Comparison of Air Emissions from Waste-to-Energy Facilities to Fossil Fuel Power Plants

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The SWANA Applied Research Foundation's FY2005 Waste-to-Energy Group identified the need for a public information document that compares the air emissions from waste-to-energy facilities to those of conventional fossil fuel power plants. This paper is based on a research report that was prepared by SWANA in the course of developing the public information document.

1.0 INTRODUCTION

The SWANA Applied Research Foundation's (ARF) Year 4 (FY2005) Waste-to-Energy (WTE) Group identified the issue of comparing emissions from WTE facilities to those of conventional fossil fuel power plants as one of high importance to the group.

Three public-sector solid waste authorities supported the SWANA ARF's FY2005 WTE Group. Each of these organizations made a "penny per ton" funding commitment to the conduct of collective applied research in the WTE area.[1] A listing of the three WTE Group subscribers is provided in Table 1.

TABLE 1
SWANA ARF FY 05
Waste-To-Energy Group

Jurisdiction	Contact	Title
Southeastern Public Service Authority	Ron Angus	SPSA Power Plant Manager
Lancaster County Solid Waste Authority	Gary Forster, P.E.	Environmental Engineer
Three Rivers Solid Waste Authority	Colin Covington	General Manager

The following description of this topic was submitted by Gary Forster of the Lancaster County Solid Waste Management Authority.

> "the one topic that seemed to have the best potential for being useful to persons in the industry would be the comparison of emissions from a modern WTE facility to those from the three most common sources of fuel for energy generation: coal, oil, and natural gas. The emissions comparison could be done on a pound of pollutant emitted per megawatt-hour generated or something similar to that. In our interactions with the public (on tours and during presentations), we are frequently asked how our industry fares, on an emissions/environmental basis, in comparison with the other three. It would be nice to have a handy reference to be able to consult in these instances."

This paper is based on a report that was developed by the SWANA Applied Research staff to summarize the findings of recent research, as well as currently available data and published information, regarding the comparison of WTE emissions with those of traditional power plants.

2.0 WASTE-TO-ENERGY

2.1 Waste-to-Energy Systems[2]

2.1.1 Introduction

Waste-to-energy systems combust non-hazardous municipal solid waste (MSW) to generate electricity and/or steam as well as to sterilize and reduce the volume of waste requiring landfill disposal.

According to the Integrated Waste Services Association, there are 89 WTE plants in the United States that process about 95,000 tons of waste per day (35 million tons per year), generate about 2,500 megawatts of electricity, and provide for the waste disposal needs of more than 36 million people. In Europe, WTE facilities are estimated to process over 56 million tons per year. The percentage of waste combusted in the United States (17 percent) is considerably lower than that of several countries. Denmark, for example, processes over 80 percent of its MSW in WTE plants while Japan's rate is over 60 percent.

WTE is considered a renewable energy alternative by the United States Department of Energy (DOE). In addition, the United States Environmental Protection Agency (EPA) has concluded that WTE plants produce electricity "with less environmental impact than almost any other source of electricity."[3]

WTE plants work very much like fossil fuel fired power plants.[4] The difference is the fuel. WTE plants use garbage—not fossil fuels like coal, oil, or natural gas—to fire an industrial boiler. The same steps are used to make electricity in a WTE plant as in a coal-fired power plant:

- The fuel is burned, releasing heat.
- The heat turns water into steam.
- The high-pressure steam turns the blades of a turbine generator to produce electricity.
- A utility company sends the electricity along power lines to homes, schools, and businesses.

In 2000, WTE facilities achieved compliance with new Clean Air Act pollution control standards for municipal waste combustors. More than $1 billion was spent to upgrade WTE facilities, leading EPA to write that the "upgrading of the emissions control systems of large combustors to exceed the requirements of the Clean Air Act Section 129 standards is an impressive accomplishment."[5] In addition to combustion controls, WTE facilities employ sophisticated pollution control equipment.[6]

- A "baghouse" works like a giant vacuum cleaner with hundreds of fabric filter bags that clean the air of soot, smoke, and metals.
- A "scrubber" sprays a slurry of lime and water into the hot exhaust. The lime neutralizes acid gases, just as a gardener uses lime to neutralize acidic soil. Scrubbing also can improve the capture of mercury in the exhaust.
- "Selective Non-Catalytic Reduction" converts nitrogen oxides – a cause of urban smog – to harmless nitrogen by spraying ammonia or urea into the hot furnace.
- "Carbon Injection" systems blow activated carbon charcoal into the exhaust gas to absorb mercury. Carbon injection also controls organic emissions such as dioxins.

Ash residue from WTE facilities represents about 10 percent by volume of the original trash. The ash is tested in accordance with strict state and federal leaching tests and is consistently shown to be safe for land disposal and reuse. Ash makes good cover in landfills because it exhibits concrete-like properties causing it to harden once it is placed and compacted, reducing the potential for rainwater to leach contaminants into the ground. More than 600,000 tons of WTE ash is beneficially reused each year as daily cover, roadbed, or building material.

A number of WTE plants are operated as "cogeneration" plants which produce both electricity as well as steam that can be used for heating purposes. The cogeneration of steam and electricity from the combustion of MSW can cause the thermal efficiency of WTE plants to be significantly higher than traditional power plants.

3.0 Electricity Generation from WTE and Conventional Fossil Fuel Power Plants

3.1 Introduction

WTE systems rely on a renewable energy source (i.e., non-recycled, non-hazardous solid waste) that can displace the use of fossil fuels.

A ton of non-recycled waste has a heating value roughly equal to half a ton of coal and can produce as much electricity as 0.25 tons of coal. Combusting this waste in WTE plants can eliminate the environmental impacts associated with the mining, transport, and combustion of coal or other conventional, non-renewable fossil fuels.

EPA has established a "Clean Energy" web site that provides information to enable the user to compare the environmental impacts associated with the generation of electricity through the combustion of different fuels. The web site provides comparative environmental impact data on the following fuels and technologies used to generate electricity in the United States:

- Natural Gas
- Coal
- Oil
- Nuclear Energy
- Municipal Solid Waste
- Hydroelectricity
- Non-Hydroelectric Renewable Energy

The percentage breakdown of fossil fuels and other fuels used to generate electricity in the United States in 2003 is shown in Table 2. As indicated, fossil fuels accounted for 71 percent of the electricity generated, with coal used to generate the largest portion (51 percent), followed by natural gas (17 percent) and oil (3 percent). WTE plants generated 0.6 percent of the electricity used in the United States in 2003.

This following sections present excerpts of information that is available on the EPA Clean Energy web site. This information is provided by the EPA to enable the public to develop a better understanding of the environmental impacts associated with the electricity that they use.

3.2 Electricity Generation – Municipal Solid Waste[7]

MSW is typically sent to landfills or composted after it is collected. As an alternative, MSW can be directly combusted in WTE facilities to generate electricity. Because the waste is continuously generated and would otherwise be sent to landfills, MSW has been considered a renewable energy source. However, while MSW consists mainly of renewable resources such as food, paper, and wood products, it also includes nonrenewable materials derived from fossil fuels such as tires and plastics.

TABLE 2
Electricity Generation in the United States (2003)

Fuel	Thousand Megawatt—Hours		Percent
Fossil Fuels		2,743,051	71%
▪ Coal	1,973,737		51%
▪ Oil	119,406		3%
▪ Natural Gas	649,908		17%
Nuclear		763,733	20%
Hydroelectric		275,806	7%
Renewable		87,410	2%
▪ MSW	21,900		0.6%
Other		13,185	0%
TOTAL		**3,883,185**	**100%**

Source: United States Department of Energy — Energy Information Administration

At the power plant, MSW is unloaded from collection trucks, shredded, or processed to ease handling, and then fed into a boiler to be burned. The heat released from burning the MSW is used to produce steam, which turns a steam turbine to generate electricity.

Although power plants are regulated by federal and state laws to protect human health and the environment, there is a wide variation of environmental impacts associated with power generation technologies.

Although MSW includes renewable resources, its use as a source of energy has been met with controversy. Despite recent toughening of emission standards for MSW combustion, the process creates significant emissions, including trace amounts of hazardous air pollutants.

Burning MSW produces nitrogen oxides and sulfur dioxide as well as trace amounts of other pollutants such as mercury compounds and dioxins. Although MSW power plants emit carbon dioxide (the primary "greenhouse gas"), a portion of it is considered to be part of the Earth's natural carbon cycle. The plants and trees from which the paper and food waste is ultimately produced remove carbon dioxide from the air while they are growing, which is returned to the air when this material is burned. In contrast, when fossil fuels are burned, they release carbon dioxide that has not been part of the Earth's atmosphere for a long time (i.e., within a human timescale).

The variation in the composition of MSW raises concerns regarding its combustion as a fuel. For example, if MSW containing batteries and tires are burned, toxic materials may be released into the air. However, a variety of air pollution control technologies are used to reduce pollutant emissions from MSW power plants.

The average air emission rates in the United States from municipal solid waste-fired generation are 837 pounds of carbon dioxide per megawatt-hour of electricity generated (lbs/MWh), 0.8 lbs/MWh of sulfur dioxide, and 5.4 lbs/MWh of nitrogen oxides.

It should be noted that the carbon dioxide emission rate indicated above – 837 lbs/MWh – is significantly lower (i.e., 62 percent lower) than the value of 2,988 lbs/MWh currently reported on the EPA's web site. Based on the research conducted for this project, the SWANA ARF provided information to the EPA indicating that the EPA was over-reporting the carbon dioxide emission rates for WTE power plants on its Clean Energy web site. The reason for this was that EPA was including carbon dioxide emissions from both the biomass-based and fossil-fueled portions of the waste.[8] The EPA has tentatively agreed with the

SWANA ARF that the CO_2 emission rate number reported on the Clean Energy web site should be lowered to 837 lbs/MWh.[9]

3.3 Electricity Generation – Coal[10]

Coal is a fossil fuel formed from the decomposition of organic materials that have been subjected to geologic heat and pressure over millions of years. Coal is considered a non-renewable resource because it cannot be replenished.

The activities involved in generating electricity from coal include mining, transporting it to power plants, and burning of the coal in power plants. Initially, coal is extracted from surface or underground mines. The coal is often cleaned or washed at the coal mine to remove impurities before it is transported to the power plant—usually by train, barge, or truck. Finally, at the power plant, coal is burned in boilers to produce steam; and the steam is run through a turbine to generate electricity.

Although power plants are regulated by federal and state laws to protect human health and the environment, there is a wide variation of environmental impacts associated with power generation technologies.

When coal is burned, carbon dioxide, sulfur dioxide, nitrogen oxides and mercury compounds are released. For that reason, coal-fired boilers are required to have control devices to reduce the amount of emissions that are released.

The average emissions rates in the United States from coal-fired generation are 2,249 lbs/MWh of carbon dioxide, 13 lbs/MWh of sulfur dioxide, and 6 lbs/MWh of nitrogen oxides.

Mining, cleaning, and transporting coal to the power plant generate additional emissions. For example, methane – a potent greenhouse gas that is trapped in the coal–is often vented during these processes to increase safety.

3.4 Electricity Generation – Oil[11]

In the United States, oil is used mostly for transportation or home heating purposes, although a small percentage is used as a fuel for electricity generating plants. As with other fossil fuels, oil is found in underground reservoirs. It is the end product of the decomposition of organic materials that have been subjected to geologic heat and pressure over millions of years. Oil is considered a nonrenewable resource because it cannot be replenished.

The activities involved in producing electricity from oil begin with the extraction of the oil and end with its burning in boilers and turbines at power plants. Initially, crude oil is removed from the ground by drilling deep wells and pumping it up to the surface.

The crude oil is then transported to a refinery where it is refined into a number of fuel products, including gasoline, kerosene, liquefied petroleum gas (such as propane), distillates (diesel and jet fuels), and "residuals" that include industrial fuels. Refineries remove a portion of the impurities in the crude oil, such as sulfur, nitrogen, and metals.

From the refinery, oil is transported to power plants by ship, pipelines, truck, or train. At power plants, several methods can be used to generate electricity from oil. One method is to burn the oil in boilers to produce steam, which is used by a steam turbine to generate electricity. A more common method is to burn the oil in combustion turbines, which are similar to jet engines. Another technology is to burn the oil in a combustion turbine and use the hot exhaust to make steam to drive a steam turbine. This technology is called "combined cycle" and is more efficient because it uses the heat energy from the same fuel source twice.

Burning oil at power plants produces nitrogen oxides, sulfur dioxide, carbon dioxide, methane, and mercury compounds. The amount of sulfur dioxide and mercury compounds can vary greatly depending on the sulfur and mercury content of the oil that is burned.

The average emissions rates in the United States from oil-fired generation are 1,672 lbs/MWh of carbon dioxide, 12 lbs/MWh of sulfur dioxide, and 4 lbs/MWh of nitrogen oxides.

In addition, oil wells and oil collection equipment are a source of emissions of methane, which is a potent greenhouse gas. The large engines that are used in the oil drilling, production, and transportation processes burn natural gas or diesel that also produce emissions.

3.5 Electricity Generation – Natural Gas[12]

Natural gas is a fossil fuel formed when layers of buried plants and animals are exposed to intense heat and pressure over thousands of years. The energy that the plants and animals originally obtained from the sun is stored in the form of carbon in natural gas. Natural gas is combusted to generate electricity, enabling this stored energy to be transformed into usable power. Natural gas is another nonrenewable resource that cannot be replenished.

The natural gas power production process begins with the extraction of natural gas, continues with its treatment and transport to the power plants, and ends with its combustion in boilers and turbines to generate electricity.

Initially, wells are drilled into the ground to remove the natural gas. After the natural gas is extracted, it is treated at gas plants to remove impurities such as hydrogen sulfide, helium, carbon dioxide, hydrocarbons, and moisture. Pipelines then transport the natural gas from the gas plants to power plants.

Power plants use several methods to convert gas to electricity. One method is to burn the gas in a boiler to produce steam, which is then used by a steam turbine to generate electricity. A more common approach is to burn the gas in a combustion turbine to generate electricity. Another technology that is growing in popularity is to burn the natural gas in a combustion turbine and use the hot combustion turbine exhaust to make steam to drive a steam turbine. This technology is called "combined cycle" and achieves a higher efficiency by using the heat energy generated by the same fuel source twice.

Although power plants are regulated by federal and state laws to protect human health and the environment, there is a wide variation of environmental impacts associated with power generation technologies. EPA has summarized the specific air, water, and solid waste releases associated with natural gas-fired generation.

At the power plant, the burning of natural gas produces nitrogen oxides and carbon dioxide, but in lower quantities than burning coal or oil. Methane, a primary component of natural gas and a greenhouse gas, can also be emitted into the air when natural gas is not burned completely. Similarly, methane can be emitted as the result of leaks and losses during transportation. Emissions of sulfur dioxide and mercury compounds from burning natural gas are negligible.

The average emissions rates in the United States from natural gas-fired electricity generation are 1,135 lbs/MWh of carbon dioxide, 0.1 lbs/MWh of sulfur dioxide, and 1.7 lbs/MWh of nitrogen oxides. Compared to the average air emissions from coal-fired generation, natural gas produces half as much carbon dioxide, less than a third as much nitrogen oxides, and 99 percent fewer sulfur oxides.

3.6 Electricity Generation – Comparison of Air Emissions

The data provided on the EPA Clean Energy web site for air emissions from WTE plants and fossil fueled power plants is summarized in Table 3.

As indicated, on the basis of "pounds of pollutant per megawatt-hour of electricity generated," WTE power plants emit significantly less carbon dioxide than any of the fossil fuel power plants. They emit significantly less sulfur dioxide than coal-fired or oil-fired power plants but more than power plants using natural gas.

TABLE 3

Waste-to-Energy and Fossil Fuel Power Plants — Comparison of Air Emissions

Fuel	Carbon Dioxide	Sulfur Dioxide	Nitrogen Oxides
	Pounds per Megawatt—Hour		
MSW	837	0.8	5.4
Coal	2,249	13	6
Oil	1,672	12	4
Natural Gas	1,135	0.1	1.7

Finally, they are comparable to coal- and oil-fired power plants with respect to nitrogen oxide emissions but somewhat higher than natural gas-fired power plants. Based on this data, it is clear why EPA has concluded that WTE power plants produce electricity "with less environmental impact than almost any other source of electricity."

4.0 LITERATURE REVIEW

4.1 Introduction

The SWANA ARF project included a review of recently published articles and presentations on the air emissions from WTE plants and fossil fuel power plants, as summarized below.

4.2 U.S. EPA Clean Energy Publications[13]

As described above, EPA maintains a web site called "Clean Energy," which compares the environmental impacts of generating electricity through combustion using conventional fuels (i.e., coal, oil, natural gas, etc.) as well as MSW.

The environmental impacts for which data and information are provided include:

- Air emissions
- Water Resource Use
- Water Discharges
- Solid Waste Generation
- Land Resource Use

4.3 Power Scorecard[14]

"*Power* ScorecardTM" is a rating mechanism that enables the user to assess the environmental impacts of different types of electricity generation. Sponsored by a number of environmental organizations,[15] *Power* Scorecard allows a user to input his or her location and provides a ranking of the environmental performance of the utilities that serve the user's location.

The *Power* Scorecard database currently includes utilities in the following states: California, Pennsylvania, New Jersey, and Texas. Utilities in these states have been ranked (from "Excellent" to "Unacceptable") based on the number and degree of their environmental impacts regarding the parameters listed in Table 4.

TABLE 4
Power Scorecard Ranking Mechanism — Environmental Impact Areas

Area	Parameter
Air Impacts	Climate Change Acid Rain Ozone (Smog) and Fine Particulates Air Toxics (Mercury)
Water Impacts	Consumption of Water Resources Pollution of Water Bodies
Land Impacts	On-Site Land Impacts (Permanent Plant Footprint) Off-Site Land Impacts (Solid Waste Disposal and Fuel Processing)

Similar to the EPA Clean Energy web site, the *Power* Scorecard web site provides short (two-page) summary descriptions of the environmental impacts associated with electricity production using the following technologies:

- Biomass
- Coal
- Geothermal
- Hydro
- Landfill Gas
- Municipal Solid Waste
- Natural Gas
- Nuclear
- Oil
- Solar
- Wind

However, no environmental emissions data are provided to enable the user to perform a quantitative comparison of these technologies.

The *Power* Scorecard does not consider MSW to be a renewable energy source because the waste stream includes materials from fossil resources.

4.4 An Overview of the Global Waste-to-Energy Industry (Themelis, 2003)[16]

As the title indicates, this 2003 paper presents an overview and status report on the global WTE industry. With respect to air emissions from WTE plants, the author reported the following recent developments:

- Emissions of dioxins from large WTE plants in the United States decreased from 4,260 grams toxic equivalent (TEQ) in 1990 to 12 grams TEQ in 2000. During this 10-year period, WTE facilities were transformed from being a major to a minor source of dioxins. According to the author, WTE facilities are now characterized as being an "insignificant" source of dioxins.

- WTE emissions of mercury decreased by a factor of 60 between 1987 and 2000 due to mercury reductions in the waste stream and the use of activated carbon injection and fabric bag filters in WTE air pollution control systems. In 2000, WTE emissions represented a small fraction of the mercury in comparison with those from coal-fired power plants.

4.5 Review of Environmental and Health Impacts of Waste Management (Enviros Consulting Ltd. 2004)[17]

This report is described by the British Minister of State, Environment and Agriculture as "a very comprehensive report that brings together, for the first time, a wealth of evidence, which allows us to consider the health and environmental impacts of waste management on the basis of all available information." The report was peer-reviewed by the Royal Society – an independent scientific academy of the United Kingdom (UK) dedicated to promoting excellence in science.

Among the findings presented in the report are the following:

- MSW accounts for about 1 percent of all dioxin emissions in the UK. Domestic sources such as burning coal for heating and cooking represent the largest source of dioxins in the UK.
- MSW management in Great Britain accounts for less than 1 percent of the total nitrogen dioxide emissions. The major sources of NO_2 emissions in Great Britain are electricity generation (24 percent) and road traffic (42 percent).
- MSW management in Great Britain accounts for about 10 percent of cadmium emissions with almost all of the MSW cadmium emissions being emitted from landfills.
- Mercury emissions from WTE plants were found to contribute 20 percent of the overall background mercury concentrations at locations surrounding these facilities.
- No link could be established between health effects and the current generation of WTE plants. In reaching this conclusion, the authors considered cancers, respiratory diseases, and birth defects but found no evidence for a link between the incidence of disease and MSW incineration in state-of-the art WTE facilities.
- The most important environmental impact of MSW management is the effect on global warming due to methane and carbon dioxide emissions from MSW landfills.

4.6 A Decision Support Tool for the Life Cycle Management of MSW (Weitz, 2002)[18]

Over the last ten years, Research Triangle Institute, with support from the EPA's Office of Research and Development, has spearheaded the development of a "Municipal Solid Waste Decision Support Tool (DST)."[19]

The DST is a computer-based tool developed to analyze cost and life-cycle environmental aspects of MSW management. The DST combines sound science and state-of-the-art computer technologies to provide decision-makers with quantitative data and information regarding local solid waste management alternatives. The DST, which has been used by approximately 20 state and local governments, is currently being upgraded to be accessible through a web-based platform.

The DST includes an extensive database of air emission and waterborne pollutant emission factors for MSW management system options, including WTE. The tool can be used by local planners and state policy-makers to develop quantitative estimates of air and water emissions from a specific local solid waste management alternative.

4.7 MSW Management and its Impact on Resource Conservation and GHG Emissions (Ecobalance/R.W. Beck, 1999)

This report was commissioned by the Minnesota Office of Environmental Assistance to quantify the resource conservation benefits and greenhouse gas (GHG) emission impacts of various MSW management options.

The report presents the results of a "Life-Cycle Assessment" (LCA)[20] that uses Minnesota-specific data to analyze a variety of solid waste management alternatives, including WTE materials recycling (by individual material recycled), landfilling, composting (yard waste and MSW), and source reduction. The report presents quantitative information on the natural resource impacts, air emissions, water effluents, and waste generated by each option.

5.0 Conclusions

Based on a review of recent literature as well as data from ongoing projects, the following conclusions are offered with respect to the comparison of air emissions from WTE facilities compared to fossil-fuel power plants.

- Air emissions from WTE facilities have been dramatically reduced over the last ten years, due to the requirements for "Maximum Achievable Control Technology" contained in a 1995 EPA rule issued pursuant to the Clean Air Act.

- With respect to criteria air pollutants, WTE facilities emit significantly less carbon dioxide than any of the fossilfuel power plants. They emit significantly less sulfur dioxide than coal-fired or oil-fired power plants but more than power plants using natural gas. Finally, they are comparable to coal- and oil-fired power plants with respect to nitrogen oxide emissions, but somewhat higher than natural gas-fired power plants. Based on this data, the EPA has concluded that WTE power plants produce electricity "with less environmental impact than almost any other source of electricity."

- When compared to the total amount of mercury emitted from coal-fired power plants, WTE facilities represent a minor source of anthropogenic mercury emissions to the environment.

- Dioxin emissions from WTE facilities have been reduced by over 99 percent since 1990. WTE facilities are now considered minor sources of dioxins.

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1 If the jurisdiction or organization was already an ARF subscriber and had made a penny per ton funding commitment to another group, the funding rate for the WTE group was reduced to $0.005 per ton.

2 Integrated Waste Services Association. "Waste-To-Energy: Clean, Renewable Reliable Power." (http://www.wte.org/waste.html).

3 Letter from Marianne Lamont Horinko, Assistant Administrator, U.S. EPA Office of Solid Waste and Emergency Response to Maria Zannes, President, Integrated Waste Services Association, February 14, 2003.

4 U.S. Department of Energy. *Energy Kid's Page – Waste-To-Energy*. (http://www.eia.doe.gov/kids/energyfacts/saving/recycling/solidwaste/wastetoenergy.html) Accessed 4/29/05.

5 Horinko Letter, February 14, 2004.

6 Integrated Waste Services Association. *Waste-To-Energy: Clean, Renewable Reliable Power*.

7 U.S. Environmental Protection Agency. Clean Energy Web site. "Electricity from Municipal Solid Waste". (http://www.epa.gov/cleanenergy/muni.htm). Accessed 4-29-05.

8 Biomass-based emissions of greenhouse gases (GHG) are typically not included in GHG emissions reporting due to the fact that the biomass is considered to be part of the Earth's natural carbon cycle and, therefore, does not contribute to a net increase in emissions.

9 A copy of the correspondence to this effect is included in Appendix A.

10 U.S. Environmental Protection Agency. Clean Energy Web site. "Electricity from Coal". (http://www.epa.gov/cleanenergy/muni.htm). Accessed 4-29-05.

11 U.S. Environmental Protection Agency. Clean Energy Web site. "Electricity from Oil". (http://www.epa.gov/cleanenergy/muni.htm). Accessed 4-29-05.

12 U.S. Environmental Protection Agency. Clean Energy Web site. "Electricity from Natural Gas". (http://www.epa.gov/cleanenergy/muni.htm). Accessed 4-29-05.

[13] U.S. Environmental Protection Agency. Clean Energy. (http://www.epa.gov/cleanenergy). Accessed 4-28-05.

[14] *Power* Scorecard™ (http://www.powerscorecard.org). Accessed 6-24-05.

[15] Sponsoring organizations include: Environmental Defense Fund, The Izaak Walton League, Natural Resources Defense Council, The NW Energy Coalition, and the Pace University Energy Project.

[16] Themelis, Nickolas J., "An Overview of the Global Waste-To-Energy Industry", *Waste Management World*, July-August, 2003, p. 40-47.

[17] Enviros Consulting Ltd. *Review of Environmental and Health Effects of Waste Management – Extended Summary*. London: Department for Environment, Food, and Rural Affairs, May 2004.

[18] Weitz, Keith. "A Decision Support Tool for the Life Cycle Management of Municipal Solid Waste." (InLCA-LCM 2002). Research Triangle Park, North Carolina: Research Triangle Institute, 2002.

[19] The project web site for the DST is www.rti.org/units/ese/p2/lca.cfm.

[20] LCA is recognized as a tool which can be used to comprehensively assess the overall environmental performance of a system.