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HUMANS HAVE BEEN TOSSING OUT TRASH for, well, close to forever. Archaeologists have found shell middens in South Africa that date back 140,000 years. Indeed, trash heaps and garbage pits are some of the best windows we have to ancient cultures.

Future generations of archaeologists may try to understand us through mountains of disposable—and non-biodegradable—diapers.

But present-day municipal solid waste is also a potentially valuable resource: the stuff we routinely throw out is rich in locked-up energy. The trick is designing the right system for extracting that energy in an efficient and cost-effective manner. If it is done in a sustainable way, many experts believe that these sorts of waste-to-energy systems can be critical for reducing our dependence on fossil fuels and non-renewable materials and for improving our environment.

The standard WTE approach is incineration. After materials that might interfere with the combustion process are removed, the remaining solid waste is transported to a combustion chamber, where it is burned. In a boiler above the combustion chamber, the heat of combustion converts water to steam, which powers a traditional steam-driven electric generator.

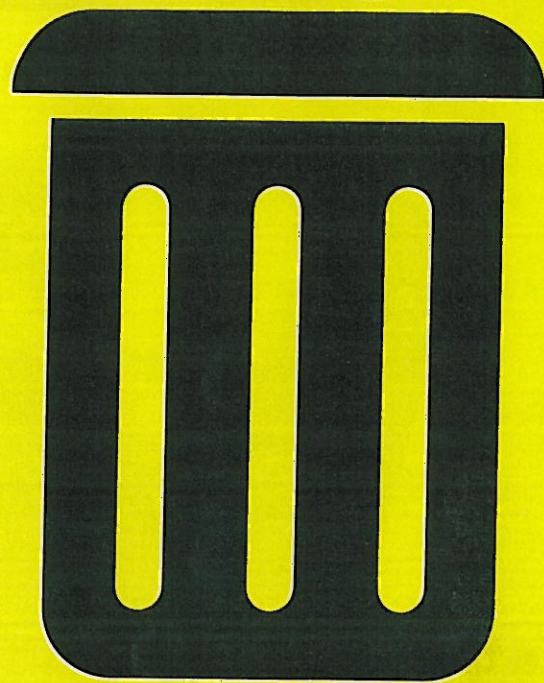
Cooled combustion gases are passed through pollution control devices to remove particulates and other contaminants before the gases are released to the atmosphere. Ash in the bottom of the combustion chamber is recovered; metals and other valuable materials are separated before the ash is disposed (often used as a covering at landfills).

The 87 WTE facilities in the U.S. have a total generation capacity of 2.6 GW. But most of these facilities were built in the mid-1980s and early 1990s. Stricter emissions requirements, which called for more expensive pollution control equipment, were enacted, and energy prices and landfill disposal costs fell, beginning in the mid-1990s. Together, these changes made WTE plants economically unattractive. Even though WTE facilities, when outfitted with top-notch air pollution control equipment, produced significantly cleaner electricity than coal or oil plants did, no new WTE capacity was added in the U.S. from the mid-1990s to mid-2000s.

Today, Americans continue to send most of their non-recycled waste to landfills. This, however, is starting to change as improvements in WTE technologies and emission control systems take hold.

“WTE facility emissions have been on a steady decline for many years,” said Marco J. Castaldi, research associate in the Earth and Environmental Engineering Department at Columbia University in New York. “This reduction is the result of both optimization of combustion within the boiler and the introduction of various

TURNING TRASH



INTO TREASURE

TAKING OUT THE GARBAGE HAS ALWAYS BEEN A DIRTY BUSINESS. BUT ADVANCED WASTE-TO-ENERGY TECHNOLOGIES ARE CONVERTING TRASH INTO A CLEAN — AND VALUABLE — RESOURCE.

for energy savings and greenhouse gas reductions is immense.”

BY MARK CRAWFORD



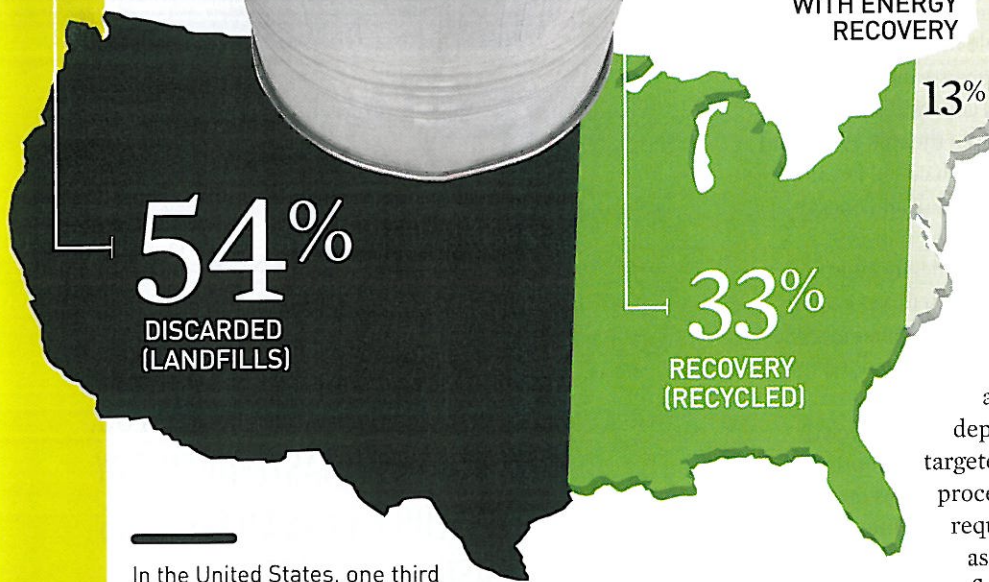
On average, it takes about one hour to process a ton of municipal solid waste at a WTE facility and deliver the resulting electricity to the power grid. In contrast, it is estimated that waste decomposition at a modern landfill takes 100 to 150 years.

SOURCE: Covanta.com



MANAGEMENT OF MUNICIPAL SOLID WASTE IN THE U.S., 2010

SOURCE: EPA



In the United States, one third of the municipal solid waste stream is recycled or composted. Most of the rest – 135 million tons in 2010 alone – winds up in landfills.

control technologies.”

As a result, five expansions of WTE facilities in the U.S. are in progress.

What’s more, according to Ted Michaels, president of the Energy Recovery Council, “New WTE plants are also being constructed in Palm Beach, Florida, and in Ontario, Canada. Other projects in Maryland, California, and Puerto Rico are still seeking final approvals.”

HIGHER TECH

Renewed interest in WTE is largely driven by new technologies, improved economic models, energy trends, and policy changes.

Gasification of municipal solid waste is gaining attention as new technological advances make this process more affordable.

“There has been a lot of activity in the U.S. recently regarding the implementation of new energy recovery technologies such as gasification and pyrolysis,” said Jeremy O’Brien, director of applied research for the Solid Waste Association of North America in Silver Spring, Md. “Everyone is looking to see how these projects will perform on U.S. MSW on a commercial basis.”

Gasification is the partial oxidation of the organic content in the MSW feedstock to produce a synthesis gas, or syngas, rich in hydrogen and carbon monoxide. The process falls between pyrolysis, an endothermic process in an airless reaction chamber, and combustion, which involves excess air and is highly exothermic. The reduced, sub-stoichiometric amount of air in gasification means smaller equipment can be used to produce higher energy and lower emissions.

This process is, however, technically and economically challenging. Success is dependent on the design of the process and the targeted use of syngas. For example, gasification processes originally developed for coal or biomass require significant pre-processing of waste, such as moving bed, fluidized bed, and entrained flow reactor methods. The heterogeneous nature of municipal solid waste complicates

In Denmark, **69%** of waste is recycled, **7%** landfilled,

equipment design, process design, and process control, because of the variability of physical and chemical properties of the waste, including heating value.

“The heating value and the purity of the syngas produced from the gasification of MSW depend on many parameters,” said Steve Goff, vice president of research and development for Covanta Energy, a major player in the waste-to-energy field. “These include gasification temperature, the use of air or oxygen, other reactants, and other energy inputs, as well as the gasifier design and control system.”

Covanta Energy has developed and commercialized a gasification process for unprocessed, post-recycled MSW, in an air-based process requiring no other reactants or energy inputs. The system does not require expensive shredding and sorting systems to prepare the waste. An advanced control system closely regulates the movement of waste through the process and the mixing of the waste with air to produce a stable syngas for subsequent combustion and the recovery of renewable energy.

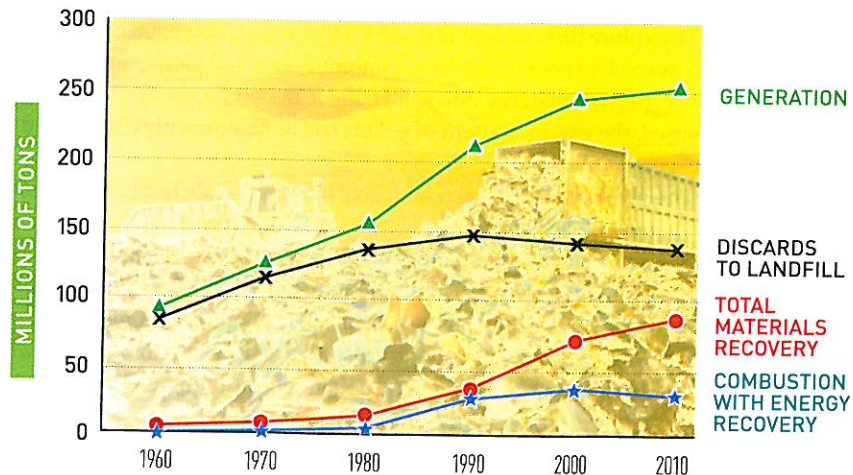
The process yields lower emissions of NO_x and CO, and decreased particulate carryover into the boiler reduces fouling and saves on maintenance costs.

“Burnout zone energy is recovered to drive the gasification process, which reduces the required stoichiometric ratio of air and increases the syngas heating value,” Goff said. “The cylindrical waterwall syngas combustor with staged air injection reduces the overall air requirement and NO_x formation. The lower air requirement means lower flue gas flow, higher boiler efficiency, lower particulate, and smaller equipment.”

Another solution for recovering energy from waste is pyrolysis, a thermochemical reaction at high temperatures that does not require oxygen. In this process, waste plastics decompose into the molecular components of fuels, which are then processed to form gases, oils, and even

GENERATION, MATERIALS RECOVERY, COMPOSTING, COMBUSTION WITH ENERGY RECOVERY, AND DISCARDS OF MUNICIPAL SOLID WASTE

SOURCE: EPA



Though recycling expanded in the 1990s, WTE has been relatively flat for the past 20 years. New technology and concerns over coal combustion may make WTE more attractive going forward.



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high-quality liquid fuels.

In an August 2012 article in *Earth* magazine, a publication by the American Geosciences Institute, Michael E. Webber, co-director of the Clean Energy Incubator, wrote, “Several companies in the U.S. and Europe have recently commercialized pyrolysis techniques and more are in the initial testing phases.”

According to Webber, who is also an associate professor of mechanical engineering at the University of Texas-Austin, the drawback is that the waste stream must contain high-quality, homogeneous plastic, and separating this material from the typical mixed-residue waste stream would be difficult, time-consuming, and costly.

Another WTE approach is converting waste into solid recovered fuels—blends of non-recycled waste that are engineered into a fuel-pellet feedstock. This technology is especially suitable for plastics such as disposable diapers that are difficult to recycle, or that decompose slowly in landfills.

“Although diapers will almost certainly be an interest-

and **24%** is sent to waste-to-energy plants.



ing archeological find many centuries from now, today they could make a great fuel,” Webber said. “That invites the broader question of how many other non-recycled plastics could be turned into fuels, instead of wasted in landfills.”

To explore this concept further, Webber’s research team created solid recovered fuel pellets, or SRFs, combining selected plastic and paper and converting the material into solid pellets. Depending on the raw materials used, the energy content of pellets can be significantly higher than most types of coal, noted Webber.

The product was co-fired with coal in a large-scale test burn in a cement kiln.

“Our experimental results showed that the SRFs had a predictable energy content of about 25 million Btu per ton,” Webber said. “Bituminous coal has almost exactly the same energy density, leading to a nearly one-to-one displacement opportunity. The SRFs in our experiment were also 40 percent more energy-dense than sub-bituminous coals and 80 percent more so than lignite. When the whole production, transporta-

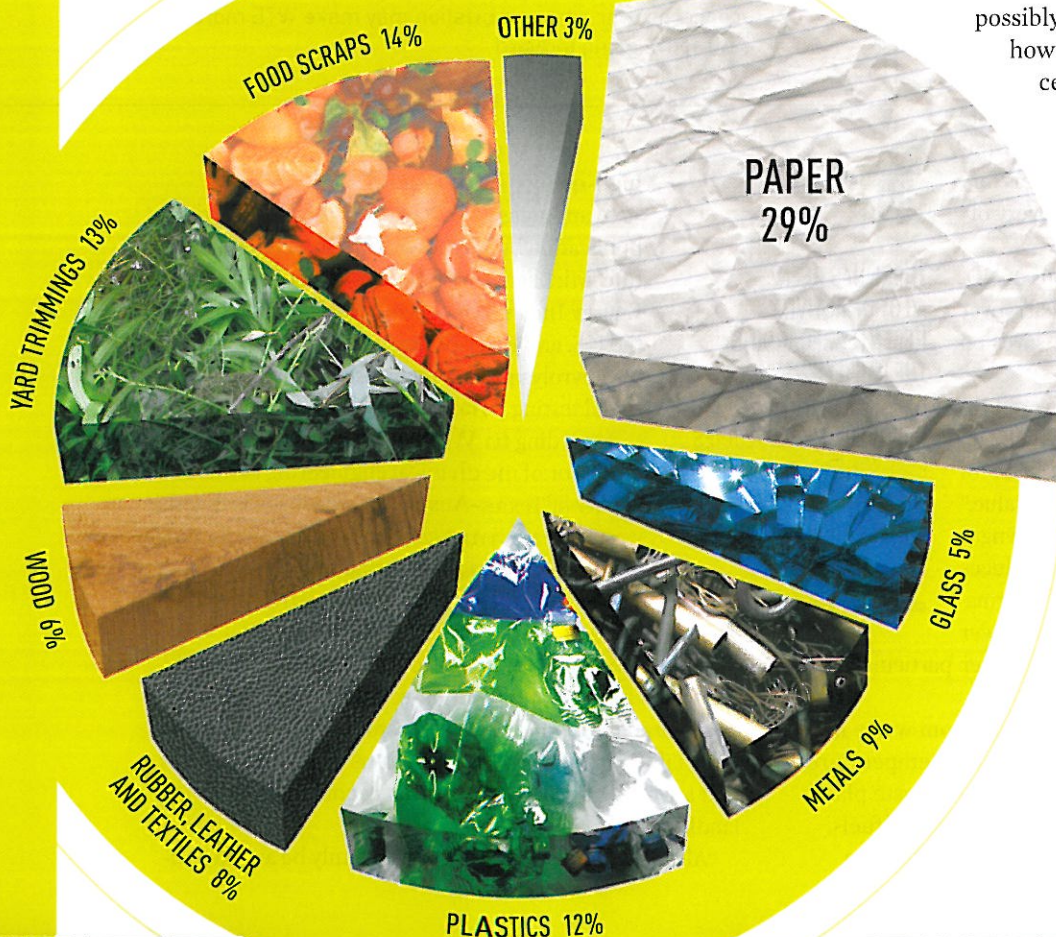
tion, and combustion life cycle of the SRFs is considered, large fossil fuel energy savings can be realized. On a larger scale, when the magnitude of the waste residue stream that flows through the U.S. every day is considered, the potential for energy savings and greenhouse gas reductions is immense.”

BRINGING DOWN THE PRICE

Key waste-to-energy research areas include reducing boiler corrosion, reducing NO_x emissions, improving waste stream characterization and separation, co-generation implementation (for example, utilizing both the steam and the electricity), and the impact of energy prices on the economics of WTE operations.

A continuing issue in WTE technology is ash content. Castaldi at Columbia is looking at new ways to extract valuable materials from the ash, as well as using ash as a catalyst to reduce emissions such as tars, dioxin, and possibly NO_x. “We are also exploring how to utilize ash for some novel processes such as microbial fuel cells, since the ash usually has good conductivity,” he said.

Castaldi’s group is also



TOTAL MUNICIPAL SOLID WASTE GENERATION BY CATEGORY, 2010 250 MILLION TONS BEFORE RECYCLING

SOURCE: EPA

Paper, plastics, food, and yard trimmings make up the largest categories (by weight) of solid waste. But while more than half the paper, yard waste, and some metals are routinely recycled, as little as 8 percent of plastics and 15 percent of wood, and 3 percent of food is recovered. The potential benefit of turning that waste into energy is significant.

Solid recovered fuels have a predictable

working to understand how nitrogen that's locked up in solid waste is turned into NO_x during burning, with hopes of reducing it.

One of the most exciting possibilities about exploiting solid waste streams is creating high-quality liquid fuels.

According to Webber, "Waste has been used for decades to generate heat, electricity, and biogas, but generating liquids has been too costly. Some new technologies are bringing down the price, which means we might be able to use unrecycled plastics to displace petroleum. This also helps divert waste from landfills while avoiding fossil fuel consumption."

Not all the developments advancing waste-to-energy production are technological. Many U.S. WTE facilities are close to paying off their capital finance bonds or have already done so. That means that they essentially will be able to operate debt-free for the next 10 to 20 years—keeping money in the community that would otherwise go to bondholders.

"For example," O'Brien said, "at the WTE facility in Lancaster County, Pennsylvania, almost a billion dollars will have been kept in the local economy over the facility's service life. An opposite example is New York City, which decided not to implement WTE. As a result, it is sending \$1 million per day (10,000 tons times \$100 per ton) out of the city. Over 40 years, this



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THAT AMOUNTS TO ALMOST

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LEAVING ITS ECONOMY.

amounts to almost \$15 billion."

Webber said he is excited about the possibilities of solid recovered fuels.

"Coal is SRF's closest fossil fuel analog in terms of fuel content and handling characteristics," he said. "U.S. consumers use nearly a billion tons of this non-renewable fossil fuel every year for power production, resulting in 2-plus billion megawatt-hours of power—and 2-plus billion metric tons of carbon dioxide emissions per year."

To put the potential of solid recovered fuels in perspective, Webber noted that the cement industry burns 10 million tons of coal every year. In contrast, the U.S. generates 250 million tons of municipal solid waste annually, about one-third of which is nonrecycled plastic and paper—a vast untapped resource. SRFs derived from these resources could create a renewable domestic alternative to coal, decrease the amount of waste sent to landfills, and reduce greenhouse gas production.

Making that happen, however, will require new procedures for classifying and sorting waste streams, larger-scale and longer-term pilot programs to better understand real-life production economics, and updated regulatory policies. For example, there is no clear regulatory guidance regarding SRF. Waste-to-energy policies also vary drastically between states.

"The lack of policies specifically addressing emerging technologies such as SRFs and plastics-to-fuels suggests an information gap between technology developers and policymakers," Webber said. "Despite technical, social, political, and economic hurdles, harnessing the energy content of nonrecycled plastics, papers, and other wastes provides many benefits while complementing regional recycling efforts. Now, the materials that even the recycling industry once considered trash are quickly becoming a national treasure." **ME**

MARK CRAWFORD is a geologist and independent writer based in Madison, Wis.



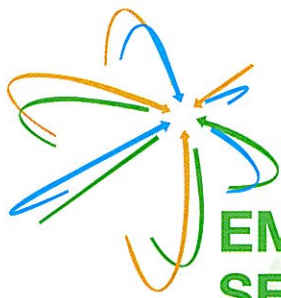
COVANTA ENERGY
www.covantaenergy.com

LOCATION: Morristown, NJ
FOUNDED: 1983

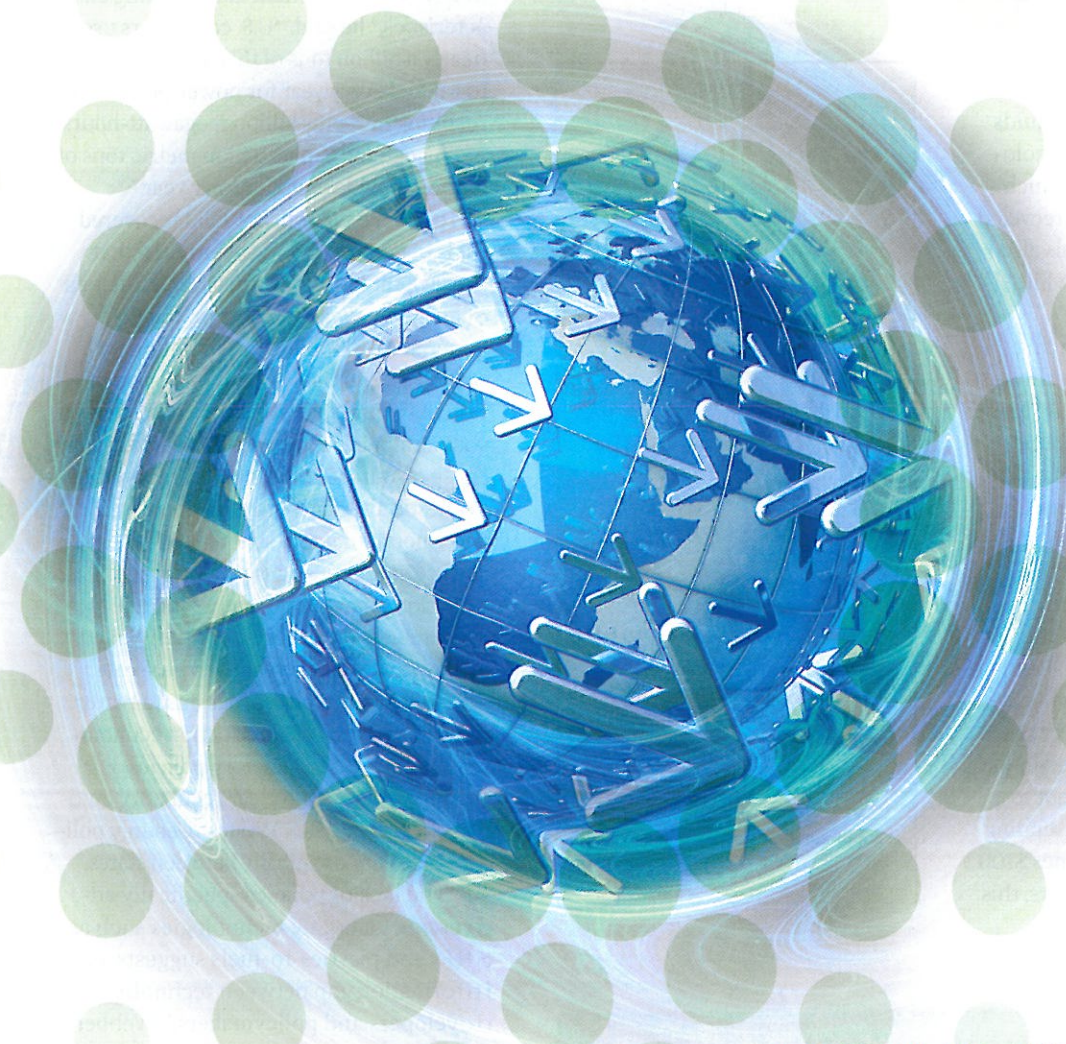
Covanta Energy is an owner and operator of infrastructure for the conversion of waste-to-energy (such as this site in Indianapolis) as well as other waste disposal and renewable energy production businesses.



energy content of 25 million Btu per ton – about the same as bituminous coal.



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