Final Report

Comparison of Select Materials and Energy Recycling Scenarios

City and County of Honolulu
Department of Environmental Services

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R·W·BECK

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Background

The City and County of Honolulu, Department of Environmental Services, Refuse Division (Division), contracted with R. W. Beck, Inc. to prepare a limited comparison of the environmental and economic impacts of materials recycling of wastepaper to produce new products (Scenario 1) versus recycling wastepaper to produce electricity at Honolulu's H-POWER facility (Scenario 2). The study analyzes selected impacts associated with managing 73,555 tons of wastepaper as was recycled in Honolulu during 2005.

To provide a balanced analysis, the scenarios were analyzed in two distinct ways:

- First, a variety of environmental and economic impacts accruing on the Island of O'ahu were estimated directly; and
- Second, global life-cycle energy and greenhouse gas impacts accruing both on- and off-Island were estimated using the Waste Reduction Model (WARM), developed by the U.S. Environmental Protection Agency (EPA).

The study findings are intended to illustrate the broad differences between materials recycling and energy recycling, and to thereby inform discussion as it relates to alternative waste management practices in Honolulu. The study provides a general sense of the order of magnitude of each impact analyzed, and yields defensible qualitative conclusions regarding the relative benefits of the two study scenarios. Readers are encouraged to focus attention on these broad qualitative conclusions regarding the relative benefits of the two study scenarios, and to consider the specific numeric values as illustrative.

Key Conclusions

Following is a synopsis of the study's key conclusions.

Managing wastepaper through materials recycling (Scenario 1) and through the H-POWER facility (Scenario 2) both yield environmental benefits. This is true in part because they offset other environmental drawbacks. For example:

- Generating electricity from combustion of wastepaper at the H-POWER facility provides <u>*on-island*</u> energy benefits by offsetting the need to generate electricity through combustion of fuel oil; and
- Materials recycling of wastepaper yields <u>*off-island*</u> benefits because it provides alternative raw material to paper manufacturers, thereby reducing the need for logging and production of "virgin" pulp products.

If only on-island impacts are considered, Scenario 2 (H-POWER) provides greater energy and greenhouse gas benefits compared to Scenario 1 (materials recycling). As shown in Figure ES-1, materials recycling has a modest net energy cost due to the transportation and processing conducted on-island, while energy recycling at the H-POWER facility provides a significant energy benefit due to the generation of electricity which offsets the need for combustion of oil to produce electricity.

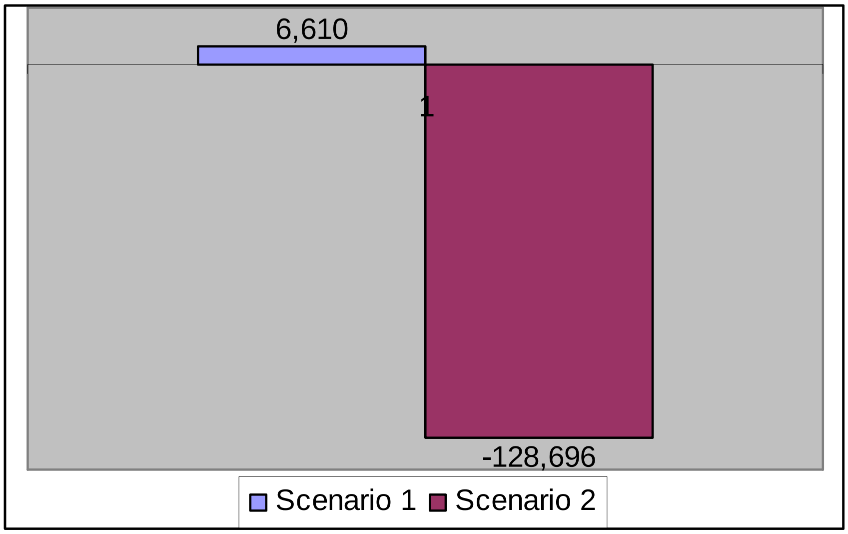

Figure ES-1 Comparison of Net On-Island Net Energy Impacts (MWh)

Likewise, the energy use associated with materials recycling produces modest amounts of greenhouse gas, as shown in Figure ES-2. While combusting wastepaper at the H-POWER facility under Scenario 2 produces greenhouse gases, this method offsets generation of significantly greater quantities of greenhouse gas from the use of fuel oil in electricity generation. This analysis does not “count” carbon dioxide emitted from combustion of paper, since it is assumed that this gas is part of a natural cycle of emission and sequestration that would occur even without processing of forestry resources into paper products. (The use of biomass for energy causes no net increase in carbon dioxide emissions to the atmosphere. This is because, as trees and plants grow, they remove carbon from the atmosphere through photosynthesis. If the amount of new biomass growth balances the biomass used for energy, then bio-energy is carbon dioxide "neutral." That is, the use of biomass for energy does not increase net carbon dioxide emissions.)

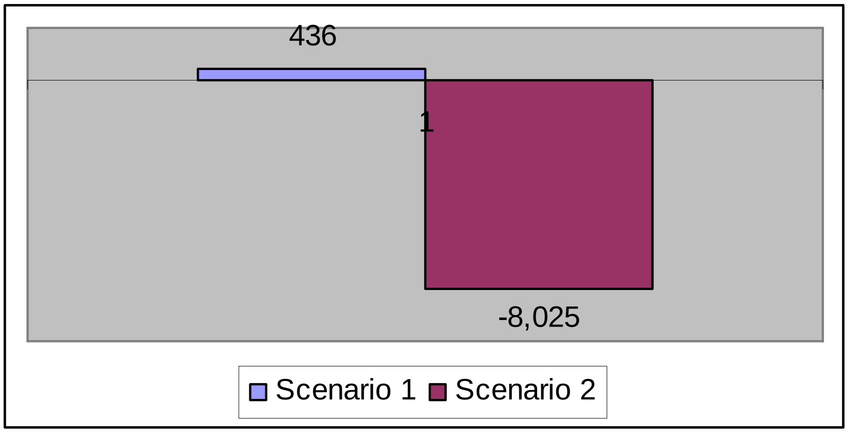

Figure ES-2 Comparison of On-Island Net Greenhouse Gas Emissions (MTCE)

The analysis does "count" nitrous oxide emissions from H-POWER, as well as estimated emissions due to transportation of ash to landfill. The magnitude of on-island energy and greenhouse gas impacts is modest. To provide some context, the net difference in energy impact is equal to about 1.75 percent of all electricity consumed on O'ahu in 2005[1], or equivalent to the electrical use of about 2,400 households for one year. The greenhouse gas benefit is less than one percent of total greenhouse gas emissions in the entire State of Hawai'i[2], or the equivalent of one year's use of about 6,700 passenger cars.

Considering only direct, on-island impacts, Scenario 1 (materials recycling) creates more on-island direct jobs than Scenario 2 (H-POWER); however Scenario 2 generates greater overall economic values, including total jobs (direct, indirect and induced), wages, and industrial output. Wastepaper materials recycling, including collection and processing activities, creates approximately 132 jobs in Honolulu with total wages of about $4.1 million, compared with about 70 jobs for H-POWER with total wages of about $4.8 million. The number of additional jobs (indirect and induced) created as a result of Scenario 2 is estimated to be 141 for a total jobs multiplier of 3.01, as compared to 103 for Scenario 1 for a total jobs multiplier of 1.78. Scenario 2 is estimated to generate $80.4 million in overall industrial output, whereas Scenario 1 is estimated to generate $31.2 million in overall industrial output. Moreover, it is estimated that an overall savings of approximately $823,000 due to lower energy production costs using waste paper as fuel, as opposed to fuel oil, could accrue to residential electric ratepayers.

Scenario 1 (materials recycling) results in larger on-island air emissions related to collection vehicles than Scenario 2, but collection emissions under both scenarios are relatively small. Scenario 2 also results in a variety of additional air emissions that do not result from Scenario 1. The relatively small amount of air emissions associated with collection and processing activities under both scenarios include carbon monoxide, nitrous oxides and particulates, with proportionately more

[1] Hawaiian Electric Company, Inc.
[2] U.S. EPA, Climate Change.

emissions from recycling collection than MSW collection due to the greater energy use associated with recycling collection activities. Some of the emissions from the H-POWER facility, similar to emissions from conventionally fueled power generation facilities, include nitrogen oxide, sulfur dioxide, carbon monoxide, lead, dioxins and furans. Based on a compliance test conducted in May 2006, H-POWER air emissions were within the limits allowed under its permit. Specific estimates of emissions due to combustion of wastepaper were not compared as part of this analysis. While wastepaper can be expected to be a cleaner fuel than MSW, wastepaper also includes bleached products that may contribute to generation of dioxin during combustion.

If all impacts are considered, both on-island and off-island, a global life-cycle inventory analysis indicates that Scenario 1 (materials recycling) has energy and greenhouse gas benefits that are greater than those of Scenario 2 (H-POWER). Both scenarios provide energy and greenhouse gas benefits from a global life-cycle perspective; however, the benefits associated with Scenario 1 (materials recycling) are greater. According to the lifecycle inventory analysis, material recycling has a net energy benefit of approximately 330,000 MWh, while energy recycling provides a net energy benefit of about 49,000 MWh. In addition, material recycling provides a net greenhouse gas benefit of about 58,000 MTCE, while energy recycling provides a net benefit of about 14,000 MCTE. The advantages of materials recycling accrue largely due to the reduced need for processing of wood pulp, as well as paper product manufacturing advantages that occur at off-island end-markets. These global life-cycle conclusions are consistent with many other studies. On a global scale, the energy and GHG benefits identified above are extremely small, with the net energy benefit equal to about 0.0002 percent of all electricity generated in the world in 2004[3] and the greenhouse gas benefit is approximately 0.0001 percent of the total greenhouse gas emissions in the world in 2005[4].

These WARM model results are based on the assumption that the recycled paper is processed at mills in the US, while much of Honolulu's recycled paper is processed at mills in Asia. Analysis of paper mill operations in Asia was beyond the scope of this study. Some Asian mills may operate at significantly less energy efficiency levels than in the U.S., which would tend to increase the amount of energy used in manufacturing recycled paper products. However, using recycled paper would still offset the need for processing of pulp from harvested wood, resulting in energy savings. Air and water emissions from Asian mills may also vary compared to U.S. mills and in some cases may be significantly higher. Detailed analysis of air and water emissions associated with recycled paper manufacturing was also beyond the scope of this study.

Summary

In summary, the choice of whether to pursue materials recycling or energy recycling can be characterized as a public policy decision that requires the weighing of subtle

[3] Based on figures from the International Energy Administration, International Energy Annual 2004 Website, accessed online. March 21, 2007.
[4] Based on 2005 figures from the US EPA, Climate Change Web Site, accessed online. March 21, 2007.

tradeoffs between local and global impacts. The key findings above reflect that recycling wastepaper to produce electricity at the H-POWER facility provides local energy, greenhouse gas and economic benefits. On the other hand, recycling wastepaper to new products provides energy and greenhouse gas benefits greater than H-POWER, but these benefits are geographically dispersed to locations off the island of Oʻahu. Determining the "optimal path forward" requires evaluating whether the local benefits of H-POWER, in the context of local conditions and perspectives, outweigh the global dispersed benefits of materials recycling.

Section 1
INTRODUCTION

1.1 Background

The City and County of Honolulu, Department of Environmental Services, Refuse Division (Division), contracted with R. W. Beck, Inc. to prepare a limited analysis comparing the environmental and economic impacts of materials recycling versus energy recycling (i.e., combustion at Honolulu's H-POWER facility to generate electricity). The study is intended to help inform discussion of the advantages and disadvantages of alternative approaches for managing Honolulu's waste stream.

1.2 Definition of the Scenarios Being Compared

The Division identified two scenarios to be compared, both focusing on the management of wastepaper. As characterized in Table 1-1, Scenario 1 is based on the wastepaper recycling that occurred in Honolulu during the study year 2005, and in Scenario 2 this same quantity of wastepaper is assumed to be processed and combusted at the H-POWER facility to generate electricity. Table 1-2 provides further details on the type of materials recycling programs used to recover wastepaper for materials recycling under Scenario 1.

Table 1-1
Scenarios Compared in the Study

Wastepaper Grade	Tons (2005)	Scenario 1: Materials Recycling	Scenario 2: Energy Recycling
Old Corrugated Containers	45,334	Wastepaper is collected, processed, and shipped to off-island recycling markets.	Wastepaper is collected with refuse, processed and combusted at Honolulu's H-POWER facility, with electricity sold to on-island customers.
Old Newspapers	18,372		
Magazines	14		
Mixed Wastepaper	5,746		
Office Pack	1,769		
Computer/Ledger	1,799		
Other	521		
Total	73,555		

Source: Honolulu Department of Environmental Services, Refuse Division

Table 1-2
Type of Materials Recycling Collection Programs Used Under Scenario 1

Type of Program	Description	Amount of Wastepaper Collected (Tons, 2005)
Drop-Off	Residents, schools and small businesses recycle materials at one of 74 drop-off locations, primarily located at schools. Under government contract, private companies pick-up, process and ship the recovered paper to off-island markets.	7,432
Retail Cardboard	Large retailers separate and bale cardboard on-site and backhaul it to off-island markets through company channels.	12,188
Commercial and Other	Private haulers pick-up wastepaper from office buildings, institutions and other locations, for processing and shipment to off-island markets.	53,935
Total		73,555

Source: Honolulu Department of Environmental Services, Refuse Division

1.3 Study Approach and Report Organization

The study includes two distinct analyses comparing the two scenarios.

The first analysis, described in Section 2, estimates impacts accruing strictly on the island of O‘ahu. Included are environmental impacts such as energy use, greenhouse gas and other air emissions, and economic impacts such as direct, indirect and induced employment and wages associated with each scenario. This on-island analysis provides information that is most directly relevant to Honolulu’s economy and environment.

The second analysis, described in Section 3, estimates energy and greenhouse gas impacts from a global, life-cycle perspective, incorporating the key activities related to the production, use and management of wastepaper, including both on-island and off-island impacts. The life-cycle analysis accounts for the key energy use and offsets throughout the production cycle, in addition to energy use and offsets associated with managing discarded waste. While more complex than the on-island analysis, this global life-cycle analysis is important because some of the most energy intensive and environmentally significant impacts associated with the paper life-cycle management accrue off-island.

The following two Sections present the methodology and results of the on-island and global life-cycle analyses, respectively. Following Section 3, Section 4 presents the study’s key conclusions, including important information on how to understand and use the study results, and a discussion of the level of confidence in the results.

Section 2
ANALYSIS OF ON-ISLAND IMPACTS

This section compares the materials recycling and energy recycling scenarios described in Section 1, focusing exclusively on impacts that accrue on the island of O‘ahu. The following sections describe the methodology used, and present the findings on environmental and economic impacts, respectively. Appendix A provides details on the assumptions and calculations underlying these findings.

2.1 Methodology

Table 2-1 identifies the key on-island roles and activities involved in materials recycling (Scenario 1) and energy recycling (Scenario 2) of wastepaper. Each activity involves associated energy use and other impacts, and also associated offsets, as shown in the table. One goal of the analysis is to determine when the offsets are positive and when they are negative. For example, as discussed below, collecting wastepaper (along with other municipal solid waste) and using it as fuel to generate electricity at the H-POWER facility requires using energy for collection vehicles and at the facility itself, but a far larger amount of energy is produced in the form of electricity, offsetting the need to generate electricity from fuel oil or other conventional fuels at other facilities. On the other hand, wastepaper recycling offsets energy used for MSW collection, but the offset is negative since the analysis reflects that recycling collection requires more energy than MSW collection.

To analyze on-island impacts, R. W. Beck, Inc. directly estimated the magnitude of key impacts related to the activities listed in Table 2-1. While Honolulu specific information was used wherever possible, in some cases it was necessary to use estimates and assumptions derived from limited samples or from national sources. Appendix A lists key assumptions and calculations used to derive the results.

Table 2-1
Range of On-Island Roles and Activities

Stage	Scenario 1: Wastepaper Materials Recycling			Scenario 2: Wastepaper Energy Recycling
	Drop-off Program	Retailer Cardboard	Commercial and Other Recycling	H-POWER
Generator	Residents, schools, small businesses.	Big box" retail stores (e.g., Wal-Mart, Costco, Sam's Club, etc.)	Commercial and governmental offices, institutions, etc.	All wastepaper generators.
	Activities: Separate paper and deliver to drop-off bins (often in combination with other tasks).	Activities: Separate paper and bale on site. Back haul to off-island markets through company channels.	Activities: Separate paper on site.	Activities: Include paper with disposal of mixed garbage.
Collector and processor	City/County-contracted hauler. Activities: Pick-up wastepaper along with other recyclables from drop-off bins according to regular schedule. Sort, bale and ship materials to off-island markets.	Handled by generator.	Private hauler. Activities: Pick up materials and sort, bale and ship materials to off-island markets.	Commercial and government haulers Activities: Pick-up mixed garbage, haul to H-POWER.
End-User	Off-Island (e.g., Mainland or Pacific Rim Recycled Paper manufacturers)	Off-Island (e.g., Mainland or Pacific Rim Recycled Paper manufacturers)	Off-Island (e.g., Mainland or Pacific Rim Recycled Paper manufacturers)	H-POWER facility. Activities: Process mixed garbage to prepare RDF. Combust RDF to produce electricity.
Recycled Product Consumer	Off-island	Off-Island	Off-Island	On-island consumers purchase electricity through grid.
On-Island Offsets	Reduces garbage hauling and landfill/WTE.	Reduces garbage hauling and landfill/WTE.	Reduces garbage hauling and landfill/WTE.	Reduces conventional electricity generation and reduces landfill.

2.2 On-Island Environmental Impacts

This section presents the study findings related to on-island environmental impacts. The environmental focus on this study is on energy use and greenhouse gas emissions. However, to illustrate the range of environmental impacts associated with the two scenarios this section also describes four additional topics – air emissions, residual waste disposal, water effluent and land use.

2.2.1 Energy Use

Table 2-2 compares on-island energy impacts. As detailed in Appendix A, the analysis includes:

- Energy used by collection vehicles;
- Energy used in processing recyclables for shipment to market, and for processing MSW for use at H-POWER;
- Energy used to operate the H-POWER facility; and
- Offset energy use reductions by the Hawaiian Electric Company, Inc. (HECO).

No energy use is included for residents' transporting wastepaper to drop-off facilities, since it was assumed that these trips would be taken as part of other trips that would have otherwise occurred. Also, no energy use is included for transportation of retailer recycling efforts, since these activities are considered backhaul of recyclables in vehicles.

The analysis reflects that, considering only on-island impacts, managing wastepaper through the H-POWER facility provides significant energy benefits compared to materials recycling, with a net difference of 135,306 MWh between the two scenarios. On a unit basis, the analysis indicates that for every ton of wastepaper combusted at H-POWER rather than being managed through material recycling programs, there is a net on-island energy benefit of 1.84 MWh. The energy benefit of H-POWER derives from the generation of power. The analysis shows that H-POWER would deliver approximately 44,944 MWh of electricity from combustion of the 73,555 tons of wastepaper under study. However, the offset is greater, since, according to operating data provided by HECO, fuel oil with an energy value content of approximately 139,722 MWh would need to be consumed to produce this quantity of electricity on O'ahu, equivalent to over 82,000 barrels of number 2 grade fuel oil. Moreover, the table also shows that the amount of energy required to collect wastepaper for combustion at H-POWER is somewhat lower than for materials recycling, since wastepaper is included with mixed garbage, requiring less energy on a per-ton basis.

To provide some context for these numbers, the net difference in energy impact between the two scenarios is equal to about 1.75 percent of all electricity consumed on O'ahu in 2005.[5]

[5] Hawaiian Electric Company, Inc.

Table 2-2
Comparison of On-Island Energy Impacts (MWh)

Stage	Drop Off Recycling	Retailer Recycling	Commercial & Other Recycling	Scenario 1 Totals	Scenario 2 Totals	Total Difference	Difference Per Ton
Collection	1,005	0	4,023	5,027	3,085	1,942	0.03
Processing	174	143	1,265	1,582	0	1,582	0.02
End-Use	*Off Island*	*Off Island*	*Off Island*	*0*	7,940	-7,940	-0.11
Offsets	*Off Island*	*Off Island*	*Off Island*	*0*	-139,722	-139,722	-1.90
Total	1,179	143	5,288	6,610	-128,696	135,306	1.84

Note: Energy associated with processing under Scenario 2 is included under end-use (i.e., energy used to operate the power production facility).

2.2.2 Greenhouse Gas Emissions

Table 2-3 summarizes on-island greenhouse gas emissions (GHG) associated with the two study scenarios. Since greenhouse gas emissions are closely tied to energy use, the GHG analysis includes the same activities as the energy analysis discussed in the previous section. The analysis shows that, considering only on-island impacts, managing wastepaper through the H-POWER facility provides greenhouse gas emission benefits compared to materials recycling of wastepaper, with a net difference of approximately 8,461 MTCE between the two scenarios.[6] Put another way, the analysis indicates that for every ton of wastepaper recycled instead of processed through H-POWER, a potential opportunity to reduce on-island emissions of greenhouse gases by 0.12 MTCE is lost. Generally, other than electricity generation, the other greenhouse gas emission estimates in Table 2-3 track the energy use estimates of the previous section, with relatively small amounts of greenhouse gases being generated through combustion of diesel in trucks used to transport wastepaper, and in rolling stock at processing facilities, as well as the combustion of oil used to generate electricity used during processing. An important note is that the estimate of greenhouse gas emissions from the H-POWER facility itself (labeled “end use” in Table 2-5) does not include carbon dioxide, since it is assumed that the raw material inputs to these paper products are managed “sustainably,” and that the release of this carbon dioxide does not contribute a net increase to global greenhouse gas quantities, since it is part of a cyclical source and sink process. H-POWER greenhouse gas emissions do include relatively small generation of nitrous oxide and also small amounts of GHG generation related to transportation of ash for disposal.

To put these results in context, the net potential reduction in on-island greenhouse gas emissions associated with processing wastepaper at H-POWER is relatively small,

[6] Greenhouse gas emissions are presented in Metric Tons of Carbon Equivalent (MTCE), a commonly used reference unit that accounts for the varying heat trapping potential of different types of greenhouse gases, such as carbon dioxide, methane (CH_4), chlorofluorocarbons, and nitrous oxide (N2O).

equivalent to less than one percent of the total greenhouse gas emissions in the state of Hawai‘i.[7]

Table 2-3
On-Island Greenhouse Gas Emissions (MCTE)

Stage	Drop Off Recycling	Retailer Recycling	Commercial & Other Recycling	Scenario 1 Totals	Scenario 2 Totals	Total Difference	Difference Per Ton
Collection	66	0	264	330	202	127	0.00
Processing	12	10	85	107	0	107	0.00
End-Use	*Off Island*	*Off Island*	*Off Island*	0	1,471	-1,471	-0.02
Offsets	*Off Island*	*Off Island*	*Off Island*	0	-9,698	9,698	0.13
Total	78	10	349	436	-8,025	8,461	0.12

Source: R .W. Beck, Inc.

2.2.3 Collection Emissions

Table 2-4 summarizes on-island emissions associated with collection activities for the two study scenarios. As with GHG emissions, collection transportation emissions are based on the same activities included and described for the energy analysis in Section 2.2.1 above. The analysis shows that, because of the somewhat greater transportation needs, emissions are greater for Scenario 1 (materials recycling) compared to Scenario 2 (energy recycling), with net differences of approximately 4,185 pounds of Carbon Monoxide, 25,526 pounds of Nitrogen Oxides, and 1,447 pounds of Particulate matter.

Table 2-4
On-Island Collection Emissions

Pollutant	Drop Off Recycling (lb/ton)	Retailer Recycling (lb/ton)	Commercial & Other Recycling (lb/ton)	Scenario 1 Totals (lb/ton)	Scenario 2 Totals (lb/ton)	Difference (Materials - Energy Recycling) (lb/ton)	Total Difference (lb)
Carbon Monoxide	0.031	0	0.059	0.090	0.033	0.057	4,185
Nitrogen Oxide	0.233	0	0.261	0.494	0.147	0.347	25,526
Particulate Matter (PM-10)	0.005	0	0.033	0.038	0.019	0.020	1,447

Source: R. W. Beck, Inc.

[7] US EPA, Climate Change Web Site, accessed online. December 26, 2006.

2.2.4 H-POWER Air Emissions

On-island air emission impacts are also associated with combustion of wastepaper at the H-POWER facility under Scenario 2, which are offset by reductions in similar types of emissions at other electricity generation facilities generally combusting fuel oil. As shown in Table 2-5, the H-POWER facility permit regulates 13 different types of pollutants. The table shows results of compliance tests in May of 2006 involving combustion of mixed solid waste, included in this analysis to illustrate the type and amount of emissions from the H-POWER facility. Some of the emissions from the H-POWER facility, similar to emissions from conventionally fueled power generation facilities, include nitrogen oxide, sulfur dioxide, carbon monoxide, lead, dioxins and furans. Based on a compliance test conducted in May 2006, H-POWER air emissions were within the limits allowed under its permit. Specific estimates of emissions due to combustion of wastepaper were not compared as part of this analysis. Other than greenhouse gas generation (discussed in Section Chapter 3), analysis of such emissions was beyond the scope of this study.

Table 2-5
Average Air Emissions from Honolulu's H-POWER Facility and Permit Limits

Emission Type	Average		Permit Limits	
	Value	Unit	Value	Unit
Dioxins/Furans	34.435	ng/dscm	60	ng/dscm
Cadmium	0.007	mg/dscm	0.04	mg/dscm
Mercury	<.044	mg/dscm	0.08	mg/dscm
Hydrogen Chloride	10.8035	ppm	29	Ppm
Sulfur Dioxide	13	ppm	29	Ppm
Nitrogen Oxides	182.5	ppm	250	Ppm
Carbon Monoxide	28.5	ppm	200	Ppm
Opacity	0		20	
Particulate Matter	0.004	lb/100lb RDF	0.2	lb/100lb RDF
Total Hydrocarbons	2.5395	ppm	21	Ppm
Hydrogen Fluoride	0.0319	lb/hr	2.6	lb/hr
Beryllium	ND to <7.135E-05	lb/hr	9.00E-04	lb/hr
Lead	0.0763	lb/hr	0.2	lb/hr

Source: Covanta Honolulu Resource Recovery Venture
Based on compliance tests involving combustion of mixed municipal solid waste, including materials other than wastepaper. Tests conducted in May 2006.

2.2.5 Residual Waste and Landfill Capacity

Both scenarios result in significant reductions in the amount of waste sent to landfill. Residual waste from wastepaper collection and processing under Scenario 1 is assumed to be very low, given that most of the wastepaper is collected source separated. For illustration purposes, at a residual rate of 3 percent, Scenario 1 would generate approximately, 2,206 tons of residual waste requiring disposal. However, this is offset by the fact that the remaining 71,348 tons of wastepaper recycled reduces landfill capacity needs, for a net benefit of 69,142 tons landfill capacity saved, or approximately 138,284 cubic yards of landfill space per year.[8] Residual waste under Scenario 2 is primarily ash, a by-product of the combustion process. Residual ash under Scenario 2 is assumed to be approximately 12 percent of incoming tons (relatively low compared to mixed solid waste combustion), or 8,826 tons.[9] This results in a net benefit for Scenario 2 of 64,728 tons landfill capacity saved, or approximately 129,456 cubic yards of available space.

2.2.6 Land Use

While not a major focus of this study, land use impact is noted here for completeness. Under Scenario 1, land uses include allocation of space for collection containers at schools, stores and other locations, land used by processors and the space allocated for cardboard recycling and baling at retail stores. The primary land use under Scenario 2 is the H-POWER facility and landfill space needed for residual ash.

2.2.7 Water Effluent

As with land use, water effluent impacts are not a major focus of this study, but are noted for completeness. Water effluent is assumed to be negligible under both scenarios. Small amounts of fiber may enter the wastewater system as a result of collection and processing under both Scenarios. Water effluent related to paper manufacturing can be significant, whether recycled materials or virgin materials are used in the manufacturing process. Consideration of such off-island water impacts was considered beyond the scope of this study.

2.3 On-Island Economic Impacts

This section discusses economic impacts accruing on the Island of O‘ahu, related to the two study scenarios. *Direct* economic impacts are those immediately experienced, including employment, wages, value-added, industrial output, and costs/revenues. All industries require inputs into production – goods, services, etc. The value of those inputs supplied by Hawai‘i industries constitutes the *indirect* values. In addition, laborers in the direct industry and in the indirect suppliers to the industry convert their paychecks into household spending. These are the *induced* effects that accrue to the economy. The sum of direct, indirect, and induced effects is the total effect. The savings accruing to households from using wastepaper, as opposed to fuel oil, to generate electricity also was estimated.

[8] Assuming a density of 1,000 pounds per cubic yard for wastepaper in landfills.
[9] Honolulu Department of Environmental Services, Refuse Division.

2.3.1 Direct, Indirect, and Induced Economic Values

Table 2-6 compares estimates of direct on-island employment and total wages under the two study scenarios. The analysis generally includes the same activities described for the energy analysis in Section 2.2.1. Material recycling employment under Scenario 1 includes collection and processing activities. Energy recycling under Scenario 2 includes collection (as part of general MSW collection) and all activities undertaken at the H-POWER facility. These estimates cover both employees that handle materials as well as administrative, managerial and others who provide support services. This information was gathered through direct surveys of the relevant firms.

As shown in Table 2-6, material recycling under Scenario 1 employs nearly twice as many individuals as energy recycling under Scenario 2, with the difference largely due to employment related to processing of wastepaper. However, because of per employee higher wages in County MSW collection employment and at the H-POWER facility, total direct wages are about 15 percent less for Scenario 1 as compared to Scenario 2.

Table 2-6
Comparison of Estimated Direct Employment and Wages

Item	Employment	Wages
Scenario 1 (Materials Recycling)	132	$4,101,745
Scenario 2 (Energy Recycling)	70	$4,826,864
Difference	62	-$725,119
Difference Per Ton	0.001	-$9.86

Source: R. W. Beck, Inc.

Economic analyses of these kinds are best accomplished using detailed revenue and cost data from the industries studied. Industries, however, rarely reveal all of their cost of operation information. They generally are willing to release their labor requirements and some of their labor costs. Analysts can then use these values to scale the industry to a size indicative of those values.

2.3.2 Materials Recycling Economic Effects

The on-island recycling industry is estimated to employ 132 workers making $4.1 million. Total earnings are estimated to be approximately 28 percent higher or $5.25 million. Total earnings contain the cash value of benefits, like health and dental insurance, employer contributions to retirement and social insurance, and other components of workers' total compensation package beyond wage and salary.

The economic values are measured using an input-output (IO) model of the Hawai‘i economy, as modified for this analysis. The IO model is a compilation of all industrial activity in the Hawai‘i economy, to include all inter-industrial transactions – that is, who buys what from whom and who sells what to whom. After accounting for all inter-industry transactions, the statistical relationship between the different industries is simulated within the Hawai‘i economy as part of the analysis. Once the model is formulated, the employment level of the recycling industry of 132 jobs is incorporated into the model, which in turn produces the already entered labor income statistic, and estimates of value added and industrial output. This statistical relationship can then be expressed as a multiplier value.

Table 2-7 reflects the model results for the on-island recycle paper industry. The model expects this industry to produce $18.5 million in *industrial output*, a figure analogous to annual sales, generate $7.54 million in value added, and pay the 132 workers a total of $5.225 million in earnings. *Value added* is composed of all labor incomes, which are payments to workers and normal returns to sole proprietors, plus all payments to investors and all indirect tax payments that are part of the production process.

Indirectly, the model expects the on-island paper recycling industry to require $7.5 million in inputs from industries in Hawai‘i, which in turn will sustain $3.2 million in value added, of which $1.83 million will be labor income for 51 jobs. Lastly, the direct and indirect workers will spend their pay and induce $5.2 million in industrial output that will need 52 additional workers making 1.7 million in labor incomes.

Table 2-7
Materials Recycling Economic Effects

Impact Summary	Direct	Indirect	Induced	Total	Total Multiplier
Industrial Output	$18,518,056	$7,510,235	$5,193,942	$31,222,233	1.69
Value Added	$7,539,423	$3,168,248	$3,081,955	$13,789,625	1.83
Labor Income	$5,255,964	$1,834,779	$1,667,590	$8,758,333	1.67
Jobs	132	51	52	235	1.78

This table also contains a column of multipliers. Multipliers are simply the total value divided by the direct value in any of the rows of measure. Thus, an output multiplier of 1.69 means that for every $1 of output in the recycling industry, $0.79 in output is supported in the remaining state economy. The value added multiplier of 1.83 means that for every dollar of value added in the paper recycling industry, $0.83 in value added is realized in the rest of the economy. A 1.67 multiplier for labor income says that for each dollar of worker earnings in recycling, there is $0.67 in labor income earnings in the rest of the economy. The jobs multiplier of 1.78 says that for every job in the paper recycling industry, there is 78/100ths of a job added to the economy.

2.3.3 Energy Recycling Economic Effects

The analysis for H-POWER (waste-to-energy) uses the same methodology as used for the recycling industry assessment. However, the simulation of the power generation sector was modified to shift the linkage of this industry away from solely purchasing refined oil products to one purchasing the value of the commodities supplied by the paper recycling industry.

The model results for H-POWER are contained in Table 2-8. The 70 jobs at the WTE plant are expected to generate $65.2 million in annual industrial output, $51.3 million in value added, and $6.1 million in labor income. The value added amount is based on expected returns to industrial output that were the average for that industry in 2005 plus a reported annual payment to governments.

Table 2-8
Energy Recycling Economic Effects

Impact Summary	Direct	Indirect	Induced	Total	Total Multiplier
Industrial Output	$65,164,348	$8,724,786	$6,564,615	$80,453,749	1.23
Value Added	$51,307,392	$4,205,537	$3,884,229	$59,397,158	1.16
Labor Income	$6,144,000	$2,834,981	$2,124,185	$11,103,166	1.81
Jobs	70	74	67	211	3.01

H-POWER is expected to require $8.7 million in state economy supplied inputs, thereby sustaining 74 additional jobs making $2.8 million in labor income. When household spending is added (the induced effects), another 67 jobs are generated requiring $2.124 million in labor incomes. In all, H-POWER operation would generate $80.4 million in industrial output, $59.4 million in value added, $11.1 million in labor incomes statewide, and 211 jobs.

The output multiplier is a low 1.23, and it is quite indicative of a large declining cost industry that buys a majority of its inputs external to the local economy. The value added multiplier is also low at 1.16 as a consequence. The labor income multiplier is 1.81 – $0.81 in additional labor income is sustained statewide per dollar paid to facility workers. Lastly, the jobs multiplier is very high at 3.01. That means that for every job in the WTE facility, there are just over 2 jobs in the rest of the economy. This high multiplier is due to the low labor requirements of this type of capital intensive firm as compared to the scope of the labor generated in the supplying sector, as well as the labor stimulated from household spending.

2.3.4 Potential Savings to Electric Ratepayers

Burning waste paper generated on the island as fuel to generate electricity, as opposed to a conventional feedstock such as fuel oil, may yield savings to residential ratepayers (i.e. households). For this segment of our analysis, we have compared the estimated costs of power production using the two different types of fuel to quantify any potential savings on a per kilowatt hour basis. The estimated energy production costs for waste paper are estimated at 10.5 cents per kWh. This assumes net processing costs at H-POWER of $70 per ton, 5000 BTU/pound of wastepaper, and 15,000 BTU/kWh. The estimated energy production costs for HECO using conventional fuels on O‘ahu were estimated to be 12.33 cents per kWh based on HECO’s reported avoided energy costs in 2006. These production costs appear to have nearly tripled since 2002.

Our analysis then assumes rates charged electricity users will reflect all of the estimated savings. The savings will result in either lower prices for consumed goods or enhanced disposable income among consumers.

The above calculations estimate the cost of producing the electricity from waste paper is $0.0183 less per kilowatt hour than from using fuel oil. Assuming 450,000 megawatts of electricity are produced from the waste paper the savings is calculated as follows:

450,000,000 kWh X $0.0183 = $823,500

The $823,500 in savings to consumers were incorporated into the I/O model simply as increased spending by households. Table 2-9 summarizes the effects of extra household spending attributable to lower electric rates from the use of waste paper for fuel instead of fuel oil. In demanding $823,500 in more consumer goods, an additional 5.7 jobs are sustained in the Hawaii economy earning $172,534 in labor incomes. The firms that are stimulated will, collectively, require additional inputs of $137,305, thereby adding 1.3 jobs and $46,293 in labor income to the supplying sector. The workers in the direct and indirect sector will, in turn, convert their pay into household consumption inducing $158,460 in sales requiring 1.6 jobs and $51,274 in labor income. In summary, $1.12 million in output, $0.497 million in value added, $0.27 million in labor income, and 8.6 jobs could be attributed to the cost savings.

Table 2-9
Energy Savings Economic Impacts

Impact Summary	Direct	Indirect	Induced	Total	Total Multiplier
Industrial Output	$823,500	$137,305	$158,460	$1,119,264	1.36
Value Added	$329,505	$73,968	$93,759	$497,232	1.51
Labor Income	$172,534	$46,293	$51,274	$270,101	1.57
Jobs	5.7	1.3	1.6	8.6	1.51

2.3.5 Transactional Costs and Revenues

A conclusive, quantitative analysis of transactional costs and revenues related to the two scenarios is beyond the scope of this study. A high degree of variability was identified within the transactions among the many players in the Honolulu waste management system. These players include:

- Residential and commercial waste generators;
- Schools which benefit from drop-off program revenue;
- County agencies and staff;
- Private waste haulers and recyclers;
- H-POWER operator Covanta ;

- The Hawai‘i Electricity Company, Inc. and its shareholders; and
- Electricity consumers

Appendix B summarizes the results of the analysis of transactional costs and revenues.

Section 3
GLOBAL LIFE-CYCLE ANALYSIS

This Section compares two environmental impacts (energy use and greenhouse gas emissions) of the two study scenarios from a global, life-cycle perspective. Whereas the analysis presented in Section 2 considers only those impacts that accrue on the Island of O‘ahu, the global, life-cycle analysis presented in this section considers all activities that contribute significantly to energy or GHG emissions throughout the materials use cycle.

While the on-island analysis presented in Section 2 provides information most directly relevant to Honolulu's environment and economy, the global life-cycle analysis presented in this Section includes some impacts that may be accrue in many different locations. The following sections describe the methodology and results of the global life-cycle analysis.

3.1 Methodology

This limited Environmental Life-Cycle Analysis is used to illustrate how the waste management approaches compare from a global (on-island plus off-island impacts) point of view. The analysis is based on application of the Waste Reduction Model (WARM) developed by the U.S. Environmental Protection Agency (EPA). This model was developed and refined over many years, with input from a range of groups including industry experts, environmental organizations, government agencies and academia.

The WARM model is designed to compare the net energy use and greenhouse gas emissions of managing a specified amount of waste in different ways, for example through recycling or through waste-to-energy facilities. The model is based on unique assumptions tailored for 34 different material types. Inputs to the model include the scenarios to be compared (e.g., the amount of each material type and the method used to manage it including source reduction, recycling, landfill or waste-to-energy), and the average shipping distance of recyclables to market.

In the current study, values for the amount of each type of wastepaper managed under each study scenario were input. The average distance for materials recycling was entered as 382 miles. This is the sum of the assumed on-island average hauling distance (20 miles), the shipping distance to markets, and the hauling distance to processing facilities (20 miles). R. W. Beck, Inc. assumed that Honolulu wastepaper is most commonly shipped to markets in the Pacific Rim or on the mainland on average 3,500 miles away by container ship and used a conversion of 10.24[10] container ship miles to land truck miles to determine an appropriate input into the WARM

[10] This conversion is based on data from US EPA's Smart Way Transportation Initiative.

model. This conversion factor accounts for the difference in energy use between trucking via land and ocean freight.

The WARM model includes estimates of energy use and greenhouse gas impacts for the activities listed in Table 3-1. While the scope of included activities is broad, not all activities and impacts are included. For example, combusting wastepaper to generate electricity offsets the use of fuel oil, and the model includes fuel oil production costs but does not appear to include costs related to extracting oil resources to produce the fuel oil.

Some Honolulu local conditions do differ from assumptions in the WARM model. These differences include:

- Assumed local transport distances for MSW and ash.
- The mix of conventional fuels used to generate electricity (offset by energy recycling activities).
- Location and specific type of recycling markets used.

Table 3-1
Activities Analyzed in the WARM Model

Scenario 1: Materials Recycling	Scenario 2: Energy Recycling
Recycling collection	MSW collection
Recycling processing	Processing MSW for use in energy recycling facilities
Shipment to recycling markets	Energy used to operate energy recycling facilities
Manufacturing new products with specified percentages of recycled material inputs	Energy used to transport and dispose ash at landfills
Offset impacts of reduced use of virgin or primary materials, including energy used in resource extraction, processing and manufacturing.	Offset energy used to generate electricity using conventional fuels.

Source: US Environmental Protection Agency.

While these differences affect the numerical results, the study team determined that they are not likely to alter the WARM model's key, broad conclusions including:

- The offset impacts of energy recycling (i.e., reduced combustion of fossil fuels to produce electricity) and many types of material recycling (i.e., reduced energy used for materials extraction, processing and manufacture) generally far outweigh the energy used locally to collect and process materials.
- For many materials (including wastepaper), the net energy savings associated with manufacturing with recycled materials is greater than the net energy savings associated with energy recycling, although the energy benefits of material recycling are widely dispersed, while the benefits of energy recycling are usually local.

These two broad conclusions are consistent with the results of many other lifecycle analysis studies sponsored by groups with diverse interests, using a range of different assumptions for the three key differences noted above. In particular, while much of Honolulu generated wastepaper may go to mills in the Pacific Rim with substantially different operating practices than mills in the US (which were specifically analyzed in building the WARM model), use of recycled wastepaper by these mills still offsets the same types of activities involving use of virgin wood pulp.

In contrast to the on-island analysis of Section 2, environmental impacts beyond energy and greenhouse gas emissions were not evaluated. These impacts include, but are not be limited to, air, water and waste discharges as a result of paper manufacturing, and effects resulting from the production and use of various chemicals in paper manufacturing and materials extraction. It is not likely that these impacts would affect the energy conclusions of this analysis. It also should be noted that this analysis does not constitute a full-fledged environmental life-cycle analysis study, but rather only an inventory of impacts based on WARM model results. The following section presents the model results.

The WARM model results are based on the assumption that the recycled paper is processed at mills in the U.S., while much of Honolulu's recycled paper is processed at mills in Asia. Analysis of paper mill operations in Asia was beyond the scope of this study. Some Asian mills may operate at significantly less energy efficiency levels than in the U.S., which would tend to increase the amount of energy used in manufacturing recycled paper products. However, using recycled paper would still offset the need for processing of pulp from harvested wood, resulting in energy savings. Air and water emissions from Asian mills may also vary compared to U.S. mills and in some cases may be significantly higher. Detailed analysis of air and water emissions associated with recycled paper manufacturing was also beyond the scope of this study.

3.2 Global Life-Cycle Environmental Impacts

The Environmental Life-Cycle Analysis Results are presented in Table 3-2. The analysis shows that, from a global life-cycle perspective, managing wastepaper through materials recycling provides substantial energy benefits compared to managing wastepaper through the H-POWER facility, with a net difference of over 280,000 MWh between the two scenarios. In other words, the analysis indicates that for every ton of wastepaper recycled, there is a net energy benefit of about 4 MWh. The most important reason for this is the significant amount of energy used during logging and wood processing involved in making pulp and paper products. This offset occurs off-island, with impacts dispersed across many locales, in contrast to the on-island energy benefits of energy recycling, which accrue directly to the County of Honolulu.

To put these numbers in context, from a global life-cycle perspective, the amount of energy saved by materials recycling in comparison to H-POWER processing is equivalent to about 3.6 percent of the total electricity consumed in Honolulu in 2005[11]

[11] Based on data from the Hawai‘i Electricity Company, Inc. of 7.7 million MWh purchased.

and 0.0002 percent of the total electricity generated in the world in 2004.[12] An important note, however, is that this energy savings is dispersed, accruing in many different locales around the world.

Table 3-2
Environmental Life-Cycle Results

		GHG Impacts (MTCE)				Energy Use (MWh)			
Commodity	Tons	Scenario 1 Recycling	Scenario 2 H-POWER	Total Difference	Difference Per Ton	Scenario 1 Recycling	Scenario 2 H-POWER	Total Difference	Difference Per Ton
Corrugated Cardboard	45,334	-33,323	-8,152	-25,171	-0.57	-196,487	-29,406	-167,081	-4
Magazines/ third-class mail	14	-10	-2	-8	-0.57	0	-7	6	0
Newspaper	18,372	-17,268	-3,771	-13,497	-0.73	-85,374	-13,657	-71,716	-4
Office Paper	3,568	-2,371	-617	-1,754	-0.49	-9,887	-2,224	-7,663	-2
Phonebooks	521	-468	-107	-361	-0.69	-1,647	-387	-1,260	-2
Mixed Paper, Broad	5,746	-4,897	-1,038	-3,860	-0.67	-37,567	-3,743	-33,824	-6
Total	73,555	-58,337	-13,687	-44,651	-0.61	-330,962	-49,424	-281,538	-4

Notes:
1. Negative values indicate a net emission reduction.
2. Input transport distances assume on-island transport of 20 miles (for both materials recycling and H-POWER), and freighter transport of 3500 miles, equivalent to 362 truck miles for shipment of recyclables to market. Based on US EPA's SmartWay Transport Initiative, one truck mile is assumed to be equivalent in energy and greenhouse gas emissions to 10.24 freighter miles.

Table 3-2 also shows the net life-cycle greenhouse gas emissions of each Scenario, based on the WARM model results. The analysis shows that, *from a global life-cycle perspective*, managing wastepaper through materials recycling provides substantial greenhouse gas emission reductions compared to managing wastepaper through the H-POWER facility, with a net difference of nearly 45,000 MTCE. Both approaches have a net positive greenhouse gas impact, however, with Honolulu's materials recycling efforts in 2005 saving 58,337 MTCE in Greenhouse Gas emissions, compared with 13,687 MTCE if the same tonnage were sent to H-POWER. In other words, the analysis indicates that for every ton of wastepaper recycled, there is a net GHG emissions benefit of about 0.61 MTCE versus sending the wastepaper to H-POWER. The most important reason for this is the significant amount of GHG emissions during logging, wood processing and pulp and paper manufacturing, which is avoided due to the inclusion of recycled feed stocks. This important offset occurs off-island, accounting for the different conclusions of the on-island as compared to the off-island results.

[12] International Energy Administration, International Energy Annual 2004 Website, accessed online. March 21, 2007.

To put these numbers in context, *from a global life-cycle perspective,* the amount of energy saved by materials recycling in comparison to H-POWER processing is equivalent to about 0.2 percent of the total GHG emissions associated with Hawai‘i's use of fossil fuels, and is an extremely small amount with respect to global emissions of GHG, amounting to approximately 0.0001 percent of the total world emissions. [13]

3.2.1 Sensitivity Analysis: Effects of Transportation Distance

To test the sensitivity of results to assumptions concerning the distance over which wastepaper is shipped for materials recycling, the WARM model was run again with the assumed off-island shipping distance doubled from 3,500 miles to 7,000 miles. Honolulu recyclables are shipped to either Asia (e.g., at an over-ocean distance of 3,800 miles to Japan or 4,900 miles to China) or to the U.S. mainland (e.g., at an over-ocean distance of 2,400 miles to California). On-land trucking distances at these destinations of course vary as well, so comparing results with a relatively high distance of 7,000 is intended to account for all possible variables. Under this higher transportation distance assumption, the magnitude of the benefits of materials recycling over energy recycling were reduced by a small amount; however, the qualitative conclusions of the analysis did not change. Net energy savings associated with Scenario 1 materials recycling declined by 14,202 MWh, or 4.3 percent, and net greenhouse gas savings declined by 963 MTCE, or 1.7 percent. The net energy benefit of materials recycling compared to energy recycling, on a global lifecycle basis, declined by 5.0 percent, and the net greenhouse gas benefit by 2.2 percent. This sensitivity analysis illustrates that the energy and greenhouse gas impacts associated with collection transportation are generally far-outweighed by the impacts associated with end-use, whether on-island (in the case of producing energy at the H-POWER facility under Scenario 2) or off-island (in the case of substituting recycled materials for virgin materials under Scenario 1).

[13] US EPA, Climate Change Web Site, March 21, 2007.

Section 4
CONCLUSIONS

The following two sections discuss the intended use of study findings and the level of confidence in the study results. Subsequent to that, the study's key conclusions are presented.

4.1 Understanding and Using the Study Findings

4.1.1 Intended Uses

The findings of this study are intended to illustrate the broad differences between materials recycling and energy recycling, and to thereby generally inform discussions as related to alternative waste management practices in Honolulu. The study provides a general sense of the order of magnitude of each impact analyzed, and yields defensible qualitative conclusions regarding the relative benefits of the two study scenarios. Readers are encouraged to focus attention on these conclusions and to consider the specific numeric values as illustrative.

The scenarios analyzed were not intended to represent specific proposals for adjusting Honolulu's current waste management system. For example, Scenario 2 assumes that all current wastepaper flowing to recycling markets would instead flow to the H-POWER facility. This is not a likely scenario, since much of this wastepaper recycling is collected within the private, commercial sector, and is controlled by a large number of independent decision makers.

4.1.2 Level of Confidence

In general, the study team has a high level of confidence in the qualitative conclusions presented below comparing the two study scenarios. The quantitative findings rely on many assumptions about the flow of Honolulu-generated wastepaper and of specific impacts throughout the material management chain, both on-island and off-island. Some of these assumptions are very applicable and some are less applicable. Thus, the methodology has inherent limitations in the level of confidence associated with the quantitative findings. However, the study team feels the level of uncertainty associated with quantitative results is not sufficient to weaken the study's central qualitative conclusions regarding the comparison of the two scenarios. Moreover, the general conclusions are consistent with the results of several other studies R. W. Beck, Inc. has reviewed or participated in, including studies conducted sponsored by groups with distinct and diverse interests such as industry, government and environmental advocacy organizations.

R. W. Beck, Inc. has made efforts to reduce uncertainty wherever possible, within the project's time and resource constraints. Nevertheless, due to the large number of assumptions in both the on-island and off-island analyses, there remain some potential sources of uncertainty which may affect the accuracy of quantitative findings.

4.2 Key Conclusions

Following is a synopsis of the study's key conclusions.

Managing wastepaper through materials recycling (Scenario 1) and through the H-POWER facility (Scenario 2) both yield environmental benefits. This is true in part because they offset other environmental drawbacks. For example:

- Generating electricity from combustion of wastepaper at the H-POWER facility provides <u>*on-island*</u> energy benefits by offsetting the need to generate electricity through combustion of fuel oil; and
- Materials recycling of wastepaper yields <u>*off-island*</u> benefits because it provides alternative raw material to paper manufacturers, thereby reducing the need for logging and production of "virgin" pulp products.

If only on-island impacts are considered, Scenario 2 (H-POWER) provides greater energy and greenhouse gas benefits compared to Scenario 1 (materials recycling).

As shown in Figure 4-1, materials recycling has a modest net energy cost due to the transportation and processing conducted on-island, while energy recycling at the H-POWER facility provides a significant energy benefit due to the generation of electricity which offsets the need for combustion of oil to produce electricity.

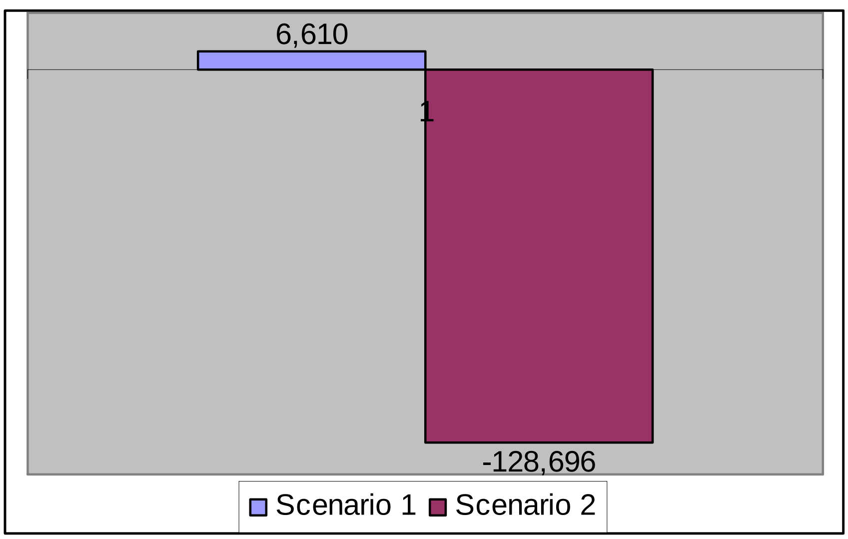

Figure 4-1 Comparison of Net On-Island Net Energy Impacts (MWh)

Likewise, the energy use associated with materials recycling produces modest amounts of greenhouse gas, as shown in Figure 4-2. While combusting wastepaper at the H-POWER facility under Scenario 2 produces greenhouse gases, this method offsets generation of significantly greater quantities of greenhouse gas from the use of fuel oil in electricity generation. This analysis does not "count" carbon dioxide emitted from combustion of paper, since it is assumed that this gas is part of a natural cycle of emission and sequestration that would occur even without processing of forestry resources into paper products. (The use of biomass for energy causes no net increase in carbon dioxide emissions to the atmosphere. This is because, as trees and plants grow, they remove carbon from the atmosphere through photosynthesis. If the amount of new biomass growth balances the biomass used for energy, then bio-energy is carbon dioxide "neutral." That is, the use of biomass for energy does not increase net carbon dioxide emissions.)

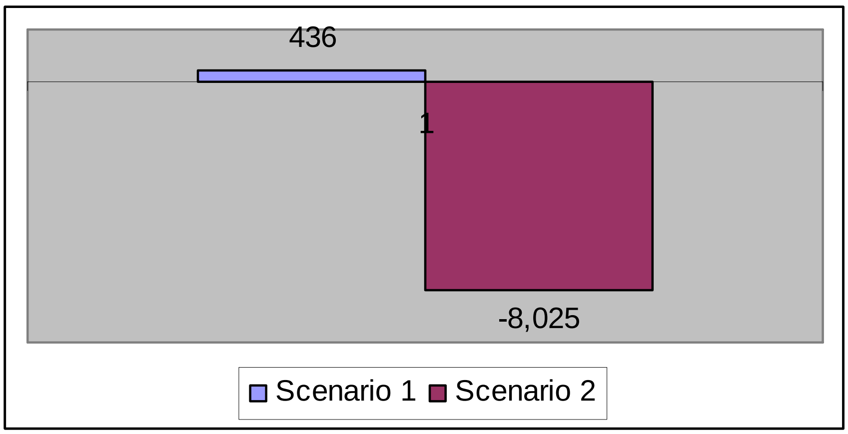

Figure 4-2 Comparison of On-Island Net Greenhouse Gas Emissions (MTCE)

The analysis does "count" nitrous oxide emissions from H-POWER, as well as estimated emissions due to transportation of ash to landfill. The magnitude of on-island energy and greenhouse gas impacts is modest. To provide some context, the net difference in energy impact between the two scenarios is equal to about 1.75 percent of all electricity consumed on O'ahu in 2005,[14] and the greenhouse gas benefit is far less than one percent of total greenhouse gas emissions in the entire State of Hawai'i.[15]

Considering only direct, on-island impacts, Scenario 1 (materials recycling) creates more on-island direct jobs than Scenario 2 (H-POWER), however Scenario 2 generates greater overall economic values, including total jobs (direct, indirect and induced), wages, and industrial output. Wastepaper materials recycling, including collection and processing activities, creates approximately 132 jobs in Honolulu with total wages of about $4.1 million, compared with about 70 jobs for H-POWER with total wages of about $4.8 million. The number of additional jobs (indirect and induced) created as a result of Scenario 2 is estimated to be 141 for a total jobs multiplier of 3.01, as compared to 103 for Scenario 1 for a total jobs multiplier of 1.78. Scenario 2 is estimated to generate $80.4 million in overall industrial output,

[14] Hawaiian Electric Company, Inc.
[15] US EPA, Climate Change Web Site.

whereas Scenario 1 is estimated to generate $31.2 million in overall industrial output. Moreover, it is estimated that an overall savings of approximately $823,000 due to lower energy production costs using waste paper as fuel, as opposed to fuel oil, could accrue to residential electric ratepayers.

Scenario 1 (materials recycling) results in larger on-island air emissions related to collection vehicles than Scenario 2, but collection emissions under both scenarios are relatively small. Scenario 2 also results in a variety of additional air emissions that do not result from Scenario 1. The relatively small amounts of air emissions associated with collection and processing activities under both scenarios include carbon monoxide, nitrous oxides and particulates, with proportionately more emissions from recycling collection than MSW collection due to the greater energy use associated with recycling collection activities. Some of the emissions from the H-POWER facility, similar to emissions from conventionally fueled power generation facilities, include nitrogen oxide, sulfur dioxide, carbon monoxide, lead, dioxins and furans. Based on a compliance test conducted in May 2006, H-POWER air emissions were within the limits allowed under its permit. Specific estimates of emissions due to combustion of wastepaper were not compared as part of this analysis. While wastepaper can be expected to be a cleaner fuel than MSW, wastepaper also includes bleached products that may contribute to generation of dioxin during combustion.

If all impacts are considered, both on-island and off-island, a global life-cycle inventory analysis indicates that Scenario 1 (materials recycling) has energy and greenhouse gas benefits that are greater than those of Scenario 2 (H-POWER). Both scenarios provide energy and greenhouse gas benefits from a global life-cycle perspective; however, the benefits associated with Scenario 1 (materials recycling) are greater. According to the lifecycle inventory analysis, material recycling has a net energy benefit of approximately 330,000 MWh, while energy recycling provides a net energy benefit of about 49,000 MWh. In addition, material recycling provides a net greenhouse gas benefit of about 58,000 MTCE, while energy recycling provides a net benefit of about 14,000 MCTE. The advantages of materials recycling accrue largely due to the reduced need for processing of wood pulp, as well as paper product manufacturing advantages that occur at off-island end-markets. These global life-cycle conclusions are consistent with many other studies. While Honolulu wastepaper may be shipped to manufacturers whose practices may vary from those assumed in the lifecycle model, using waste paper still offsets the use of wood pulp and its associated impacts. Thus, the relative energy and GHG benefits are likely to reflect similar results.

Because the energy impacts of materials recycling and energy recycling are dominated by the offsets, the global life-cycle conclusions are very robust in relation to assumptions about transportation distances. For example, doubling the assumed transportation distance to recycling markets to 7,000 miles reduces materials recycling’s energy advantage by only about 4 percent, and its greenhouse gas advantage by about 2 percent. This is because the magnitude of energy and greenhouse gas impacts associated with the offsets of both materials recycling and energy recycling generally far outweigh the impacts associated with transportation, especially local transportation involved with collection vehicles and energy used in processing activities.

4.3 Summary

In summary, the choice of whether to pursue materials recycling or energy recycling can be characterized as a public policy decision that requires the weighing of subtle tradeoffs between local and global impacts. The key findings above reflect that recycling wastepaper to produce electricity at the H-POWER facility provides local energy, greenhouse gas and economic benefits. On the other hand, recycling wastepaper to new products provides energy and greenhouse gas benefits greater than H-POWER, but these benefits are geographically dispersed to locations off the island of O‘ahu. Determining the “optimal path forward” requires evaluating whether the local benefits of H-POWER, in the context of local conditions and perspectives, outweigh the global dispersed benefits of materials recycling.

Appendix A
ASSUMPTIONS AND CALCULATED VALUES

The following tables list the quantitative assumptions and selected calculated values related to the on-island impact analyses. Assumptions related to the global life-cycle analysis are outlined in detail on the US EPA's WARM Users Guide web site at http://www.epa.gov/climatechange//wycd/waste/calculators/Warm_UsersGuide.html.

Key	Parameter	Value	Unit	Source / Calculation Notes
Recycling Tonnages				
A	Drop-Off Recycling	7,431.92	tons	Derived from ENV data.
B	Commercial Recycling	53,935.35	tons	Derived from ENV data.
C	Retail Recycling	12,188.00	tons	Derived from ENV data.
D	Total Paper in Study Scenarios	73,555.27	tons	Derived from ENV data.
Constants				
E	Energy Conversion	292.90	kwh/MMBTU	Constant
F	Barrel Volume Conversion	42.00	gallons/barrel	Constant
G	Diesel Fuel Energy Potential	5.25	MMBTU/barrel	US EPA, Inventory of Greenhouse Gas Emissions and Sinks
H	Diesel Energy Potential per Gallon	36.61	kwh/gallon	Calculated (G x E / F)
I	Oil Fuel Energy Potential	5.80	MMBTU/barrel	US EPA, Inventory of Greenhouse Gas Emissions and Sinks
J	Oil Fuel Energy Potential	1.70	MWh/barrel	Calculated (I x F / 1,000 Kwh/Mwh)
K	Diesel GHG Generation per gallon	0.0024	MTCE/gallon	US EPA, Inventory of Greenhouse Gas Emissions and Sinks
L	Diesel GHG Generation per kwh	0.0001	MTCE/kwh	Calculated (K / H)
M	Fuel Oil GHG Generation per barrel	0.1179	MTCE/barrel	US EPA, Inventory of Greenhouse Gas Emissions and Sinks
N	Fuel Oil GHG Generation per MWh	0.0694	MTCE/MWh	Calculated. Does not include efficiency of production (M / J)

Key	Parameter	Value	Unit	Source / Calculation Notes
		Recycling Collection Assumptions		
O	Haul Distance	30.00	miles	R. W. Beck estimate, based on discussions with Honolulu haulers.
P	Haul Fuel Efficiency	5.00	miles/gallon	R. W. Beck estimate, based on discussions with Honolulu haulers.
Q	Commercial Route Length	10.00	miles	R. W. Beck estimate, based on discussions with Honolulu haulers.
R	Route Fuel Efficiency	2.00	miles/gallon	R. W. Beck estimate, based on discussions with Honolulu haulers.
S	Recycling Truck Utilization	0.75	Percent of truck capacity when full	R. W. Beck estimate, based on discussions with Honolulu haulers.
T	Typical Truck Size	32.00	CY	R. W. Beck estimate, based on discussions with Honolulu haulers.
U	Material Density	450.00	lb/CY	R. W. Beck estimate
		Commercial Recycling Collection - Energy and Greenhouse Gas		
V	Pounds per Truck	10,800.00	lb/truck	Calculated (S x T x U)
W	Number of trips per year	9,988.03	trips	Calculated (V x B)
X	Commercial Fuel Consumption per Trip	11.00	gallons/trip	Calculated (O/P + Q/R)
Y	Total Gallons Used	109,868.31	gallons	Calculated (W x X)
Z	Commercial gallons per ton	2.04	gallons/ton	Calculated (fX / (V x 2,000 lb.s/ton))
A1	Commercial energy per ton	74.58	kwh/ton	Calculated (H x Z)
B1	Total energy used	4,022.55	MWh	Calculated (A1 x B/1,000 Kwh/Mwh)
C1	Total MTCE	263.68	MTCE	Calculated (Y x K)
		Drop off Recycling - Collection Energy & GHG		
D1	Residential Fuel Consumption	6.00	gallons/trip	Calculated (O / P)
E1	Number of drop off trips	5,445.00	trips	Honolulu ENV, 2005 SCRP excel file

Key	Parameter	Value	Unit	Source / Calculation Notes
F1	Percent allocated to paper	0.84	Percent	Percent of all drop off materials collected that is paper. Based on % weight, Honolulu ENV, 2005 SCRP excel file
G1	Total gallons	27,442.80	gallons	Calculated (F1 x E1 x D1)
H1	Total energy	1,004.75	MWh	Calculated (D1 x H/1,000 Kwh/Mwh)
I1	Total MTCE	65.86	MTCE	Calculated (G1 x K)
Commercial Recycling - Processing Energy and GHG				
J1	Warehouse Unit Energy Consumption	10.75	kwh/ton	Warehouse operations. Municipal Solid Waste Management and Its Impact on Resource Conservation and Greenhouse Gas Emissions, Prepared for MN OEA, by R.W. Beck and Ecobalance, Inc., 1999.
K1	Rolling Stock Unit Fuel Consumption	0.35	gallons/ton	Warehouse and grounds rolling stock. Municipal Solid Waste Management and Its Impact on Resource Conservation and Greenhouse Gas Emissions, Prepared for MN OEA, by R.W. Beck and Ecobalance, Inc., 1999.
L1	Rolling Stock Energy Consumption	12.70	kwh/ton	Calculated (K1 x H)
M1	Combined unit energy use	23.45	kwh/ton	Calculated (J1 + L1)
N1	Total Energy	1,265.03	MWh	Calculated (M1 * B/1,000 Kwh/Mwh))
O1	MTCE Rolling Stock	44.92	MTCE	Calculated (L1 x L x B)
P1	Unit MTCE Rolling Stock	0.0008	MTCE/ton	Calculated (O1 / B)
Q1	MTCE Warehouse (assume oil)	40.24	MTCE	Calculated (J1 x B x N/1,000 Kwh/Mwh)
R1	Unit MTCE Warehouse	0.0007	MTCE/ton	Calculated (Q1 x B)
S1	Total MTCE	85.16	MTCE	Calculated (O1 + Q1)

Key	Parameter	Value	Unit	Source / Calculation Notes
Drop Off Recycling - Processing Energy and GHG				
P1	Total energy	174.31	MWh	Calculated, Assume same energy use as for commercial processing (A x M1 / 1,000 Kwh/Mwh)
Q1	MTCE	11.73	MTCE	Calculated (P1 + R1) x A
Retailer Processing Energy and GHG				
R1	Combined unit energy use	11.73	kwh/ton	Calculated. Assumes half of commercial energy rate for processing. (M1 x 0.5)
S1	Total energy	142.93	MWh	Calculated (R1 x C / 1,000 Kwh/Mwh)
T1	MTCE	9.62	MTCE	Calculated - Assumes half the combined ghg generation rate as commercial. (P1 + R1) x 0.5 x C / 1,000 Kwh/Mwh
H-POWER Collection (paper collected as a part of the MSW Collection system)				
U1	Truck Size	32.00	CY	R.W. Beck estimate, based on discussion with Honolulu haulers.
V1	Material Density	750.00	lb/CY	R.W. Beck estimate
W1	MSW collection truck utilization	0.80	percent	R.W. Beck estimate
X1	Truck weight	19,200.00	lb/truck	Calculated (U1 X V1 X W1)
Y1	Trips	7,662.01	trips/year	Calculated (D / (X1 / 2,000 lb.s/ton))
Z1	Fuel Consumption	11.00	gallons/trip	Calculated (O / P + Q / R)
A2	Unit Fuel Consumption	1.15	gallons/ton	Calculated (Z1 / X1 x 2,000 lb.s/ton)
B2	Unit Energy Consumption	41.95	kwh/ton	Calculated (H x A2)
C2	Total energy	3,085.78	MWh	Calculated (B2 x D / 1,000 Kwh/Mwh)
D2	Unit GHG Emissions	0.0028	MTCE/ton	Calculated (A2 x K)
E2	Total GHG	202.28	MTCE	Calculated (D2 x D)
H-POWER Processing and Power Generation				
F2	Wastepaper potential heat value	12.60	MBTU/ton	Honolulu ENV, Refuse Division
G2	Total potential heat value	926,796.40	MBTU	calculated (F2 x D)

Key	Parameter	Value	Unit	Source / Calculation Notes
H2	Total potential heat value	271,458.67	MWh	calculated (G2 x E / 1,000 Kwh/Mwh)
I2	Efficiency of RDF production	100.00%	percent	Estimated by R.W. Beck. Assumed for wastepaper only.
J2	Efficiency of steam production	65.00%	percent	Covanta/ENV, Refuse Division - assumed to refer to steam production efficiency.
K2	Efficiency of electricity production from steam	30.00%	percent	R.W. Beck estimate
L2	Portion of generated electricity used for facility operations	15%	percent of output electricity	R.W. Beck estimate
M2	net electricity output rate	16.5750%	Percent	Calculated (J2 x K2 x (1-L2))
N2	net output per ton	2.09	mBTU/ton	Calculated (M2 x F2)
O2	net electricity output (mBtu)	153,616.50	mBTU	Calculated (G2 x M2)
P2	net electricity output (Mwh)	44,994.27	MWh	Calculated (E x O2 / 1,000 Kwh/Mwh)
Q2	net energy use for operations	7,940.17	MWh	Calculated (P2/0.85) x 0.15
R2	total electricity generation	52,934.44	MWh	Calculated (P2 + Q2)
S2	Unit GHG Emissions	0.02	MTCE/ton	US EPA, Solid Waste Management and Greenhouse Gases, a Life Cycle Analysis of Emissions and Sinks http://www.epa.gov/climatechange//wycd/waste/SWMGHGreport.html#sections. Does not count CO2 from biogenic sources like paper.
T2	GHG emissions	1,471.11	MTCE	Calculated (S2 x D)
H-POWER Avoided Emissions (Power Generation from Fuel Oil)				
U2	No. 2 fuel oil heat content	140,000.00	Btu/gallon	R. W. Beck estimate
V2	Oil power generation electricity delivery rate (reciprocating diesel engine)	10,602.00	Btu input/ kWh delivered	HECO, based on PUC target heat rate.

Key	Parameter	Value	Unit	Source / Calculation Notes
W2	Oil power generation delivery rate (reciprocating diesel engine)	13.21	kwh delivered/ gallon input	calculated (U2 / V2)
X2	Oil power generation delivery rate (reciprocating diesel engine)	3.11	Mwh input/ Mwh delivered	calculated (V2 / 1,000,000 x E)
Y2	Offset Energy - Input energy value of fuel required to match H-POWER output	-139,721.88	MWh	Calculated (X2 x P2 x (-1))
Z2	Offset Energy (bbl)	-82,246.43	Bbl	Calculated (Y2 / J)
A3	MTCE generated from oil power offset	-9,698.01	MTCE	Calculated (Y2 x N)
Direct Employment and Wages				
B3	Commercial and Drop-Off tons per Direct Employee	781.0	ton/emp	R. W. Beck estimates, based on discussions with Honolulu haulers.
C3	Comm and drop off direct employee wages with benefits	$15.09	$/hr	R. W. Beck estimates, based on discussions with Honolulu haulers.
D3	Retail OCC Recycling tons per direct employee	556.7	ton/emp	R. W. Beck estimates, based on discussions with Honolulu retailers.
E3	Retail OCC recycling direct employee wages with benefits	$12.50	$/hr	R. W. Beck estimates, based on discussions with Honolulu retailers.
F3	Comm/Drop off tons per indirect employee	2,083.0	ton/emp	R. W. Beck estimates, based on discussions with Honolulu haulers.
G3	Comm/Drop off indirect wages with benefits	$16.25	$/hr	R. W. Beck estimates, based on discussions with Honolulu haulers.
H3	Retail tons per indirect employee	6,680.0	ton/emp	R. W. Beck estimates, based on discussions with Honolulu retailers.
I3	Retail indirect wages with benefits	$18.75	$/hr	R. W. Beck estimates, based on discussions with Honolulu retailers.
J3	Comm and Drop off tons	61,367.0	tons	Honolulu ENV
K3	Retail tons	12,188.0	tons	Honolulu ENV
L3	Hours per year	2,080	hrs	R. W. Beck Estimate

Key	Parameter	Value	Unit	Source / Calculation Notes
M3	H-POWER total employment (direct and indirect)	147	employees	Honolulu ENV
N3	H-POWER total tons handled	615,000.0		Honolulu ENV
O3	H-POWER processing and power production tons per emp	4,184	tons/emp	Calculated (N3 / M3)
P3	H-POWER processing and power production wages with benefits	$21.18	$/hr	US Department of Labor, Bureau of Labor Statistics. Mean value for occupation code 51-8099, Plan and System Operators, All Other.
Q3	Collection FTEs (all County MSW services, include indirect)	256	employees	Honolulu ENV
R3	County MSW collection tonnage	361,820	tons	Honolulu ENV
S3	Total County MSW Collection salary and wages with 39.7% benefits included	$19,933,459	$	Honolulu ENV
T3	H-POWER collection tons per employee (inc. direct and indirect)	1,413	tons/emp	Based on County residential MSW collection. Calculated. (R3 / Q3)
U3	H-POWER collection wages per ton	$55.09	$/ton	Based on County residential MSW collection. Calculated. (S3 / R3))
V3	Scenario 1 total employment	132	employees	Calculated (J3/B3 + J3/F3 + K3/D3 + K3/h3)
W3	Scenario 1 total wages	$4,101,745	$	Calculated ((J3/B3)xC3 + (J3/F3)xG3 + (K3/D3)xE3 + (K3/h3)xI3) x L3
X3	Scenario 2 total employment	70	employees	Calculated (D/O3 + D/T3)
Y3	Scenario 2 total wages	$4,826,864	$	Calculated (D/O3) x P3 x L3 + (D x U3)

Appendix B
TRANSACTIONAL COSTS AND REVENUES

As discussed in Section 2.3.2, a conclusive, quantitative analysis of transactional costs and revenues related to the two study scenarios is beyond the scope of this study, due to high variability and uncertainty among the transactions experienced by the many players in the Honolulu waste management system.

This appendix provides a partial analysis of transactional costs and revenues. And, Section 2.4 estimates the overall net economic benefit associated with producing electricity through H-POWER as compared to conventional power sources.

Table B-1 below identifies the key players in Honolulu's waste management system and summarizes the range of costs and revenues experienced by each. Following this, Table B-2 provides the assumptions and details for the quantitative conclusions presented in Table B-1.

Table B-1
Key Players and Their Transactional Costs and Revenues

Type of Program	Player	Revenues and Costs
Drop-Off Recycling	Residents and Other Participating Waste Generators	Cover county costs through County funding mechanisms.
	Schools	Revenues of $14,864 ($2/ton) from private recycler per county contract.
	County	Total costs of $654,381 ($88.05/ton). Includes operations, education, administration and other.
	Contracted Private Recycler/Processor	Undetermined profit rate and costs. Service revenue of $583,926 per county contract. Material sales revenue of $203,970 - $614,366 ($27.44 - $82.67 per ton).
Commercial Recycling	Commercial Generators	Highly variable cost of recycling services (as low as $0/ton) and avoided disposal benefits.
	Commercial Recycler/Processor	Highly variable profit rate, costs and revenues for commercial recycling services.
Retail Recycling	Retailer	Variable costs of approx. $65/ton (assumes labor is 80% of total recycling cost). Market revenue of $304,700 - $487,520 ($25 - 40 per ton). Avoided disposal benefits of $731,000 - $935,000 ($60 - $80 per ton)

Table B-1 Key Players and Their Transactional Costs and Revenues		
Type of Program	**Player**	**Revenues and Costs**
H-POWER	County	Costs for collection of residentially generated wastepaper with MSW. (County assumed to collect drop off tons from Scenario 1.) Revenue from H-POWER operations derived from tip fees and sales of electricity.
	Private Waste Haulers	Variable profit rate, costs and revenues for collection of commercial and retailer generated wastepaper with MSW. (Commercial haulers assumed to collect commercial and retailer tons from Scenario 1.)
	H-POWER Facility and Associated Operator and Holding Company	Operating cost for MSW processing and electricity production. Revenues through tip fees for delivered MSW. Revenue for sale of electricity to HECO.
	Hawaiian Electricity Company, Inc. (HECO)	Costs for purchase of electricity from H-POWER. Reduced costs through offset conventional power generation.

Table B-2
Assumptions and Calculations Supporting Transactional Cost and Revenue Estimates

Key	Parameter	Value	Unit	Source / Calculation Notes
		Drop-Off Recycling Revenues and Costs		
Z3	School Revenue per Ton	$2.00	$/ton	Derived from County ENV data, revenue allocated to paper.
A4	Total Revenue to Schools	$14,864	$	Calculated (A x Z3)
B4	County Drop-Off Program Unit Cost	$88.05	$/ton	ENV, Refuse Division. Includes: operations, education, administration, and misc.
C4	Total County Costs, Drop-Off Recycling	$654,381	$	Calculated (A x B4)
D4	County Drop Off Unit Operations Costs	$78.57	$/ton	Derived from ENV, Refuse Division data - total operations for mixed containers and paper recycling assumed to cover contracted hauler services.
E4	Assumed Low Mixed Ton Recycling Market Revenue	$27.44	$/ton	RW Beck Estimate. Derived from discussions with Honolulu haulers and other data sources.
F4	Assumed High Mixed Ton Recycling Market Revenue	$82.67	$/ton	RW Beck Estimate. Derived from discussions with Honolulu haulers and other data sources.
G4	Low Drop Off Hauler Market Revenue	$203,917	$	Calculated (A x E4)
H4	High Drop Off Hauler Market Revenue	$614,366.65	$	Calculated (A x F4)
I4	Collector/Processor Service Revenue	$583,926	$	Calculated. (D4 x A)
J4	Low Drop-Off Collector/Processor Costs	$669,666	$	Calculated. (G4 + I4) x 0.85 Assumes a 15% profit margin on revenue from service fees and material sales.
K4	High Drop-Off Collector/Processor Costs	$772,086	$	Calculated (G4 + I4) x 0.98 Assumes a 2% profit margin on revenue from service fees and material sales
		Retail Recycling Revenues and Costs		
L4	Retailer Recycling Cost	$800,521.71	$	Calculated. ((K3/D3)xE3 + (K3/h3)xI3) x L3 X 0.80 Assumes retailer labor costs comprise 80% of total recycling costs. Assumes transportation is "free" due to backhaul.
L41	Retailer Recycling Cost Rate	$65.68	$/ton	Calculated. (L4 / C)

Table B-2 Assumptions and Calculations Supporting Transactional Cost and Revenue Estimates				
Key	Parameter	Value	Unit	Source / Calculation Notes
M4	Assumed Low Retail OCC Market Revenue	$25.00	$/ton	RW Beck Estimate. Derived from discussions with Honolulu haulers and other data sources.
N4	Low Total Retail Revenue	$304,700.00	$	Calculated. (M4 x C)
O4	Assumed High Retail OCC Market Revenue	$40.00	$/ton	RW Beck Estimate. Derived from discussions with Honolulu haulers and other data sources.
P4	High Total Retail Revenue	$487,520.00	$	Calculated. (O4 x C)
Q4	Low Estimate - Retail Avoided Disposal Cost	$60.00	$/ton	RW Beck Estimate. Derived from discussions with Honolulu retailers.
R4	High Estimate - Retailer Avoided Disposal Cost	$80.00	$/ton	RW Beck Estimate. Derived from discussions with Honolulu retailers.
S4	Low Total Retailer Avoided Disposal Cost	$731,280.00	$	Calculated (C x Q4)
T4	High Total Retailer Avoided Disposal Cost	$975,040.00	$	Calculated (C x R4)
Commercial Recycling Revenues and Costs				
U4	Commercial Generator Recycling Cost Range	Highly Variable ($0 - NA)	$	RW Beck. Based on discussions with Honolulu haulers.
V4	Commercial Generator Avoided Disposal Cost Range	Highly Variable ($0 - NA)	$	RW Beck. Based on discussions with Honolulu haulers.
W4	Commercial Recycler/Hauler Profit Range	0% - 15%	$	RW Beck Estimate. Based on discussions with Honolulu haulers. Rate varies with customers and market conditions.
X4	Commercial Recycler Material Value - Low Estimate	$25	$	R.W. Beck Estimate. Based on data from Honolulu haulers and other sources. Weighted average based on material grade tons.
Y4	Commercial Recycler Material Value - High Estimate	$40.00	$	R.W. Beck Estimate. Based on data from Honolulu haulers and other sources. Weighted average based on material grade tons.
Z4	Total Commercial Recycler Material Value - Low Estimate	$1,348,383.75	$	Calculated. (X4 x B)
A5	Total Commercial Recycler Material Value - High Estimate	$2,157,414.00	$	Calculated. (Y4 x B)

Appendix C
ACRONYM GLOSSARY

BTU/MMBTU: British Thermal Unit/Million British Thermal Units

CY: Cubic Yard

ENV: City and County of Honolulu Department of Environmental Services

FTE: Full-Time Equivalent

GHG: Greenhouse Gas

H-POWER: Honolulu Program of Waste Energy Recovery

HECO: Hawaiian Electric Company, Inc.

IO: Input-Output

Kwh: Kilowatt-hour

MN OEA: Minnesota Office of Environmental Assistance

MSW: Municipal Solid Waste

MTCE: Metric Tons Carbon Equivalent

MWh: Megawatt-hour

OCC: old corrugated cardboard

PUC: Public Utilities Commission

RDF: Refuse Derived Fuel

US EPA: United States Environmental Protection Agency

WARM: Waste Reduction Model

WTE: Waste-to-Energy