Utilization of Municipal Solid Waste as a Sustainable Energy Resource

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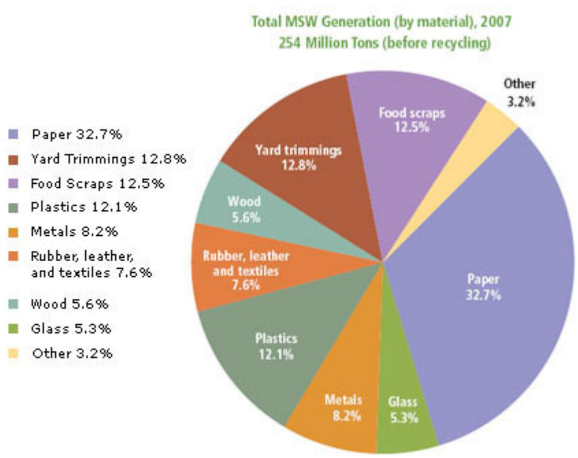
ABSTRACT

Americans generated approximately 254 million tons of municipal solid waste (MSW) in 2007, enough to fill a modern day baseball stadium more than 2 times! Of this, 117 million tons was recovered for beneficial reuse in recycling, composting or energy recovery. Of the remaining 137 million tons discarded to landfills, it is estimated that at least 70% consists of materials that could be recovered for its energy content. Mainstream adoption of a program to recover these discarded materials as a consistent, renewable energy resource would result in a decreased need for landfill space and an increase in national energy independence.

The sustainable utilization of MSW as a renewable energy resource will require educated and collaborative efforts by industry, government and the public. The goal of this paper is to demonstrate how and why MSW should be viewed as a resource to be exploited rather than a waste requiring disposal.

Introduction

The energy and land requirements associated with managing the enormous amount of waste our society generates is a leading topic of discussion in the growing sustainability movement. In 2007, the U.S. generated close to 254 million tons of municipal solid waste (MSW), the equivalent of 4.6 pounds per person per day.[1] Of that 254 million tons, 63 million tons (24.8%) were recycled, 22 million tons (8.5%) were composted, and 32 million tons (13.8%) were combusted for energy recovery, leaving 137 million tons (54%) to be discarded in landfills. The percent by weight of the MSW stream that is discarded to landfills has remained in the 54-55% range since 2003. It is estimated that approximately 70% of the materials discarded to landfills is comprised of organic matter that could be harvested for its energy content. Nearly 3,100 landfills are currently in operation to manage this volume.



[1] MSW, otherwise known as trash or garbage, consists of everyday items such as food scraps, product packaging, grass clippings, furniture, clothing, bottles, newspapers, appliances, and batteries. Not included are materials that also may be disposed in landfills, such as construction and demolition materials, medical waste, municipal wastewater treatment residues and hazardous industrial wastes.

The U.S., with only 4.6% of the world's population, consumes about 25% of the energy used in the world today. We consume 101 EJ /year (equivalent to 280.6×10^8 MWh) of energy, compared to the world total of 423 EJ ($1{,}175 \times 10^8$ MWh). We have the dubious distinction of having one of the highest per capita rates of energy consumption of any country, using the equivalent of 7 gallons of oil or 70 pounds of coal per person per day. This is 5 times the world's average!

Biomass provides a mere 3.8 % of U.S. total energy supply as compared to countries like Sweden and Finland that presently obtain 20 % of their energy from biomass.

Currently, 86% of our energy is supplied by fossil fuels (Oil – 39%, Coal – 24%, and Natural Gas – 23%). We consume these fossil fuels 10,000 times faster rate that they are formed. Only 14% of our energy is currently supplied by renewable energy sources (hydro and nuclear are considered renewal energy sources for the purpose of this discussion). Less than 5% of our energy is provided by biomass, despite the numerous potential benefits that could be realized including:

- Landfill diversion; landfill capacity drops over time resulting in continued need for more open space.
- More stable costs; the cost of oil and other fossil fuel-based raw materials is high and fluctuates constantly.
- Increased energy security from more diversity in energy sources.

Overview of Biomass Conversion Technologies

Organic matter that can be used as a fuel source, such as MSW, agricultural crops (grain, grasses), agricultural and forestry wastes (crop residues and manure), is commonly referred to as biomass. While the composition of MSW can be highly variable, the typical energy content varies between 4500 and 6000 btu/lb[2].. It contains about one-third of the calorific value of coal. There are a number of conversion options available to make use of harvesting this energy. These conversion technologies either release the energy directly, in the form of heat or electricity, or convert it to another form, such as liquid biofuel or combustible biogas.

Thermochemical Conversion

Thermochemical conversion processes are best utilized with biomass feedstock of low moisture content (less than 50%) such as dry municipal solid waste, woody biomass, and fibrous industrial waste. These are processes in which heat is the dominant mechanism to convert the biomass into another chemical form. The basic alternatives are separated principally by the extent to which the chemical reactions involved are allowed to proceed. The most common thermochemical conversion processes utilized include:

- Direct Combustion: Thermal conversion of biomass, in the presence of excess air /oxygen, to produce primarily carbon dioxide and water. The direct burning/combustion of the biomass produces heat or steam that is then used to generate electricity.

[2] Source: EIA Renewable Energy Annual 2004. http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/tableb6.html

- Gasification: The thermal decomposition of biomass at elevated temperature s, in the presence of partial air/oxygen, to produce primarily permanent gas or liquid fuels with char, water, and condensibles as minor products.
- Pyrolysis: The thermal decomposition of biomass at lower temperatures , in the absence of oxygen, to produce primarily liquid fuels with the possibility of chemical and food byproducts.

Thermal conversion processes are highly beneficial in situations where the excess heat generated in the conversion process can be utilized as part of a cogeneration, or combined heat and power, system. Air emissions tend to be an issue in thermochemical conversion techniques. This is easily overcome, however, by the use of air emission controls.

There are a number of other less common, more experimental or proprietary thermal processes that may offer benefits such as hydrothermal upgrading (HTU) and hydroprocessing. Some have been developed for use on high moisture content biomass, including aqueous slurries, and allow biomass to be converted into more convenient forms.

Technology in action. In the U.S., there are currently 89 waste-to-energy (WTE) facilities generating the equivalent of 2,500 megawatt-hours of electricity while disposing more than 30 million tons of trash (a combination of MSW and other biomass sources). The Wheelabrator Spokane WTE facility is one such facility that provides dependable, environmentally safe disposal of MSW for the Greater Spokane area, while generating clean, renewable electricity for sale to the local utility. Wheelabrator Spokane serves Greater Spokane's 418,000 residents by processing up to 800 tons per day of MSW via direct combustion. In 2007, the facility processed 269,000 of the 356,000 tons of MSW not recovered for recycling or composting and therefore headed for landfills. The plant has an electric generating capacity of 26,000 kilowatts; the equivalent of supplying the electrical needs of 16,000 Washington homes. In 2007, the facility generated over 171,000 MWh of electricity.

Biochemical Conversion

As biomass is a natural material, highly efficient biochemical processes have developed in nature to break down the molecules of which biomass is composed, many of which can be harnessed. As a general rule of thumb, biochemical conversion methods are most efficient when used to convert feedstock of high moisture content (>50%). Biochemical conversion processes convert biomass into other useful fuel forms, such as methane or biodiesel, that are more conveniently used, transported or stored than the original biomass itself. Biochemical conversion makes use of the enzymes of bacteria and other micro-organisms to break down biomass. In most cases micro-organisms are used to perform the conversion process. The most common biochemical conversion processes utilized include:

- Aerobic Digestion: A biological process in which biomass is degraded by micro organisms, in the presence of oxygen, with the majority of the energy stored in the starting material being released as heat via oxidization into carbon dioxide and water.
- Anaerobic digestion: A biological process in which biomass is degraded by micro organisms, in the absence of oxygen, to produce combustible gas, typically referred to as biogas, principally composed of methane and carbon dioxide.
- Fermentation (Acid Hydrolysis and Enzymatic Hydrolysis): The anaerobic conversion of starches in organic matter using microbial yeasts to produce carbon dioxide and alcohols such as biodiesel and ethanol.

Technology in action. The University of California at Davis is currently piloting an Anaerobic Digester system that can convert up to 10 tons/day of food waste from San Francisco Bay Area restaurants into methane and hydrogen. In the process, food waste is collected from restaurants and institutions and then fed to bacteria that thrive in low-oxygen environments. One type of bacteria turns carbohydrates into simple sugars, amino acids and fatty acids. A second group of bacteria eats those compounds and turns them into hydrogen gas, carbon dioxide, and acetic acid -- the primary component of vinegar. Then a third group of bacteria takes those broken-down compounds and turns them into methane and carbon dioxide. Between 60 and 80 percent becomes methane. The methane can be used as fuel for an internal combustion engine that provides electricity. The facility currently generates enough fuel to power up to 80 homes.

"In 2007, only 2.6 percent of the nearly 29.2 million metric tons of organic waste generated in North America was recovered, due to inefficient collection processes."

Khalilah Hammond
The Value of Waste
Biomass Magazine

Challenges to Mainstream Utilization of MSW as an Sustainable Energy Resource

Feedstock Supply

The consistency, quality and quantity of MSW as a feedstock supply continue to be an issue for most processing plants. Despite the abundance of raw organic waste generated, there are very few mainstream channels currently in place to divert those materials to plants at the frequency and volume needed to ensure a consistent and optimized output of energy production. Most plants must rely on multiple independent sources for their feedstock. This results in increased fluctuations in the supply chain.

The solution to normalizing these variables will most likely lie in extensive collaboration between processing plants and the entities that manage the largest and most consistent flow of MSW: waste management companies. Designing processes that allow waste haulers to work in conjunction with processing plants in a way that is economically beneficial will be key to ensuring that the greatest percentage of MSW is properly recovered.

Regulatory Barriers

Many states have standards that prohibit the use of MSW as a renewable energy resource, despite the Federal government's explicit promotion of these technologies. Part of the problem lies in the lack of clear definition of what biomass is and what kinds of biomass can be utilized for energy harvesting. Another issue is the lack of targeted directives for the utilization of MSW as an energy resource compared to other renewable energy alternatives. With the current administration's push to promote renewable energy as a means of increasing national security, the time is ripe for implementing aggressive legislation to drive new development and establish efficient processes such as:

- Providing targeted government funding for biomass to energy technology development
- Providing government funding for MSW collection-Processing plant collaboration efforts
- Enacting legislation that promotes informed acceptance of MSW as a renewable energy resource.

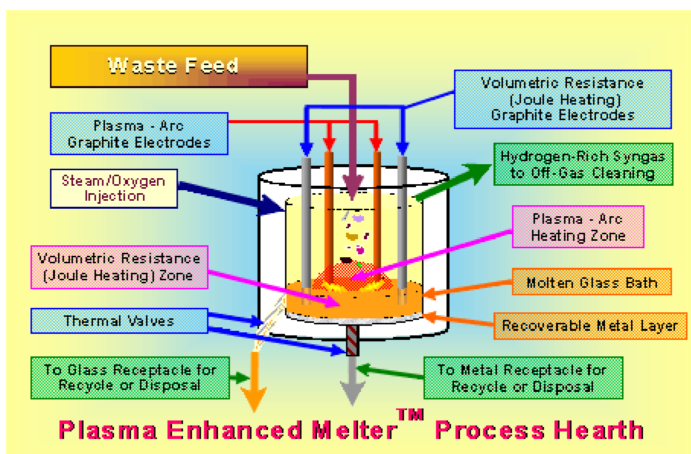
Emerging New Innovations

Various new technologies are being developed with the goal of promoting waste as a major energy resource. Several of the technologies will work in conjunction with existing waste collection methods to provide alternatives to existing waste handling post-collection. Others are hoping to, like distributed generation, provide easy on-site solutions that distribute waste handling and energy generation efforts. Examples of each approach are included below.

Plasma Enhanced Melter

Plasma Enhanced Melter (PEM™) technology can produce a variety of environmentally beneficial end-use products, such as renewable fuels and industrial products, as well as generate electricity from a wide range of segmented commercial, industrial and residential waste streams.

Technology overview. The PEM™ system uses heating from electrically conducting gas (a plasma) in a special gasification system to convert wastes to valuable products. With the PEM™ process, waste materials are fed into a closed chamber where they are superheated to temperatures of between 10,000 and 20,000 degrees Fahrenheit using an electricity-conducting gas called plasma. The intense heat of the PEM™ rearranges the molecular structure of the waste, transforming organic (carbon-based) materials into an ultra-clean synthesis gas (syngas). The clean syngas could



be converted to transportation fuels such as ethanol and diesel, industrial products like hydrogen and methanol or used as a substitute for natural gas for heating or electricity generation.

PEM™ systems are highly effective in processing a wide variety of waste streams, including MSW, hazardous, medical, radioactive, industrial, and tire wastes. The systems are also highly capable of creating commercially valuable products from waste in the form of useful solid byproducts (roofing tiles, insulating panels, sand-blasting media and other construction-related products). The environmental attractiveness of the PEM™ system results from nearly total destruction of organic materials (high volume and weight reduction) with very low emission of hazardous air pollutants. Because the waste is processed by gasification rather than by combustion, emission of dioxins and furans is virtually eliminated. Heavy metals, including mercury, are virtually eliminated and any emissions are below U.S. EPA emission standards.

The very low emissions improve the likelihood of obtaining air permit and achieving public acceptance.

Plasma gasification provides an opportunity that is complementary to current recycling, landfill and waste-to-energy practices. The technology has demonstrated its ability to process a number of waste streams on a small scale.

Gasification is not a new technology. There are many different kinds of gasification and other WTE processes, but none are operating yet in North America on a commercial scale. The technology involved in plasma gasification, or perhaps more properly plasma arc waste disposal, has been around for about fifty years, but few facilities exist that utilize it to both dispose of waste and create energy, and none are in the United States.

Green Energy Machine

For individual businesses that produce at least two tons of waste a day and have about three parking spaces to spare in the parking lot, IST Energy may have created the perfect “portable” on-site solution. The Green Energy Machine (GEM) is a mobile and compact WTE processing unit that can convert 95% of daily consumer wastes such as paper, plastic, food, wood and agricultural materials into electricity.

Technology overview. The GEM is designed to process a maximum of three tons of waste a day, with a rated capacity of 120 kW. To generate this electricity the GEM turns the waste feed into it into pellets which are then converted into synthetic gas and then electricity. The unit is 30 feet long, 8.5 feet deep and 8 feet tall.

3 Tons Maximum Capacity = 120 kW Electricity

The unit is completely self-contained and requires minimal manpower to load the feedstock and provide routine maintenance. This technology, once commercially available, will allow larger waste generators to process their own organic waste stream on site while generating energy to offset production energy demand.

Conclusion

Ultimately, the best strategies for utilizing MSW as a sustainable energy resource moving forward will include a blend of various conversion methods and technologies, promotionary legislation and extensive collaboration between waste haulers, energy generators and the communities they serve. Industrial sized technologies, like PEM, will work best in collaboration with waste hauling, collection and processing mechanisms currently in place for smaller individual waste generators (residential and commercial market sectors for example). On-site technologies, like GEM, will be instrumental in promoting responsible corporate waste management processing and distributed energy generation goals. Together with other renewable energy initiatives, the utilization of MSW as a renewable energy resource can help the country move toward meeting two of its biggest sustainability goals: increasing energy independence through renewable energy production within our borders and managing our waste stream without the need for additional landfill capacity.

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