300.00 | 26.6% | |
| Lake of the Woods | 2,600.00 | 38.8% | 2008 |
| St. Louis* | 10,000.00 | 58.7% | |
| **U.S. Total** | **92,500.00** | | |

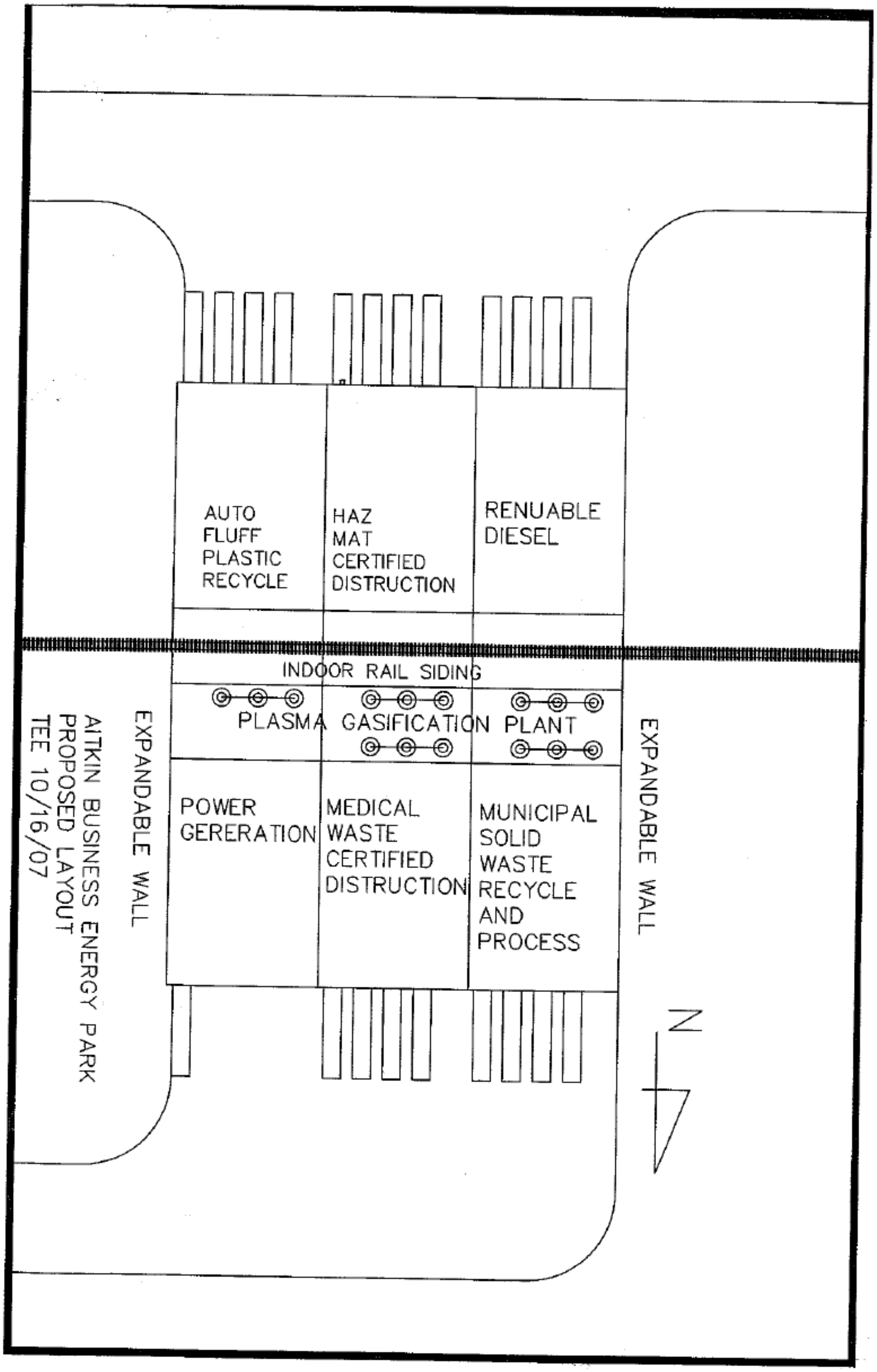
A. Coronal: Potential MSW Feedstock per County




B. Minnesota Counties, MSW Annual Tonnage




C. Aitkin Plasma Gasification Proposed Site




D. Proposed Aitkin Facility Layout