MATERIALS AND ENERGY RECOVERY FROM MUNICIPAL SOLID WASTE: WHY THEY ARE BOTH NEEDED
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ABSTRACT
The United States is the largest generator of municipal solid waste (MSW) in the world. It also landfills the largest amount of MSW. In this article, the authors present a comprehensive argument for implementing a more sustainable approach to the management of MSW. This approach includes the significant expansion of energy recovery from MSW, both to avoid burying massive amounts of waste and to expand generation of renewable, carbon-efficient electricity.

INTRODUCTION
The convergence of the threat of global climate change with the reality of ever increasing global energy demand requires the expansion of renewable energy sources wherever and whenever it can be done. The purpose of this paper is to make a comprehensive argument for significantly increasing one such energy source: energy from the combustion of MSW. Through this paper, we hope to stimulate discussion on the desirability of integrating combustion with recycling and composting to produce a different, and more sustainable, waste management infrastructure in this country. A principal goal of this article is to offer decision makers cogent arguments for developing waste-to-energy (WTE; also, called energy from waste or EfW) systems. The authors firmly believe that WTE is an essential component of the U.S. materials management strategy and that this energy source could supply up to 4% of the nation's total electricity needs, thus reducing dependence on fossil fuels while also providing communities with a better way to manage solid wastes.

DISCUSSION
There have been many papers published on the benefits or disadvantages of energy recovery from waste. Often, these papers focus on one or two technical arguments and contrast them to other materials management options. However, the argument for adopting WTE in an integrated materials management structure is a complex one involving more than technical arguments for reducing the carbon footprint of waste management or theoretical impacts of WTE on recycling rates. A full rationale for increasing the current level of WTE in the U.S. (currently 7% of the total MSW generation) must include other factors, such as national and local politics and the economy. No single factor will ever compel a community to make the decision to construct a combustion facility. Integrating WTE into a local materials management system will be the result of a careful weighing of all benefits, disadvantages, and especially, costs.

WTE in this country is, in our opinion, badly underutilized, particularly when compared to its use in other developed parts of the world. While "zero waste" as a strategy for handling materials flowing through society may seem a commendable goal, its impracticality, particularly in the near term, results in the freezing of the status quo, i.e., increased landfilling. The only practical alternative to
increased landfilling is, in our opinion, energy recovery by means of controlled combustion. Over the next several decades, the primary consideration for establishing a more sustainable MSW management strategy will not be do we incinerate or do we recycle, but what to do with the post-recycling MSW, i.e., do we landfill it or incinerate it. Our overall goal should be more complete utilization of materials flowing through our society.

As a nation, we need to stress practicality over idealism and develop an integrated MSW management system that will be able to divert much more MSW from landfills.

We summarize the reasons why we so strongly believe in expanding energy recovery from MSW:

- The U.S. is presently the world’s largest landfiler with over 65% of its MSW being landfilled
- Renewable energy is essential; WTE is a partially renewable energy recoverable through proven, safe, and available technology
- Landfilling is wasteful, environmentally unsustainable, and ultimately more costly than WTE.
- Zero waste is not possible, at least in the foreseeable future; insisting on a national zero waste MSW management has led to a stagnant, landfill-dependent disposal strategy
- Integrated materials management following the reduce, reuse, recycle, compost and energy recovery hierarchy (Figure 1) is proven to work and is embraced by most developed countries, all of which rely on energy recovery as a key component to achieve MSW diversion and carbon reduction goals
- Modern incinerator systems are efficient, highly regulated, renewable power generators. Emissions are very small relative to other sources, particularly toxics releases, which are vastly reduced from pre-Maximum Achievable Control Technology (MACT) regulatory emissions levels
- Communities benefit economically more from integrated materials management than from landfill-based strategies due to increased local economic activity and land conservation.

**Expanded Hierarchy of Waste Management**
(Themelis, GWMS, 2008)

![Diagram](image)

**Figure 1. The “hierarchy” of waste management**

1. Current MSW management in the U.S. is stagnant and unnecessarily wasteful.
but EPA, in calculating the carbon footprint of the waste management industry, often uses the BioCycle/Columbia University values (BioCycle, October 2010) Figures 2 and 3 show the current disposition of MSW in the U.S. Sixty-nine percent of generated MSW is buried in landfills. Although annual per capita generation rates have stabilized at about 1.3 U.S. tons, increasing population and changing consumer practices in the past twenty years have increased MSW generation in the same period by 50%. Furthermore, the increased urbanization of America places most of the waste generation in the expanding cities. This indicates that MSW generation will be increasingly concentrated in a few areas with reduced capability for siting new landfills. Unless there is a major change in current waste management practice, this increased volume of waste will have to be transported via truck and rail to distant, regional landfills. Figure 4, by the Congressional Research Service, shows how MW is transported over long distances, sometimes in both directions.

**Figure 2. Disposition of MSW in the U.S. (2008 data; BioCycle, October 2010)**

**Figure 3. Disposition of MSW across the U.S. (BioCycle, November 2010)**
There is no question that recycling should be of the first priority, as was illustrated in Figure 1. Recycling plus composting rates have doubled over the past 20 years from about 16% to about 29% (although, in the recent economic downturn, recycling rates have dipped, probably in response to sluggish markets). We believe that further increases in recycling and composting will and must occur but will be increasingly difficult because the successes of the past 20 years have come from collecting the "low hanging fruit" of the more valuable commodities, such as some types of paper and plastics, ferrous metals, and aluminum.

The plateau we have now attained is the creation of a frozen materials management landscape, complete with a continuing loss of land, energy, and metals through landfilling. During the last seven years, the U.S. EPA has estimated that the U.S. landfilled nearly one billion tons of MSW. That, in energy recovery terms, is an estimated 600 billion kilowatt hours (kWh) of wasted energy, enough to run 54 million houses for a year.

2. WTE as a source of renewable energy

We face the specter of global climate change caused by the use of non-renewable energy sources like coal, oil, and natural gas. Yet the economic advantages of fossil fuels keep the world dependent, in the foreseeable future, on these energy sources. Coal, on which the U.S. relies for 49% of our electricity, is a particularly carbon intensive fuel. Thus, any renewable source that can ease our dependence on coal-derived electricity production is particularly valuable from a climate change perspective. WTE is one such energy source.

Various federal government agencies have addressed the issue of whether or not WTE should be considered a renewable energy source. There is no current nationally-binding interpretation of the issue in the Executive Branch. Congress has not taken action past the Energy Policy Act of 2005, which extended preexisting tax benefits for renewable energy production, including production from WTE facilities. However, all renewable energy legislation passed by either the House or the Senate (but not both) in the past several years has defined WTE as a renewable energy that qualifies for renewable energy credits. While such legislation has yet to be signed into law, it is significant that the effort to write it has specifically provided for inclusion of WTE, perhaps in recognition that any and all realistically deliverable
sources of renewable (read carbon efficient) energy must be promoted.

The most direct position taken has been by the Energy Information Administration (EIA) of the U.S. DOE that states "EIA will now include MSW in renewable energy only to the extent that the energy content of the MSW source stream is biogenic". \(^1\) Current figures in the report show that 56% of available energy from MSW is considered biogenic. We submit that, at a minimum, this figure should be used as a national baseline to calculate how much WTE should be considered renewable for purposes of calculating renewable energy credits.

Recovering energy from MSW has a very desirable carbon emissions impact because the positive carbon balance of WTE is significant. The carbon emissions savings accrue from a combination of avoiding GHG generation in landfills, energy offsets from the replacement of more carbon-intensive electricity, and recycling benefits of metals recovery from incinerator ash. EPA's two models for calculating GHG emissions reductions from the various MSW management techniques are the Waste Reduction Model (WARM) and the Decision Support Tool (DST). These models are designed somewhat differently: WARM is a more generic model used to compare GHG emissions from business-as-usual waste management practices with emissions from alternative strategies; the DST is designed for use on specific facilities to compare MSW management strategies with respect to cost, energy consumption, and environmental releases to the air, land, and water. However, both of them calculate a positive effect on carbon emission when MSW is incinerated for energy recovery. WARM calculates that 0.5 tons of carbon equivalents are avoided per ton of MSW incinerated for energy recovery. The DST calculates a somewhat higher value, around 1.0 tons per ton of MSW incinerated. Either model shows the value of WTE in terms of carbon emission reductions.

The above reductions in carbon emission are computed for WTE systems where only electricity is generated. Where WTE facilities are designed to provide both electricity and district heating (e.g., as in all WTE plants in Denmark), the carbon benefits increase.

Most conventional renewable energy sources, such as solar and wind, are located outside of population centers. For example, analysis by the California Energy Commission (Panama Bartholomy, personal communication) shows wide-ranging solar and wind energy potential resources in the Southern California basin. All of these resources relocated in an arc around the population centers of Los Angeles and San Diego, at distances of between 20 to 100 miles. Thus, delivery of this renewable energy to these cities will necessitate the construction of new transmission lines. Siting large electrical transmission lines will create a whole new problem in the continuing battle to incorporate renewable energy into our electricity grid. In Southern California, public sentiment supporting the development and use of renewable energy, like wind and solar power, has run into the problem of public opposition to the construction of the new transmission systems needed to convey the renewable power from rural to urban areas. In contrast, renewable energy from locally generated WTE facilities can avoid this difficulty because such plants can be located in urban areas and connect into existing transmission systems. In fact, WTE plants are usually sited very close to the grid. WTE represents an achievable and proven carbon reduction from MSW management, not a theoretical one based on the development of unproven technologies, like anaerobic digestion or gasification, which can be suitable for source-separated yard waste and plastics but not for mixed MSW. The electricity and heat from WTE is generated where it is needed and does not require the development of a massive new energy delivery grid. Modern mass burn incineration is a proven, readily available technology already at work around the world.

Finally, WTE facilities generate a product, i.e., energy. Recycling does save energy by conserving resources and recovering the latent energy in materials themselves. However, recycling itself does not produce energy; it consumes energy, just at a reduced rate compared to primary production.

### 3. Landfilling is the least desirable form of MSW management

In most cases, materials management at the community level has traditionally been an exercise in handling wastes as cheaply as possible. Landfilling is invariably the cheapest MSW disposal practice. However, landfilling costs are low because the hidden costs of landfilling do not find their way into these standard market prices. Market costs of landfilling conceal full costs behind the expedient near term actual costs of land acquisition, labor, operations, and maintenance. They ignore actual long term costs simply because they can. There is no need to calculate and include all the economic effects of long term impacts in the price per ton landfilled.

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\(^1\) See U.S. Energy Information Administration's "Methodology for Allocating Municipal Solid Waste to Biogenic/Nonbiogenic Energy, May, 2007. The term biogenic used here means the energy recovered comes from materials produced by life processes of contemporary origin.
Yet these costs are real. They include possible landfill leachate migration impacts past the 50 year active management requirements (e.g., groundwater contamination, surface water seepage), lost productive land use due to the eternal nature of landfills, lost material value for usable materials locked into the landfill (including lost energy value), and, particularly, carbon emissions to the atmosphere because of the emission of methane. The costs associated with these impacts are very difficult to calculate and do not find their way into market pricing. Yet they do represent a cost to the country in legacy terms. Thus, we need to consider the long term economic impacts of continuing landfilling.

Clearly, landfills are significant sources of greenhouse gases. U.S. EPA's analysis of methane emissions shows that in the United States, the largest methane emissions come from the decomposition of wastes in landfills, ruminant digestion and manure management associated with domestic livestock, natural gas and oil systems, and coal mining. In 2008, landfill methane accounted for an estimated 22.2% of total U.S. methane emissions, the equivalent of 126 Tg CO2. By contrast, in 2008, incineration of waste emitted only 13.1 Tg CO2, over half of which, as shown earlier, is biogenic. It stands to reason that adding to the largest source of methane that is under our direct control is poor mitigation policy for climate change, particularly when it can be done by means of combustion of MSW with energy recovery. Also, while capturing and using landfill gas is much preferable to simply landfilled MSW (see Figure 1), there are still fugitive methane emissions. The Earth Engineering Center at Columbia University has estimated that, on average, only 50% of landfill methane is captured in U.S. landfills. Landfill gas energy recovery, on the average, amounts to only a tenth of the energy that can be captured through mass burn incineration. Life cycle comparative studies of emissions from energy from landfills and WTE facilities show incineration to be a more efficient and lower carbon intensity technology (see cited comparisons below).

4. Zero waste is not achievable in the foreseeable future

The U.S. has worked over 30 years to increase recycling rates from dreadful, single digit values in the 1960's to a current national average of about 25%. Most of this recycling involves the more valuable commodities, like paper fiber and metals that pay to recycle under most economic conditions. Data from the U.S. EPA's Office of Resource Conservation and Recovery suggest the recycling rate has leveled off in the past several years. This result suggests that the low hanging fruit, i.e., the valuable commodities, have entered a permanent recycling system but the less valuable ones have not. Composting of organics is a promising area but it can be applied only on source-separated organics. Increasing the recycling rate has become increasingly difficult and will become more so at higher rates. A realistic MSW recycling rate is peaking at around 40-45% at a few locations. However, when the U.S. rate climbs, hopefully, to such levels, there will still be a significant volume of MSW that has to be either combusted or landfilled.

Continuing efforts to reduce the national MSW waste stream volume are essential but have been of obviously limited success. It has been shown at an international level that waste generation is nearly proportional to energy consumption per capita. This is certainly true for the U.S., where both waste generation and energy consumption per capita are double those of Japan and the northern European nations. Any dramatic change in total generation of MSW will have to rely on significant cultural changes adopted by the total U.S. population (i.e., embracing a more sustainable lifestyle). Lifestyle changes that reduce or modify consumption seem difficult to sell to the general public and will be embraced slowly, if at all. It could be argued that the leveling off of both the per capita waste generation rate and the national recycling rate means Americans are increasingly unwilling to further change a higher consumption lifestyle because of the benefit of that sacrifice at this point has become unclear to them. If it becomes necessary to charge the public to increase recycling/composting rates, say through increased municipal waste management fees, the sacrifice will become even less acceptable. Public opinion is, for the most part, highly in favor of recycling as a national strategy. However, this positive opinion continues to fail to translate into zero waste or

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Increasing total volumes of MSW will have to go somewhere and that somewhere, as of now, is to regional mega-landfills. As an aside, the authors have personally witnessed the green container-filled trash trains from the northeast urban areas make their daily journeys via rail through urban northern Virginia to large southern landfills. The sight of thousands of tons of material being transported past an EPA office window under a cloud of diesel exhaust is truly disheartening. 

Most MSW is generated in dense population centers. Most major U.S. cities now long haul MSW to distant, out-of-state commercial landfills. This is an "out of sight, out of mind" strategy that enables large metropolitan populations to ignore their continuing contribution to the waste management problem. It also creates fertile ground for a public susceptible to arguments against the development of an energy recovery infrastructure "in their backyard" in favor of an unattainable zero waste strategy whose near term outcome is continued landfilling "in someone else's backyard". A public that doesn't see its waste as an immediate local problem can favor idealistic goals and disfavor practical solutions. 

Large urban populations, therefore, consciously or unconsciously, are hiding behind the chimera of 100% recycling rates at the expense of smaller, rural populations who accept urban waste for what income it can bring them. This is a dynamic that supports the status quo. 

Another, equally compelling factor in this argument is the fact that metropolitan centers whose waste management strategies require long haul landfilling have set aside concerns for the local impacts of their trash on rural populations, often populations that are lower income and/or indigenous tribal populations. This is an ongoing situation we recently observed in Vancouver, Canada, where the leaders of the First Nations of Canada implored the city board to halt the disposal of Vancouver's MSW in a landfill impacting First Nation lands. Vancouver's recent response to this was to approve the construction of an energy recovery facility. 

We have observed that a synergy has developed across the world, unstated and perhaps unintentional, created through the combination of the energies of proponents of recycling and composting to achieve zero waste and the economic power of the lucrative landfilling industry. The former seek a laudable, but unrealizable goal, of 100% reduction/recycling/composting of waste. The latter, quietly continue their landfilling business, investing in new and bigger units, and thus showing with their investment capital that they believe a high level of landfilling will continue well into the foreseeable future so long as the status quo is maintained. This synergy has locked most jurisdictions into that status quo: landfilling over 60% of the MSW generated. 

The solution to this is, we believe, an integrated materials management system located in or near urban population centers that combines all practical tools: single stream recycling to a modern Materials Recovery Facility (MRF), composting of source-separated organics that citizens and the MRF are able to separate, and combusting the post-recycling materials to produce energy and recover metals and construction materials. The balance of material flows through such a system will fluctuate to account for market forces and local efforts at increasing recycling and composting. A 25 to 30 year timeframe to increase recycling/composting to maximum levels (perhaps to 40%?) while recovering energy seems a realistic model. Most experts agree that a percentage of MSW will always be left over from any materials management system. An incinerator could be scaled to provide a constant destination for most of these materials as maximum recycling rates are identified and eventually attained. And while this is not zero waste in any sense, it is a far better materials management solution that results in a vastly better diversion rate than can otherwise be achieved. 

5. Integrated materials management systems must include energy recovery 

We are firm believers in reduce, reuse, recycle, recover. However, it is counter-productive to demand that a complex society utilize one approach to achieve a level of sustainability. All tools available to achieve sustainability goals must be applied. It simply makes no sense to develop an intransigent position on which combination of management approaches would be best for the U.S. and then demonize all other combinations. An integrated materials management system should be fitted to the conditions of localities. For example, advanced composting systems that use comprehensive public participation in separating food and yard wastes are excellent ways to generate a valuable commodity and divert these materials from landfills. Some California communities appear to be leading the way in this strategy. Even so, the BioCycle/Columbia 2010 national survey shows that California citizens landfill nearly as much tonnage
per capita (0.77 tons) as the average U.S. citizen (0.89 tons). Despite its strong recycling and composting efforts, the city of San Francisco landfills about 500,000 tons per year\(^5\), i.e. about 0.67 tons per capita.

Energy recovery systems are compatible with recycling programs because they have been shown not to compete with recycling markets for material. In fact, where both are comprehensively employed, WTE enhances recycling efforts by recovering metals from the mixed MSW. In the European Union and also in the U.S., the communities relying on electricity and heat recovery from wastes usually have also high recycling rates (Figure 5). The Netherlands, Germany, Austria, Japan and others have high recycling rates and utilize WTE for the bulk of the remaining material. By contrast, countries without WTE infrastructure tend to have high rates of landfilling. Energy recovery systems exist in harmony with practical recycling systems by taking remaining materials, those that cannot be recycled for various reasons (including market downturns), and converting them into power and heat. There just does not appear to be adverse competition between recycling and energy recovery where both tools are used to achieve materials management goals. Energy recovery opponents insist it must happen; we have not seen it happen.

It is evident from Figure 5 that the countries that have the highest recycling rates also have high WTE rates. These are the nations we should try to emulate.

We recognize that a thoughtful opposition to the development of an expanded, nation-wide WTE infrastructure may see it as simply rationalizing both the continuation of a throw-away culture and the production of more electricity to feed what they believe is an unsustainable national lifestyle. As noted earlier, the U.S. is using twice the amount of energy and generating twice the amount of wastes compared to other highly developed nations. However, we also showed that such nations still generate post-recycling wastes and, invariably, have opted to treat them by waste-to-energy rather than landfilling. There is not a single urban community in the world that has attained zero waste without the use of WTE. Even with the best outcome of significantly increasing recycling and composting over the next 20 to 30 years, there will still be a massive amount of material remaining that will need to be managed effectively.

To illustrate, we analyzed two different waste management scenarios, one that is based on vastly increased recycling rates over a realistic timeframe and one where both recycling and WTE are increased, to see if the analysis would change our position.

If the national recycling rate is given the concentrated attention it deserves, a very positive outcome may be to double the national recycling plus composting rate in the next 30 years. It took the U.S. at least 30 years to achieve the current level of recycling (RCRA was passed in 1980). It is not absurd to believe that approximately a doubling of the recycling rate could be achieved in that timeframe even though the most valuable materials are currently recycled at high levels while the remaining materials in the waste stream, which are more difficult to recycle, are not. So, let us assume that in another 30 years we will achieve a 50% recycling rate on a national basis. Let us further assume the MSW generation rate stays constant at about 400 million tons per year and the WTE rate at 7% (Figure 6). In the absence of a substantial infrastructure to extract energy from the waste stream, a significant amount of material will have to be landfilled during the time it takes to reach a 50% recycling level.

Using a rough calculation, under this scenario an estimated 6 billion tons of MSW will have to be landfilled out of the 12 billion tons generated over those 30 years. Given that each pound of MSW contains an average of 5000 Btu of energy and that the electrical conversion efficiency of advanced incinerators is about 20%, 6 billion tons of MSW represent about four trillion kilowatt hours of electricity (for comparison, the U.S. uses about 4 trillion kwh per year). And, even with this optimistic scenario, i.e., a 50/43/7 distribution ratio, at the end we will still have approximately 43% of the MSW generated going to landfills. In the year 2040, that amount of material would be (conservatively) 172 million tons per year, or 86 billion kilowatt hours of recoverable electricity, enough power to run about eight million households annually. In the absence of new WTE capacity, that large amount of potential power would continue to be lost to landfills. It is a lost opportunity in the carbon reduction arena and, also, of renewable energy.

Figure 5. Disposition of MSW in the European Union and some other nations

The Sustainable Waste Management Ladder
Earth Engineering Center, Columbia University (based on Eurostat 2008 data)

Figure 6. Doubling of Recycling and composting in 30 Years without additional WTE capacity
Let us consider a second MSW management future; one where the same material is handled in a system designed to ramp up to a 45/45/10 structure over 30 years (Figure 7). A significant national effort would have to be launched to simultaneously boost recycling and also construct an energy recovery infrastructure. Again, using a rough calculation, as the amount of landfilled MSW decreases, the amount of MSW diverted to energy recovery over this period is about 2.5 billion tons, representing about 1.2 trillion kilowatt hours of power. At the end of the period, only 40 million tons per year of MSW will need to be landfilled, and a significant amount of methane production is eliminated.

Figure 7. Increasing Both Recycling/composting and WTE in a 45/45/10 Ratio

The carbon emissions advantages of moving to a 45/45/10 MSW management system are significant. Currently, the combination of landfill emissions and incineration under a 28/7/64 ratio accounts for the management of a total of 289 million tons of MSW per year, with an estimated total carbon emission of 139 Tg CO2E (landfills emit 126 Tg and incinerators 13 Tg). Under a 45/45/10 ratio, landfill and incineration would handle 227 million tons of MSW, but the estimated total carbon emission drops to 102 Tg CO2E (landfill contribution would theoretically emit only 19 Tg at this reduced volume of 41 million tons while incinerators emit 83 Tg CO2E due to increased volume from 29 million tons to 186 million tons). However, because 56% of the carbon emission is biogenic, i.e., already in the carbon cycle, we would calculate the real carbon emission for incinerators at only 36 Tg CO2E. Therefore, the carbon impact of switching to a 45/45/10 MSW management ratio would be to drop yearly carbon emissions from 139 Tg CO2E to 55 Tg CO2E, or a 60% reduction of CO2E. We do not include here the carbon emissions benefits of increasing the recycling rate under this distribution because these are described well in other publications.

A 45/45/10 MSW management system is certainly achievable. The European Union is moving in this direction now, with some member countries already there. In the U.S., some jurisdictions, such as Montgomery County, Maryland, have achieved this MSW management distribution.

A final advantage to the use of WTE is the extension of landfill capacity. We have noted that landfills will always be needed to handle those waste materials that have no value or use. However, a common problem across the country is that the permitted capacity of many such landfills is, with current landfilling rates, quickly being used up. With widespread public opposition to extending landfilling capacity or especially to building new ones, the problem is acute in many locations. WTE capacity can extend existing landfill life by reducing the volume of MSW by about 85% to 90% and thus dramatically extending the ability of counties to rely on their existing landfills. This can save a significant amount of money (closure costs are particularly high) and provides communities additional time to achieve diversion goals.

6. Contrary to public perceptions, WTE plants have highly advanced emission controls and relatively low emissions.

Much negative public perception of incineration of trash is an antique artifact of vaguely
remembered, and decades old, horror stories of units that were basically open burners of sloppily delivered MSW. A picture from the 1960's, often used in public meetings, shows a trash truck unloading raw MSW directly into a concrete pit full of smoking trash. Nowhere in the U.S. do such units exist in 2010. The MACT standards for Large Municipal Waste Combustors (MWCs), issued by the U.S. EPA under the requirements of the Clean Air Act section 129, effectively put an end to unregulated or inefficient combustors by establishing mandatory emissions limitations that are protective of human health and the environment. The current 87 MWCs in this country must be in compliance with these requirements to operate. Future units will be required to achieve even stricter standards imposed for new sources, i.e., those constructed after September 20, 1994 (Part 60, Subpart Eb).

Opponents of WTE often employ scare tactics using very old data to paint incinerators as inefficient polluters who will cover the earth with a toxic "soup" of air emissions. No current credible data back these claims up.

To illustrate, we provide three ways to consider the relative impacts of modern MWCs. First, Table 1 shows the impact of MACT on the industry as a whole by comparing pre-MACT national emissions rates to post-MACT national emissions rates. With the exception of NOx, emissions reductions nationwide of the MACT-regulated pollutants approached or exceeded 90%.

We note that in comparison to the dioxin levels shown here, the dioxins emitted from what EPA call "backyard barrel burning" of residential waste were over 500 grams TEQ.

Second, the regulatory requirements that must be met by any new MWC unit include assessment under EPA’s New Source Review (NSR) program, where units must demonstrate that ambient impacts are below National Ambient Air Quality Standards. These programs evaluate the worst case operating condition which sets emission concentrations at the permit limit and an atmospheric condition that maximizes ambient impacts. All existing facilities must, and did, meet applicable standards at the time of permit application, otherwise they could not operate. New units have to comply with even lower ambient standards. In fact, U.S. WTE facilities have to operate well under their permitted emissions rates to avoid exceeding any of the emissions requirements. The facility owned by the Lancaster County Solid Waste Management Authority in Lancaster, Co., Pennsylvania, is an example. The plant's continuous monitoring emissions data (see Lancaster County Waste-to-Energy Facility Information Guide at www.lcswma.org.) show that emissions are substantially below permitted levels. For example, the facility's permit limit for SO2 is 30 ppm, 1 hour average, while the stack emissions levels have averaged 5 ppm over an eight year period. For particulates, the permit limit is 0.012 g/dscf and the stack emissions levels have averaged less than 0.002 g/dscf over the eight year period.

Third, we can assess relative emissions (and relative potential impact) in terms of emissions per unit energy where the mass of a pollutant is relative to the production of electricity, expressed as tons or pounds emission per megawatt hour delivered to the grid. Figure 8 shows that when compared on a emissions rate per megawatt hour (MWh), WTE facilities have low carbon emissions relative to other sources, particularly to landfill gas recovery systems. Only natural gas and nuclear power plants had lower carbon emissions per MWh. SOx and NOx emissions are comparably low (Figures 9, 10).

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6 see 40 CFR Subchapter C, Part 60
Table 1. Effect of implementation of MACT by the U.S. WTE industry

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>1990 Emissions</th>
<th>2005 Emissions</th>
<th>Percent Reduction</th>
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<tr>
<td>CDD/CDF, TEQ basis*</td>
<td>4,400 g/yr</td>
<td>15.0 g/yr</td>
<td>99+%</td>
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<td>Mercury</td>
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<td>2.3 tons/yr</td>
<td>96%</td>
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<td>Cadmium</td>
<td>9.6 tons/yr</td>
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<td>96%</td>
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<td>Lead</td>
<td>170 tons/yr</td>
<td>5.5 tons/yr</td>
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<td>Particulate Matter</td>
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<td>780 tons/yr</td>
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<td>NOₓ</td>
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</table>

*dioxin/furan emissions in units of toxic equivalent quantity (grams TEQ), using 1989 NATO toxicity factors. It should be noted that since 2005, the average dioxin emissions of U.S. WTE plants have been reduced to 0.045 nanograms TEQ, corresponding to an annual total of 6 grams TEQ.

Figure 8. Comparison of carbon dioxide emissions (MT CO₂/MWh) of different energy sources

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7. Novel energy recovery technologies versus proven technologies

Technologies are being developed that appear desirable on paper and may have been demonstrated in a bench or pilot scale. However, technologies need large amounts of capital to become operational. We have observed that capital sources demand proven operational capability, stated usually as the need for a five to ten year record of operations. Otherwise, capital must expose itself to too large a risk and will simply not be available for construction. This argues for the proven capability of mass burn incineration, using the most modern pollution control
systems available (mandated by regulatory agencies around the world) as the only energy recovery systems that can gather the necessary capital for large scale operations. Other systems, such as gasification have yet to prove themselves on the U.S. market and may be several years from operational capacity.

8. Esthetic appearance of WTE facilities

The view that these plants are undesirable neighbors from an esthetic viewpoint has also been an obstacle to the development of WTE in this country. However, WTE facilities constructed during the last decade in Europe, Japan, and elsewhere have been designed with this concern in mind. Plants located in the center of architecturally sensitive cities, such as Vienna, Osaka, and Paris have shown that designs can be made compatible with local esthetic requirements. The French facility pictured in Figure 11 is on the Seine, about two miles from the Eiffel Tower.

Figure 11. Isseane WTE Plant, Paris, France

9. WTE adds economic benefit to sustainable materials management systems

One repeated criticism of WTE is that it is expensive. It is true that modern mass burn incinerators are expensive to construct. A typical 1,500 ton per day EfW plant will cost approximately $400 million. It is also generally true that the gate (“tipping”) fee for MSW received at energy recovery facilities is higher than landfilling. We prefer to view issue in a different way. The construction and associated costs involved in installing WTE provide a significant economic benefit to the local community, both in terms of money moving through a community during the construction phase and in the permanent jobs that accompany the operation of a unit. An analysis by Berenyi (2008) for a facility in central Maryland showed that the economic activity associated with construction and operation of an EfW plant is significant and positive. The construction phase of the facility was estimated to involve the creation of 2685 jobs in the region. About one thousand jobs are created in the construction of the facility and even more are created in support industries. Berenyi estimated that this would result in $260 million of positive economic impact on the County through $65 million in wages and benefits paid to construction workers; $100 million in new household earnings for employees in supporting industries; $20 million spent on the purchase of supplies/materials from local businesses; and $76 million added to the County economy in the form of taxes, profits, and investment income due to the

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9 Impacts were estimated using the U.S. Bureau of Economic Analysis Regional Input-Output Modeling System (RIMS II), Regional Product Division, Bureau of Economic Analysis, Department of Commerce.
increase in construction output required for the new facility.

The operating phase of the new WTE would result in the creation of about sixty permanent jobs at the WTE facility, and another forty in supporting industries. This was estimated to provide $12.3 million per year (2009 dollars) in total positive economic impact on the County through $5.5 million per year in wages and benefits paid to facility employees; $1.3 million per year in new household earnings for employees in supporting industries; $1.5 million per year in spending by the facility on local goods and services, and; $4.0 million added to the local economy in the form of taxes, profits, interest, and investment income generated across all industries due to the increase in economic output.

Local support for such projects is a natural result of this increased positive economic activity. We observed this recently in a public hearing in Vancouver, Canada, where the project had the active support of several local labor unions.

The gate fees of a WTE plant are higher than landfilling fees. However, in nearly all cases landfills are situated some distance from urban centers and this requires the construction of waste transfer stations, where the load of the collection trucks is transferred to long distance trucks, plus the transportation costs from transfer stations to landfills. For example, implementation of WTE for New York City would result in the shutdown of over fifteen transfer stations and sending nearly 150,000 diesel trucks annually to other states, hundreds of miles away (CU Thesis, Monica DeAngelo).

Of course, a second and equally important source of revenues for the WTE is the sale of its products, electricity and steam. At this time, U.S. WTE only sell the electricity produced, amounting to about $30 per ton of MSW at an assumed price of only $0.06 per kWh. However, as States continue to pass laws requiring the use of renewable energy on the grid, these products will become more valuable. We believe that there will always be a market for this energy and its value will increase in the future as the world grapples with the large scale development of low carbon energy. It is not an exaggeration to suggest that any source of renewable energy will be increasingly more valuable in the years ahead simply because in the short term such sources are scarce. A lesser source of WTE revenue is the recovery of metals from WTE ash; at this time nearly one million tons of ferrous and non-ferrous metals are recovered from WTE plants. This is nearly 2% of all metal recycled in the U.S. Some argue against WTE by saying that it ties up waste destinations for a set period of time while creating fewer jobs than would be produced by recycling the same material. This argument is spurious given the reality of current MSW management. Simply put, there is plenty of MSW to manage properly. One materials management practice does not exclude the other and, therefore, the jobs issue should be subject to the same logic. More jobs, and the accompanying economic benefits, are created when a comprehensive MSW management system is put in place. The least beneficial jobs for any community are those that are outsourced to distant landfills.

Some of these same stakeholders also say that, in contrast to countries such as Denmark, the U.S.’s vast capacity for landfilling gives us the time to beef up recycling and composting rates. Is this a reasonable position to hold? Because we have the capacity to throw things away easily and cheaply, should we assume that it buys the U.S. time to somehow attain previously unattainable zero waste goals? It is a poor argument on its face. The U.S. has been working to beef up recycling/composting for many years and our history shows that progress has been steady but slow. It will not become faster from here on out.

CONCLUSIONS

The authors do not maintain that there should be WTE capacity in every U.S. community. In areas where nearby land for landfilling is plentiful, it may make economic sense to landfill with LFG recovery. In other places, where WTE would best fit the needs of both the communities and the country, it should not be opposed based on outdated arguments and scare tactics about toxic releases nor should use of it be cast aside in favor of zero waste ideologies that have been proven to be unattainable anywhere on the planet. We have argued elsewhere that the current culture of impassioned argument between the various materials management stakeholders is counter-productive and leads to gridlock. Cooperation among concerned stakeholders serves the country best. We appeal to the MSW management stakeholders, particularly those who have been extremely reluctant to accept energy recovery from MSW combustion in the past, to take another look at what a realistic sustainable materials management system should be in the U.S. and the world. The evidence provided above leads to the conclusion that sustainable management of wastes must include a productive way to extract all possible values from those materials that are not and cannot be

30 see Guest Editorial by Rick Brandes, "Cooperation, Not Conflict: Municipal Solid Waste Management in the 21st Century", MSW Management, March/April, 2010, p. 8
recycled or composted. Factors such as cultural change and climate impacts must be considered when crafting a national materials management strategy. We believe a national system that achieves high levels of recycling and composting and uses the remaining non-recyclable materials for their energy value will provide the highest service to our shared national goals of energy independence, carbon reduction, and sustainable management of our resources.