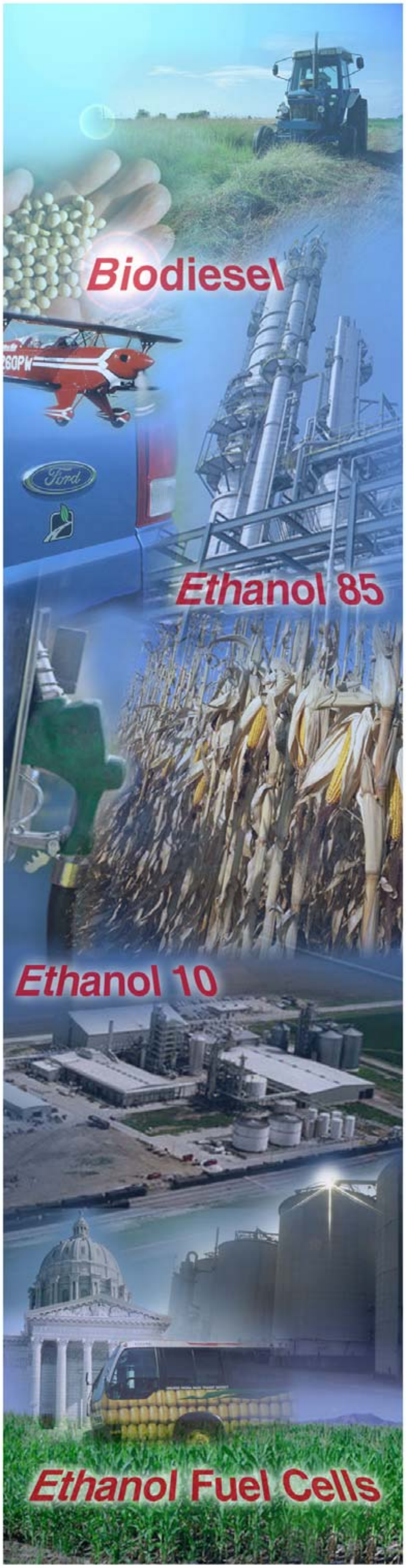

Economic Impact Assessment for Ethanol Production and Use in Hawaii

Prepared for:

Energy, Resources and Technology Division
Department of Business, Economic Development and Tourism
State of Hawaii

Revised Final Report
November 14, 2003

DRAFT FOR REVIEW

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BBI International

Economic impact assessment for ethanol production and use in Hawaii. Prepared for Hawaii. Dept. of Business, Economic Development and Tourism. Strategic Industries Division. Honolulu: Dept. of Business, Economic Development and Tourism, State of Hawaii, October 2003.

62 p.

1. Alcohol as fuel. 2. Motor fuels. I. Hawaii. Dept. of Business, Economic Development and Tourism. Strategic Industries Division. II. Title.
TP358 B34 2003

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I. Executive Summary

Background

The ethanol industry in the United States is experiencing significant growth due to the imminent adoption of the Renewable Fuels Standard, combined with the need to replace MTBE in the nation's gasoline supply.

Hawaii relies on imported oil for approximately 90% of its transportation needs. Because of this strategic vulnerability, the State of Hawaii Energy Policy Statement stresses that the adoption of alternate fuels is an important component in the state's energy strategy. Existing transportation sector plans for Hawaii predict continued growth in transportation fuel consumption, further increasing the state's dependence on imported petroleum. Previous work (*Project 5 Report*) indicates little opportunity to affect the use of petroleum-derived fuels in the air and marine sectors, but locally-produced alternative fuels, i.e. ethanol, could have a significant impact on ground sector demand.

To further assess this opportunity, BBI International has been retained to assess the economic impact of ethanol production and use in the state.

Feedstock Availability

Previous works by Kinoshita, Shleser and others have quantified the availability of biomass feedstocks in Hawaii. Major feedstocks evaluated include sugar and molasses, energy crops, sugar cane and banagrass, tropical hardwoods, Eucalyptus and Leucaena, and biomass from the organic fraction of municipal solid waste (MSW), primarily green waste, food waste, paper and cardboard. Adequate supplies of feedstock were shown to exist currently on three of the six major Hawaiian Islands: Oahu, Maui and Kauai.

Oahu has enough organic waste to support a 40 million gallon per year (MMGY) ethanol plant; Maui, Hawaii and Kauai cannot support an ethanol plant from waste organics alone. Organic waste and food recycling have not yet been developed sufficiently to support an ethanol facility based on these feedstocks alone. Use of MSW as a feedstock would require using the emerging lignocellulosic biomass to ethanol technology.

Maui and Kauai, the only islands still supporting sugar production, produce enough sugar and molasses to support commercial ethanol production. Current sugar and molasses production on Maui is sufficient to support up to 25 MMGY of ethanol capacity; Kauai's current production could support potentially up to 15 MMGY of ethanol capacity.

All the primary Hawaiian Islands have sufficient acreage to support ethanol production from dedicated crops like sugar cane or energy cane, but this would require rejuvenating acreage that has been retired from production.

The primary assumption regarding feedstocks for this study is that in the near term, ethanol will be produced from locally available sugar and/or molasses. These are the only starch- or sugar-based feedstocks locally available in sufficient quantities to support a commercial scale ethanol production capability.

Long term, the preferred feedstocks are lignocellulosic: the cellulosic fraction of organic waste from MSW or cellulosic energy crops, principally the grasses sugarcane and banagrass (Napier grass). Production of the tropical hardwood Eucalyptus was not considered due to the long cycle time for the crop and relatively low yields per acre per year. Adequate supplies of cellulosic residues, primarily paper from MSW, are available locally to supplement supplies of energy crops. (Following the scenarios developed by Kinoshita and Shleser.)

Ethanol Market Potential

The results of the study indicate that the current market potential in the state for ethanol is approximately 41 million gallons per year. This figure is based on the actual gasoline consumption figures for the state (DOE Energy Information Administration data, Hawaii DOT, personal communication with R. Shleser), which for the year 2001 was estimated at 410 MMGY, with ethanol blended at 10%. At a predicted annual growth rate of 1.05% (*Project 5*), the ethanol demand in the year 2005 is estimated at 50 MMGY and 64 MMGY in 2010, with 78 MMGY projected for 2014. Based on this demonstrated market potential, the current study explores the impact of introducing 40 MMGY of ethanol production capacity into the state.

Ethanol Production Scenario Development

Previous works by Kinoshita, Shleser, and others have identified the indigenous feedstocks and sites that hold promise for the development of an ethanol production capability in the state. Using these earlier findings as a starting point, BBI has assumed a scenario for this project where three ethanol production plants totaling 40 MMGY of ethanol capacity are established in the state, one on each of the islands of Oahu, Maui and Kauai.

For this project, BBI has assumed a scenario where one 15 MMGY ethanol plant designed to utilize MSW as a feedstock is located on Oahu. The plant is assumed to use enzymatic hydrolysis technology to produce ethanol from the lignocellulosic substrates in MSW. The scenario further assumes that the MSW utilized for ethanol production does not impact H-Power operations.

The other two ethanol plants are assumed to be located on the two islands that still produce sugar and molasses: Maui and Kauai. The impact scenario places a 15 MMGY ethanol plant on Maui, and a 10 MMGY plant on Kauai. Both plants are designed to use currently available, conventional technology with molasses, supplemented with sugar, as the primary feedstock.

Summary of Construction and Operating Cost Estimates

The project scenario calls for three plants as outlined above totaling 40 MMGY of ethanol capacity. The construction costs for the 15 MMGY Oahu-MSW plant are estimated at $45 million including all startup and preoperational costs. The construction costs for the Maui and Kauai plants are estimated at about $34 million and $25 million, respectively. The total construction costs of the three plants providing 40 MMGY of ethanol production capacity is estimated to be $104 million. The estimated construction costs are summarized in Table 1.

Table 1 – Construction Cost Estimates for Ethanol Production on Hawaii

Construction Phase	Oahu	Maui	Kauai
Ethanol Plant Capital Cost (millions)	$45.02	$33.86	$25.31

Summary of Economic Impact on the State of Hawaii

Construction and operation of ethanol plants on Hawaii will create significant economic activity in the state. The ethanol plant construction and operation will involve expenditures, income, employment and payment of taxes. The expenditures of any business become the income of other businesses or individuals, which in turn is re-spent in the economy to provide income for others. Thus the initial economic activity has a multiplier effect that ripples through the economy. Economic impact analysis is an analytical method that provides a measure of the economic effects of an activity within a specified region.

BBI estimated the economic impacts of ethanol production on Hawaii using indigenous feedstocks to produce 40 million gallons of fuel ethanol annually for the local gasoline market. The proposed ethanol facilities would use approximately 238,000 dry tons (BDT) of MSW on Oahu, 168,000 BDT of molasses on Maui and 112,000 BDT of molasses on Kauai to produce 15, 15 and 10 million gallons of denatured ethanol, respectively.

The final demand impact, household earnings impact and job impacts presented here were estimated by applying the final demand multipliers calculated by the U.S. Bureau of Economic Analysis for ethanol plants in the United States. The resulting economic impacts are reported as estimated changes in the economic base (final demand), income and jobs resulting from ethanol production on Hawaii.

The inputs required for the economic analysis are the ethanol project direct impacts for both the construction phase and operations phase of the project. This distinction is important because the construction phase impacts are a one-time event while the operations phase impacts are ongoing impacts. Construction phase impacts for the ethanol plant are assumed to occur over a 14-month construction and startup period, while the operations phase will normally last many years and is characterized by expressing the impacts on an annual basis.

The Construction Phase economic impact analysis inputs are the construction costs presented in Table 1. Table 2 lists the Operations Phase economic impact analysis inputs, for each of the proposed Hawaii ethanol plants, based on the estimated cost to construct and operate the proposed ethanol plants. Operating annual expenditures include all payments made directly by the ethanol plant owner, including all fixed and variable costs and debt service.

Table 2 – Operations Phase Economic Impact Analysis Inputs for Hawaii Ethanol Plants

Operations Phase Impacts			
Operating Expenditures (millions)	$21.3	$20.8	$14.5
Ethanol Plant Direct Jobs	31	31	22

Operating costs are estimated at about $21 million for the ethanol plant on Oahu, $21 million on Maui and $15 million on Kauai. These are estimated annual operating costs including all fixed and variable costs and debt service. The number of employees at each ethanol plant inclusive of all management and operational personnel are estimated at 31 for the Oahu and Maui plants and 22 for the Kauai ethanol plant.

The economic impact analysis results for the three hypothetical Hawaii ethanol plants are discussed here and summarized in Table 3 below.

15 MMGY Oahu MSW-to-Ethanol Plant

The construction spending associated with building the 15 MMGY ethanol plant on Oahu will add approximately $109 million to the final demand in the local economy and generate $35.5 million in new household income and provide for more than 1,108 direct and indirect jobs during construction. These are one-time impacts spread over the approximately 14-month construction period.

During operations the Oahu plant will create approximately 257 new jobs in Hawaii (the impacts are estimated for the state of Hawaii, not each island). New household income will be approximately $7.5 million annually and the final demand impact will be approximately $42 million each year.

15 MMGY Maui Molasses-to-Ethanol Plant

The construction spending associated with building the 15 MMGY ethanol plant on Maui will add approximately $82 million to the final demand in the local economy and generate $26.7 million in new household income and provide for more than 833 direct and indirect jobs during construction. These are one-time impacts spread over the approximately 14-month construction period.

During operations the Maui plant will create approximately 252 new jobs. New household income will be approximately $7.3 million annually and the final demand impact will be approximately $41 million each year.

10 MMGY Kauai Molasses-to-Ethanol Plant

The construction spending associated with building the 10 MMGY ethanol plant on Kauai will add approximately $61 million to the final demand in the local economy and generate $19.9 million in new household income and provide for more than 623 direct and indirect jobs during construction. These are one-time impacts spread over the approximately 14-month construction period.

During operations the Kauai plant will create approximately 176 new jobs. New household income will be approximately $5.1 million annually and the final demand impact will be approximately $29 million each year.

Table 3 – Economic Impacts of Ethanol Production in Hawaii

Construction Phase Impacts	Oahu	Maui	Kauai
Ethanol Plant Capital Cost (millions)	$45.0	$33.9	$25.3
Final Demand Impact (millions)	$109.2	$82.2	$61.4
Earnings Impact (millions)	$35.5	$26.7	$19.9
Employment Impacts (indirect jobs)	1,108	833	623

Operations Phase Impacts	Oahu	Maui	Kauai
Operating Expenditures (millions)	$21.3	$20.8	$14.5
Final Demand Impact (millions)	$42.0	$41.1	$28.6
Earnings Impact (millions)	$7.5	$7.3	$5.1
Employment Impacts (direct jobs)	31	31	22
Employment Impacts (indirect jobs)	226	221	154
Total Jobs	257	252	176

Conclusions

Total constructions costs are estimates to be $104 million for the three ethanol plants proposed for Oahu, Maui and Kauai with a combined capacity of 40 MMGY. The resulting total economic impact during construction is estimated to be $253 million. Total jobs created during construction are approximately 2,564 with an increase in personal income of $82 million.

Following construction, the combined annual operating costs for the three ethanol plants are estimated to be $57 million, creating $112 million in total annual economic activity. Direct employment at the three ethanol plants is estimated to be 84 employees and indirect and induced jobs are estimates to be 602 for a total increase in jobs of 686.

II. Introduction and Purpose

As the part of the Hawaii Energy Strategy Program, the State Department of Business, Economic Development and Tourism (DBEDT) has been given the responsibility of formulating plans and objectives to achieve optimal development of Hawaii's energy resources. The objectives of the state energy program are:

1) dependable, efficient, and economical statewide energy systems capable of supporting the needs of the people;
2) increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased; and
3) greater energy security in the face of threats to Hawaii's energy supplies and systems.

Towards that end, the Hawaii Energy Strategy (HES) Program was created to produce an integrated energy strategy for the state. The goals of the program are:

1) increased diversification of fuels and sources of supply of these fuels;
2) increased energy efficiency and conservation;
3) development and implementation of regulated and non-regulated energy development strategies with the least possible overall costs to Hawaii's society;
4) establishment of a comprehensive energy policy analysis, planning and evaluation system;
5) increased use of indigenous, renewable energy resources; and
6) enhanced contingency planning capability to effectively contend with energy supply disruptions.

Because of its unique geography and infrastructure, Hawaii relies on imported oil for the bulk of its energy needs (over 85% in 1999). In 1999, Hawaii's transportation sector consumed over 50% of the petroleum used in the state. Even with anticipated conservation measures, existing transportation sector plans for Hawaii predict continued growth in transportation fuel consumption, further increasing the state's dependence on imported petroleum. In recognition of this strategic vulnerability, the State of Hawaii Energy Policy Statement stresses that the adoption of alternate fuels is an important component in the state's energy strategy.

As part of its responsibility for developing the state's energy strategy, the DBEDT is analyzing the possibility of satisfying a portion of the state's future transportation energy demand through alternative fuels. Previous work (*Project 5 Report*) indicates little opportunity to affect the use of petroleum-derived fuels in the air and marine sectors, but locally-produced alternative fuels, i.e. ethanol, could have a significant effect on ground sector demand. The DBEDT has also shown that the state has adequate indigenous feedstock resources to support a commercial ethanol production capacity. Feedstock and site evaluations have been performed, identifying the most promising substrates and potential locations for ethanol installations.

To further develop and quantify the potential benefits of establishing an ethanol production capability in the state, BBI International has been retained to assess the economic impact of introducing ethanol production and use in the state. The DBEDT is interested in quantifying the economic impacts of ethanol production and use in the state to allow it to make informed decisions regarding future public policy and energy self-sufficiency.

III. Study Approach and Methodology

The current study is intended to assess the economic impacts associated with ethanol production and use in the state. The objective of this assessment is to determine the economic benefits to the public and the return on investment to the state for establishing ethanol incentives. The assessment is not intended to evaluate the feasibility of ethanol production in Hawaii, but rather to quantify the economic impacts if ethanol plants are established in the state. The assessment will also examine the impact on the existing transportation fuel infrastructure, as the use of ethanol as a transportation fuel will require modifications to existing equipment and practices.

Definition of Ethanol Production Potential

In order to assess the economic impacts of establishing an ethanol production capability in the state, the first task was to assess the realistic amount of ethanol that could potentially be produced in the state from indigenous biomass resources.

BBI reviewed current and historical data on agricultural crops, biomass residues and solid waste generation in the state. Candidate feedstocks were first evaluated for annual production or tonnage, to establish if adequate supplies are available to support commercial ethanol production. BBI then estimated the potential volume of fuel ethanol that could conceptually be produced from the candidate feedstocks. The results were then used to gauge the ethanol production capacity that could be supported by the state.

Definition of Ethanol Market Potential

In order to assess the economic impacts of establishing an ethanol production capability in the state, the next task was to assess the realistic amount of ethanol that could potentially be marketed and used in the state. Various methods were combined to define the potential ethanol market demand in Hawaii:

> 1) <u>The ethanol production potential was defined based on feedstock availability</u>. In the review of feedstock availability, BBI estimated the availability and composition of indigenous feedstocks. The results were used to develop projections of the volume of ethanol that could be produced from those feedstocks.
>
> 2) <u>The ethanol production potential was defined based on demand for the product</u>. The fuel ethanol market was estimated by the volume of the proposed end-uses. BBI established gasoline consumption in the ground transportation sector and estimated the probable volume of ethanol that would be incorporated into the fuel at a 10% blending level.
>
> 3) <u>The ethanol production potential was defined by examining fuel ethanol projects currently under development</u>. BBI contacted and collected information

from ethanol project developers currently working to develop ethanol plants in Hawaii. These contacts have an awareness of the overall energy situation in Hawaii and can provide input from the commercial perspective of what scale of production capacity is currently justified.

For the current study, BBI estimated the ethanol production potential using all three approaches, incorporating projected feedstock availability, market demand, and finance potential, to determine a target production capacity for the state of Hawaii.

Definition of Ethanol Production Scenario

Having established feedstock availability, ethanol production potential, and market demand, the next task required to assess the economic impacts of establishing an ethanol production capability in the state was to identify hypothetical ethanol plant locations and plant capacities. Specific plant sites were not determined, but rather the islands where an ethanol plant would have access to sufficient local feedstocks were identified. This study also reviewed previous site evaluations conducted for the DBEDT, to develop likely production scenarios for the state. The production scenario developed was used as the basis to assess the economic impact of ethanol production and use in the state.

Estimation of Construction and Operational Costs

Once the number and size of the prospective ethanol plants was established, BBI combined input from current project developers with data from its extensive database on existing ethanol facilities to develop construction and operating estimates representative of the hypothetical production scenarios developed for the state.

Assessment of State Economic Impacts

Economic activities, such as ethanol production, involve expenditures, income, employment and payment of taxes. The expenditure of any business becomes the income of other businesses and individuals, which in turn is reinvested in the local economy, providing more jobs, income and tax revenues. Thus any initial economic activity has a multiplier effect that ripples through the economy. Economic impact analysis is a set of techniques that provide measures of these economic effects in the area where the activity takes place.

An economic impact assessment must be made for a specific geographic region or locale that is defined in advance. The method used here calculates the economic impact based on the state of Hawaii, where the economic activities are located. For the current study, BBI utilized statewide multipliers derived from IMPLAN, a national economic input/output model. It combines direct input on ethanol plant construction costs, operation costs and state-specific data on costs, salaries and labor requirements with input/output model-derived multipliers, to assess indirect and induced employment, income and tax revenues.

The method used in the current study provides specific measures of economic impact in the following categories.

Total Expenditures – Total expenditures are the sum of all direct spending made by the proposed ethanol facilities in Hawaii. This category includes all direct costs associated with two distinct phases of activity and spending: construction and operation. Construction is a short-term, one-time activity associated with establishing an ethanol production capability. The operations phase is a longer term, ongoing activity associated with ethanol production.

Total expenditures includes salaries and wages paid to direct employees, profits or compensation paid to owners and managers, purchases of equipment, feedstocks and process raw materials, and all contracted services.

Data for total expenditures come from construction and operating cost estimates developed from project-specific data where possible, as well as from industry averages and existing data on comparable facilities.

Direct Income – Direct income is the sum of money paid directly by the facility or project to its direct employees in the state. Direct income also includes profits or dividends paid to owners in the state. It does not include payments to contractors.

Direct Employment – Direct employment is the number of persons employed directly by the proposed plant(s) in the state, including owners and managers. This information is obtained from project developers or estimated from industry sources.

Indirect Income – Indirect income, as used in this analysis, is the sum of the indirect and induced income. It is composed of the sum of the expenditures made by the companies that supply the planned facility (indirect income), plus the expenditures made by employees of the facility and the expenditures made by employees of the suppliers (induced income). These expenditures typically include such items as spare parts, supplies, fuel, utilities, trucking, financial services, and the retail or other personal expenditures of employees. Estimates of indirect income are obtained by taking the plant's expenditure for supplies, equipment, and services and applying IMPLAN multipliers to estimate the amount of indirect and induced income from each class of expenditure.

Indirect Employment – Indirect employment is the number of persons employed as a result of the indirect income generated by the facility in the area of interest. The indirect employment is estimated by applying the

IMPLAN indirect employment multiplier to the total amount of indirect income associated with the plant.

State Tax Revenue – The amount of corporate tax revenue paid to the state by an ethanol plant will be dependent on the profitability of the plant as well as its parent company. Since it is impossible to predict the future profitability and financial performance of a given facility, or the actual amount of facility-specific tax payments, in the present study taxes paid to the state are assumed to be a percentage of net income for the facility, and all directly and indirectly related activities are the same as the state average. (The state average is the total state tax revenues divided by the gross state product.)

Any incentives provided by the state are included in the analysis of state tax revenues. Incentive payments, producer credits, tax exemptions and credits, and subsidies are factored into the analysis, to estimate the impact of the proposed facilities on state tax revenues. In the case where incentive payments and tax credits are offered by the state, the return on incentives to the state can also be calculated.

IV. Feedstock Availability

In order to assess the economic impacts of establishing an ethanol production capability in Hawaii, the first task was to assess the realistic amount of ethanol that could potentially be produced in the state. Various methods were combined to define the potential ethanol production potential in Hawaii.

BBI conducted a review of renewable resources in the state that could potentially be utilized for ethanol production. These were used to develop projections of the volume of ethanol that could be produced from those feedstocks. There are basically four indigenous feedstock categories available for consideration. These are:

- Starch- and Sugar-Based Agricultural Products
- Food Waste
- MSW
- Lignocellulosic Biomass

Supplies of these locally-available feedstocks were evaluated for their ability to support ethanol production.

Starch-based Agricultural Crops

BBI conducted a review of the agricultural products produced in the state to identify the volume of annual production by crop. A summary of the crops produced in Hawaii and the associated acreage dedicated to their production is presented in Table 4.

Table 4 – Acreage in crop, number of crop farms and value of crop sales

Crop	Hawaii County	Maui County	Oahu	Kauai County
Acreage in crop (1,000 acres):				
Sugarcane	-	36.9	-	23.1
Pineapples (land used for pineapple)	(1/)	11.6	9.1	(1/)
Vegetables and melons (harvested acreage)	1.8	1.3	3.1	.2
Fruits, excluding pineapples	4.1	0.3	1.7	1.0
Coffee	3.3	(D)	(D)	(D)
Macadamia nuts	(D)	(D)	(D)	(D)
All other crops	1.9	1.9	11.0	1.1
Number of crop farms:				
Sugar	-	1	-	2
Pineapples	5	5	2	3
Vegetables and melons	250	120	160	50
Fruits (excluding pineapples)	705	231	162	156
Coffee	650	(D)	(D)	(D)
Macadamia nuts	(D)	(D)	(D)	(D)
Taro	85	15	15	70
Flowers and nursery products	365	140	215	35
Value of crop sales ($1,000):				
Sugar (unprocessed cane)	-	43,900	-	18,700
Pineapples (fresh equivalent)	(2/)	29,445	72,085	(2/)
Vegetables, ginger root, herbs, and melons	17,910	9,569	30,836	1,446
Fruits (excluding pineapples)	17,522	1,102	8,985	3,755
Coffee (parchment)	15,200	(D)	(D)	(D)
Macadamia nuts (in shell)	(D)	(D)	(D)	(D)
Taro	506	(D)	(D)	2,520
Seed crops	(D)	(D)	(D)	(D)
Flowers and nursery products	47,811	9,947	24,161	1,461

D Withheld to avoid disclosure of individual operations.
1/ Less than 50 acres.
2/ Less than $50,000.
Source: Hawaii Agricultural Statistics Service, *Statistics of Hawaii Agriculture* (2000 data); and <http://www.nass.usda.gov/hi/stats/t_of_c.htm>.

Table 5 through Table 8 present a summary of the tonnage of major crops produced by the state.

Table 5 – Vegetable and Melon Statistics State of Hawaii 2000 and 2001

Commodity	Harvested acreage[2/]		Production		Farm value	
	2000	2001	2000	2001	2000	2001
	Acres		*1,000 pounds*		*1,000 dollars*	
Beans, snap	210	210	1,200	1,100	1,092	1,067
Bittermelon	20	15	300	250	255	200
Broccoli	100	155	400	550	240	358
Burdock	15	15	180	150	270	218
Cabbage, Chinese	320	320	7,200	7,000	1,512	1,610
Cabbage, head	540	490	14,600	12,500	2,774	2,750
Cabbage, mustard	130	130	1,500	1,600	645	800
Celery	50	50	1,100	1,150	341	368
Corn, sweet	440	440	2,400	1,900	1,320	1,216
Cucumbers	400	370	5,700	5,300	2,508	2,332
Daikon	350	330	3,100	3,200	870	896
Eggplant	50	50	1,200	1,000	840	660
Lettuce [3/]	150	140	1,300	1,200	650	600
Onions, dry	340	300	4,300	5,400	3,053	4,052
Onions, green	150	120	1,500	1,400	1,290	1,246
Peppers, green	200	210	2,800	3,100	1,541	1,860
Pumpkins	15	35	170	400	77	164
Radish	10	15	100	150	63	90
Romaine	190	190	2,000	2,000	860	900
Squash, Italian	180	160	2,200	1,800	1,033	900
Squash, Oriental	25	20	600	500	222	175
Sweet potatoes	260	220	2,500	1,800	1,500	900
Tomatoes	500	580	16,500	17,500	8,580	9,275
Watercress	35	35	970	860	1,067	946
Watermelon	560	620	12,600	10,500	3,150	2,520
Other vegetables and melons	850	1,000	10,600	12,300	9,116	11,931
Total vegetables and melons	6,090	6,220	97,020	94,610	44,869	48,034

[1/]Sum of island estimates may not add to State total due to rounding. Only selected crops are shown separately. All other vegetables and melons are included in the "Other vegetables and melons" category. Does not include ginger root and herbs. [2/]Vegetables and melons: Acreage harvested (e.g., 1 acre planted and harvested 3 times during the year = 3 harvested acres). Watercress: Average acreage during the year. [3/]Includes head and semi-head (manoa) lettuce. Leaf lettuce and salad greens included in "Other vegetables and melons." See lettuce feature on page 6.

Table 6 – FRUITS: Acreage, utilization and value, State of Hawaii, 2000-2001

Fruit	Acreage				Utilization						Farm value	
	Total		Harvested [2]		Fresh		Processed		Total			
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
	Acres				*1,000 pounds*						*1,000 dollars*	
Avocados	360	360	220	230	640	600	--	--	640	600	371	342
Bananas	1,710	1,660	1,460	1,490	29,000	28,000	--	--	29,000	28,000	10,440	10,640
Guavas	800	710	680	610	--	--	15,900	15,300	15,900	15,300	2,051	2,157
Papayas	2,845	2,860	1,650	1,950	50,250	52,000	4,250	3,000	54,500	55,000	16,007	14,598
Pineapples	20,700	20,100	*	*	244,000	220,000	464,000	426,000	708,000	646,000	101,530	96,337
Others [3]	1,410	1,554	555	728	2,715	2,630	134	166	2,849	2,796	2,495	2,453
Total	**27,825**	**27,244**	**4,565**	**5,008**	**326,605**	**303,230**	**484,284**	**444,466**	**810,889**	**747,696**	**132,894**	**126,527**

-- = Not Applicable. * = Not Available.
[1] Data for current year are preliminary. [2] Average or total during the year. [3] Some of the fruits included in this category are orange (since 1987), lime, grape, grapefruit, lychee, mango, atemoya, passion fruit, persimmon, poha, rambutan, starfruit, strawberry, tangerine, tangelo, and others. Specialty pineapple was excluded from other fruits beginning in 1998 but included in prior years.

Table 7 – MACADAMIA NUTS: Statistics for State of Hawaii, 1997-2001 crop years

Crop year [1]	Farms	Acreage		Yield per acre [3]	Production [4]		Average moisture		Farm prices [4]		Farm value [8]
		In crop	Harvested [2]		Gross [5]	Net [6]	Entire crop	Purchases only	Gross [7]	Net	
	Number	*Acres*		*1,000 pounds*			*Percent*		*Cents per pound*		*1,000 dollars*
1997-98	800	20,200	19,200	3.0	65,000	58,000	19.5	19.6	66.9	75.0	43,500
1998-99	800	20,200	19,200	3.0	66,000	57,500	20.5	20.8	57.0	65.0	37,375
1999-00	750	19,900	18,900	3.0	64,000	56,500	19.3	19.3	59.1	67.0	37,855
2000-01	650	18,400	17,700	2.8	56,000	50,000	21.0	21.0	52.7	59.0	29,500
2001-02	650	18,000	17,800	3.1	62,000	56,000	21.2	21.9	52.4	58.0	32,480

[1] Season begins July 1st and ends June 30th of the following year. [2] Called bearing acreage prior to 1993-94 crop year. [3] Net production per bearing acre. [4] Wet in-shell basis, delivered to processors. [5] Gross pounds delivered for processing. [6] Gross pounds delivered for processing less total spoilage. [7] Farm value divided by gross production. [8] Net production multiplied by net farm price.

Table 8 – Hawaii Coffee Statistics

County and crop year [1/]	Farms	Acreage		Yield [2/]	Marketings [3/]	Farm prices			Value of sales	Green production
		In crop	Harvested			Cherry	Parchment	All [4/]		
	Number	*Acres*		*1,000 pounds*		*Cents per pound*			*$1,000*	*1,000 pounds*
State										
1997-98	585	7,000	5,800	1.6	9,400			300.0	28,200	7,720
1998-99	610	7,400	6,100	1.6	9,500			260.0	24,700	7,600
1999/00	650	7,700	6,400	1.6	10,000			210.0	21,000	8,100
2000/01	670	7,900	6,800	1.3	8,700			265.0	23,055	7,000
2001/02	**700**	**8,000**	**6,300**	**1.3**	**8,000**			**245.0**	**19,600**	**6,400**
Hawaii										
1997-98	575	2,490	1,900	1.5	2,850	135.0	700.0	570.0	16,245	2,300
1998-99	600	2,800	2,170	1.6	3,500	130.0	500.0	460.0	16,100	2,800
1999/00	635	3,200	2,400	1.2	3,000	70.0	360.0	310.0	9,300	2,400
2000/01	650	3,350	2,700	1.4	3,800	85.0	425.0	400.0	15,200	3,000
2001/02	**675**	**3,430**	**2,850**	**1.1**	**3,100**	**85.0**	**425.0**	5/	5/	**2,500**
Kauai/Maui/Honolulu [6/]										
1997-98	10	4,510	3,900	1.7	6,550			183.0	11,955	5,420
1998-99	10	4,600	3,930	1.5	6,000			143.0	8,600	4,800
1999/00	15	4,500	4,000	1.8	7,000			167.0	11,700	5,700
2000/01	20	4,550	4,100	1.1	4,900			160.0	7,855	4,000
2001/02	**25**	**4,570**	**3,450**	**1.4**	**4,900**			5/	5/	**3,900**

1/ Coffee harvesting occurs throughout the year in Hawaii. The main harvest normally begins in late summer and extends to the early part of the following year. 2/ Average yields based on parchment equivalent marketings and harvested acreage. 3/ Expressed in parchment equivalent pounds. Coffee marketed in cherry form was converted to an equivalent parchment weight and added to parchment marketings. 4/ Represents an average farm price for parchment equivalent sales. Obtained by dividing farm revenues from the sale of cherry and parchment coffee by total marketings (parchment equivalent basis). 5/ Not published to avoid disclosure of individual operations. 6/ Kauai, Maui, and Honolulu counties combined to avoid disclosure of individual operations.

A review of the data shown above shows that of the agricultural crops produced in Hawaii, there are only a few crops grown at the scale required for production of alcohol. Using a typical corn ethanol plant as a working example, a 25 MMGY corn ethanol plant requires approximately 750 tons per day for 350 days of operation, representing over 260,000 tons of corn per year. In comparison, total statewide production of vegetables and melons in 2001 was only 47,000 tons.

Based on the volumes of production required to support a commercial scale ethanol plant, there are only two crops open to consideration: sugarcane and pineapples. In the case of pineapples, a single 25MMGY ethanol plant would consume over 80% of the entire annual crop. This is not realistic for several reasons, primarily the fact that the pineapples are more valuable per pound than ethanol, therefore the cost of pineapples for use as a feedstock would be prohibitive.

Sugarcane is therefore the only indigenous sugar-containing crop available for use as feedstock for ethanol production. Table 9 and Table 10 summarize the annual tonnage of sugar and acreage dedicated to sugarcane production in Hawaii for the year 2000.

Table 9 – SUGARCANE: Hawaii statistics by counties, 1996-2000

Year	Farms [2]	Acreage		Yield per acre		Production of cane for sugar	Farm price [3]	Value of cane for sugar [4]
		In crop [2]	Harvested for sugar	Sugarcane [3]	Raw sugar 96°			
	Number	*1,000 acres*		*Tons*		*1,000 tons*	*Dollars per ton*	*Million dollars*
State								
1996	7	68.8	42.9	82.6	10.18	3,544	30.50	108.1
1997	4	67.8	32.0	91.4	11.15	2,925	29.20	85.5
1998	4	67.6	30.3	90.0	11.66	2,727	32.00	87.4
1999	4	67.0	35.4	81.7	10.38	2,892	30.00	86.8
2000	**3**	**60.0**	**32.6**	**72.5**	**9.23**	**2,364**	**26.50**	**62.6**
Counties: Hawaii								
1996	1	0	1.3	62.3	5.56	81	21.50	1.7
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0
2000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Honolulu								
1996	1	0	4.8	85.0	8.69	408	25.40	10.4
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0
2000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Kauai								
1996	3	26.5	16.7	81.0	9.34	1,353	28.70	38.8
1997	2	25.4	12.3	92.8	10.80	1,141	27.70	31.6
1998	2	24.7	11.3	83.5	10.29	944	30.40	28.7
1999	2	23.7	13.9	66.0	8.08	917	29.00	26.6
2000	**2**	**23.1**	**14.0**	**53.6**	**6.50**	**751**	**24.90**	**18.7**
Maui								
1996	2	42.3	20.1	84.7	11.55	1,702	33.60	57.2
1997	2	42.4	19.7	90.6	11.36	1,784	30.20	53.9
1998	2	42.9	19.0	93.8	12.48	1,783	32.90	58.7
1999	2	43.3	21.5	91.9	11.86	1,975	30.50	60.2
2000	**1**	**36.9**	**18.6**	**86.7**	**11.29**	**1,613**	**27.20**	**43.9**

[1] Primary data source, Hawaii Agricultural Research Center.
[2] At end of year.
[3] Yield and farm price may not compute exactly due to rounding.
[4] Value of cane for sugar estimated by deducting processing and marketing costs from value of sugar and molasses. Processing costs based on toll charges paid by independent producers.

Table 10 – SUGAR: Production of raw sugar and molasses by counties, 1996-2000

Year	Mill production		Average returns received [2]		Value of production		
	Raw sugar 96°	Molasses [3]	Raw sugar 96°	Molasses [3]	Raw sugar 96°	Molasses [3]	Total
	1,000 tons		*Dollars per ton*		*Million dollars*		
State							
1996	437	147	368	54.50	160.8	8.0	168.8
1997	357	131	357	38.60	127.5	5.0	132.5
1998	354	118	368	23.50	130.3	2.8	133.1
1999	368	137	352	13.30	129.5	1.8	131.3
2000	**301**	**102**	**309**	**27.20**	**93.1**	**2.8**	**95.9**
Counties: Hawaii							
1996	7	3	350	38.60	2.5	.1	2.6
1997	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0
2000	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Honolulu							
1996	42	17	363	48.20	15.2	.8	16.0
1997	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0
2000	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Kauai							
1996	156	52	370	56.20	57.7	2.9	60.6
1997	133	41	354	39.80	47.1	1.6	48.7
1998	117	33	366	24.50	42.8	.8	43.6
1999	113	38	351	13.70	39.7	.5	40.2
2000	**91**	**31**	**305**	**29.60**	**27.8**	**.9**	**28.7**
Maui							
1996	232	75	368	55.40	85.4	4.2	89.6
1997	224	90	359	38.00	80.4	3.4	83.8
1998	237	85	369	23.10	87.5	2.0	89.5
1999	255	99	352	13.20	89.8	1.3	91.1
2000	**210**	**71**	**311**	**26.20**	**65.3**	**1.9**	**67.2**

[1] Primary data source, Hawaii Agricultural Research Center.
[2] Derived from production and value. State and county prices may not compute exactly due to rounding.
[3] Commercial.

These data indicate that of the starch- and sugar-bearing agricultural crops produced in Hawaii, only sugarcane is produced in quantities large enough to support ethanol production at a commercial scale.

The data show that 301,000 tons of raw sugar (96º) was produced from 2,364,000 tons of sugarcane harvested from a total of 32,600 acres. This crop was generated by the three remaining Hawaiian plantations; two on Kauai and one on Maui. In addition, there was 102,000 tons of molasses and produced as a by-product of sugar production. This represents a total of 403,000 tons of sugar-based feedstock that could theoretically be used for ethanol production.

Conceptually, the 400,000 tons of combined raw sugar and molasses could be used to produce ethanol. The 301,000 tons of 96º sugar is essentially sucrose that can be expected to yield as much as 147 gal ethanol/ton, or approximately 44 MMGY of ethanol. The 100,000 tons of molasses, at 50% total solids and approximately 60% sugar (of which 80% is assumed to be sucrose and glucose), could potentially yield approximately 4 MMGY of ethanol. Combined, the 403,000 tons of sugar-based feedstock that could theoretically be used for ethanol production would produce nearly 50 MMGY of fuel ethanol from indigenous sugar-based cane.

Food Waste

BBI also investigated the potential use of food waste for the production of ethanol. Food waste includes residential food residuals, commercial food residuals, and commercial food processing wastes. In order to estimate the quantity of food waste available for use as a feedstock for ethanol production, BBI examined the composition of solid waste generated in the state. A summary of the composition and volume of MSW generated in Hawaii by county is presented in Table 11.

Table 11 – Quantities of Municipal Solid Waste Available in Hawaii (data for 1991)

Island Population 1991	**Oahu** 836,231	**Maui** 100,504	**Hawaii** 120,317	**Kauai** 51,177
Paper (tons per year)				
Old corrugated cardboard	71,200	26,500	15,200	7,800
Old newspaper	65,500	9,500	5,500	2,800
High-grade paper	26,500	23,500		700
Mixed paper	120,400	10,400	19,500	3,000
Total Paper	283,600	69,900	40,200	14,300
Other Organics	244,300	58,100	36,100	14,000
Green Waste	200,600	53,800	13,900	15,800
Total Other	444,900	111,900	50,000	29,800
MSW w/ ethanol production potential	***708,500***	***181,800***	***90,200***	***44,100***
Other Solid Waste				
Glass	61,800	12,300	7,000	3,600
Aluminum	15,900	2,500	1,400	800
Tin		5,000		1,400
Metals (ferrous/non ferrous)	153,900	11,200	13,900	3,300
Mixed plastics	74,000	13,600	11,100	5,500
Batteries	12,000			
Tires	6,000	1,300		400
Construction demolition	93,200			
Others	335,900	45,300	15,500	21,200
TOTAL MSW (tons per year)	1,481,200	273,000	139,100	80,300

The data in Table 11 are from 1991, and while dated, indicate the general composition and volume of solid waste available on the various islands of Hawaii. More recent data from Oahu for the year 2001 is presented in Table 12.

Table 12 – Volume and Composition of MSW for the City and County of Honolulu

(data for 2001)

Items	Material Total Generation	Material Disposed (H-POWER & Landfill)	Material Recycled	Percentage Recycled
Paper	**267,931**	**197,991**	**69,940**	**26%**
Newspaper	40,817	25,027	15,790	39%
Cardboard	85,520	43,130	42,390	50%
High Grade	17,740	12,550	5,190	29%
Low Grade	79,039	72,469	6,570	8%
Compostable	31,844	31,844	0	0
Other Paper	12,971	12,971	0	0
Plastic	**71,176**	**71,016**	**160**	**0.22%**
PET #1 Bottles	3,427	3,347	80	2%
HDPE #2 Bottles	3,737	3,657	80	2%
Other Bottles	949	949	0	0
Other Rigid Plastic	27,943	27,943	0	0
Film Plastic	29,712	29,712	0	0
Mixed Plastic/Other Material	5,408	5,408	0	0
Metal	**209,803**	**93,863**	**115,940**	**55%**
Ferrous (inc. autos)	170,572	64,802	105,770	62%
Nonferrous (inc. aluminum)	14,322	4,152	10,170	71%
Mixed Metals/Other Materials	24,909	24,909	0	0
Glass	**26,375**	**17,185**	**9,190**	**35%**
Glass Containers	22,913	13,723	9,190	40%
Other Glass	3,462	3,462	0	0
Other Inorganics	**349,522**	**230,692**	**118,830**	**34%**
Gypsum Wallboard	52,390	51,260	1,130	2%
Asphalt Roofing	25,462	8,862	16,600	65%
Asphalt Paving	92,635	52,075	40,560	44%
Concrete	121,429	69,919	51,510	42%
Sand/Soil/Dirt	20,105	19,945	160	1%
Ceramic Products	7,226	7,216	10	0%
Misc. Inorganics	30,275	21,415	8,860	29%

Items	Material Total Generation	Material Disposed & Landfill)	Material Recycled	Percentage Recycled
Other Wastes	**31,548**	**25,580**	**5,990**	**19%**
Hazardous/Chemicals (including batteries)	8,040	4,910	3,130	39%
Furniture/Mattresses	17,289	15,039	2,250	13%
Electronic Equipment	6,219	5,609	610	1%
Yard Waste	**200,212**	**141,282**	**58,930**	**29%**
Wood	**202,353**	**176,182**	**26,170**	**13%**
Untreated Lumber	53,621	45,941	7,680	14%
Untreated Plywood	20,207	5,207	15,000	74%
Pallets/Crates	53,259	51,969	1,290	2%
Treated Wood	70,729	69,759	970	1%
Stumps	4,536	3,306	1,230	27%
Other Organics	**211,691**	**135,471**	**76,220**	**36%**
Food	134,503	86,643	47,860	36%
Textiles	14,419	719	13,700	95%
Carpet	14,955	14,945	10	0%
Tires	6,909	239	6,670	97%
Sewage Sludge	40,905	32,925	7,980	20%
Misc. Organics	34,173	34,173	0	0%
Total Island-wide	**1,570,610**	**1,089,240**	**481,370**	**32%**
Total Processed at H-POWER		**600,000 (40%)**		
Total Disposed in Landfill		**489,240 (28%)**		

Table 12 shows that the quantity and composition of MSW on Oahu has remained relatively constant over the last 10 years. Recent data from the county of Hawaii show that in the year 2000, the Big Island generated 160,000 tons of MSW, of which approximately 15% was made up of food waste. Again, this is in line with the earlier data from 1991.

BBI's review of organic residuals in the state shows that Oahu is the only island capable of supporting ethanol production from food waste alone. Based on the data for Oahu in the year 2000, approximately 135,000 tons of food waste was generated by the residential and commercial sectors. Applying an average moisture content of 70% for the food waste, this represents just 40,500 tons of dry biomass to be converted to ethanol. Assuming the food waste contains 40% sugar and carbohydrates, which is optimistic, the amount of ethanol that could be potentially be generated from food waste on Oahu is less than 2.5 MMGY.

Municipal Solid Waste

Another indigenous biomass resource evaluated for ethanol production is the organic fraction of MSW. For the current study, BBI reviewed data on solid waste generation, composition and management in Hawaii to determine the potential volume of ethanol that could be generated from MSW. A summary of the composition and volume of MSW generated in Hawaii by county in 1991 was presented previously in Table 11; Table 12 showed comparable data for Oahu for the year 2001.

Additional data on MSW was taken from *Project 5 Report*- Chapters 7 and 10, Oahu May, 1999 Technical Report "Oahu Municipal Refuse Disposal Alternatives Study: Waste Composition Study", Shleser's 1994 Ethanol Report- Chapter 3. *Biocycle* and the report at http://170.12.99.3/researchpdf/IWAS041202RPT.PDF quote Hawaii in 1999 as disposing of 1.4 million tons of MSW.

Previous work, DBEDT *Project 5*-Chapter 7 concluded that at 65% of the total waste stream, the organic fraction of MSW represented the second largest biomass resource in the state. The report also concluded that "MSW is produced in much smaller quantities and is more dispersed on the neighbor islands than on Oahu…". For the current study, the consideration of converting the organic fraction of MSW into ethanol is limited to the City and County of Honolulu on Oahu.

As shown in Table 13, 1.57 million tons of MSW were generated on Oahu in 2001. Of the total, 480,000 tons were recycled, 490,000 tons were land-filled, and 600,000 tons was converted to electricity. Table 13 provides a breakdown of the organic fraction of MSW from Oahu in 2001, showing the tonnages produced in each of the major organic categories, and the current disposition of these materials.

Table 13 – Organic Waste Volumes and Disposal Fates on Oahu, Year 2001

Component	Total (Tons)	Burned or Land-filled (Tons)	%	Recycled (Tons)	%
Paper	270,000	200,000	74.1	70,000	25.9
Yard Waste	200,000	141,000	70.5	59,000	29.5
Wood	202,000	176,000	86.9	26,000	12.9
Other Organics	212,000	135,000	63.7	77,000	36.3
Total Organics	884,000	652,000	73.8	232,000	26.2
Total MSW	1,570,000	1,089,000	69.4	481,000	30.6

Based on the current data, the organic fraction of MSW on Oahu represents 56% of the total MSW waste stream. Up to 884,000 tons of organic solid waste could potentially be made available for ethanol production. Assuming an average moisture content of 30% across all categories of organics, 620,000 tons of feedstock, dry basis, would be available for conversion to ethanol. Applying the figure for ethanol production potential developed by Shleser of 60 gallons of ethanol per dry ton of MSW yields an ethanol production potential of 37 MMGY.

Lignocellulosic Biomass

In its evaluation of potential indigenous feedstocks to be considered for conversion to ethanol, BBI also reviewed the availability and ethanol production potential of lignocellulosic feedstocks in Hawaii. Previous work has identified the most promising candidate feedstocks. These include:

- the organic fraction in MSW
- agricultural residues
- energy crops

The organic fraction of MSW was discussed previously and demonstrated the potential for nearly 37 MMGY of ethanol. This level of production would require using the entire organic waste stream on Oahu.

Of the presently available agricultural residues, only sugarcane and pineapple production were shown to yield the tonnages of residues required to support ethanol production.

Pineapple Residues

The annual production of pineapples in Hawaii in the year 2000 is shown in Table 14. As shown in the table, there were just over 20,000 acres dedicated to pineapple production in 2001 yielding 323,000 tons of fresh production weight.

Table 14 – PINEAPPLES: Statistics for State of Hawaii, 1997-2001

Year	Farms [1]	Acreage used for crop	Production (fresh weight)	Disposition		Farm price		Value of production (fresh weight)
				Processed (fresh weight)	Fresh market	Processed [2]	Fresh market [3]	
	Number	*1,000 acres*	*1,000 tons*			*Dollars per ton*		*Thousand dollars*
1997	15	19.9	324	221	103	127	618	91,721
1998	15	21.0	332	221	111	131	575	92,776
1999	15	21.0	352	230	122	126	594	101,448
2000	15	20.7	354	232	122	130	585	101,530
2001	**15**	**20 .1**	**323**	**213**	**110**	**129**	**626**	**96,337**

[1] Includes specialty pineapple.
[2] Estimate to reflect value of fresh fruit delivered processing plant door based on average contract prices of independent growers.
[3] Estimate to reflect value at wholesale establishments for local sales and shipper dock for mainland & foreign sales.

The total acreage in production and fresh production weight has remained relatively constant over the last nine years.

Pineapple residues have historically been burned in the field or plowed under and are therefore difficult to quantify. Based on historical data on pineapple production, pineapple residues on a dry basis are estimated to be approximately 55% of the fresh pineapple production tonnage. Based on the 323,000 tons of fresh pineapple harvested in 2001, BBI estimates there would be approximately 181,000 tons of residues available from pineapple production. As the ethanol production potential of pineapple residues have not been clearly demonstrated, a range of conversion rates were used to bracket the range of ethanol production that might be possible. Using the figure 60 gallon per ton of ethanol per dry ton of residue as the low end of the range, and 105 gallon per ton as an upper limit, between 11 and 19 MMGY of ethanol could be potentially be produced from pineapple residues. This level of production could merit further consideration.

Sugarcane Residues

The most promising agricultural residues in the state are generated as a by-product of sugarcane production. Residues from sugarcane production include tops, leafy trash, usually burned in the field, and bagasse, the fibrous residue of the cane plant stalk left behind after sugar extraction. Historically, bagasse has been burned to power the sugar extraction process, with excess energy being exported as electricity. More than half of all sugarcane residues generated on an annual basis has been converted to energy. To estimate the quantity of sugarcane residues available for use in ethanol production, BBI reviewed current and historical data on sugar production.

In 1991, 1.7 million tons of sugarcane residues (dry basis) were available in the field. Studies have shown (Kinoshita, 88; *Report 5*) that approximately 35% of the residues were consumed by open-field burning, leaving roughly 65% of the sugarcane residues available for use as renewable energy. In 1991, approximately one million tons was used to generate renewable energy for the sugar refining process. A review of historical production is presented in Table 15. This data shows that the amount of bagasse available as a feedstock for renewable energy has dropped precipitously over the last decade with the closing of most of the sugar plants. The amount of bagasse available for renewable energy or ethanol production has dropped in proportion to the amount of acres harvested each year and the tonnage of cane produced. The volume of bagasse generated per acre of harvested crop averages 16.7 dry tons per acre.

Table 15 – Annual Production of Bagasse in Hawaii, 1987-2001

Year	Tons of Harvested Cane	Acres Harvested	Raw Sugar Tons	Molasses Tons	Total Dry Cane Field Residues Tons (est. from tons)	Dry Bagasse Tons for fuel (est. from tons)	Total Dry Cane Field Residues Tons (est. from acres)	Dry Bagasse Tons for fuel (est. from acres)
1987	8012899	79498	979209	283250	2327473	1512858	1995785	1297260
1988	7602414	78861	928195	274375	2208241	1435357	1979794	1286866
1989	7078479	74660	863614	229377	2056056	1336437	1874328	1218313
1990	6540925	71998	819631	220859	1899915	1234945	1807499	1174874
1991	5852668	67716	724100	202214	1700000	1105000	1700000	1105000
1992	5432286	62123	652304	203739	1577893	1025631	1559589	1013733
1993	5506072	64705	677405	211658	1599326	1039562	1624409	1055866
1994	5268859	64951	658538	200835	1530423	994775	1630585	1059880
1995	3952347	48507	492346	163305	1148022	746214	1217761	791545
1996	3542460	36769	437262	145369	1028964	668826	923080	600002
1997	2923594	32033	356917	131173	849204	551983	804184	522719
1998	2725744	30347	353893	125909	791735	514628	761857	495207
1999	2891499	35329	367532	1414481	839882	545923	886929	576504
2000	2364357	30194	301165	101329	686765	446397	758016	492710
2001	1876613	19292	246203	85894	545092	354310	484323	314810

Year	Total Dry Cane Field Residues Tons (est. from raw)	Dry Bagasse Tons for fuel (est. from raw)	Bagasse Dry Tons (low est.)	Bagasse Dry Tons (high est.)	Bagasse Dry Tons (avg. est.)	Avg. Bagasse Dry tons/Acre	Total Avg. Cane Field Residues Dry Tons
1987	2298930	1494305	1297260	1512858	1434808	18.0	2207396
1988	2179162	1416456	1286866	1435357	1379559	17.5	2122399
1989	2027543	1317903	1218313	1336437	1290884	17.3	1985976
1990	1924282	1250783	1174874	1234945	1220201	16.9	1877232

1991	1700000	1105000	1105000	1105000	1105000	16.3	1700000
1992	1531442	995437	1013733	1025631	1011600	16.3	1556308
1993	1590372	1033742	1055866	1039562	1043057	16.1	1604702
1994	1546077	1004950	1059880	994775	1019869	15.7	1569029
1995	1155901	751336	791545	746214	763032	15.7	1173895
Year	Dry cane field residues Tons (est. from raw)	Dry bagasse Tons (est. from raw)	Bagasse Tons (low est.)	Bagasse Tons (high est.)	Bagasse Tons (avg. est.)	Avg. Dry tons/Acre	Total Avg. Field dry residues
1996	1026578	667276	600002	668826	645368	17.6	992874
1997	837949	544667	522719	551983	539790	16.9	830446
1998	830849	540052	495207	514628	516629	17.0	794814
1999	862870	560866	545923	576504	561098	15.9	863227
2000	707058	459588	446397	492710	466232	15.4	717279
2001	578021	375714	314810	354310	348278	18.1	535812
						Average = 16.7	

Based on current production in 2001, bagasse residues were estimated at approximately 350,000 dry tons from just over 19,000 acres harvested. Applying the ethanol production potential established by Shleser (1994) of 75 gallons of ethanol per dry ton of bagasse, this quantity of feedstock could potentially yield as much as 26 MMGY of fuel ethanol.

If the sugarcane residues currently left in the field were harvested and incorporated into ethanol production, the ethanol potential based on the 2001 harvest would increase to over 40 MMGY of ethanol.

Other process options must be considered when discussing the use of bagasse for ethanol production. If sugarcane were dedicated to ethanol production, it is more likely the whole plant would be utilized for bioconversion, not just the bagasse component. Use of the whole plant adds the contribution of the sugar content to that of the fiber, increasing the yield of ethanol per dry ton of feedstock over 30%, from 75 gallon per bone dry ton (BDT) to approximately 100 gallon per BDT. Using data from 2001 and estimating the yield of ethanol from bagasse, raw sugar and molasses, indicates a potential production of 85 MMGY.

Another consideration is to put historical acreage back into production, dedicated strictly to ethanol production. As recently as 1990, over 70,000 acres were harvested. In 1987, nearly 80,000 acres were harvested. The ethanol production potential from 70,000 harvested acres is estimated at 285 MMGY; for 80,000 acres, the ethanol potential is 340 MMGY. To produce 40 MMGY of ethanol from the whole plant would require approximately 10,000 acres of dedicated crop production.

To summarize, conversion of present stocks of bagasse would yield over 25 MMGY of fuel ethanol. If the residues currently burned are included as feedstock, the potential increases to 40 MMGY. Alternatively, if the entire crop in 2001 were used for ethanol production rather than for sugar production, approximately 85 MMGY of ethanol could be produced. Finally, if the acreage of production was increased to historical levels ethanol production could exceed 300 MMMGY.

Summary of Feedstock Availability

Table 16 presents a summary of BBI's review of feedstock supplies and their potential for use as feedstock for ethanol production.

Table 16 – Summary of Ethanol Potential for Candidate Feedstocks

Feedstock Resource	Supply (tons - dry basis)	Ethanol Yield (gal/ton)	Ethanol Potential (MMGY)
Starch-based crops			
Raw sugar	300,000	150	45
Molasses	100,000	72	7
Food Waste	40,500	62	2.5
Organics in MSW	620,000	60	37
Lignocellulosics			
Pineapple Residues	181,000	60-105	11-19
2001 Sugarcane Residues	535,000	75	40
2001 Whole plant	867,000	98	85
70,000 harvested acres	2,918,000	98	285
80,000 harvested acres	3,470,000	98	340

V. Ethanol Market Potential

Hawaii relies on imported oil for approximately 90% of its transportation needs. Because of this strategic vulnerability, the State of Hawaii Energy Policy Statement stresses that the adoption of alternate fuels is an important component in the state's energy strategy. Existing transportation sector plans for Hawaii predict continued growth in transportation fuel consumption, further increasing the state's dependence on imported petroleum. Previous work (*Project 5 Report*) indicates little opportunity to affect the use of petroleum-derived fuels in the air and marine sectors, but locally-produced alternative fuels, i.e. ethanol, could have a significant effect on ground sector demand.

In order to assess the economic impacts of establishing an ethanol production capability in the state, it is necessary to assess the realistic amount of ethanol that could potentially be marketed in the state. Various methods were combined to define the potential ethanol market demand in Hawaii:

1) The ethanol production potential was defined based on feedstock availability. BBI estimated the availability and composition of indigenous feedstocks. These were used to develop projections of the volume of ethanol that could be produced from those feedstocks.

2) The ethanol production potential was defined based on demand for the product. The fuel ethanol market was estimated by the volume of the proposed end-uses. BBI established gasoline consumption in the ground transportation sector and estimated the probable volume of ethanol that would be incorporated into the fuel at a 10% blending level.

3) The ethanol production potential was defined by examining fuel ethanol projects currently under development. BBI contacted and collected information from ethanol project developers currently working to develop ethanol plants in Hawaii. These contacts have an awareness of the overall energy situation in Hawaii and can provide input from the commercial perspective of what scale of production capacity is currently justified.

Ethanol Market Potential Based On Feedstock Availability

The previous section reviewed and summarized the ethanol production potential for available indigenous feedstocks. The findings were summarized in Table 16, which indicates that under present conditions, there are three potential feedstocks available in volumes required for ethanol production. These are sugar and molasses from current production, the organic fraction of MSW (75% of which is currently converted to power by H-POWER), and sugarcane residues.

If the current total production of raw sugar and molasses were dedicated to ethanol production, approximately 50 MMGY of ethanol would be available for market.

If the organic component of the entire waste stream on Oahu were turned over to ethanol production, the potential ethanol available for market would be 37 MMGY.

Lastly, if the current supply of bagasse were completely dedicated to ethanol production, approximately 25 MMGY would be produced. If the entire residue of the sugarcane plants were utilized, including both the bagasse residues and the sugarcane "trash" that is currently burned in the field, the potential ethanol production would be 40 MMGY.

These data show that three feedstocks are currently available that could supply a 40 to 50 MMGY ethanol market. If the three candidate feedstock resources were combined, a total market supply of approximately 125 MMGY of ethanol would be available.

Ethanol Market Potential Based On Product Demand

Another basis for defining the potential market for fuel ethanol in Hawaii is to examine the proposed end-use of the product as a transportation fuel and oxygenate. BBI established gasoline consumption in the ground transportation sector and estimated the probable volume of ethanol that would be incorporated into the fuel at a 10% blending level.

Data on gasoline usage and consumption in Hawaii was obtained from several independent sources, including the Hawaii Department of Taxation, the State of Hawaii Annual Data Book for the year 2001, and the Energy Information Administration service of the US Department of Energy. The results are summarized in Table 17.

Table 17 – State of Hawaii Gasoline Consumption

Year	HI - DOTaxation	EIA-DOE	2001 HI Data Book
2001	409909645	NA	NA
2000	400928438	NA	428,425,000
1999	384259968	376000,000	417,374,000
1998	394673693	392,000,000	422,928,000
1997	400435127	393,000,000	421,499,000
1996	NA	394,000,000	426,370,000
1995	NA	395,000,000	422,884,000
1994	NA	392,000,000	428,558,000
1993	NA	380,000,000	409,940,000
1992	NA	372,500,000	405,963,000
1991	NA	376,740,000	406,819,000
1990	NA	364,140,000	395,185,000
State Dept. of Taxation Average 1997-2001 = 398,041,374 gallons			
State Data Book Average 1990-2000 = 416,900,000 gallons			

This information indicates that the present annual consumption of gasoline by the ground sector in Hawaii is on the order of 400 MMGY.

Projections (*Project 5*) indicate the market will grow by a factor of 1.05 percent annually through the year 2014. The projected increase in gasoline consumption in the state is shown in Table 18.

Table 18 – State of Hawaii Projected Gasoline Consumption and Growth of the Ethanol Market through 2014

Year	Gasoline Usage (MMGY)	Ethanol Market (MMGY)
2001	410	41
2005	498	50
2010	635	64
2014	772	78

Based on the projected use of ethanol as a transportation fuel and oxygenate at a 10% level in gasoline, and the total consumption of gasoline by the ground sector in the state, the current market demand for fuel ethanol is about 40 MMGY. This market is projected to nearly double by the year 2014 to 78 MMGY.

Ethanol Market Potential Based on Projects under Development

Another estimate of the potential market demand for fuel ethanol in Hawaii can be made from information on current fuel ethanol projects under development in the state. BBI has learned from the DBEDT that there are currently three, or possibly four, ethanol projects being considered. At least two are investigating the conversion of molasses to ethanol. Total estimated ethanol production from the projects under consideration, assuming all four were implemented, is approximately 80 MMGY.

Summary of Ethanol Market Potential

The results of the study indicate that the current market potential with ethanol blended at 10% is approximately 41 million gallons per year. This figure is based on the actual gasoline consumption figures for the state (EIA data, HI DOT, personal communication with R. Shleser). For the year 2001 Hawaii gasoline consumption was estimated at 410 MMGY. At a predicted annual growth rate of 1.05% (*Project 5*), the demand in the year 2005 is estimated at 50 MMGY, 64 MMGY in 2010, and 78 MMGY in 2014. Based on this demonstrated market potential, the current study explores the impact of introducing 40 MMGY of ethanol production capacity into the state.

VI. Ethanol Production Scenario Development

Considerations for Ethanol Production Scenario Development

Having established the magnitude of indigenous feedstock supplies and fuel ethanol market potential in Hawaii, the current study requires further definition of the ethanol production scenario. The possible production scenarios described herein are only a few of the possibilities. Market forces, project developers and other considerations will influence future ethanol production in Hawaii.

The location of the production plant(s) will impact the study results. Because of the unique geography of Hawaii as an island group, the choice of production scenario(s) is significant for the economic impact assessment. Putting the ethanol plant(s) on a single island, for instance, would create an economic impact that might be disproportionately large for that island, compared to the other islands that saw no development (jobs, contracts, services, etc.). The revenues would still be seen on the state level, but indirect impacts might be limited to the one island. In contrast, putting one smaller plant on each of the four larger islands would potentially distribute the indirect impacts more evenly throughout the state.

The number of production plants assumed for the scenario will impact the study results, which are completely dependent on the construction and production cost estimates. Due to economies of scale, a single large facility will generate less overall impact than two or more smaller plants of equivalent production capacity, because the overall costs for construction and operation of a single facility will be less.

The choice of feedstock also impacts the study results. The capital and operating costs for ethanol production will be affected by the technology selected, which is dependent on the feedstock. The use of sugar, MSW or lignocellulosic biomass resources drive different production scenarios.

Kinoshita evaluated the potential sites and came up with three, one each on Oahu, Maui and Hawaii. Since the time of that report, the sugar production plants on Oahu and Hawaii have shut down; Kauai and Maui are the only islands currently producing sugar. No single island produces enough agricultural feedstock for a 40 MMGY plant, although either Kauai or Maui could support a 25 MMGY or smaller plant.

Due to the importance of these considerations, BBI considered many different scenarios for ethanol production in Hawaii before arriving at the scenario described in the next subsection. The scenarios considered, but rejected are described in the following bulleted list.

- A single 40MMGY plant based designed to utilize the organic fraction of MSW on Oahu. Oahu has an adequate supply of organic waste to support a 40MMGY ethanol plant. In addition, Oahu represents approximately two-thirds of the state market for transportation fuels, where blending could occur. Centrally located, blended gas or ethanol would be shipped to the other, less populated islands. This would put the new plant on the most populous island, where population pressure and other land uses might compete for acreage, driving up cost of production. For capacity to grow, the site could be expanded or a second plant could be put on Oahu using a different feedstock.

This scenario has two major problems. 1) It assumes that the entire organic component of Oahu's MSW waste stream be dedicated to ethanol production and does not take into account the effect on the existing H-POWER waste-to-energy plant. Diverting the entire organic waste stream to ethanol production would eliminate over 80% of the primary source of fuel for H-POWER. 2) The use of the organic fraction of MSW implies full use of the feedstock, which is primarily lignocellulosic. Lignocellulosic biomass to ethanol technology is still emerging, and has an inherently higher level of risk.

- A single 40MMGY sugar-based plant designed to utilize the entire current production of sugar and molasses in the state, or utilize sugar produced from land put back into production. Under this scenario, sugar and molasses production would be devoted to ethanol production. There are two options for the location of the production facility.

  The plant could be located on Kauai or Maui where the sugar is produced, most likely Maui because of the proximity of the neighbor islands Lanai, Molokai, and Hawaii. Assuming the site is in Maui County, feedstock from Kauai would have to be shipped to the plant for processing into ethanol. In this scenario, about 1/2 of the feedstock would have to be shipped in, and over 80% of the ethanol shipped from Maui to the other island markets. Under this scenario, for capacity to grow, additional acreage would have to be put back into production for sugar, or, the expansion would be designed to utilize sugarcane trash and lignocellulosic technology. The additional capacity could be a plant expansion or a second facility.

  Alternatively, the site could be on Oahu which is centrally located between Kauai and Maui, and represents about 2/3 of the market for fuel ethanol. Under this scenario, 100% of the feedstock would be shipped from the sugar plants to Oahu for processing. Most of the ethanol product would not have to be shipped; about 30% of the ethanol product would be shipped to the other island markets. For capacity expansion, additional acreage would have to be put back into production for sugar, or, the expansion would be designed to utilize lignocellulosic technology and another indigenous feedstock, either sugarcane trash or the organic fraction of MSW. The additional capacity could be a plant expansion or a second facility.

- Similar to the previous scenario but with two plants comprising 40MMGY: a 25 MMGY plant on Maui to utilize the sugar and molasses produced locally, and a

15 MMGY plant on Kauai to convert the sugar and molasses produced there. Feedstock would not have to be shipped in, but the bulk of the ethanol product would require shipping to other island markets. Under this scenario, for capacity to grow, additional acreage would have to be put back into production for sugar, or, the expansion would be designed to utilize sugarcane trash and lignocellulosic technology. The additional capacity could be a plant expansion or a second facility on one or both islands.

- Establish 40 MMGY of ethanol production capacity based on currently available bagasse and sugarcane trash generated by existing sugar operation. BBI has concluded that using currently available bagasse or sugarcane trash as a feedstock for ethanol production isn't a feasible scenario because 1) it would deprive sugar factories of their fuel source, making sugar production too expensive to continue, threatening the remaining sugar industry, 2) the bagasse feedstock wouldn't even be produced if the sugar product wasn't extracted, and 3) lignocellulosic technology is still emerging. The best option is to start with sugar and switch over to lignocellulosic feedstocks when the technology is commercialized.

- Establish 40 MMGY of ethanol production capability based on lignocellulosic technology and conversion of sugarcane grown specifically for ethanol. The capacity could be established as one centrally-located plant on Oahu close to the principal market, or several plants could be sited on each island in close proximity to the acreage of feedstock. This scenario assumes retired acreage is brought back into production and dedicated to supply cane-for-ethanol, independent of sugar operations. Capacity expansion could only be achieved by increasing acreage dedicated to cane-for-ethanol.

Ethanol Production Scenario for Economic Impact Assessment

Based on this review of feedstock, market and technology considerations, BBI has selected a scenario for further assessment of the economic impacts of ethanol production and use in Hawaii. The economic impact assessment will focus on a scenario where 40 MMGY of fuel ethanol production capacity is established based on three production facilities as follows:

One 15 MMGY MSW-to-ethanol plant on Oahu

The Oahu plant would utilize lignocellulosic biomass to ethanol technology. We have assumed that at this size the operation of the H-Power facility will not be affected. One option for future consideration is to integrate an organic recycling program focused on generating biogas from food processing waste and food residuals. Converting food residuals into biogas would provide energy for the ethanol facility, reducing the purchased energy requirement of the plant and improving the overall economic performance of the integrated facility.

One 15 MMGY Molasses-to-ethanol plant on Maui

The Maui plant would utilize molasses from current sugar operations, supplemented with sugar from existing operations or from new sugar cane production from land put back into production.

One 10 MMGY Molasses-to-ethanol plant on Kauai

This plant would also utilize molasses from current sugar operations, supplemented with sugar from existing operations or from new sugar cane production.

VII. Cost Estimation

Having developed a proposed ethanol production scenario to establish 40 MMGY of ethanol production capacity at three plants in Hawaii, the next task was to develop the construction and operating cost estimates that are the basis for the economic impact assessment. BBI used its proprietary in-house database and financial model, cost and mass balance data from NREL's enzymatic model for conversion of lignocellulosic biomass to ethanol, and pertinent literature reports, to estimate the construction and operating costs associated with each of the three proposed ethanol production plants. The key financial model input parameters used to estimate the capital and operating costs for the three ethanol plants are shown in Table 19.

Construction Costs

15 MMGY Oahu MSW-to-Ethanol Plant

An estimate of the construction cost for the 15 MMGY MSW-to-Ethanol plant proposed for Oahu was developed based equipment cost and mass balance data from the NREL model for enzymatic hydrolysis of lignocellulosic biomass. Scaling factors were applied to adapt the results of the NREL model to the scale required for Oahu. This information was then used in the BBI financial model to estimate the total project cost for the Oahu ethanol plant. The capital cost estimate for the Oahu plant is summarized in Table 20.

15 MMGY Maui Molasses-to-Ethanol Plant

An estimate of the construction cost for the 15 MMGY Molasses-to-Ethanol plant proposed for Maui was developed using the proprietary BBI in-house model for conventional ethanol technology. Scaling factors were applied to adapt the results of the BBI model to the scale required for Maui. The capital cost estimate for the Maui plant is summarized in Table 20.

10 MMGY Kauai Molasses-to-Ethanol Plant

An estimate of the construction cost for the 10 MMGY Molasses-to-Ethanol plant proposed for Kauai was developed using the proprietary BBI in-house model for conventional ethanol technology. Scaling factors were applied to adapt the results of the BBI model to the scale required for Kauai. The capital cost estimate for the Kauai plant is summarized in Table 20.

Table 19 – Ethanol Cost Model Input Parameters

Model Input Parameter	Oahu 15 MMGY MSW Plant	Maui 15 MMGY Molasses Plant	Kauai 10 MMGY Molasses Plant
Denatured ethanol production	15,000,000 gallons per year	15,000,000 gallons per year	10,000,000 gallons per year
Ethanol Plant Cost*	$2.80/gallon of anhydrous ethanol	$2.04/gallon of anhydrous ethanol	$2.28/gallon of anhydrous ethanol
Ethanol yield (anhydrous)	60 gal/BDT (anhydrous)	85 gal/BDT (anhydrous)	85 gal/BDT (anhydrous)
Ethanol selling price	$1.37 per gallon	$1.37 per gallon	$1.37 per gallon
Ethanol transportation cost	$0.05 per gallon	$0.10 per gallon	$0.10 per gallon
Ethanol sales commission	0.00% of sales price	0.00% of sales price	0.00% of sales price
Delivered feedstock price	$20/ton	$50/ton	$50/ton
Lignin residue yield	1303 lb/BDT (50% moisture)	NA	NA
Lignin residue price	$0.00 per ton FOB plant	NA	NA
Lignin residue transportation	$5.00/ton	NA	NA
CO2 sold	No	No	No
CO2 price	$0.00 per ton	$0.00 per ton	$0.00 per ton
Electricity use	1.40 kWh/gallon ethanol	0.80 kWh/gallon ethanol	0.80 kWh/gallon ethanol
Electricity price	$0.10/kWh	$0.10/kWh	$0.10/kWh
Fuel oil use	40,915 BTU/gallon ethanol	38,889 BTU/gallon ethanol	38,889 BTU/gallon ethanol
Fuel oil price	$5.00 per MMBTU	$5.00 per MMBTU	$5.00 per MMBTU
Makeup water use	376.7 gal/BDT	477.5 gal/BDT	533.6 gal/BDT
Makeup water price	$1.00 per 1,000 gallons	$1.00 per 1,000 gallons	$1.00 per 1,000 gallons
Wastewater effluent	241 gal per BDT	341 gal per BDT	341 gal per BDT
Wastewater effluent cost	$2.00 per 1,000 gallons	$2.00 per 1,000 gallons	$2.00 per 1,000 gallons
Solid waste generated	0.0579 ton/BDT	0	0
Solid waste disposal cost	$20/ton	$20/ton	$20/ton
Denaturant use	5% of ethanol sold	5% of ethanol sold	5% of ethanol sold
Denaturant price	$0.90 per gallon	$0.90 per gallon	$0.90 per gallon
Chemicals & enzymes	$0.1781 per gallon of ethanol	$0.08 per gallon of ethanol	$0.08 per gallon of ethanol
Maintenance materials	2.00% of capital cost	2.00% of capital cost	2.00% of capital cost
Property tax and insurance	2% of depreciated plant equip cost	2% of depreciated plant equip cost	2% of depreciated plant equip cost
Number of employees	31	31	22
Employee benefits	35% of salaries	35% of salaries	35% of salaries
% primary debt and terms	60% debt, 8% interest, 10 yr term	60% debt, 8% interest, 10 yr term	60% debt, 8% interest, 10 yr term
% subordinate debt and terms	0% sub debt	0% sub debt	0% sub debt
Land	15 acres at $20,000 per acre	15 acres at $20,000 per acre	10 acres at $20,000 per acre
State Incentives	$0.30 per gallon of ethanol	$0.30 per gallon of ethanol	$0.30 per gallon of ethanol
* Ethanol Plant Cost does not include Owner's costs			

Table 20 – Summary of Ethanol Plant Construction Cost Estimates

Cost Item	Oahu	Maui	Kauai
Ethanol Plant Engineering and Construction			
General Contractor	$23,988,565	$17,485,714	$13,028,571
Major Equipment Cost	$9,995,235	$7,285,714	$5,428,571
Engineering	$3,998,094	$2,914,286	$2,171,429
Contingency	$1,999,047	$1,457,143	$1,085,714
Ethanol Plant Cost	$39,980,941	$29,142,857	$21,714,286
Cost per denatured gallon of ethanol	$2.66	$1.94	$2.17
Owner's Costs			
Inventory - Feedstock	$136,000	$240,000	$160,000
Inventory - Chemicals	$66,000	$67,000	$45,000
Inventory - Ethanol & Lignin	$453,000	$435,000	$290,000
Spare Parts	$300,000	$300,000	$200,000
Startup Costs	$700,000	$700,000	$500,000
Land	$300,000	$300,000	$200,000
Administration Building & Furnishing	$200,000	$200,000	$200,000
Site Development Costs	$500,000	$500,000	$500,000
Tools and Laboratory Equipment	$200,000	$200,000	$200,000
Organizational Costs	$700,000	$700,000	$500,000
Capitalized Fees and Interest	$1,079,000	$787,000	$586,000
Working Capital	$400,000	$291,000	$217,000
Total Owner's Costs	$5,034,000	$4,720,000	$3,598,000
Total Project Cost	**$45,014,941**	**$33,862,857**	**$25,312,286**

Operating Costs

15 MMGY Oahu MSW-to-Ethanol Plant

An estimate of the annual operating cost for the 15 MMGY MSW-to-Ethanol plant proposed for Oahu was developed using the BBI financial model for ethanol production. Energy and utility rates were derived from the NREL model for enzymatic hydrolysis of lignocellulosic biomass. The operating cost estimate for the Oahu plant is summarized in Table 21.

15 MMGY Maui Molasses-to-Ethanol Plant

An estimate of the construction cost for the 15 MMGY Molasses-to-Ethanol plant proposed for Maui was developed using the proprietary BBI financial model for conventional ethanol technology. Scaling factors were applied to adapt the results of the BBI model to the scale required for Maui. The operating cost estimate for the Maui plant is summarized in Table 21.

10 MMGY Kauai Molasses-to-Ethanol Plant

An estimate of the construction cost for the 10 MMGY Molasses-to-Ethanol plant proposed for Kauai was developed using the proprietary BBI financial model for conventional ethanol technology. Scaling factors were applied to adapt the results of the BBI model to the scale required for Kauai. The operating cost estimate for the Kauai plant is summarized in Table 21.

Table 21 – Summary of Ethanol Plant Annual Operating Cost Estimates

Cost Item	Oahu	Maui	Kauai
Annual Production & Operating Expenses			
Feedstocks	$4,809,524	$8,487,395	$5,658,263
Purchased Cellulase Enzymes	$1,454,400	$0	$0
Other Chemicals	$1,115,329	$1,154,286	$769,524
Fuel Oil	$2,980,950	$2,833,333	$1,888,889
Electricity	$2,040,000	$1,165,714	$777,143
Denaturants	$655,714	$655,714	$437,143
Makeup Water	$90,581	$81,059	$60,388
Effluent Disposal	$115,796	$115,796	$77,198
Solid Waste Disposal	$278,379	$0	$0
Direct Labor & Benefits	$978,035	$978,035	$695,750
Total Production Costs	$14,518,708	$15,471,333	$10,364,296
Administrative & Operating Expenses			
Maintenance Materials & Services	$649,296	$473,295	$352,631
Repairs & Maint., Wages & Benefits	$381,915	$381,915	$232,470
Consulting Services	$24,480	$24,480	$24,480
Property Taxes & Insurance	$819,957	$605,915	$455,158
Admin. Salaries, Wages & Benefits	$702,392	$702,392	$662,540
Legal & Accounting /Comm. Affairs	$36,720	$36,720	$36,720
Office/Lab Supplies & Expenses	$36,720	$36,720	$36,720
Travel, Training & Miscellaneous	$35,343	$35,343	$35,343
Total Admin. & Operating Expenses	$2,686,822	$2,296,779	$1,836,061
Principle and Interest	$4,044,693	$3,010,683	$2,259,829
Total Annual Operating Costs	**$21,250,223**	**$20,778,795**	**$14,460,187**

The Year 2 pro forma economic projections for the three scenarios are provided in Table 22.

Please bear in mind the goal of the present study was to determine the economic impact of the proposed ethanol production scenarios; this work was not intended to establish the economic feasibility of the hypothetical cases. The following results from the financial projections are necessarily preliminary and are provided here for informational purposes only. The preliminary economic model results presented here are not intended for use in financial planning or project development.

Table 22 – Year 2 Pro Forma Income Statement

Proforma Income Statement for Year 2

Ethanol Plant Site		**Oahu**		**Maui**		**Kauai**
Denatured Ethanol Production (Gal/Year)		**15,000,000**		**15,000,000**		**10,000,000**
Revenue	**$/Year**	**$/Gal**	**$/Year**	**$/Gal**	**$/Year**	**$/Gal**
Ethanol	$20,196,000	$1.414	$19,431,000	$1.360	$12,954,000	$1.360
Lignin Residue	($791,164)	($0.055)	$0	$0.000	$0	$0.000
Carbon Dioxide	$0	$0.000	$0	$0.000	$0	$0.000
State Producer Payment	$4,200,000	$0.294	$4,200,000	$0.294	$2,700,000	$0.284
Federal Small Producer Tax Credit	$1,428,571	$0.100	$1,428,571	$0.100	$952,381	$0.100
Total Revenue	$25,033,408	$1.752	$25,059,571	$1.754	$16,606,381	$1.744
Production & Operating Expenses						
Feedstocks	$4,809,524	$0.337	$8,487,395	$0.594	$5,658,263	$0.594
Purchased Cellulase Enzymes	$1,454,400	$0.102	$0	$0.000	$0	$0.000
Other Chemicals	$1,115,329	$0.078	$1,154,286	$0.081	$769,524	$0.081
Fuel Oil	$2,980,950	$0.209	$2,833,333	$0.198	$1,888,889	$0.198
Electricity	$2,040,000	$0.143	$1,165,714	$0.082	$777,143	$0.082
Denaturants	$655,714	$0.046	$655,714	$0.046	$437,143	$0.046
Makeup Water	$90,581	$0.006	$81,059	$0.006	$60,388	$0.006
Effluent Disposal	$115,796	$0.008	$115,796	$0.008	$77,198	$0.008
Solid Waste Disposal	$278,379	$0.019	$0	$0.000	$0	$0.000
Direct Labor & Benefits	$978,035	$0.068	$978,035	$0.068	$695,750	$0.073
Total Production Costs	$14,518,708	$1.016	$15,471,333	$1.083	$10,364,296	$1.088
Gross Profit	$10,514,700	$0.736	$9,588,239	$0.671	$6,242,085	$0.655
Administrative & Operating Expenses						
Maintenance Materials & Services	$649,296	$0.045	$473,295	$0.033	$352,631	$0.037
Repairs & Maintenance, Wages & Benefits	$381,915	$0.027	$381,915	$0.027	$232,470	$0.024
Consulting Services	$24,480	$0.002	$24,480	$0.002	$24,480	$0.003
Property Taxes & Insurance	$819,957	$0.057	$605,915	$0.042	$455,158	$0.048
Admin. Salaries, Wages & Benefits	$702,392	$0.049	$702,392	$0.049	$662,540	$0.070
Legal & Accounting/Community Affairs	$36,720	$0.003	$36,720	$0.003	$36,720	$0.004
Office/Lab Supplies & Expenses	$36,720	$0.003	$36,720	$0.003	$36,720	$0.004
Travel, Training & Miscellaneous	$35,343	$0.002	$35,343	$0.002	$35,343	$0.004
Total Administrative & Operating Expenses	$2,686,822	$0.188	$2,296,779	$0.161	$1,836,061	$0.193
EBITDA	$7,827,877	$0.548	$7,291,460	$0.510	$4,406,023	$0.463
Less:						
Interest - Operating Line of Credit	$0	$0.000	$0	$0.000	$0	$0.000
Interest - Senior Debt	$2,094,296	$0.147	$1,575,456	$0.110	$1,177,626	$0.124
Interest - Subordinated Debt	$0	$0.000	$0	$0.000	$0	$0.000
Depreciation & Amortization	$1,950,397	$0.137	$1,435,227	$0.100	$1,082,203	$0.114
Annual Net Earnings Before Income Taxes	$3,783,184	$0.265	$4,280,777	$0.300	$2,146,195	$0.225
Year 2 Net Earnings Before Income Taxes		$3,783,184	$0	$4,280,777	$0	$2,146,195
11-Year Annual Average Net Income		**$3,831,978**		**$4,005,068**		**$2,056,970**
Internal Rate of Return (IRR)		**16.3%**		**27.5%**		**14.0%**

Note - $/GAL figures are based on annual *anhydrous* ethanol production

VIII. Economic Impact

Construction and operation of ethanol plants on Hawaii will create significant economic activity in the state. The ethanol plant construction and operation will involve expenditures, income, employment and payment of taxes. The expenditures of any business become the income of other businesses or individuals, which in turn is re-spent in the economy to provide income for others. Thus the initial economic activity has a multiplier effect that ripples through the economy. Economic impact analysis is an analytical method that provides a measure of the economic effects of an activity within a specified region.

BBI estimated the economic impacts of ethanol production on Hawaii using indigenous feedstocks to produce 40 million gallons of fuel ethanol annually for the local gasoline market. The proposed ethanol facilities would use approximately 238,000 BDT of MSW on Oahu, 168,000 BDT of molasses on Maui and 112,000 BDT of molasses on Kauai. The three ethanol plants would produce 15, 15 and 10 million gallons of denatured ethanol annually.

The final demand impact, household earnings impact and job impacts presented here were estimated by applying the final demand multipliers calculated by the U.S. Bureau of Economic Analysis for ethanol plants in the United States. The resulting economic impacts are reported as estimated changes in the economic base (final demand), income and jobs resulting from ethanol production on Hawaii.

Analysis Inputs

The inputs required for the economic analysis are the ethanol project direct impacts for both the construction phase and operations phase of the project. This distinction is important because the construction phase impacts are a one-time event while the operations phase impacts are ongoing impacts. Construction phase impacts for the ethanol plant are assumed to occur over a 14-month construction and startup period, while the operations phase will normally last many years and is characterized by expressing the impacts on an annual basis. This distinction is important because the construction and operations impacts are usually very different in character as well as magnitude. Construction may bring temporary workers into the area that take up temporary residences near the site and therefore have a different impact than the permanent workers and contractors of the operations phase.

Table 23 lists the economic impact analysis inputs for each of the proposed Hawaii ethanol plants based on the estimated cost to construct and operate the proposed ethanol plants. The construction and operating costs in the following table are discussed in the previous section of this report.

Operating expenditures include all payments made directly by the ethanol plant owner. These payments include all production and administrative costs projected for the first full year of commercial operation for the project.

Table 23 – Economic Impact Analysis Inputs for Hawaii Ethanol Plants

Construction Phase Impacts	Oahu	Maui	Kauai
Ethanol Plant Capital Cost (millions)	$45	$34	$25
Operations Phase Impacts			
Operating Expenditures (millions)	$21	$21	$14
Ethanol Plant Direct Jobs	31	31	22

Results

The economic impact analysis results for the three hypothetical Hawaii ethanol plants are presented in the table below. Please note that these results are based on economic multipliers derived from the U.S. Bureau of Economic Analysis for output, earnings, and employment for ethanol plants in the U.S.

There are two primary measures of economic impact presented in Table 24, which should be considered separately. These are income and employment. Income and employment impacts include both indirect and induced impacts. The results are separated into the construction phase and operations phase impacts. Construction phase and operations phase impacts should be considered separately and should not be added together. Although the impacts are expressed in the same manner, they are not directly comparable.

15 MMGY Oahu MSW-to-Ethanol Plant

The construction spending associated with building the 15 MMGY ethanol plant on Oahu will add approximately $109 million to the final demand in the local economy and generate $35.5 million in new household income and provide for more than 1,108 direct and indirect jobs during construction. These are one-time impacts spread over the approximately 14-month construction period.

During operations the Oahu plant will create approximately 257 new jobs in Hawaii (the impacts are estimated for the state of Hawaii, not each island). New household income will be approximately $7.5 million annually and the final demand impact will be approximately $42 million each year.

15 MMGY Maui Molasses-to-Ethanol Plant

The construction spending associated with building the 15 MMGY ethanol plant on Maui will add approximately $82 million to the final demand in the local economy and generate $26.7 million in new household income and provide for more than 833 direct and indirect jobs during construction. These are one-time impacts spread over the approximately 14-month construction period.

During operations the Maui plant will create approximately 252 new jobs. New household income will be approximately $7.3 million annually and the final demand impact will be approximately $41 million each year.

10 MMGY Kauai Molasses-to-Ethanol Plant

The construction spending associated with building the 10 MMGY ethanol plant on Kauai will add approximately $61 million to the final demand in the local economy and generate $19.9 million in new household income and provide for more than 623 direct and indirect jobs during construction. These are one-time impacts spread over the approximately 14-month construction period.

During operations the Kauai plant will create approximately 176 new jobs. New household income will be approximately $5.1 million annually and the final demand impact will be approximately $29 million each year.

Table 24 – Economic Impacts of Ethanol Production in Hawaii

Construction Phase Impacts	**Oahu**	**Maui**	**Kauai**
Ethanol Plant Capital Cost (millions)	$45.0	$33.9	$25.3
Final Demand Impact (millions)	$109.2	$82.2	$61.4
Earnings Impact (millions)	$35.5	$26.7	$19.9
Employment Impacts (indirect jobs)	1,108	833	623

Operations Phase Impacts	**Oahu**	**Maui**	**Kauai**
Operating Expenditures (millions)	$21.3	$20.8	$14.5
Final Demand Impact (millions)	$42.0	$41.1	$28.6
Earnings Impact (millions)	$7.5	$7.3	$5.1
Employment Impacts (direct jobs)	31	31	22
Employment Impacts (indirect jobs)	226	221	154
Total Jobs	257	252	176

Note: The above results are based on economic multipliers derived from the U.S. Bureau of Economic Analysis for output, earnings and employment for ethanol plants in the U.S.

IX. Macroeconomic Evaluation of Proposed Rules for Blending of Ethanol into Gasoline in Hawaii

This component of the study determines the capital and operating cost impacts of blending fuel grade ethanol with gasoline in the State of Hawaii at a macroeconomic level. For this study, ethanol is assumed to be manufactured in Hawaii and blended with gasoline at 10% by volume. Several cases were investigated with current and potential regulations and alternative market volume scenarios. It is concluded that, with the assumptions used, both refiners and consumers will be able to maintain their economic status when requiring ethanol blending.

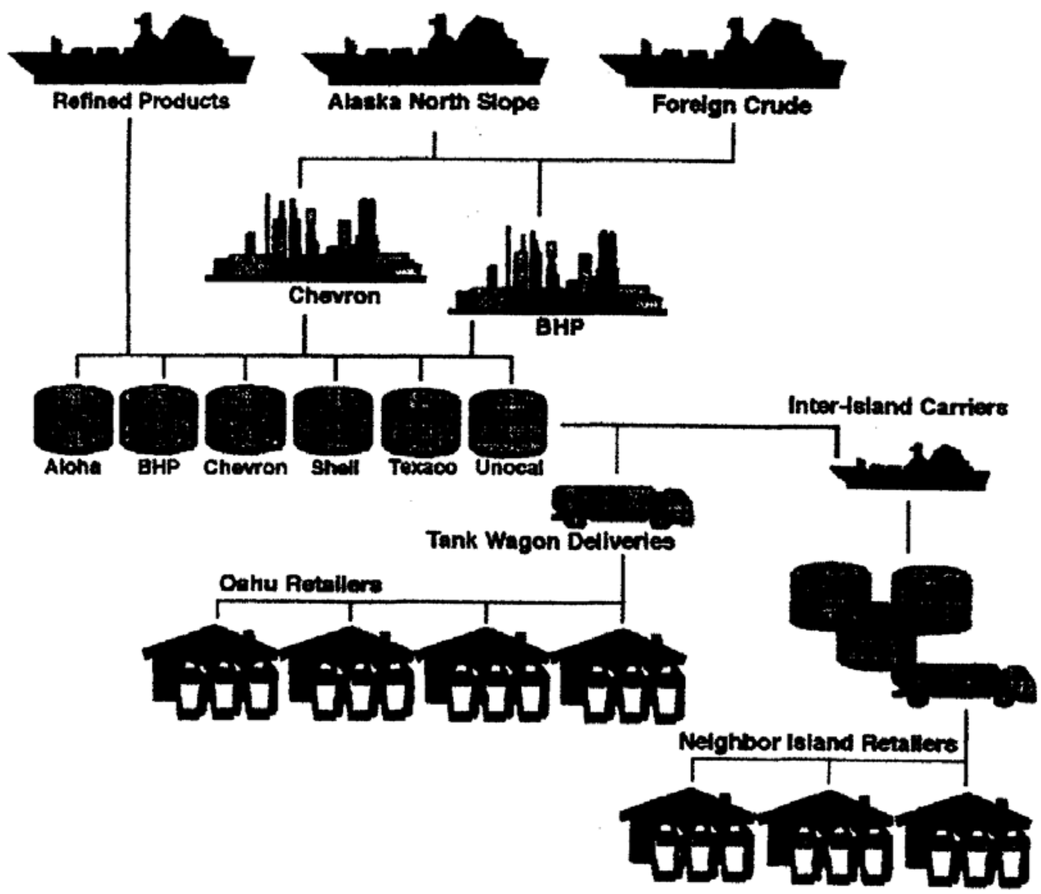
Ethanol Blending Locations

Figure 1 shows a simplified version of the gasoline distribution system in Hawaii. Crude oil is imported into Hawaii and is processed at the two refineries located near Barbers Point on Oahu. Some refined products are imported and mixed in tankage with the refinery products. Tank wagon trucks handle fuel deliveries to retailers on Oahu, while inter-island carriers deliver products from Barbers Point tankage to distribution points on other islands. Tank wagon trucks handle fuel deliveries to retailers on these other islands from these distribution points.

There are two main options for blending ethanol into gasoline in Hawaii – either near the refineries where all the gasoline enters the state or at the distribution terminals on each island. If blended at the refineries, the refiners will need added tankage at Barbers Point for ethanol supply and modified blending equipment and procedures. Shippers and gasoline blenders may need to modify equipment and procedures for the different properties of an ethanol/petroleum blend as compared with the pure petroleum product that they currently handle.

If the ethanol is manufactured on an island other than Oahu, shippers will have to transport the ethanol to the Barbers Point site. If the ethanol is added at each island, blenders will need to add additional ethanol storage tankage and blending equipment and to revise operating procedures, while shippers will need to handle the transportation of ethanol to each island's blending site. Since most of the population and fuel use is on Oahu, less than 1/4 of the gasoline product is carried to other islands.

Figure 1 – Gasoline Distribution System in Hawaii



Source: The Energy Division, State of Hawaii Department of Business, Economic Development & Tourism

Note: Most Hawaii gasoline and diesel starts out as crude oil brought in by tankers. Two local refineries process the crude oil into the products sold by various companies to gas stations.

Since the volume of gasoline sold in the State of Hawaii is about 10,000,000 barrels or 400,000,000 gallons per year and the goal is to blend ethanol at 10% by volume, the total amount of ethanol blended will be about 40,000,000 gallons per year in either blending case. Since all the gasoline supply is funneled through the one site at Barbers Point, the simplest system would blend ethanol into gasoline at this site.

Locating the ethanol blending at Barbers Point can minimize the number of ethanol storage tanks and the people who must do the ethanol blending. Calculations can be made to show that storing that quantity of ethanol in several smaller tanks on multiple islands requires more capital than blending at a single location. The only disadvantage of this case over the multiple site blending case is that the inter-island carrier vessels will have to be run “dry.” The reason for this is that gasoline and water are not very soluble in each other, so it is possible to have a layer of water contamination located at the bottom of a gasoline storage tank. Tanks are designed so that this contamination is not delivered to the customers.

When ethanol is added to gasoline, the high solubility of ethanol with water affects the blend, so that, if less than about 0.5 volume % water is present below the blend, the water will dissolve in the mixture. If more than 0.5% water is present, the ethanol will tend to separate out into the water phase. This will affect the octane and volatility of the remaining hydrocarbon-rich gasoline phase.

To prevent this from happening, the water contamination that may be present in the system will have to be removed to “dry” the system prior to ethanol introduction. This will incur a one-time charge to remove this water contamination and to establish proper procedures to keep water from entering the system, for instance when a tank wagon is filling an underground storage tank at a retail outlet while it is raining. Pump seals and piping may also have to be checked for compatibility with gasoline/ethanol mixtures.

The cost for converting and “drying” a typical retail outlet has been estimated in the $300 to $700 range. The cost for drying a tank or carrier will, of course, be higher, and these costs will be considered later in this section of this report. In either case, assuming in-line blending of ethanol into the gasoline base stock, the gasoline tanks at both Barbers Point and the remote islands and all tank wagon delivery trucks will have to be “dried” in order to blend ethanol into gasoline in Hawaii.

Ethanol Blending Scenarios

Petroleum refiners will need to remove light gasoline components, like butanes and pentanes, from current blend recipes in order to accommodate the relatively high vapor pressure that results when ethanol is blended with gasoline at 5 to 10 percent by volume ethanol (ethanol alone does not have a high vapor pressure). This may require modification of distillation and storage facilities, as well as finding markets for the removed components. Several cases are considered below to meet these requirements.

In this report, it is assumed that the existing gasoline pool of blendstocks contains 5 volume % butane, at least 5 volume % light naphtha (also called light straight run, LSR, or light virgin naphtha, LVN), and other components such that the mixture meets maximum Reid Vapor Pressure (RVP) and minimum Road Octane. These assumptions are usually met when refiners try to meet customer requirements at the lowest processing costs. The assumed simplified pool composition is shown in Case 1 of Table 25.

Table 25 – Assumed Cases for Blending Ethanol into Gasoline in Hawaii

Component	Volume 10^6 gal/yr	RVP psi	Octane RM/2	Weight 10^3 T/yr	LHV 10^9Btu/yr
Case 1	Existing Blend				
Butane	24	51.5	92	58	-2295
LVN	16	12.0	61	43	-1685
Other Gasoline Base	360	8.8	89	1206	-45828
Total	400	11.5	88.2	1308	-49807
Content per gallon (# or Btu)				6.54	-124518
Case 2	Add ethanol, waive RVP limit				
Ethanol	44	18.0	113	145	-3454
Butane	24	51.5	92	58	-2295
LVN	14	12.0	61	38	-1464
Other Gasoline Base	360	8.8	89	1206	-45828
Total	442	12.1	90.8	1447	-53041
Content per gallon (# or Btu)				6.55	-120027
Case 3	Add ethanol, keep RVP limit				
Ethanol	43	18.0	113	141	-3375
Butane	18	51.5	92	43	-1675
LVN	14	12.0	61	38	-1469
Other Gasoline Base	360	8.8	89	1206	-45828
Total	434	11.5	90.7	1428	-52348
Content per gallon (# or Btu)				6.57	-120485
Case 4	Replace lights with Ethanol, keep RVP				
Ethanol	41	18.0	113	135	-3211
Butane	8	51.5	92	19	-765
LVN	0	12.0	61	0	0
Other Gasoline Base	360	8.8	89	1206	-45828
Total	409	10.6	91.6	1360	-49803
Content per gallon (# or Btu)				6.65	-121799

The gasoline market is growing in Hawaii, so one way to increase the supply is to add ethanol to the existing gasoline pool. Case 2 in Table 25 shows the effect of adding denatured ethanol blended at 10 volume % to the existing gasoline pool. In this study, it is assumed that the denaturant used for ethanol is light naphtha supplied by the refiners from the gasoline pool. The ethanol producer's cost is usually minimized when the maximum denaturant content is used, so that limit (5 gal in 100 gal of pure ethanol) is used here. Case 2 increases the gasoline volume by 10%, but fails the RVP limit by 0.6 psi, while exceeding the octane limit by 2.6 ON.

There are other gasoline specifications that are not considered here, like temperature limits at specified volume recoveries, like T_{20} and T_{50}, but it is assumed that adjustments can be made in refinery processing to meet these additional specifications. In certain areas that are not designated as an ozone non-attainment area, federal regulations are applicable that allow oxygenated gasoline to meet the RVP specification if the base gasoline meets the specification and the ethanol-containing blend is no more than 1.0 psi higher than that. If this were the case in Hawaii, the Case 2 gasoline would be valid for consideration. Case 3 in Table 25 shows a gasoline blend where denatured ethanol has been added to the pool at 10 volume % and normal butane has been removed until the mixture also meets the RVP limit. A fuel market would have to be found for the butane removed.

Table 25 also shows that some additional features of ethanol-gasoline blends are that the blends are denser (more weight per volume) and have lower volumetric heating value (less energy delivered per gallon). Case 4 considers a gasoline blend containing 10 volume % ethanol that delivers the same fuel content to the consumers as the Case 1. In this case, it is assumed that the light naphtha content has been removed and the needed volume is provided by butane so that the volatility is near that of Case 1. With this assumption, RVP is still 0.9 psi below the maximum specification. A fuel market would have to be found for the light naphtha removed that is not needed as ethanol denaturant.

Another option to provide the same amount of gasoline product with ethanol addition would be to reduce the crude supply to the refinery by an appropriate amount to make less gasoline range stocks in a similar ratio to Case 3 and to adjust refinery processing conditions to provide relatively less gasoline to mid-distillate products (lower G/D ratio) so that the existing distillate product slate could also still be produced. This alternative was not pursued since it would make less use of existing refinery processing equipment. To make up for lower usage of the capital that refiners have already spent would require adding pro-rata costs to the remaining product slate. However, refinery processing costs do generally decrease as G/D decreases, so this may be a lower priority option to consider.

Refiners Capital and Operating Costs for Ethanol Blending & Use

Table 26 shows the additional capital or one time costs that would be incurred by the refiners for these four cases. In some cases, existing locations may be limited in areas where new facilities may be constructed, so novel concepts, like tankage on barges may have to be considered. If so, the capital costs for tankage may be somewhat higher than presented here.

Table 26 – Refiners Capital or One-Time Costs for Ethanol Blending

		Case 1			Case 2			Case 3			Case 4	
					Add Ethanol			Add Ethanol			Replace lights	
		Current Case			Waive RVP			Keep RVP limit			with Ethanol	
		Quantity	MM$	No	Quantity	MM$	No	Quantity	MM$	No	Quantity	MM$
Ethanol tankage	Bbl	0	0.0	2	28,702	1.0	2	28,050	1.0	2	26,680	0.9
Blending facilities	Bbl/yr	0	0.0	2	523,810	0.5	2	511,905	0.5	2	486,905	0.5
Butane tankage	Bbl	0	0.0	0	0	0.0	2	4,224	1.3	3	6,958	2.8
Ethanol revamp	Stations		0.0		2,593	1.3		2,549	1.3		2,399	1.2
Tankage/ship revamp	Locations		0.0	20		0.2	20		0.2	20		0.2
Total			0.0			3.0			4.3			5.7

Refinery operations normally keep blend stocks stored separately so that they can be combined to meet all gasoline specifications at minimal cost and maximum usage of available stocks. It is assumed that the Hawaiian refineries follow this procedure so that no additional capital or operating costs are incurred for isolation and storage of normal butane of the light naphtha streams. However, capital costs are needed for tankage to store an assumed twenty days supply of ethanol for blending. This is consistent with the 10-15 days of working capacity assumed for ethanol plant product. Two tanks are assumed for ethanol storage in the 25-30,000 barrel range so that one could be devoted to each refinery supplier, if desired.

Capital is also needed to revamp or provide in-line blending of the ethanol with other gasoline blend stocks. Capital investment was provided to store twenty days supply of product (butane or naphtha) for fuel or denaturant sales, since these would be in addition to the current refinery product slate. Three butane tanks were assumed in Case 4 to keep the size below 10,000 barrels each. One-time costs were also estimated for revamping service stations and drying refinery blending, tank wagon, inter-island transport, and remote island storage tanks. The estimated one-time costs for allowing ethanol blending amount to $3-6 million, depending on the rules and market assumptions used.

Because refinery blending operations are highly automated, changes from existing blending procedures to include ethanol should not increase the operating costs for the refiners, other than the added capital and inventory costs. Shipping costs are sometimes prorated per ton-mile shipped, so the added density of the ethanol-containing product might incur added delivery costs. However, loading, travel, and unloading times, as in this case, sometimes dominate short-range hauling costs. The small increase in fuel density is not expected to affect the loaded capacity of the tank wagon and thus not increase product per-volume delivery costs. There will be additional volume needed to supply the same amount of fuel content to the consumer, but this is included in the analysis here.

By-Product Markets and Value

It was assumed for this study that light naphtha would be sold to the ethanol producers at $0.02 per gallon cheaper than gasoline price. The ethanol producer will then blend it into the pure ethanol product and sell it back to the refiners at the higher price of ethanol. By-product butane and naphtha were assumed to be sold for fuel value (80% of crude oil value or $3.72 per million Btu. In the economics and personnel analyses, marketing was included at 10 hours per million gallons of product.

Impact on Employment

Table 27 shows the additional personnel that were estimated to be needed for the cases studied over Case 1 levels. The assumptions that went into this result are that maintenance labor was 1% per year of capital, tank wagon delivery time was three hours with an 8,000 gallon capacity, marketing and overhead for sales was 10 hours per million gallons of product, and paperwork was needed to account for ethanol blending at 0.5 hour per refinery tank of ethanol (25-3000 barrels). The added requirement was 8-9 full-time persons, mostly for delivery of the additional products and by-products.

Refinery and Consumer Macroeconomics for Ethanol Blending

The upper half of Table 28 shows a macroeconomic view of the four cases considered from the refiners' point of view. Revenues will come from gasoline sales at $0.89 per gallon, denaturant at $0.87 per gallon, and butane and light naphtha at fuel value. Feedstock was assumed to be valued at a crude oil price of $27 per barrel plus a crack spread (average price of products less price of crude oil) of $3 per barrel with a 5% loss of volume on processing. Other costs included were ethanol purchase at a rational price of $1.37 per gallon (with a $0.10 per gallon margin improvement allowance). A credit was given for improvement in the octane value of the pool at $0.30 per barrel octane number. Costs were also included for maintenance labor and materials, property taxes, and insurance at 4% per year of capital cost, and personnel from Table 27 at $80,000 per year costs for maintenance and $50,000 per year for clerical personnel, inclusive of benefits.

Income taxes were assumed to be at 35% of net revenue. Then tax credits were added for ethanol blending amounting to $0.54 per gallon of ethanol from the Federal government and 4% of gasoline price from the State of Hawaii. Also allowance was added for after-tax recovery of capital expenditures with 3% inflation per year, 12% return on capital per year for the refiners, 20 year project life, 10 year depreciable life, one year construction period, Capital Cost Recovery System depreciation (double declining balance, switching to straight line when advantageous), indirect construction cost of 4%, and imputed interest during construction at 6% per year. These assumptions result in a cost of capital of 20% per year. Table 28 shows that the net return to the refiners is $36 million per year for Case 1, $72 million per year for Case 2, $65 million per year for Case 3, and $46 million per year for Case 4.

Table 27 – Personnel Estimates for Blending Ethanol into Gasoline

Component	Scaling Basis	Case 1 Current Case Quantity	Case 1 Current Case Person Hours/yr	Case 1 Current Case Cost MM$/yr	Case 2 Add Ethanol Waive RVP Quantity	Case 2 Add Ethanol Waive RVP Person Hours/yr	Case 2 Add Ethanol Waive RVP Cost MM$/yr	Case 3 Add Ethanol Keep RVP limit Quantity	Case 3 Add Ethanol Keep RVP limit Person Hours/yr	Case 3 Add Ethanol Keep RVP limit Cost MM$/yr	Case 4 Replace lights with Ethanol Quantity	Case 4 Replace lights with Ethanol Person Hours/yr	Case 4 Replace lights with Ethanol Cost MM$/yr
Fuel blending			0	0.0		0	0.0		0	0.0		0	0.0
Truck gasoline to stations	10^6 gal/yr	0	0	0.0	42	15714	2.4	34	12929	1.9	9	3337	0.5
Truck butane fuel	10^6 gal/yr	0	0	0.0	0	0	0.0	6	2428	0.4	16	6000	0.9
Truck denaturant	10^6 gal/yr	0	0	0.0	2	786	0.1	2	768	0.1	2	730	0.1
Truck LVN fuel	10^6 gal/yr	0	0	0.0	0	0	0.0	0	0	0.0	14	5270	0.8
Maintenance on equipment	MM$	0.0	0	0.0	3.0	758	0.0	4.3	1075	0.0	5.7	1413	0.1
Sales & OH	10^6 gal/yr	0	0	0.0	44	440	0.0	43	430	0.0	41	409	0.0
Ethanol bookkeeping	tank fill/yr	0	0	0.0	40	20	0.0	37	19	0.0	37	19	0.0
Total			0	0.0		17718	2.5		17648	2.5		17178	2.4
Full- time person equivalent			0			8.9			8.8			8.6	

Table 28 – Macroeconomic Summary of Ethanol Blending

Refiners' Cost Analysis	Scaling	Current Case		Add Ethanol Waive RVP		Add Ethanol Keep RVP limit		Replace lights with Ethanol	
	Basis	Quantity	MM$/yr	Quantity	MM$/yr	Quantity	MM$/yr	Quantity	MM$/yr
Gasoline Sales	10^6 gal/yr	400	356.0	442	393.3	434	386.7	409	363.9
Denaturant Sales	10^6 gal/yr	0	0.0	2	1.8	2	1.8	2	1.7
Butane Fuel Sales	10^6 gal/yr	0	0.0	0	0.0	6	2.3	16	5.7
LVN Fuel Sales	10^6 gal/yr	0	0.0	0	0.0	0	0.0	14	5.5
Gasoline + Byproduct Revenue		400	356.0	444	395.1	443	390.8	441	376.8
Crude Oil Purchase	10^6 gal/yr	420	270.0	420	270.0	420	270.0	420	270.0
Crack Spread	10^6 gal/yr	420	30.0	420	30.0	420	30.0	420	30.0
Ethanol purchase	10^6 gal/yr	0	0.0	44	60.1	43	58.7	41	55.9
Octane pool increase credit	10^6 BON/yr	0	0.0	115	-40.2	98	-34.3	52	-18.1
Maint matl,Taxes,Insur, &OH	MM$	0	0.0	3.0	0.1	4.3	0.1	5.7	0.2
Personnel costs for Ethanol			0.0		2.5		2.5		2.4
Gasoline + Byproduct Costs			300.0		322.5		327.0		340.3
Net Revenue			56.0		72.6		63.8		36.5
Income Taxes			-19.6		-25.4		-22.3		-12.8
Federal tax credit	10^6 gal/yr	0	0.0	44	23.8	43	23.2	41	22.1
State tax credit	10^6 gal/yr	0	0.0	44	1.6	43	1.5	41	1.5
Capital recovery & profit	MM$	0	0.0	3.0	-0.6	4.3	-0.9	5.7	-1.1
Gasoline + Byproducts Net Revenue									
after taxes & capital costs			36.4		71.9		65.4		46.1
"/gasoline sales gallon	$/gal		0.09		0.16		0.15		0.11
Net Increase to refiners	$/gal		Base		0.07		0.06		0.02
Retail cost			$/gal		$/gal		$/gal		$/gal
Refiners Gate Gasoline Sales			0.89		0.89		0.89		0.89
Transport to retail station			0.05		0.05		0.05		0.05
Retail margin			0.06		0.06		0.06		0.06
Federal Excise Tax			0.09		0.09		0.09		0.09
State fuel tax			0.16		0.16		0.16		0.16
City & County of Hawaii fuel tax			0.17		0.17		0.17		0.17
Retail Total			1.42		1.42		1.42		1.42
Gasoline Btu/gal			-124518		-120027		-120485		-121799
Gasoline Fuel Content, 10^12 Btu/yr			49.8		53.0		52.3		49.8
Cost, $ per gasoline equivalent gallon			1.42		1.47		1.47		1.45
Theoretical increase to consumers [1]	$/gal		Base		0.05		0.05		0.03

Note 1. The actual change in automobile mileage and the increased cost to consumers is very difficult to measure when E10 is used. The values shown are theoretical only and do not include potential improvement in mileage due to more complete combustion and other factors.

This amount to $0.09 per gallon for Case 1, $0.16 for Case 2, $0.15 for Case 3 and $0.11 for Case 4. Thus refinery profitability is increased for all cases, but is best for Case 2. There is only $0.01 per gallon penalty for keeping the RVP limit over Case 2. There is only a negligible $0.02 value to ethanol blending if the market volume does not increase (Case 4).

The consumer's view of these cases is shown in bottom half of Table 28. The gasoline consumer will be affected by the cost of production and, to a lesser degree, the performance of the fuel. To an assumed $0.89 rack price of gasoline must be added costs for transport to the retail station, profit margin at the station, and Federal, State and local taxes. Since the refiners' costs are no higher per gallon with ethanol blending, this could result in the same cost to the consumer for these cases.

The heating content of ethanol-containing blends is typically less than conventional gasoline, so theoretically more gallons will have to used for the same vehicle miles. In reality there are so many variables that relate to fuel mileage, such as the season, the weather, how the vehicle may be driven, etc., that small changes in fuel mileage are difficult to measure on the road. Every vehicle is somewhat different in drivability characteristics as well. Some carbureted vehicles that run rich may actually experience an increase in fuel economy when using ethanol blends. The most current information derived from controlled environmental testing is that on fuel injected vehicles, fuel mileage may decrease by approximately two percent. A vehicle that averages 30 miles per gallon on the highway would average 29.4 miles per gallon using ethanol-blended fuel. The effective cost to the consumer shown in Table 28 may be overstated by about 50%. Making the Federal, State, and local taxes based on energy content rather than the gallon volume would help equalize the potential cost differential.

Conclusions

Several cases were investigated with current and potential regulations and alternative market volume scenarios.

Since all the gasoline supply is funneled through the one site at Barbers Point, the simplest system would be to blend ethanol into gasoline at this site. Assuming in-line blending of ethanol into the gasoline base stock, the gasoline tanks at both Barbers Point and the remote islands and all tank wagon delivery trucks will have to be "dried" in order to blend ethanol into gasoline in Hawaii.

The estimated one-time costs for ethanol blending amount to $3-6 million, depending on the rules and market assumptions used. The cost for converting and "drying" a typical retail outlet has been estimated in the $300-700 range.

Locating the ethanol blending at Barbers Point can minimize the number of ethanol storage tanks and the people who must do the ethanol blending. The added labor requirement was 8-9 full-time persons, mostly for delivery of the additional products and by-products.

Refinery profitability is increased for all cases considered here, but is best for Case 2. There is only $0.01 per gallon penalty for keeping the RVP limit over Case 2. There is only a negligible $0.02 value to ethanol blending if the market volume does not increase (Case 4).

The gasoline consumer will be affected by the cost of production as well as the performance of the fuel. Since the refiners' costs are no higher per gallon with ethanol blending, this could result in the same cost to the consumer for these cases. However, the heating content of ethanol-containing blends is less, so more gallons will have to used for the same vehicle miles. This results in a theoretical cost (based on ethanol and gasoline energy content only) to the consumer of an additional $0.05 per gallon in Cases 2 & 3, and $0.03 per gallon in Case 4. The actual cost if difficult to predict, but may be 50% less than the theoretical costs.

It is concluded that, with the assumptions used, both refiners and consumers will be able to maintain their economic status when requiring ethanol blending.

X. Conclusions

With the drastic reduction in sugar production in Hawaii over the past decade, sugar-based feedstocks for ethanol production are no longer plentiful and are now limited to sugar cane production on Maui and Kauai only. Starch based feedstocks are not available in any significant quantities in Hawaii. Lignocellulosic feedstocks are the most plentiful in the state, but the technology to produce ethanol from these feedstocks has yet to be commercialized. A combination of MSW and molasses feedstocks was selected for the economic impact study.

If 10% ethanol blends are used in gasoline throughout Hawaii, the resulting ethanol market demand will be about 40 MMGY. Gasoline use is projected to grow at about one percent per year.

Total constructions costs are estimates to be $104 million for the three ethanol plants proposed for Oahu, Maui and Kauai with a combined capacity of 40 MMGY. The resulting total economic impact during construction is estimated to be $253 million. Total jobs created during construction are approximately 2,564 with an increase in personal income of $82 million.

Following construction, the combined annual operating costs for the three ethanol plants are estimated to be $57 million, creating $112 million in total annual economic activity. Direct employment at the three ethanol plants is estimated to be 84 employees and indirect and induced jobs are estimates to be 602 for a total increase in jobs of 686.

There are two main options for blending ethanol into gasoline in Hawaii – either near the refineries where all the crude oil and gasoline enters the state or at the distribution terminals on each island. Since all the gasoline supply is funneled through the one site at Barbers Point, the simplest system would be to blend ethanol into gasoline at this site. Assuming in-line blending of ethanol into the gasoline base stock, the gasoline tanks at both Barbers Point and the remote islands and all tank wagon delivery trucks will have to be “dried” in order to blend ethanol into gasoline in Hawaii.

The estimated one-time costs for allowing ethanol blending amount to $3-6 million, depending on the rules and market assumptions used. The cost for converting and “drying” a typical retail outlet has been estimated in the $300-700 range.

Locating the ethanol blending at Barbers Point can minimize the number of ethanol storage tanks and the people who must do the ethanol blending. The added labor requirement was 8-9 full-time persons, mostly for delivery of the additional products and by-products.

Refinery profitability is increased for all cases, but is best for Case 2. There is only $0.01 per gallon penalty for keeping the RVP limit over Case 2. There is only a negligible $0.02 value to ethanol blending if the market volume does not increase (Case 4).

The gasoline consumer will be affected by the cost of production as well as the performance of the fuel. Since the refiners' costs are no higher per gallon with ethanol blending, this could result in the same cost to the consumer for these cases. However, the heating content of ethanol-containing blends is less, so more gallons will have to used for the same vehicle miles. This results in a theoretical cost (based on ethanol and gasoline energy content only) to the consumer of an additional $0.05 per gallon in Cases 2 & 3, and $0.03 per gallon in Case 4. The actual cost if difficult to predict, but may be 50% less than the theoretical costs.

It is concluded that, with the assumptions used, both refiners and consumers will be able to maintain their economic status when requiring ethanol blending.

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