WASTE-TO-ENERGY

White Paper

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ABSTRACT

This white paper (WP) discusses one of the topics from the list of critical national needs – waste-to-energy (WTE). This topic, in turn, is intimately connected with, and therefore substantially impacts, other identified topics of critical national need, including: renewable energy generation, climate change, electric power generation, US energy independence, sustainable chemistry, and recycling. Cost-effectively implemented, WTE will impact the lives of every resident, involve over one million employees, occupy millions of acres of land for landfills, resolve many identified, serious environmental problems, and become one of the 21st century's major challenges. It is a challenge waiting for implementation of our solution.

This WP provides an overview of the problem, suggests feasible and technically sound solutions, and presents practical strategies for engaging national and international involvement and cooperation in order to achieve rapid and wide implementation.

1. INTRODUCTION

Throughout the history of civilization people have left behind mountains of waste. With 2.02 billion tons of municipal solid waste (MSW) generated in 2006 worldwide, the total amount accumulated in landfills is well over a trillion tons.

The U.S. leads the industrialized world in MSW generation, with each person generating an average 2.1 kg of household waste per day, with a total 251 million tons of MSW generated in 2006 (www.epa.gov/msw). With a recycling rate of about 35%, the remaining 65%, or about 163 million tons, are largely dumped in landfills. A small portion is burned in 89 MSW-fired power generation plants, generating ~2,500 megawatts (MW), or perhaps 0.3% of the total national electric power generation. There are 1,754 active, and over 10,000 inactive/legacy, municipal landfills in the U.S. (www.epa.gov/msw/facts). These landfills are a major source of methane, which has 21 times the global warming impact of CO_2. Landfills also poison ground water, an extremely valuable and largely non-renewable national resource. As the elementary texts on ground water point out, even the 2,000 year-old landfills of the Roman Empire still generate leachate which to this day still leaks into the ground water.

The U.S. Solid Waste Services and Recycling Industry has over 56,000 recycling and reuse establishments, employs approximately 1.1 million people, generates an annual payroll of $37 billion, and grosses $236 billion in annual revenues.

It is obvious that waste is a planetary problem, which effects climate and the environment in every country, and touches the lives of all human beings through the air, water, and/or food they consume. To solve (or even just remediate) this problem, national and international cooperative action must be undertaken. Because the prime driver behind improved waste management is legislation, the environmental and waste management laws and regulations should be constructively modified and updated, and a vigorous, comprehensive national waste program needs to be developed and implemented. The government should also develop a mechanism to support the new generation of waste processing technologies, with validation, certification and (ultimately) worldwide implementation.

2. DISCUSSION

2.1. Technological overview.

An overview of the global waste-to-energy (WTE) industry reveals that only about 130 million tons of MSW worldwide are combusted annually in over 600 WTE facilities that generate electricity, perhaps heat for district heating and recovered metals, plastics, etc. for recycling. Located in 35 nations, mostly in Europe, these facilities utilize relatively old and inefficient technologies that provide an estimated 650 kWh of electricity per ton of MSW combusted. The most common grate technology, developed by Martin GmbH (Munich, Germany), has an annual installed capacity of about 59 million metric tons. The Martin grate at the Brescia (Italy) plant is one of the newest WTE facilities in Europe. The Von Roll (Zurich, Switzerland) mass-burning process follows with 32 million metric tons combusted worldwide. All other mass-burning and refuse-derived-fuel (RDF) processes together have a total estimated processing capacity of perhaps 40 million tons [1].

It needs to be pointed out that MSW-fired facilities do not eliminate waste, but change the form of waste into generally more hazardous air emissions and toxic ash, which need further treatment to be rendered harmless. Incinerator fly ash and, to a lesser degree, bottom ash contain leachable heavy metals, including lead, chromium, arsenic, mercury, cadmium and zinc. In addition, these ashes can also contain very hazardous persistent organic pollutants (POPs), such as dioxins and furans.

During the past decade, scientific and engineering efforts, mainly in the U.S., Canada and the UK, have led to the development and testing of small-scale prototypes of plasma waste gasification technology. Its key element is a plasma gasifier, which provides much higher process temperatures, about 2,500ºC, in comparison with ever the highest temperatures, 1,200-1,400ºC, such as are employed in classic incineration for hazardous waste. These much higher temperatures allow waste conversion with total destruction of all organic chemical constituents, generating pure synthesis gas (syngas: primarily CO and H_2), and a chemically inert, fully vitrified slag (similar to basalt rock). Subsequently, the syngas is used for power generation through combustion in IC engines, power boilers or gas turbines. The major players in this field are: Advanced Plasma Power, Ltd. (UK), Plasco Group (Canada), GeorgiaTech (USA), and PyroGenesis Canada Inc. (Canada) [5-7]. The current status of their efforts could be characterised as a phase of scaling up from a demonstrated 2-3 tons per day capacity to a commercial level of 250-500 t/day.

Although announced by Advanced Plasma Power in November 2007 and by Plasco Group in January 2008, the successful initiation of commercial operations for their full-scale 100 t/d modules has not been supported by publication of the practical achievement of positive results. A careful review of the facts reveals that each firm has encountered significant technical problems and obstacles during their attempts to scale up their small-scale units by a factor of 10 or more. These problems include high operation and maintenance costs, a variable composition syngas with low caloric value, and therefore difficulties with its combustion and conversion into electrical power. Moreover, all plasma gasification technologies are based on three main principles, which are: (1) the application of electrically inefficient, short-lived, high maintenance DC torches, or DC arcs, for plasma generation, (2) performing plasma gasification in air, and (3) syngas quenching by water. This results in a relatively low power efficiency (a low total export power generation of 0.8-1.1 MW per ton of MSW), a high internal power consumption (about 500 kW per ton plus power for auxiliary systems), and high facility operation costs - $70-80 per ton. These high costs make these processes technically and economically unfeasible, and ultimately impractical for wide implementation as a national, or global, waste management strategy.

2.2. Alternative technology.

The detailed analysis of existing plasma waste gasification technologies has proven their advantages over incineration, but also has revealed a substantial potential for improvements, both for reduced capital and operating costs [8-18]. As a result, an alternative schematic for a much improved plasma gasification plant has been developed and discussed at scientific forums [16-18] and numerous meetings with industry experts, waste managers, and venture capitalists. The schematic shown in Fig.1 is a significant step change in the technical and the economic feasibility for waste processing, delivering as much as twice the final electricity export product at a lower capital and operating cost. Such improvements are essential for practical implementation of global waste processing. This improved technology is based on three key innovations, which are: (1) the hybrid type plasma generator having an almost endless lifetime, (2) the oxygen gasification environment, and (3) the steam catalyst treatment of raw primary syngas. The hybrid type plasma generator is a combination of radio-frequency (RF) and direct current (DC) modules, coupled with reverse vortex plasma stabilization, as recently patented by APT [11-12]. Powered by a newly designed, highly efficient solid-state power supply, this power-efficient plasma system with electrode-less design runs reliably for thousands of hours without maintenance or interruption. The current state of power electronics makes available such a plasma source power level up to 1.8 MW per unit. The switching from air to oxygen becomes affordable due to recent progress in air separation technology. With 0.3 kW/kg of O_2, we can eliminate the inert nitrogen (which behaves as an enthalpy ballast), dramatically reducing overall power consumption, NO_x emissions, and the volumetric and gravimetric parameters of the entire waste gasification system. The total power output could reach up to 1.9MW per ton of MSW. Replacement of syngas water quenching by steam catalyst conversion and syngas heat recovery dramatically improves the process thermal efficiency and increases hydrogen yield. This, in turn, leads to higher syngas caloric value and its simpler conversion in existing heat engines, including gas turbines. An upgraded, high quality syngas could also be used for synthetic fuel production, other sustainable chemistry synthesis applications, hydrogen separation, etc

2.2. A. Alternative technology optimized – “Plan B”

One of the most feasible alternatives for optimizing worldwide implementation of this new technology would be the direct feeding of this raw syngas (CO and H_2) into operating fossil fuel-fired boilers to significantly reduce their NO_x and CO emissions. This proposed technology “Plan B” can operate with significantly lower operating cost, about $20-30 per ton, as compared to $70-80 per ton for the existing technologies for plasma-based waste gasification processing. That is, eliminate all the back-end equipment employed for handling the raw syngas: steam reformer, heat recovery boiler, all air pollution control systems, and the motor generators for generating electricity. How can this savings be achieved? Install just the RDF plasma gasification facilities adjacent to existing power plants, and feed the very hot syngas directly into their boilers. Existing power plants already have systems for such air pollution control and electric power generation, and these are much less expensive due to their very significant economies of scale. If “Plan B” were adopted, then logically processing the raw waste into refuse derived fuel (RDF) would be performed on a distributed basis; i.e., locally in municipalities. Then, the RDF would be compressed, baled and transported to the regional power plants, where the bales would be shredded and plasma gasified into raw syngas.

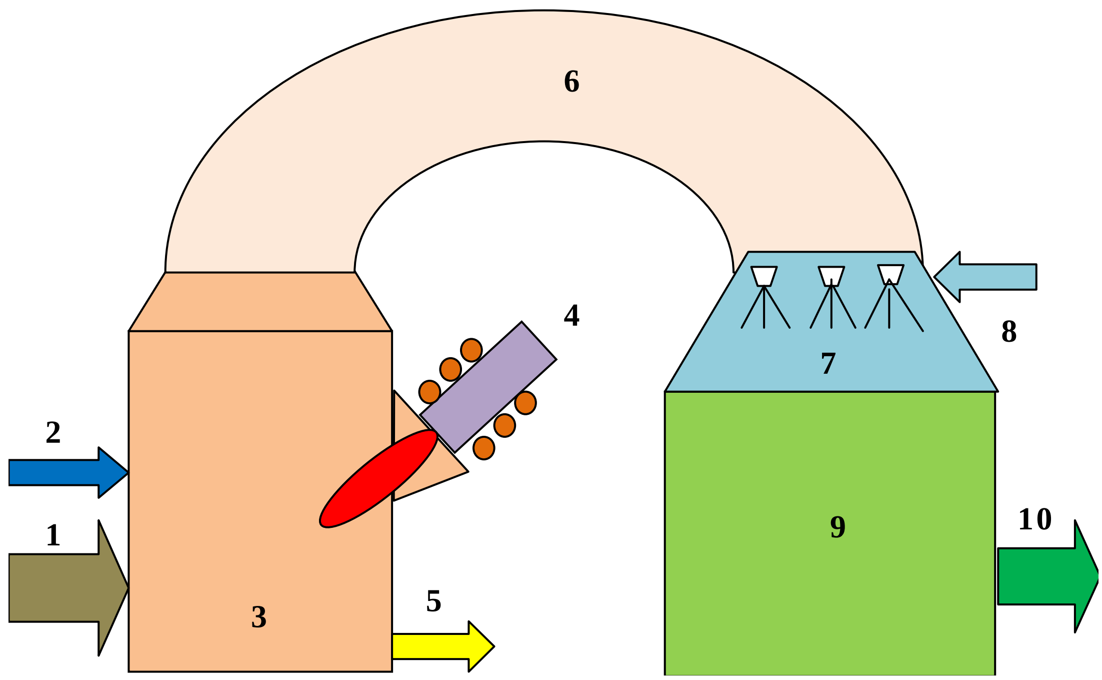

Figure 1. Pilot module for plasma oxygen waste gasification:
1 – feedstock input, 2 – oxygen input, 3 – gasifier, 4 – hybrid type plasma torch, 5 – slag output, 6 – gasifier output (raw synthesis gas), 7 – contact type steam injector, 8 – water input, 9 - catalyst steam converter, 10 – hydrogen enriched synthesis gas output.

The preliminary feasibility study of the alternative waste processing system for the city of Austin, TX with a population 775,114 and tipping fee of $25 per month per household (effective from 1 October, 2008) showed that the city could generate annually up to 594,220,000 kW*h of green electricity and the return on investment would not exceed 6 years. In the case of "Plan B" implementation return on investment could be lowered to 4.5-5 years.

2.3. Market.

The simplified U.S. market evaluation [18] was based on such input data as total annual MSW generation level of 251 million tons, averaged capacity of waste processing plants of 250 tons per day, their cost of ownership at $50 million, and a number of operating days of 330 per year. This leads to total market volume of $155 billion.

It should be noted that the estimated total net power output from MSW plasma processing (oxygen based process) is up to 326 million MW. Total national power generation for the US is 790,000 MW (2006). The waste processing (annual amount) would cover over 6% of the US power demand. Landfill recycling would add even more, from another 1 to 5%, annually. This becomes more important taking into consideration the DOE's forecast regarding the massive decommissioning of major coal-fired power stations within the next two decades. Note also that this 6% compares favorably to those contribution percentages for contribution to US national generation, as projected for wind, solar and biomass.

2.4. Strategy.

The strategy is based on seven major principles: (1) gradual scaling up of the core technology from a factor of 2 to a factor of 25, and then to 250 t/d capacity, (2) immediate implementation of the R&D results as separate market products, (3) international cooperation with leading scientists and engineers, (4) teaming with the industry partners, (5) financial support by government, private and corporate investors (especially for full-scale demonstration units), (6) aggressive worldwide marketing, and (7) flexible and customer oriented financing. This means that the first plasma-oxygen gasification module with 2-5 t/d capacity for medical, bio- and hazardous wastes will enter the market in 6-8 months, the second with 25-30 t/d in 12-14 months and the third one 250 t/d in 33-36 months. At the same time within perhaps the first year after project activation, the first development in the form of a continuously operated 300 kW hybrid torch could be available to enter the market and be sold to potential customers in different areas such as silicon melting for solar panel production, scrap metal melting, coal ignition and gasification, coke and cement production, fuel reformation, surface treatment, and so forth. The much larger 1 to 1.5 MW hybrid torches, as well as new catalytic converters, and other project byproducts will become available to be marketed to enable development of other plasma-based technologies worldwide. (Note that DC torches are inherently dirty, due to electrode consumption, while electrode-less RF torches produce clean plasma, a difference which is critical for many potential plasma applications.)

Established international cooperation with over 50 research institutions and 500 scientists in Brazil, Canada, Germany, South Korea, Kazakhstan, Serbia, Russia, Ukraine, and the U.S. has led to creation of several international research teams working on the development of a hybrid torch, a raw syngas-compatible catalyst steam converter, contact type steam generator, solid-state, highly efficient high frequency RF (radio frequency) power supplies, control systems and development of other newly developed critical elements essential for such specialized waste processing.

An international consortium with industry partners, including Air Products and Chemicals, Inc. (U.S.), a leader in the air separation technologies; Thermatool Corp. (U.S.), the main manufacturer of RF power supplies; PyroGenesis Canada Inc. (Canada), a manufacturer of the plasma waste systems for naval and land based applications; the Russian Space Agency, a developer of specialized, custom catalyst modules; and others is being developed. Various universities will also be very welcomed to participate. Preliminary negotiations have been conducted with the University of Maryland, Purdue University, and Michigan State University. Various partners will contribute technologies, IP rights, services, as well as cash.

Government support of such a high-risk, global project is vital. US Federal Government support will be especially critical for *sponsoring* the siting and the financing of the initial full-scale demonstration facilities. No private investor is willing to risk his capital to attempt to develop these waste processing technologies, find and convince municipal or utilities partners to host their demonstration, and then fund the exhaustive demonstration of them. Note that "exhaustive demonstration" requires a willing local governmental support to implement new tipping fees, or equivalent means to provide the essential revenue stream during the exhaustive demonstration. This is especially true given the difficulties inherent in siting any form of new waste processing facilities – the NIMBY syndrome (**N**ot **I**n **M**y **B**ack **Y**ard). Consequently, such government support will be essential to catalyze and facilitate the attraction of private investors, venture capital firms, international funds, and other countries' government support.

Marketing will be focused on converting the U.S. from a selective, but minor, waste processing technologies importer into the global exporter. Developed technologies and equipment should go through the state validation and certification tests to develop state standards on performance data, safety features, emissions, including dioxins, furans and toxic leachate, and other volumetric and gravimetric parameters. These standards would constitute BACT (Best Available Control Technology), and therefore it should establish the highest technology level for other nations.

Global problems need global approaches. Global waste trade, which is mainly illegal, can be eliminated by organizing an international network of high performance and environmentally friendly waste recycling facilities. This will clean up the land and ocean, as well as reduce dependence on fossil fuels. One more related global issue is the emission of greenhouse gases, as per the Kyoto protocol. It expires in 2012 and developed countries should find a compromise in dealing with the growing and polluting economies of countries such as China, India, and Brazil [3]. These countries could not meet our standards and accept requirements within several decades. In this case the internationally regulated transfer of the waste-into-energy technologies could be an option to ameliorate these expected Kyoto emission controls' shortfalls.

CONCLUSION

Development of practical, cost effective and clean MSW processing into any form of energy presents a very significant and serious global challenge and need, which affects all humanity. The worldwide implementation of a cost-effective *and* affordable, technologically optimal, future generation of advanced waste-to-energy technologies is our generation's challenge. As presented above, these are feasible approaches, backed by known and recently available scientific fundamentals, and several newly developed technologies, opportunities which are currently available to resolve the problem. But because of the global scale, and well-known and demonstrated local resistance, any hope for practical implementation will require vigorous, direct federal government guidance, support, and facilitation, a willing national and international political involvement, and a very new consortium, assembled to gather the broad and essential participation of experts within numerous fields in both science and industry. The result of implementing this technology will be the transform of an undesirable, largely unmanageable material – MSW – into a valuable commodity – electrical power, providing for a cleaner environment, reducing pollution, and creating a global trade in advanced technology (Presumably flowing out from, rather than into, the USA).

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