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Innovation Cleans Up Waste-to-Energy

By Melissa C. Lott | August 1, 2012|

Why does diverting waste from a landfill and turning that waste into energy cause so much controversy? Despite the widespread use of waste-to-energy (WTE) in European countries, here in the U.S. WTE has a reputation for being "dirty." Environmental activist groups frequently oppose WTE because of air emissions concerns. They argue WTE is not "green" and using waste as an energy source discourages reuse and recycling. Despite some successful recycling and curbside composting programs such as in Portland, Americans currently only recycle or compost 34 percent of municipal waste generated, according to the Environmental Protection Agency. The U.S. has relatively low landfilling costs which enable our wasteful ways. By comparison, in Germany the majority of waste is recycled, composted, or processed by biological and thermal methods. The success of recycling and WTE in Germany and other European countries arose because of government mandates and disposal costs that reflect the scarcity of landfill space. Globally, 70 percent of municipal solid waste is landfilled, with projections that the volume of MSW will double within the next 15 years.

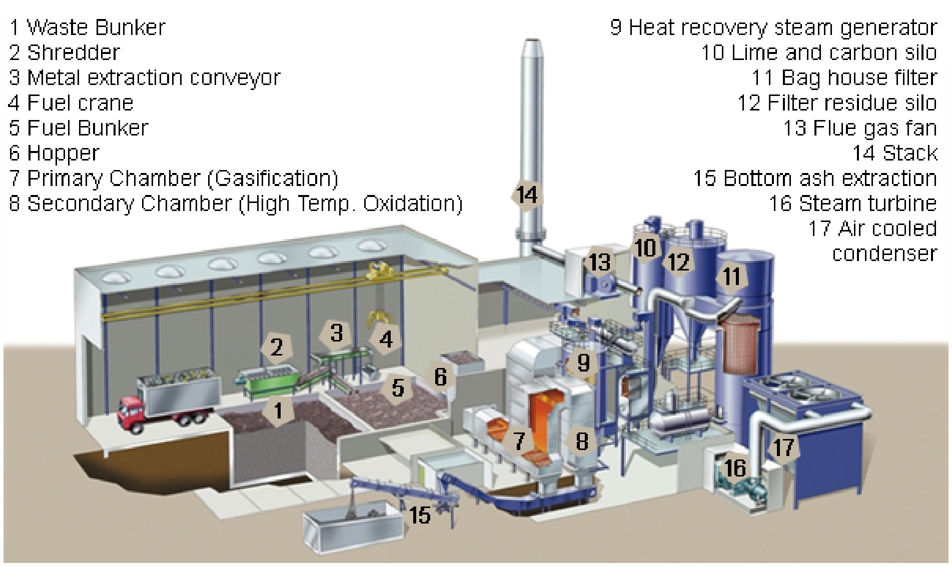
Using municipal solid waste (MSW) to generate energy can reduce the amount of material sent to landfills by 90 percent, avoiding greenhouse gas emissions from landfills – the third largest human-related source of methane emissions. Studies estimate the amount of energy in U.S. food waste alone is equivalent to 350 million barrels of oil, or enough to power 16.2 million households each year. Beyond MSW, the U.S. has issues managing animal wastes, construction and demolition debris, and sewage sludge to name a few. America needs a transformation on how we view waste and WTE. Innovative technologies are promising to help us start to see the resource in what we currently waste and demonstrate that WTE can be clean.

Battling WTE misconceptions

Waste-to-energy in the U.S. is still widely perceived as either energy derived from landfill gas or incineration. Waste-to-energy is not a single technology, but a variety of technologies – both thermal and biological – that can be used to convert waste products into electricity or fuels. While landfill gas is better used than emitted as greenhouse gas, activists want to divert waste from landfills, not produce more gas. Incineration of MSW typically employs a mass burn method and requires pollution controls including those for mercury, lead, dioxins/furans, particulate matter, nitrogen oxides and sulfur dioxide. Mass burn facilities require little or no preprocessing of waste – simultaneously an attractive economic feature and a root cause of the image problem. Prior to improved waste sorting and recycling efforts in recent years, incinerators would burn a heterogeneous mixture that included metal wastes, producing considerable air emissions. Mass burn facilities are often permitted as "major sources" of hazardous air pollutants by the EPA. Of the 87 operating WTE plants in the U.S., 63 are mass burn. In New York, efforts to generate energy from city trash have met with sharp criticism and protests, even though direct combustion methods were specifically excluded from consideration. Therein lies the problem: waste-to-energy has such a negative connotation that cleaner technologies are also being overlooked.

Thermal technologies – improved efficiency and reduced emissions

A thermal technology that eliminates many of the objections to WTE is gasification. Gasification is a fundamentally different thermal process than incineration. Waste (MSW or other) is pre-processed using a combination of screening, size reduction, and separation to remove inorganic materials such as metal and glass. The resulting waste is compressed and dried into pellets or bricks, which is used as feedstock to the gasifier. Unlike incineration where the waste is burned, gasification uses high temperatures and pressures in a substoichiometric atmosphere (less oxygen than required for complete combustion) to convert the waste into a syngas that is comprised primarily of carbon monoxide and hydrogen. The syngas can be subsequently used to produce electricity in a steam process or gas turbine, or to power an internal combustion engine. Residual ash is disposed or further processed for material recovery. The low oxygen environment prevents the formation of dioxins, furans, or large quantities of nitrogen oxides (NOx) and sulfur oxides (SOx). Due to the low volume of process gas, gasification requires less expensive emissions control equipment. How the syngas is used will dictate the extent of gas conditioning required. Dioxin and furan reformation in the syngas can be prevented by the low oxygen atmosphere, absence of metal particulates, and quenching (rapid cooling). Recent studies have shown that gasification of MSW could have substantial environmental benefits, saving 0.3 to 0.6 tons of carbon equivalent emissions per ton compared with landfill disposal.



(Schematic of a MSW Gasification and Power Generation Plant (Energos, 2009). Image credit: Waste-to-Energy Research and Technology Council)

Two other thermal technologies are plasma arc gasification and pyrolysis. Plasma gasification uses an arc of ionized gas to heat the feedstock to extremely high temperatures, breaking it down into elemental byproducts. The residual inorganic material is vitrified – turned into a glass-like substance, which is inert (non-leaching) and exceeds EPA standards. However, plasma gasification remains an expensive technology because of the energy required for the plasma arc torch. A demonstration project in Florida has received a final permit and will process 600 tons of waste per day. Notably, the facility's permit limits for the six EPA criteria pollutants are the lowest in the country for the size of the facility. Another project is Texas is still in the early planning stage. In pyrolysis, the feedstock is thermally decomposed at moderate to high temperatures in the absence of air, resulting in liquid or gaseous fuel and a solid residue called char. If pyrolytic fuels are combusted to produce electricity, emission control equipment is required. Pyrolysis and gasification are sometimes confused, even though the operating conditions and products differ. Gasification, plasma gasification, and pyrolysis offer improved waste conversion efficiencies (25 to 50 % higher) compared with conventional mass burn incineration.


(High-temperature pyrolysis chamber. Image credit: Interstate Waste Technologies)

Unfortunately, confusion over technology has led many to oppose new WTE gasification projects as incinerators in disguise, or "too good to be true." Adding to the confusion is the lack of substantive emissions data from gasification facilities in the U.S. Studies of biomass gasification (not just MSW, but woody biomass as well) show a wide range of emissions due to the variability in feedstock, pretreatment, operating conditions, and configuration. As a result, when community groups investigate thermal technologies for MSW, emissions and operational data from sources that are dissimilar from the proposed project are misinterpreted. Public opposition combined with unfavorable economics (low landfill prices, required preconditioning of waste) have hampered the commercialization of gasification, plasma arc gasification, and pyrolysis.

While gasification is still struggling to overcome the incinerator reputation for MSW, the technology has had demonstrated success with animal waste. The Denver Zoo's Elephant Passage exhibit achieved platinum LEED certification using an innovative gasification system that converts both human trash and animal waste into renewable electricity to power the exhibit. Successful gasification projects such as this may pave the way for more sustainable animal waste management. Typically, animal manure is stored on-farm or spread on fields as a nitrogen and phosphorus-rich soil enhancer. However, animal manure can be too much of a good thing. The concentration and size of animal production operations cause waste to be stored in large stockpiles (as in the case of poultry litter), lagoons (hog and dairy cow waste), or applied to over-fertilized agricultural lands. These practices can cause runoff that leads to surface water contamination. Waste-to-energy technologies can improve animal waste management by providing numerous benefits, including water quality improvement and odor reduction. Notable animal waste gasification projects include a pilot-scale Georgia gasification plant which converted Tyson poultry litter to process steam, and an Iowa poultry farm demonstration project that has recently secured funding.

Biological technologies – ready for commercial scale?

Non-thermal technologies use biological processes to break down waste. Anaerobic digestion, a process that employs bacterial decomposition in an oxygen-starved atmosphere, is becoming a preferred method for high-water-content animal manures as well as other waste streams. Anaerobic digestion is the same process that causes methane emissions from uncovered waste lagoons, but modern technology utilizes enclosed vessels to capture odors, maintain and optimize digestion conditions, and collect the nutrient-rich residue left behind. The biogas produced from anaerobic digestion is 55 to 70 percent methane, and can be used to produce electricity or refined as a biofuel. Several dairy farms across the U.S. are now utilizing biodigesters to generate energy. The barrier to large-scale penetration has been unfavorable economics and material handling limitations. Anaerobic digestion systems cannot process mixed waste and are sensitive to the moisture content of the waste. As a result, large quantities of water may be required. Innovations have overcome the latter problem as the first commercial-scale high-solids anaerobic digestion system processing food waste from regional producers recently made its debut in California.

(Anaerobic digesters for dairy cow manure. Image credit: Revmodo.com)

If anaerobic digestion suffers from an image problem, it is that commercial scale is difficult to achieve because of the time it takes to process waste and the preconditioning required. While an incinerator can process over 500 tons MSW per day, the first commercial-scale digester in California plans to process 100 tons per day by 2013. Most digesters fall into the 10 to 50 tons-per-day range. EPA is attempting to encourage WTE from anaerobic digestion with an interactive tool to match biogas producers with users, including biogas produced at wastewater treatment plants.

Exciting new technology developments utilize algae and fungi which thrive at higher temperatures to process waste into biofuels. Utilizing waste for biofuel development is preferable to using starchy food-based biomass, such as corn for ethanol. Cellulostic-derived ethanol has been produced only in laboratories and small demonstration scales due to the high cost of production, despite government mandates requiring its use. The enzymes to break down cellulosic biomass have been the main economic hurdle, accounting for half the cost of cellulosic ethanol production. Researchers at the Department of Energy are cataloging fungi that can break down cellulosic waste biomass into simple sugars for fermentation into ethanol. Large collections of fungi can be explored to identify those that produce cost-effective enzymes for the breakdown of wastes and development of biofuels.

Creating competition for waste

Lessons learned from the biodiesel market is that once waste becomes a commodity, feedstock availability and price increases can become issues, according the North Carolina Biofuels Center. As biodiesel gained in popularity with production surpassing one billion gallons in 2011, shortages of waste oil have actually induced thefts of used cooking oil. Limitations on the amount of feedstock waste, called yellow grease (as well as soybean oil) ultimately limit the volume of biofuels that can be developed. For MSW and animal wastes, supply chain management including the availability, location, volume, and control of a waste stream will make or break the economic viability of a WTE plant. Issues with waste availability can lead to the use of supplemental feedstock or reduction in material recovery efforts and is one of the main objections to new MSW WTE plants.

So do new technologies bring us closer to zero waste or sabotage our recycling efforts? If we start to look at waste as an energy resource, will that only encourage wastefulness? Data suggests that the recycling rate in communities with WTE facilities are higher than the national average, and that landfill diversion rates may be higher for WTE communities than for communities attempting zero waste. Some municipalities are successful in diverting waste from landfills by focusing on reducing and recycling first, followed by WTE. Waste-to-energy still remains less attractive than trucking to landfills because of high capital costs and the production cost for electricity. Policy at the federal, state, and municipal level can shift those economics by imposing fees to make landfilling more expensive, instituting curbside programs that make it easier for households to recycle and compost, and encouraging WTE as part of an integrated waste management solution.