Environmental and Energy Study Institute

Issue Brief

Reconsidering Municipal Solid Waste as a Renewable Energy Feedstock

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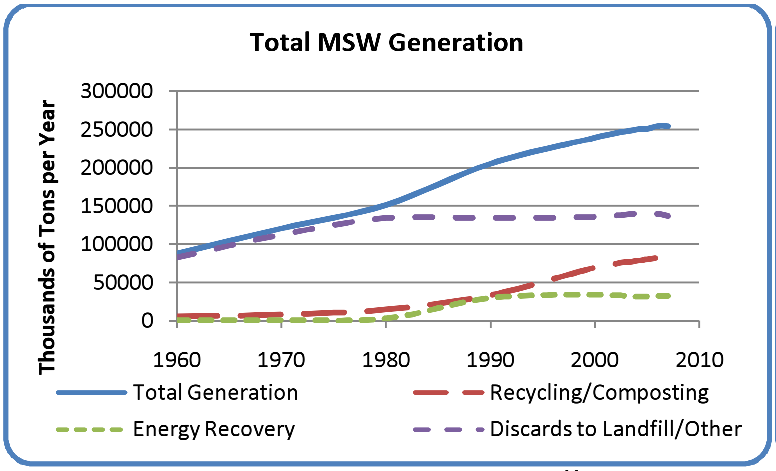
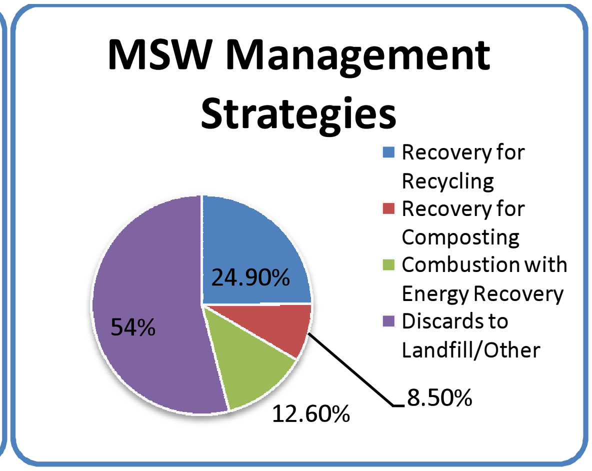
For many years, opposition to the use of municipal solid waste (MSW) as an energy resource has been nearly universal among activists and regulators. This opposition has been largely based on bad experiences with traditional garbage incineration facilities, which are associated with high levels of toxic emissions, as well as the perception that using MSW for energy will compete with recycling efforts. But growing climate, energy, and environmental concerns, coupled with technological developments and regulatory changes, have ignited new interest in MSW as an energy source with the potential to provide renewable energy while reducing greenhouse gas emissions and the need for landfill space. If the 254.1 million tons of MSW generated in 2007[1] had been diverted to produce electricity, the United States could have replaced approximately 3 to 6 percent of the electricity used in that year,[2] depending on conversion efficiency.[3] Alternatively, Fulcrum BioEnergy estimates that diverting all landfill waste to ethanol production could yield up to 21 billion gallons of renewable fuel annually,[4] which could make a significant dent in annual United States gasoline consumption of 142 billion gallons.[5]

MUNICIPAL SOLID WASTE BASICS

The U.S. Environmental Protection Agency (EPA) defines municipal solid waste as including "durable goods, non-durable goods, containers and packaging, food wastes and yard trimmings, and miscellaneous inorganic wastes."[6] The term does not include all forms of solid waste, such as construction and demolition debris, industrial process wastes, and sewage sludge. 254.1 million tons of MSW were generated in 2007. Of this, 63.3 million tons were diverted to recycling, 21.7 million tons were diverted to composting, and 31.9 million tons were combusted with energy recovery. The remaining 137.2 million tons were sent to landfills.[7] Under current policy, the Energy Information Administration (EIA) differentiates between biogenic and nonbiogenic waste in MSW, with biogenic waste excluding plastics, metals, rubber, and other nonorganic material.[8] As of 2005, approximately 63 percent of the waste stream by weight was considered biogenic. This accounted for roughly 56 percent of the total energy content of managed MSW (167 trillion Btu).[9] Some stakeholders argue that only the biogenic portion of MSW should be considered "renewable," because the items in nonbiogenic waste are derived from mineral and fossil resources. Others argue that the entire waste stream should be treated as a renewable feedstock because the alternative, sending a large percentage of the waste to landfills, is more damaging to the environment and does not harness energy sources that could be put to better use.

The per capita generation of MSW has remained relatively steady since 2000, when it peaked at 4.65 lbs/day. The per capita discard rate (the amount of trash sent to landfills after recycling, composting, and energy recovery) has remained virtually fixed at 2.5 lbs/day since 1960. This means that virtually the entire increase in individual waste generation has been treated in ways other than landfilling (see graph on next page). Regardless, the total amount of MSW generated is expected to continue rising in the foreseeable future as a result of population growth.[10]





Data Source: Energy Information Administration[11]

MSW-TO-ENERGY TECHNOLOGIES

A number of technologies can be used to create energy from MSW:

- **Landfill Gas Capture —** Waste in landfills naturally undergoes a process called anaerobic digestion, in which bacteria in an oxygen-deprived environment break down organic material. This process emits biogas, which is composed of approximately 50 percent CO_2, 50 percent methane, and a trace amount of other gases. To secure the biogas, operators dig a series of wells into the landfill, capturing between 60 and 90 percent of the gas emitted, depending on the system design.[16] The captured gas is then pumped to a central facility where the methane can be refined to pipeline-quality renewable natural gas, flared, or used for heat or electricity generation on site.[17] However, landfill gas systems require a large amount of landfill space, and a significant amount of climate-warming methane is still released.

Efficiency of Energy Conversion Technologies (kWh/Ton of Waste)[12,13]	
Landfill Gas[14]	41-84
Combustion[15]	470-930
Pyrolysis	450-530
Gasification	400-650
Plasma Arc Gasification	400-1,250

- **Combustion —** Also referred to as waste-to-energy, this technology involves burning waste in a chamber at high temperature, usually 1800 degrees Fahrenheit. While old combustion facilities often had high emissions toxic compounds, recent technological advances and tighter pollution regulations ensure that modern waste-to-energy facilities are cleaner than almost all major manufacturing industries.[18]
- **Pyrolysis —** MSW is heated in the absence of oxygen at temperatures ranging from 550 to 1300 degrees Fahrenheit.[21] This releases a gaseous mixture called syngas and a liquid output, both of which can be used for electricity, heat, or fuel production. The process also creates a relatively small amount of charcoal. While this process results in relatively low net greenhouse gas emissions and has a high conversion efficiency, technical difficulties have prevented its implementation on a commercial scale. The biggest barrier has been the difficulty of removing enough oxygen from the MSW to sustain a strong reaction.[22]

Expected Landfill Diversion (% weight)[19,20]	
Landfill Gas	0
Combustion	75*
Pyrolysis	72-95
Gasification	94-100
Plasma Arc Gasification	95-100

*90% by volume

- **Gasification —** MSW is heated in a chamber with a small amount of oxygen present at temperatures ranging from 750 to 3000 degrees Fahrenheit. This creates syngas, which can be burned for heat or power generation, upgraded for use in a gas turbine, or used as a chemical feedstock suitable for conversion into renewable fuels or other biobased products.[23] Gasification is economically viable at a small scale and tends to emit lower amounts of SO_x, NO_x, and dioxins than combustion. However, gasification has proven difficult to apply on a large scale and is not yet cost-competitive with combustion.[24]

- **Plasma Arc Gasification—**Superheated plasma technology is used to gasify MSW at temperatures of 10,000 degrees Fahrenheit or higher, an environment comparable to the surface of the sun. The resulting process incinerates nearly all of the solid waste while producing from two to ten times the energy of conventional combustion.[25] The solids left over are chemically inert, and can be used in paving surfaces.[26] While the technology is still relatively immature, several demonstration facilities have been built to provide conventional electricity, while hybrid facilities that combine conventional and plasma gasification to create ethanol are also in development.[27]

AIR QUALITY AND CLIMATE CHANGE IMPACTS

While older waste incineration plants emitted unacceptably high levels of pollutants, recent regulatory changes and new technologies have significantly reduced this concern. EPA regulations in 1995 and 2000 under the Clean Air Act have succeeded in reducing emissions of dioxins from waste-to-energy facilities by more than 99 percent below 1990 levels, while mercury emissions have been reduced by over 90 percent.[28] The EPA noted these improvements in 2003, citing waste-to-energy as a power source "with less environmental impact than almost any other source of electricity."[29] Landfill gas capture systems, meanwhile, release much lower levels of dioxins, furans, and mercury than incinerators, although they may release somewhat more SO_x and NO_x.[30,31] Gasification, pyrolysis, and plasma arc technologies are also much cleaner than waste incineration.[32]

Converting MSW to energy also has tremendous potential to reduce climate-changing greenhouse gases. According to a model developed by the EPA, each MWh of electricity generated through combustion of MSW results in a net negative CO_2 footprint of 3636 lbs of carbon dioxide equivalent (CO_2-eq).[33] This translates to approximately 1 ton of carbon equivalent for each ton of MSW combusted. Combustion systems achieve this net reduction by offsetting fossil sources of electricity, eliminating the methane emissions that would have occurred if the waste were landfilled, and recovering metals that can be recycled (which is much more energy-efficient than using raw materials).[34]

Landfill gas utilization also offers promise for reducing greenhouse gas emissions, although due to its relative inefficiency at converting waste to power it does not displace as much generation from fossil fuels as combustion. The EPA estimates that a 3 MW landfill gas plant can reduce methane emissions by 125,000 tons of CO_2-eq per year while displacing an additional 16,000 tons of CO_2-eq of fossil fuel generation.[35] Based on this projection and on the EPA estimate that the 520 additional landfills it identifies as strong candidates could generate an additional 1200 megawatts of electricity, the United States could reduce annual greenhouse gas emissions by as much as 56.4 million tons of CO_2-eq with landfill gas capture.[36]

Because conventional gasification, pyrolysis and plasma arc gasification are less-commonly used with MSW, little information exists on how carbon emissions from commercial-scale applications will compare to those of MSW combustion or landfill gas capture. Like direct combustion, however, these technologies will offset fossil fuels, reduce methane emissions from landfills, and can aid in the recovery of metals and other valuable end products. There is every reason to expect that the effect will be comparable, based on the efficiency of energy generation using these technologies.

MSW FOR ENERGY AND RECYCLING

A common concern with waste-to-energy projects is that they may crowd out recycling efforts by placing a higher value on waste, which could make diversion to waste-to-energy more attractive than investing in new recycling efforts. However, a recent study found that communities using waste-to-energy had average recycling rates of 33.3 percent, roughly 1 percent higher than the national average.[37] Waste-to-energy need not conflict with recycling for several reasons:

- Over 80 percent of all existing waste-to-energy facilities contribute directly to recycling by filtering out non-combustible metals from a waste stream that would have otherwise been sent to the landfill. At present, waste-to-energy facilities recover 49 percent of all ferrous metals and 8 percent of non-ferrous metals they process, leading to over 716,000 tons in direct recycling improvements.[41]
- One 2006 study by *MSW Management* found that 83 percent of communities with waste-to-energy projects were also expanding their recycling programs, showing that even fixed quotas do not necessarily have a negative impact on recycling rates.[42]
- While recycling and composting are important waste management options, over 50 percent of the waste stream was still diverted to landfills in 2007. Despite efforts to expand recycling programs, population growth is expected to keep this number from shrinking in the near future.

Case Study — Waste-to-Energy Facility Recovers Metals and Increases Recycling Rates

The SEMASS Resource Recovery Facility in West Wareham, Massachusetts, which has won recognition from the American Academy of Environmental Engineers and the Smithsonian Institute, among others, captures metals at its waste-to-energy plant through a two-stage process. By recovering material both from input waste and the bottom ash left after combustion, SEMASS is able to recover approximately 90% of the metal it processes for recycling.[38,39, 40]

FEDERAL POLICY

***Resource Conservation and Recovery Act* (RCRA):** Passed in 1976, RCRA (P.L. 94-580) created a role for the federal government in regulating solid waste pollution. The act requires states to implement a solid waste management strategy. The EPA was tasked with developing guidelines that states could follow in designing a strategy. These guidelines include an emphasis on source reduction and recycling of MSW as the preferred options. Ultimately, state regulations are subject to EPA review to ensure that federal requirements will be met. In addition, RCRA included a ban on open dumps for MSW. As a result of this and the economies of scale required to meet stricter landfill requirements, the number of landfills has declined from 8000 in 1988 to 1654 in 2008, while capacity has remained level.[43] A number of RCRA measures were strengthened with the 1984 Hazardous and Solid Waste Amendments, which closed several loopholes in landfill and hazardous waste treatment standards and strengthened the power of the EPA to enforce them.[44]

Production Tax Credit: According to the EIA, waste-to-energy facilities receive less federal support than virtually any major source of electricity, including coal.**[46]** Currently, electricity generated by new facilities will benefit from a production tax credit of 1 cent per kWh as authorized under section 1101 of the *American Reinvestment and Recovery Act of 2009* (P.L. 111-5).[47] This credit will last for 10 years from the date the plant is put in service for those facilities built after August 8, 2005 and for five years for those put in service between October 22, 2004 and August 8, 2005.[48] The credit does not apply to facilities built before October 2004. While this incentive is undoubtedly valuable, most other renewables receive 2.1 cents per kWh.

Total Federal Electricity Subsidies[45]

Energy Type	FY 2007 Net Generation (billion kWh)	Total Subsidies (million $)	Subsidy Per Unit of Energy ($/mWh)
Coal	1946	854	0.44
Natural Gas	919	227	0.25
Nuclear	794	1,267	1.59
Biomass	40	40	0.89
Wind	31	724	23.37
Solar	1	14	24.34
Landfill Gas	6	8	1.37
Waste-to-Energy	9	1	0.13

Case Study — Fulcrum Bioenergy Converts Waste to Ethanol

Fulcrum BioEnergy, based in Pleasanton, California, is a pioneer in MSW-to-ethanol technology. The company plans to start construction in 2009 on a demonstration facility to test its novel production process, which puts waste through both a conventional gasification unit and a plasma arc system. The facility, in Storey County, Nevada, will process 90,000 tons of waste per day while generating 10.5 million gallons of ethanol.[49]

Renewable Fuel Standard: There is currently some uncertainty regarding the eligibility of MSW-derived biofuels under the national Renewable Fuel Standard (RFS) as amended by the *Energy Independence and Security Act of 2007* (EISA, P.L. 110-140). While EISA does not explicitly include (or exclude) MSW under its definition of "renewable biomass," it does include 'separated yard waste or food waste', which make up a significant part of the municipal solid waste stream. EPA believes this could justify making MSW-derived fuels eligible for the program. In a proposed rule release on May 26, 2009, EPA solicited public comment on the appropriateness of this interpretation.[50]

RECENT TRENDS AND OBSTACLES TO INCREASED USE

To date, landfill gas capture has achieved by far the widest acceptance among technologies generating energy from MSW. In December 2008, there were bioenergy programs in place at 485 landfills. These projects provided 12 billion kWh of electricity per year, as well as 12 billion cubic feet of landfill gas per day for direct use applications such as household heating.[51] Together, this was enough to provide power for 870,000 homes and heat for an additional 534,000.[52]

Waste combustion has not benefitted from the same public acceptance as landfill gas. In fact, No new facilities have been constructed since 1996. There are currently 88 waste-to-energy plants in operation in 25 states, fueled by 26.3 million tons of MSW.[53] The industry generates almost 17 billion kWh of electricity per year and powers close to 2 million homes.[54] This represents 20 percent of all non-hydro renewable electricity generation in the United States.

Gasification and plasma arc technologies still face a number of technological hurdles to commercial-scale use, and only demonstration facilities have been built to date. The largest plasma arc demonstration facility, in Utashinai, Japan, can process up to 300 tons of waste per day, and produces 7.9 MW of electricity (4.3 MW is sold to the grid, while the rest is used to support facility operation).[55] While Ze-gen, Shaw Industries, Nexterra, and several other companies have built demonstration-scale gasification facilities, the technology has not yet been applied on a larger scale.[56]

MSW still faces a number of obstacles to wider use as a feedstock. Among the most important of these are local concerns about emissions, perceived competition with recycling, siting, financing, and low federal support. **Changes in federal policy, such as granting MSW full status under the production tax credit and the RFS and placing a firm price on carbon emissions, could play a major role in increasing the use of MSW for electricity, heat and fuel generation.**

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