Waste-To-Energy and Greenhouse Gas Emissions

By Jeremy K. O'Brien

The SWANA Applied Research Foundation's (ARF's) Waste-to-Energy (WTE) Group identified the issue of the perception and inclusion of waste-to-energy as a "green" solid waste management option as one of high importance to the group.

As a result, a report was prepared in 2009 that quantifies the environmental benefits associated with the processing of the waste remaining after recyclable materials have been removed by the consumer or business (non-recycled waste) through waste-to-energy plants for electricity generation rather than disposing of this non-recycled waste in landfills. This report is in final draft form and will be published by SWANA in December 2009.

This article focuses on one of the environmental impacts of WTE that is addressed in the report: namely, greenhouse gas emissions.

Five organizations subscribed to the SWANA ARF's WTE group in FY2009, each of which made a funding commitment to the conduct of collective applied research in the WTE area (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

Table 1 SWANA ARF FY2009 Waste-to-Energy Group

Organization	Contact	Title
HDR Engineering	John Williams	Senior Vice President
I-95 Landfill Owners Group	Carl Newby	Arlington County WTE Contract Manager
	John Snarr	Metro Washington COG Project Manager
Lancaster County Solid Waste Authority	Gary Forster, P.E.	Senior Manager, RRF Contract Administration
Waste Management/ Wheelabrator Technologies, Inc.	Mr. Frank Ferraro	Vice President of Public Affairs
Three Rivers Solid Waste Authority	Colin Covington	General Manager

Waste-To-Energy and Greenhouse Gas Emissions (cont.)

ton). A listing of the five WTE Group subscribers and their contacts are provided in Table 1.

Recent Analyses of WTE's Greenhouse Gas Impacts

The analysis of greenhouse gas impacts of waste-to-energy facilities conducted by the ARF is based, as well as builds on, data and information presented in three recent publications.

2009 EPA ORD Article–In March 2009, the EPA's Office of Research and Development (ORD) published a peer-reviewed journal article that compared the theoretical air emissions associated with the landfill disposal of 166.7 million tons of MSW to the air emissions associated with the processing of this waste in WTE facilities (Kaplan, P. O., DeCarolis, J., and Thorneloe, S. "Is It Better To Burn or Burn Waste For Clean Electricity Generation," *Environ. Sci. Technol.*, 2009, 43 (6)). To conduct the analysis, the EPA utilized its "Municipal Solid Waste Decision Support Tool," or MSW-DST, which is a computer model developed for local-government solid waste managers to determine the life cycle evaluation of integrated solid waste management options.

2006 EPA Report–In September 2006, the EPA published its third edition of the report, "Solid Waste Management and Greenhouse Gases–A Life Cycle Assessment of Emissions and Sinks". This report presents the life-cycle GHG emissions associated with the management of 23 types of waste products and materials that represent more than 65% of the wastestream on a weight basis. The model covers five waste management options: source reduction, recycling, combustion, composting, and landfilling. The GHG emission factors developed for each option include the upstream energy and non-energy emissions, collection and transportation of waste and recyclables to disposal and recycling facilities, carbon sequestration, and utility offsets that result from landfill gas collection and combustion.

2003 Wheelabrator Report on the Saugus WTE Facility–In October 2003, Wheelabrator Technologies Inc. issued a report on the greenhouse gas reductions that were attributable to its waste-to-energy facility in Saugus, MA. This facility processes 440,000 tons per year of municipal solid waste, generates 33 MW of electrical power, reduces the volume of waste landfilled by 90%, and recovers ferrous metals from ash. The report documents the GHG emissions from the facility as well as the avoided GHG emissions due to the displacement of oil and coal combustion by the local utility and the avoidance of the rail hauling of this waste to a remote landfill in Lee County, South Carolina (870 one-way miles) for disposal. To conduct its analysis, Wheelabrator utilized the MSW-DST described above.

Key Input Parameters

The key inputs regarding the data and assumptions utilized in each of these analyses are presented in Table 2 and discussed below:

Determination of Non-Biogenic GHG Emissions from Waste Combustion–A key input parameter in the analysis of WTE's GHG impacts is the percentage of GHG emissions that are attributable to the combustion of non-biogenic organic wastes (The GHG emissions from biogenic wastes are assumed to be offset during the growing stage of the biogenic source).

As indicated in Table 2, the EPA ORD determined the non-biogenic GHG emission based on an analysis of the heating value of each waste component while the EPA OSW based its estimate on the respective weight percentages of non-biogenic materials. The waste-to-energy industry has subsequently conducted extensive sampling and analysis of carbon-dioxide emissions from WTE facilities and determined that 60%–65% of the emissions are biogenic.

Table 2. Assumptions Regarding Key Input Parameters Utilized in WTE GHG Analyses

Input Parameter	2009 EPA ORD Analysis	2006 EPA OSW Analysis	2003 Wheelabrator Saugus WTE Facility Analysis
Determination of Non-Biogenic GHG Emissions from Waste Combustion	Based on heating values of non-biogenic waste components	Based on weights of non-biogenic waste components	DST Default
Utility Fuel Displacement	Coal, Oil, and Natural Gas	Coal, Oil, and Natural Gas	Actual Fuel Mix (Coal and Oil)
Electricity Generation – WTE Facilities	590 kWh/Ton	550 kWh/Ton	555 kWh/Ton
GHG Credits for Steel Recycling	Yes	Yes	Yes
Long-Haul Transport of Waste For Disposal	No	No (Assumed)	Yes
Credit for Carbon Storage in Landfills	No	Yes	No

Waste-To-Energy and Greenhouse Gas Emissions (cont.)

Utility Fuel Displacement–The generation of electricity by WTE facilities avoids the need to combust fossil fuels for electricity generation. In this regard, both the EPA ORD and the EPA OSW assumed that the national fuel mix of fossil fuels should be used to estimate the GHG reductions that would result from this displacement. For the Wheelabrator analysis, the actual fuel mix of the local utility was assumed.

Electricity Generation Rates–The electricity generation rates assumed in all of the analysis were in the range of 550–590 kWh per ton.

GHG Credits For Steel Recycling–Both of the EPA analyses assumed that ferrous metals were recovered from WTE ash for recycling and credited the WTE facility with the GHG reductions associated with recycling. As steel recycling is conducted at the Saugus facility, GHG reductions were credited for this activity.

Long-Haul Transport of Waste for Landfill Disposal–The EPA ORD analysis assumed that the landfill would be the same distance at the WTE facility from the collection service area, indicating that the waste would not have to be long-hauled for disposal. While it is not specifically stated, it is likely that the EPA OSW analysis is based on the same assumption. Alternatively, the Wheelabrator analysis assumed that MSW–if not processed in the Saugus WTE facility–would be railed hauled to Lee County, South Carolina for disposal–a distance of 870 miles since there is insufficient disposal capacity in-state.

Credit for Carbon Storage in Landfills–The most significant assumption affecting the outcome of the three analyses presented in this article regards the credit given for the long-term storage of non-decomposable biogenic carbon in landfills. In this regard, the EPA ORD and Wheelabrator do not include this credit, while the OSW analysis does. As is indicated below, the impact of this credit is very significant in its impact on the GHG analysis of solid waste

Waste-To-Energy and Greenhouse Gas Emissions (cont.)

Table 3. Waste-To-Energy Emissions

Pollutant	Chemical Abbr.	Gross Emissions		Avoided Emissions: Fossil Fuel-Generated		Avoided Emissions: Steel Recycling		Avoided Emissions: Landfill Disposal		Net Emissions	
		Lbs/Ton[1]	MTCE/Ton	Lbs/Ton[1]	MTCE/Ton	Lbs/Ton[1]	MTCE/Ton	Lbs/Ton	MTCE/Ton	Lbs/Ton[1]	MTCE/Ton
MSW-DST											
Greenhouse Gases											
Carbon Dioxide - Biogenic	CO_2-Biogenic	1,183						(350)		833	
Carbon Dioxide - Fossil	CO_2-Fossil	728		(1,051)		(91)		135		(280)	
Carbon Dioxide - Total	CO_2-Total	1,910									
Carbon Dioxide Equivalents	CO_2-E	728	0.09	(1,108)	(0.14)	(91)	(0.01)	(246)	(0.03)	(717)	(0.09)
WARM											
Landfill With LFG Recovery											
–Without Carbon Storage	CO_2-E	889	0.11	(1,131)	(0.14)	(81)	(0.01)	(566)	(0.07)	(889)	(0.11)
–With Carbon Storage[3]	CO_2-E	889	0.11	(1,131)	(0.14)	(81)	(0.01)	162	0.02	(161)	(0.02)
Year 2003 National Average Landfill Emissions											
–Without Carbon Storage	CO_2-E	889	0.11	(1,131)	(0.14)	(81)	(0.01)	(2,182)	(0.27)	(2,505)	(0.31)
–With Carbon Storage[3]	CO_2-E	889	0.11	(1,131)	(0.14)	(81)	(0.01)	(1,455)	(0.18)	(1,778)	(0.22)
Wheelabrator Saugus Waste-To-Energy Facility[4]											
Carbon Dioxide Equivalents	CO_2-E	1,286	0.16	(1,671)	(0.21)	(110)	(0.01)	(845)	(0.10)	(1,341)	(0.17)

1. Based on average stack gas limits. Units reported in pounds of emissions per short ton of MSW.
2. Based on 590 kWh/Ton MSW combusted.
3. Carbon storage in WARM model calculations based on revised carbon storage estimate of 0.11 mass/dry mass (average of 0.07-0.15) based on 10/27/08 memo from Dr. Morton Barlaz of NC State University. Assuming 25% moisture content, this equates to 0.09 MTCE ton/wet ton.
4. Wheelabrator Technologies, Inc. Greenhouse Gas Reductions from the Wheelabrator Saugus Waste-To-Energy Facility. Draft Paper - 10-14-2003.

management options. A noteworthy point regarding the carbon storage credit estimates included in the 2006 EPA OSW report is that they may be grossly overestimated. A memo issued by Dr. Morton Barlaz in October 2007 provided guidance for correcting these estimates. The carbon storage analysis presented in this article reflects the corrections recommended by Dr. Barlaz.

Results And Discussion

The findings of each analysis regarding the GHG impact of WTE facilities are summarized in Table 3 and discussed below:

Gross GHG Emissions–The gross GHG emissions refer to the GHGs that are generated at the WTE facility by the combustion of non-biogenic wastes and the production of nitrous oxides during the combustion process. As indicated in Table 3, the gross WTE GHG emission estimates are fairly close: 0.09–0.11 metric tons of carbon equivalents per ton of MSW (MTCE/ton), with the differences in the estimates likely due to the different methodologies used to determine the biogenic fraction of the waste. The gross GHG emission factor used in the Wheelabrator analysis is significantly higher: 0.16 MTCE/ton.

Avoided Emissions: Fossil Fuel Generated Electricity–The gross GHG emissions from a WTE facility are offset by three benefits associated with WTE–namely, the avoidance of fossil fuel combustion for electricity generation, the recycling of ferrous metals from WTE ash, and the avoidance of landfill disposal of the combusted waste.

Waste-To-Energy and Greenhouse Gas Emissions (cont.)

With respect to avoided utility emissions of GHGs due to electricity production from the WTE facility, both of the EPA analyses provide identical credits–namely, 0.14 MTCE/ton. As discussed above, this factor is based on the avoidance of the combustion of a national fossil fuel mix for electricity production consisting of coal (69%), oil (2%) and natural gas (28%). The Wheelabrator analysis assigns a higher credit–0.21 MTCE/ton, due to the fact that the Saugus plant electricity production is responsible for reduced coal and oil combustion by the local electric utility.

Avoided Emissions: Steel Recycling–With respect to the credit given for the recycling of ferrous metals from WTE ash, all of the analysis assumed the same credit–namely, 0.01 MTCE/ton.

Avoided Emissions: Landfill Disposal–Each of the analyses developed substantially different estimates regarding the GHG impacts of avoided landfill disposal. The value assumed in the EPA-ORD analysis was 0.03 MTCE/ton. This value is based on a scenario presented in the EPA article in which waste was landfilled for two years without landfill gas recovery, after which an LFG electrical generation facility was used to combust the collected LFG for 60 years. The crediting of avoided GHG utility emissions is included in this value.

Additional benefits include waste stabilization, metals recovery, avoidance of long-haul transport, and the long-term local control of pricing.

The results of the EPA-OSW analysis are presented for two scenarios–namely with and without the credits applied for carbon storage in the landfill. As shown, for the scenarios without carbon storage credits, the carbon credit estimates for avoided landfill GHGs range from 0.07 MTCE/ton for a landfill with an active LFG recovery system to 0.27 MTCE/ton, with the latter estimate based on national average landfill emissions for 2003. If carbon storage credits of 0.09 MTCE/ton are included, these estimated credits are reduced accordingly.

For the Wheelabrator analysis, alternative disposal was assumed at a South Carolina landfill that collected and flared the landfill gas yielding an estimated GHG carbon credit of 0.10 MTCE/ton.

Net GHG Impacts–As indicated in Table 3, all of the scenarios analysis result in GHG reductions due to the implementation of a WTE facility. These reductions vary from a low of 0.02 MTCE/ton for a landfill with an LFG recovery system where carbon storage credits are applied to a high of 0.31 MTCE/ton for a landfill where no credit for carbon storage is given and where average LFG emissions for the year 2003 are assumed. The latter value equates to 2,505 pounds of carbon dioxide equivalents (CO_2-E) per ton or 1.25 tons CO_2-E per ton, which is close to the rule of thumb of 1 ton CO_2-E per ton that has historically been used by the WTE industry.

The analyses presented in this article indicate a number of important points that should be considered with respect to the estimation of the GHG impacts of WTE facilities. The first is that the impacts will vary significantly depending on the types of fossil fuels that are displaced and the type and location of the landfill that would be used for disposal if the WTE facility is shut down or is not implemented.

The second point is the significant impact that the assumption regarding the counting of landfill carbon storage credits has on the outcome of the analysis. In this regard, the EPA OSW did not include landfill carbon storage credits, stating that "there is still a debate on how to account for any biogenic "sequestered" carbon." In addition, the Intergovernmental Panel on Climate Change (IPCC) published a guidance document for estimated GHG impacts of solid waste management in which it recommends that the long term storage of carbon in landfills should be reported as an "information item."

Conclusions

All of the analyses presented in this article indicate that the implementation of WTE reduces GHG emissions when compared with the alternative of disposing of non-recycling waste in landfills and generating electricity through the combustion of fossil fuels.

Not reflected in the evaluation of GHG impacts is the role that WTE can play in renewable energy. The Wheelabrator Saugus WTE facility presented in this article generates 38 MW of baseline (24 hours per day, seven days per week) electricity. Assuming that over half of the MSW combusted in the Saugus plant is biogenic, this means that over 19 MW of base load electric power from renewable energy sources are generated at the facility.

Additional benefits of WTE include waste stabilization, metals recovery from WTE ash, avoidance of long haul transport of waste, and the long-term local control over disposal capacity and pricing. These additional benefits should be considered by local solid waste policy makers as they evaluate the WTE alternative as a means to reduce GHG emissions and generate local renewable power.

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