10.1 Introduction

The Waste–To-Energy (WTE) industry emerged in the United States in the 1970s due to several factors. The Arab Oil Embargo resulted in oil and energy prices increasing substantially. There was also increasing recognition of the potential risks of groundwater contamination at existing unlined landfills. This led to new regulations requiring the construction of lined sanitary landfills, which increased solid waste landfilling costs. WTE facilities were considered viable alternatives for waste disposal and energy production. In 1980, less than 60 WTE facilities were operating. By 1993, the number of operating facilities reached a peak of approximately 150. From 1993 to present, the number of operating WTE facilities has declined to approximately 89 due to several factors, including:

- An abundance of landfill space with lower tipping fees than WTE facilities,
- The loss of ordinance-based flow control through the Carbone versus Clarkstown United States Supreme Court case decision,
- The implementation of more stringent federal air quality standards, and
- The issuance of federal guidelines for municipal combustion residue monitoring, sampling, and testing.

According to the United States Environmental Protection Agency (USEPA), WTE facilities process approximately 12 percent of all municipal solid waste generated in the United States.

Presented below is a discussion of the materials flow, technology, and planning assumptions we have made in evaluating the potential costs associated with a WTE facility to serve the County. Although many hybrids exist, three basic types of WTE facilities were developed to combust and recover energy from solid wastes. From an air emissions regulatory standpoint, the USEPA refers to these sources as "municipal waste combustors." The basic types include: (1) mass burn waterwall, (2) mass burn modular, and (3) refuse-derived fuel-fired waterwall (RDF). Mass burn waterwall and modular facilities typically do not preprocess waste. Waste is introduced directly from a stockpile into the feed chute of the combustion chamber. RDF facilities shred and process waste into a homogeneous mixture for metering into the combustion units. Due to economies of scale, RDF processing and dedicated boiler facilities typically have larger capacities. For example, H-POWER is a 2,000-ton-per-day RDF processing and combustion facility located on O‘ahu. Due to the projected processing capacity of the WTE facility to serve Kaua‘i, the mass burn waterwall technology was

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selected for this analysis. Mass burn modular technology was not selected because it does not offer long-term reliability (more than 20 years) and does not have the history of producing higher pressure steam for efficient electric generation.

It is important to note that the last "greenfield"[1] WTE facility utilizing mass burn technology was constructed in the United States from 1993 to 1995 in Montgomery County, Maryland. Since that date, many WTE vendors have exited the business (Westinghouse, Foster Wheeler, and General Electric) and with Covanta's recent acquisition of American Ref-Fuel, there are only five major companies in the United States with experience in the construction and operation of WTE facilities: Barlow Projects, Covanta Energy, Energy Answers, Montenay Power, and Wheelabrator Technologies. Barlow Projects has entered the market retrofitting several smaller WTE facilities. In the early 2000s, a number of older WTE facilities began to implement retrofits to continue operating beyond 20 years. In 2006, a complete retrofit is expected for an 800-ton-per-day (tpd) WTE facility in the City of Harrisburg, Pennsylvania. Lee County, Florida is proceeding with adding a 600-tpd unit to expand a WTE facility.

Higher energy prices have resulted in a renewed interest in new WTE projects as it is a processing option that is less impacted, in a negative manner, by rising oil prices. In fact, dependent upon: (1) the terms of a power sales agreement between the County and the electric utility purchasing the electricity produced by a WTE facility; and (2) the type of fuel used by the electric utility, increasing fuel costs may result in higher energy revenues for a WTE facility. The potential impact is often even less for those WTE facilities that are selling energy in the form of steam rather than electricity, when the price of steam is pegged to the price of an alternative fuel.

10.2 Material Flow

WTE facilities generally have two methods of waste receiving and storage as follows:

1. Tipping floor with pit for waste storage with overhead cranes to charge the furnace-boilers; and,
2. Tipping floor for waste unloading and storage with elevated conveyors to charge the furnace-boilers.

The planning period for a WTE facility is generally 20 years minimum. However, several mass burn WTE facilities in the United States have operated beyond 20 years. For purposes of this analysis, this option relied on the solid waste quantity projections provided in Table 2-2. The waste receipts in Table 2-2 reflect all of the residential and commercial waste that is projected to be annually disposed. Because the County collects less than 50 percent waste stream and "flow control" by ordinance may not be an option, the County should contract with private waste haulers to guarantee waste receipts.

The first year of operation for a new WTE facility on Kaua'i was set at 2011 to account for the projected timeframe needed for siting and project development. The

[1] Greenfield refers to land not previously developed for commercial or industrial use.

2020 disposal quantity projections were extrapolated 10 years to 2030 as shown in Table 10-1. The table uses the following assumptions:

- For the first 10 years (2011 – 2020) of operation, the two-unit WTE facility will have sufficient processing capacity;
- For the second 10 years (2021 – 2030) of operation, a third identical unit could be added to provide sufficient processing capacity;
- Initially, the size of the electric generating system will meet the capacity of the expanded WTE facility;
- The WTE facility will have a 90 percent availability factor due to scheduled and unscheduled equipment outages;
- The WTE facility will produce 15 (minimum) to 20 (maximum) percent residue by weight from waste processed;
- Minimize bypassing "unprocessable" waste from the WTE facility for disposal in the landfill;
- The WTE facility will receive all the commercial and residential waste that requires disposal on the Island; and,
- All waste will be initially delivered to a pre-processing/mixed waste processing facility that will separate and dispose approximately 10 percent of "unprocessable" waste, which will be landfilled. An additional 10 percent of the waste entering the pre-processing facility will be separated for recycling using automated and manual sorting methods. For example, aluminum cans will be automatically retrieved using an Eddy current separator, and tin cans will be recovered using magnets. Conversely, large corrugated cardboard and plastic bottles will be manually recovered through a conveyor system. R. W. Beck does not recommend trying to recover glass bottles, as much of the glass will be broken, which substantially deceases its market value and may pose an injury to workers.

The projected waste receipts, recycled, "unprocessable," and "processable" quantities, and average processing capacities required by year are provided in Table 10-1.

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Table 10-1
Projected Quantities for Mass Burn Waste-to-Energy Facility with Preprocessing/Mixed Waste Recovery Facility

Year	Disposal Rate (pcd) (1)	Waste Receipts Quantity (tpy) (2)	Unprocessable Quantity (tpy) (3)	Waste Delivered to Preprocessing/ Mixed Waste Recovery Facility (tpy) (4)	Front-end Recovered Materials (tpy) (5)	Processable Quantity (tpy) (6)	Average Processing Capacity (tpd) (7)	Processed Quantity (tpy) (8)	Minimum Combustion Residue Quantity (tpy) (9)	Maximum Combustion Residue Quantity (tpy) (10)
2011	6.65	115,430	11,543	103,887	10,389	93,498	285	93,498	14,025	18,700
2012	6.84	120,670	12,067	108,603	10,860	97,743	298	97,743	14,661	19,549
2013	7.04	126,260	12,626	113,634	11,363	102,271	311	102,271	15,341	20,454
2014	7.24	132,090	13,209	118,881	11,888	106,993	326	106,993	16,049	21,399
2015	7.45	138,330	13,833	124,497	12,450	112,047	341	112,047	16,807	22,409
2016	7.68	144,940	14,494	130,446	13,045	117,401	357	117,401	17,610	23,480
2017	7.92	151,860	15,186	136,674	13,667	123,007	374	123,007	18,451	24,601
2018	8.17	159,240	15,924	143,316	14,332	128,984	393	128,984	19,348	25,797
2019	8.43	167,020	16,702	150,318	15,032	135,286	412	135,286	20,293	27,057
2020	8.69	175,210	17,521	157,689	15,769	141,920	432	141,920	21,288	28,384
2021	8.73	175,017	17,502	157,515	15,751	141,763	432	141,763	21,265	28,353
2022	8.92	180,699	18,070	162,629	16,263	146,366	446	146,366	21,955	29,273
2023	9.12	186,381	18,638	167,743	16,774	150,969	460	150,969	22,645	30,194
2024	9.32	192,063	19,206	172,857	17,286	155,571	474	155,571	23,336	31,114
2025	9.52	197,745	19,775	177,971	17,797	160,174	488	160,174	24,026	32,035
2026	9.72	203,427	20,343	183,085	18,308	164,776	502	164,776	24,716	32,955
2027	9.92	209,110	20,911	188,199	18,820	169,379	516	169,379	25,407	33,876
2028	10.12	214,792	21,479	193,313	19,331	173,981	530	173,981	26,097	34,796
2029	10.32	220,474	22,047	198,427	19,843	178,584	544	178,584	26,788	35,717
2030	10.52	226,156	22,616	203,541	20,354	183,187	558	183,187	27,478	36,637

(1) Disposal Rate in pounds per capita per day equals Disposal Quantity times 2000 lbs/ton divided by 365 days/year divided by De Facto Population.
(2) Disposal Quantity in tons per year equals Generation Quantity in Table 2-2 minus projected Diversion Quantities.
(3) Unprocessable Quantity in tons per year is 10% by weight of the Disposal Quantity.
(4) Waste Delivered to Preprocessing/Mixed Waste Recovery Facility is Disposal Quantity less Unprocessable Quantity in tons per year.
(5) Front-end Recovered Materials prior to combustion in tons per year are 10% times Waste Delivered to the Preprocessing/Mixed Waste Recovery Facility.
(6) Processable Quantity equals Disposal Quantity less Unprocessable Quantity and Front-end Recovered Materials in tons per year.
(7) Average Processing Quantity in tons per day equals Processable Quantity in tons per year divided by 365 days per year and 90% facility capacity availability.
(8) Processed Quantity is the Processable Quantity up to the rated facility processing capacity in tons per year times a 90% annual availability factor.
(9) Minimum Combustion Residue Quantity is the Processed Quantity in tons per year times 15% on a weight basis after back-end ferrous metal recovery.
(10) Maximum Combustion Residue Quantity is the Processed Quantity in tons per year times 20% on a weight basis after back-end ferrous metal recovery.

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The facility and unit sizes were selected for the option analysis as follows:

1. For the first 10 years of operation, a 450-tpd WTE facility will comprise two 225-tpd processing units. The annual facility processing capacity will be approximately 147,800 tons per year.
2. For the second 10 years of operation, a 675-tpd WTE facility could comprise three 225-tpd processing units. The annual facility processing capacity will be approximately 221,700 tons per year.

If recycling diversion increases substantially or future waste generation is less than projections, the County may delay the addition of the third processing unit at the WTE facility.

10.2.1 Technology Overview

A 450-tpd mass burn WTE facility will consist of a large building, including enclosed waste receiving and storage area, furnace-boiler room, central operations control center, water treatment area, turbine-generator hall, and residue storage area. An air-cooled condenser, two independent air emissions control systems, a continuous emissions monitoring system enclosure, and single stack with multiple flues will be located outdoors behind the large building. Initially, the facility will include two 225-tpd mass burn waterwall furnace-boiler units with available space to expand the waste receiving and storage enclosure, and potentially add a third identical processing unit. The turbine hall will include a single 14-Megawatt (MW) turbine-generator rated at the anticipated maximum facility processing capacity of 675 tons per day. To conserve valuable water resources on Kaua‘i, an air-cooled condenser was selected to cool the steam turbine exhaust. The WTE facility will be situated on a minimum 8- to 10-acre site surrounded by additional buffer area. The ideal selected site should exist near a major road for ease of access, water supply source, wastewater discharge point to treat wastewater, and electrical interconnection. The design of a new WTE facility can incorporate on-site wastewater reuse.

In addition, a pre-processing facility/mixed waste recovery facility will be located adjacent to the WTE. At the first stage, “unprocessable” (i.e., large, bulky) solid waste is separated from the “processable” waste. Solid waste components that will classified as “unprocessable” include demolition/renovation/construction debris, durables, household hazardous wastes, and special wastes. County has existing program to accept the durables, household hazardous wastes, and special wastes.

Next, recyclables will be recycled from the waste stream using a combination of manual and automated recovery systems. R. W. Beck estimates that 10 percent of the waste stream will be recovered for recycling at the preprocessing/mixed waste recovery facility. Finally, ferrous metals will be recovered from the back end residue for recycling.

10.2.2 Applicability to the Waste Stream

“Unprocessable” (i.e., large, bulky) solid waste is separated in the waste receiving area for recycling or landfill disposal. Based on the 2005 solid waste composition

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presented in Table 2-8, for purposes of this analysis, a WTE facility could not process approximately 10 percent by weight of the solid waste generated on the island. The

Based on previous experience and reviewing the compositional data, the anticipated energy content (higher heating value) of the "processable" solid waste will range from 5,000 to 5,200 Btu per pound. Food waste is the highest moisture laden component with the lowest energy value and the least desirable of the potential "processable" waste components for the WTE facility. Therefore, the County should target food waste for diversion. Because food waste is over 14 percent of the waste stream, diversion programs should be instituted before the facility is designed as they may impact processing requirements.

10.2.3 Environmental Considerations

USEPA's maximum achievable control technology (MACT) requirements mandated that WTE facilities with large units (i.e., >250 tpd) comply with new Clean Air standards on or before December 19, 2000. Small unit facilities (i.e., 35 tpd to < 250 tpd) had to meet less stringent MACT rules no later than November 6, 2005. On April 28, 2006, the USEPA issued a more stringent rule that large unit facilities must satisfy within three years. The USEPA would consider the proposed units for the Kaua'i WTE facility as small units. Commercially available technologies can satisfy the stringent requirements for air emission control.

In addition, the WTE facility would have to meet the State's air quality requirements of Chapter 11-60.1 Hawai'i Administrative Rules (HAR), Subchapter 5 – Covered Sources. Relating to the State's solid waste regulations, the WTE facility must comply with HAR Section 11-58.1-20. The WTE facility will require obtaining air quality and solid waste permits to construct and operate.

Odor control is accomplished by drawing combustion air from the tipping area, and the odor-causing compounds are destroyed in the furnace-boiler units. Industry standard combustion practices will minimize formation of organics (i.e., dioxins and furans). The air emission control system will reduce emissions of nitrogen oxides (NO_x), mercury, acid gases, organics, and particulate matter) using:

- Aqueous ammonia or urea injection for selective non-catalytic reduction SNCR, reducing NO_x emissions;
- Activated carbon injection to adsorb vaporized mercury and organics;
- Lime spray dryer to absorb acid gases, such as sulfur dioxide (SO_2) and hydrochloric acid (HCl); and,
- Fabric filter, for removal of particulate matter, including fly ash and reaction products from the spray dryer.

A continuous emissions monitoring system will record the major emissions from the WTE facility. The State Department of Health will require annual stack testing for all regulated emissions. In addition, the agency will require periodic sampling and lab analysis of the residue.

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10.3 Residuals

For purposes of this analysis, a WTE facility with a pre-processing/mixed waste recovery facility that captures "unprocessable" and recyclable waste on the front-end would process approximately 80 percent by weight of the solid waste.

Generally, the bottom ash from the furnace grate and fly ash from the air emissions control system are combined. Based on the 2005 solid waste composition presented in Table 2-8, for purposes of this analysis, the potential feedstock for a WTE facility has a 3 percent ferrous content by weight. A back-end ferrous recovery system will remove metal from the combustion residue to reduce landfill disposal cost and increase diversion. Ferrous recovery will vary between 50 to 70 percent by weight. Depending on the inert content of the feedstock, the WTE facility will produce combined residue that is 15 to 20 percent by weight of the material processed. Table 10-1 presents minimum and maximum annual quantities of processing residue by weight produced by the WTE facility.

Combustion residue from H-Power on O'ahu is disposed of in a monofill cell at the Waimanalo Gulch landfill. For this option, Kaua'i would likely need to develop a monofill cell at the Kekaha Landfill to dispose of combustion residue from the proposed WTE facility. Using combustion residue as alternative daily cover would require approval from the State Department of Health. [Some states in the mainland US allow use of combustion residue as ADC. We are not aware that Oahu has sought approval for this reuse.]

10.3.1 Planning Level Cost Estimate

The data in this document represent planning level cost estimates to determine a range of first-year tipping fees for the WTE facility. This data is not intended for project financing and is intended for comparison to other alternative technologies. If the County decides to move forward with the development of the proposed WTE facility, a more detailed analysis would need to be completed. For planning purposes, the implementation time required for the proposed facility is approximately five years.

- Pre-Processing/Mixed Waste Recovery Facility
  - 10 percent of the incoming material would be considered "unprocessable" and disposed;
  - 10 percent of the incoming material would be recycled;
  - The facility would be initially sized to process 450-tpd of waste. Long-term the facility could require expansion.
  - In 2011, the facility will process approximately 115,400 tons of material
- WTE Processing Capacity
  - Approximately-80 percent of the waste that is received for processing;
  - 90 percent annual facility availability factor;

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- At the 450-tpd rated capacity, the WTE facility will process a maximum of 147,800 tons per year with the assumed availability factor;
- In 2011, the WTE facility will process approximately 94,000 tons;

- WTE Capital Cost. The estimated capital cost includes provision for the construction of the WTE facility excluding electrical interconnection. The 450-tpd facility would consist of two furnace-boilers. The estimate assumed the following components:
  - No direct costs for land for facility site
  - Waste Receiving and Storage – three days enclosed waste storage
  - Waterwall Furnace-Boilers – grate, low NO_X units, SNCR systems, flue gas recirculation, auxiliary fuel burners, and economizers
  - Air Pollution Control Equipment – spray dryers, baghouses, carbon injection, continuous emissions monitoring system, and stack
  - Balance of Plant – operations control center, metals recovery from residue, 14-MW turbine-generator, air-cooled condenser, and water treatment system
  - Pre-processing/Mixed Waste Recovery Facility Capital "Hard" Cost - $25,000 to $30,000 per tpd of installed capacity for 450 tpd (2011 dollars) which is equivalent to $11.3 to $13.5 million.
  - WTE Capital "Hard" Cost – $170,000 to $190,000 per tpd of installed capacity for 450-tpd (2011 dollars), which is equivalent to approximately $76.5 to $85.5 million.
  - Pre-processing/Mixed Waste Recovery Facility Project Development "Soft" Cost – 15 percent of the Capital Cost includes engineering, permitting, financing, air emission offsets, spare parts, start-up, and contingency, which is equivalent to $1.7 to $2.0 million.
  - WTE Project Development "Soft" Cost – 15 percent of the Capital Cost includes engineering, permitting, financing, air emission offsets, spare parts, start-up, and contingency, which is equivalent to $11.5 to $12.8 million.
- Annual Debt Service Requirements
  - Financing costs of 2 percent of the principal amount of the bond issue
  - Interest rate on the bonds of 5 percent
  - Revenue bonds with 20 years of operation and a principal repayment period of 20 years
  - Level debt service payments for 20 years
- Operating & Maintenance (O&M) Expenses
  - The O&M expenses include provision for labor, parts and supplies, extraordinary renewals and replacements, general and administration, operator profit, electricity, fuel, and "normal" pass throughs such as

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chemicals, insurance, and utilities. This does not include property taxes, host fees, or residue disposal.

  - Pre-processing/Mixed Waste Recovery Facility O&M Expenses - $30 to $35 per ton of solid waste processed.
  - WTE Facility O&M Expenses – $60 to $70 per ton of solid waste processed at 450 tpd (2011 dollars).

- Pre-processing Waste Generation and Disposal
  - For planning purposes, R. W. Beck estimates that all of the "unprocessable" waste will require landfill disposal at $70 per ton.
- Post-Processing Combustion Residue Generation and Disposal
  - 15-20 percent (on a weight basis) of the solid waste processed will require landfill disposal as combustion residue. In 2011, the facility will generate approximately 14,000 to 18,700 tons of residue [The quantities vary each year per Table 10-1].
  - In 2011, Kaua'i County will dispose of the residue at a monofill cell in the landfill for $70 per ton if the material can not be used as daily cover.
- Electricity Production Capability and Revenues
  - Net electrical generation will range from 475-525 kWh per ton of waste processed, assuming solid waste with a higher heating value ("HHV") of 5,000-5,200 Btu per pound.
  - In 2011, the facility will deliver the excess power to Kaua'i Island Utility Cooperative (KIUC) at the energy charge of $0.131 per kWh. This value was obtained from the *Renewable Energy Technology Assessments* report issued by KIUC in 2005. In future years, KIUC will likely begin paying a capacity charge as well.
- Pre-Processing/Mixed Waste Recovery Facility Revenues
  - For this analysis, it was conservatively estimated that the County would not receive revenue from materials recovered at the pre-processing/mixed waste recovery facility.
- Post-Processing Revenues
  - R. W. Beck conservatively estimates no revenues being generated from the sale of ferrous metals.
- Schedule
  - Two years to obtain permits, site facility, select a vendor, and obtain financing
  - Three years to construct and acceptance test the facility

Table 10-2 presents the planning level cost analysis for the first-year operation of the 450-tpd WTE facility in 2011 that includes a pre-processing/mixed waste recovery facility. For comparison to other technology options, the first-year cost analysis offers

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sufficient detail. The selected technology option may warrant a more in-depth life cycle analysis. The anticipated tipping fees ranges from approximately $111 to $131 per ton of solid waste received. To expand the facility to 675-tpd by 2020 or later, Kaua‘i County would need to issue additional bonds for adding the third 225-tpd processing unit.

Table 10-2
450-tpd Waste-To-Energy Facility with Preprocessing/Mixed Waste Recovery Facility
2011 First -Year Planning Level Operating Cost Analysis
($ Million)

Expense	Low	High
Debt Service	$8.2	$9.2
O&M Cost	$8.7	$10.2
Unprocessable Waste Disposal	$0.8	$0.8
Combustion Residue Disposal	$1.0	$1.3
Total Expenses	$18.7	$21.5
Revenue		
Electricity Sales (1)	$5.8	$6.4
Total Revenues	$5.8	$6.4
Net Cost ($)	$12.9	$15.1
Tipping Fee ($/ton) (2)	$111	$131

Note: Totals may not add due to rounding.
(1) Electricity Sales include an energy charge payment but not a capacity charge payment.
(2) Tipping Fee was calculated using the 115,430 tons of solid waste received in 2011.

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