An Assessment of Bioenergy in an Island Economy

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The potential of bioenergy to meet global, national, and regional greenhouse gas reduction and energy security goals is of crucial inquiry. As a small, open economy with clearly defined borders, Hawai'i is an ideal modeling case-study to better understand the economic and environmental implications of various bioenergy technologies. Hawai'i is an island chain that is currently over 90% dependent on imported fossil fuel sources to meet its energy needs. Bioenergy has been particularly appealing as an energy solution for Hawai'i because it is easily transportable between islands, from islands with a larger agricultural potential to islands with a larger urban core. As such, the State mandated in 2006 that motor fuels be blended with a 10% ethanol content. In addition, there is a $12 million ethanol plant investment credit, a 30% ethanol production subsidy, and a 100% investment tax credit with full payback over a five-year period. Even with aggressive State commitment of resources, no local ethanol production has materialized.

This study creates a Computable General Equilibrium (CGE) model of Hawai'i's economy to assess an increase in agricultural production for bioenergy purposes to meet the States' 10% ethanol-blending mandate for motor fuels. For this purpose, production costs for ethanol are estimated in order to better understand the barriers of local production. To provide better policy-making tools on whether this is a good use of State resources, economic indicators such as gross state product, job creation, and household welfare are also assessed.

1. Introduction

Rising and volatile world oil prices have brought energy to the forefront of national and local policy-making. Hawai‘i is the most oil-dependent State in the U.S., meeting nearly 90 percent of its energy needs are met through petroleum burning (EERE, 2008). As part of a national effort to increase renewable energy use, the U.S. Department of Energy launched an initiative to make Hawai‘i a national leader in renewable energy. The Federal-State partnership, launched in January 2008, is named the Hawai‘i Clean Energy Initiative (HCEI). The goal of HCEI is to attain 70% clean energy by 2030. As part of a complementary effort, the State of Hawai‘i has also committed to reduce its greenhouse gas emissions to 1990 levels by the year 2020.

The development of a local bioenergy sector is often seen as a means of “revitalizing” rural communities as well as a form of import-substitution development (De La Torre Ugarte et al., 2007; OECD, 2008). Bioenergy has been particularly appealing as an energy solution for Hawai‘i because it is easily transportable between islands, from islands with a larger agricultural potential to islands with a larger urban core. The Hawai‘ian Islands are a series of small, independent electrical grids and thus no power-sharing occurs between the islands. Biomass is seen as a potential means of storing energy, adding a source of firm power to support other intermittent renewable electricity sources such as wind and solar photovoltaic. In addition, biomass-to-liquid fuels offer the potential of increasing on-island transportation fuel production and decreasing imported fossil fuels.

Although there are many policies that support biofuel production, both at the federal and state level, almost no biofuels are currently in prodution in Hawai‘i. In 1994, a 10% ethanol-blending requirement for motor fuel was introduced and was later implemented in 2006. Although plans for a number of local ethanol production facilities have been introduced, none have materialized. The blending mandate has to date been met with imported sources of ethanol.

The State is currently undergoing a Bioenergy Master Plan in order to reassess its commitment to biofuels. As part of this effort, this study was completed to gain a better understanding of the economic impacts and barriers to biofuel production in Hawai‘i. This study assesses the economic impacts to the State of Hawai‘i’s economy of switching from imported ethanol to meet the States’ alternative liquid fuel targets to growing biomass and processing ethanol locally.

To analyze the production of ethanol from sugarcane, a Computable General Equilibrium (CGE) model of Hawai‘i’s economy, hereby called the Hawai‘i Bioenergy Model, representing macro and sector-level inter-linkages, was created. The model utilizes the 2005 State Input-Output Study for Hawai‘i as the primary data source (DBEDT, 2008). The 2005 Input-Output table is an excellent year in which to calibrate for this analysis because the price of world oil was similar to today: roughly $40/barrel. The 2005 Hawai‘i Input-Output Table outlines the production processes of 68 sectors in Hawai‘i’s economy and 11 agents of final demand, including households, visitors, state and local government, federal military, and exports. Agricultural industries such as sugarcane production and energy industries such as petroleum manufacturing are detailed within this dataset.

The model is designed to better understand the economic impacts, at both the macro- and sector-levels of a growing ethanol industry in Hawai'i. The inputs and cost of production of ethanol in Hawai'i are estimated, assuming that sugarcane is the primary feedstock. Ethanol output is then substitutable with petroleum manufacturing output within the economy. Model results are estimated for the 1) impacts of meeting 10% of our fuel needs with locally-produced ethanol and 2) with a 50% increase in the world price of oil. Model results include ethanol production costs per gallon, job creation, changes to resident welfare and gross state product.

2. Background

Economic Analysis of Biofuel Production

There is a large and growing literature on the economic impacts of local biofuel production – both at the national and state levels. With impending greenhouse gas emissions legislation and declining agricultural production, biofuels have been pushed as a part of the renewable energy solution. There are numerous studies assessing the cost of production of biofuel feedstocks (English, Jensen and Menard, 2002; Fortenberry, 2005; McAloon, Taylor, Ibsen and Wooley, 2000), greenhouse gas emissions implications (McCarl and Schneider, 2000; Schneider, 2000; Shapouri, Duffield, and Wang, 2002) and larger agricultural tradeoffs (Walsh, De La Torre Ugarte, Shapouri, and Slinsky, 2003; Baker, Hayes, and Babcock, 2008; Reilley and Paltsev, 2008; Birur, Hertel, and Tyner, 2008). From a global and national perspective, recent analysis of biofuels has been assessed in a general equilibrium framework – in order to show tradeoffs between sectors and competition for resources such as land constraints. For example, Reiley and Paltsev (2008) use the MIT Emissions Prediction and Policy Analysis (EPPA) model to incorporate bioenergy under varying world oil prices and assumptions of land scarcity. McDonald, Robinson and Thierfelder (2006) use the GTAP database to assess the impacts of the U.S. substituting towards energy from switchgrass. They find that this has considerable impacts on world grain markets and is a net loss for the U.S. economy. The analysis at a global level, however, is quite different than regional modeling. Whereas the U.S. would act as a price-setter in global biofuel and agricultural markets, a small state like Hawai'i would not. Regional analyses of biofuels have largely used economic impact analysis (i.e. Input-Output multiplier tools) rather than a general equilibrium approach (see for example De La Torre Ugarte et al, 2007). This study develops a CGE model specific to Hawai'i's economy in order to better understand the impacts and barriers to building a local ethanol industry.

An Overview of Hawai'i's Energy Economy

The State of Hawai'i imports over 50 million barrels of oil to the islands every year (DBEDT, 2007). Roughly $1.7 billion dollars are spent on imports to the two petroleum refineries located on the island of Oahu: Tesoro and Chevron (DBEDT, 2008). To meet the State ethanol-blending requirement, 55 million gallons of ethanol are also imported (Honolulu Advertiser, 2007; Pacific Business News, 2009). In terms of physical volume, ethanol comprises roughly 3% of gallons imported to the State. There is a federal blending subsidy of 51 cents per gallon, meaning that the refineries earn $28 million per year to support ethanol blending from the federal government.

The State of Hawai'i's economy produces $90 billion of economic goods and services annually. The petroleum manufacturing industry accounts for roughly 2.7% of this economic output, a $2.4 billion industry. Although this seems like a relatively modest proportion of overall economic activity, strong evidence exists to show compounding relationship between oil prices and macroeconomic indicators.[1] Primarily, there is a compounding economic effect of sudden, rising oil prices because it petroleum enters into the production of every sector of the economy. This relationship is particularly strong in Hawai'i because the electric sector meets 78% of its energy needs through petroleum-burning (Coffman, 2008). There are an estimated 423 jobs in the petroleum manufacturing industry, paying an average wage and salary of $185,000 annually[2] (DBEDT, 2008). The primary consumers of petroleum manufacturing output are the electric sector (20.7% of the value of petroleum manufacturing output is consumed in the electric sector), air transportation sector (11.9%), resident consumption of gasoline (17.2%), and exports (25.1%).

[1] See Hamilton (1983), Burbidge and Harrison (1984), Keane and Prasad (1996), and Barsky and Killian (2002, 2004) for national and international examples; Coffman (2008) and Gopalakrishnan et al (1993) for a Hawaii-specific discussion.

[2] Calculated from the 2005 Input-Output Study: total Wages and Salaries paid in 2005 ($78.4 million) divided by the number of Wage and Salary Jobs (423).

Table 1 shows Sector-Level Petroleum Manufacturing Demand in the baseline economy. It provides a perspective of direct "petroleum-intensity" by sector. It shows the value of petroleum manufacturing as demanded by each sector as a proportion of total sector productivity, thus normalizing large and small sectors within Hawai'i's economy.

Table 1. Sector-Level Petroleum Manufacturing Demand

	Value of Petroleum Manufacturing Input	Value of Total Sector Output	Proportion of Petroleum Manufacturing Input in Sector Output
	$ Million		%
Sugarcane	0.90	72.83	1.24%
Agriculture	11.82	653.95	1.81%
Mining & Construction	24.76	7,307.36	0.34%
Petroleum Manufacturing	112.04	2,425.54	4.62%
Other Manufacturing & Processing	21.47	2,739.10	0.78%
Air Transportation	**289.20**	**2,147.71**	**13.47%**
Water Transportation	73.76	1,677.32	4.40%
Other Transportation	31.33	1,411.87	2.22%
Electricity	**502.14**	**1,927.87**	**26.05%**
Gas Production & Distribution	**21.41**	**84.54**	**25.33%**
Wholesale & Retail Trade	28.39	9,030.68	0.31%
Finance & Insurance	1.53	4,399.57	0.03%
Real Estate	45.41	14,009.94	0.32%
Business & Professional Services	14.03	9,849.97	0.14%
Waste Management & Remediation Services	6.20	250.02	2.48%
Other Services	49.38	19,005.46	0.26%
Federal Government	1.80	7,608.43	0.02%
State & Local Government	20.33	5,693.40	0.36%

Source: Department of Business, Economic Development, and Tourism, State of Hawai'i (2008). The 2005 State Input-Output Study for Hawai'i.

The notably petroleum-intensive industries are air transportation (13.7% of the value of air transportation inputs are petroleum manufacturing), electricity (26.1%), and gas production & distribution (25.3%). This is a "direct" measure, i.e. sectors that directly purchase fuel products from the petroleum manufacturing industry. Many industries are substantial "indirect" consumers of petroleum manufacturing output, in the form of consumption of sectors like electricity. For example, industries like hotel and restaurant services tend to be indirectly petroleum-intensive through the substantial use of electricity.

Ethanol Production

For the purposes of this study, ethanol is assumed to use sugarcane as a feedstock. Hawai'i as over a 100-year history of growing sugarcane and thus a large body of knowledge exists on optimal growing conditions and techniques. Historically, sugarcane has been a primary export crop for Hawai'i. In the peak years of sugarcane production, between roughly 1950 and 1975, an average of one million tons of sugar was produced annually with over 200,000 acres of land committed to sugarcane production (HARC, 2009). Declines in sugarcane production began in the late 1970s and continue to the present day. For example, 55 farms were in production in 1990 in comparison to just two farms in 2005. Although a considerable amount of infrastructure still exists from sugarcane production, from irrigation systems to processing facilities, considerable retrofits and additional refinery facilities would be needed.

Table 2 provides an overview of the inputs into sugarcane production. The largest input into production is labor costs, as 43.7% of the value of total output of sugarcane production is in compensation of employees (i.e. wages and salary payments). The second largest input is capital costs, 22.4%, in the form of harvesting equipment, facilities, and other machinery.

Table 2. Sugarcane Production in Hawaiʻi

	Sugarcane Production
Sugarcane	1.91%
Agriculture	2.72%
Mining & Construction	0.33%
Petroleum Manufacturing	1.24%
Other Manufacturing & Processing	1.21%
Air Transportation	0.04%
Water Transportation	0.04%
Other Transportation	0.93%
Electricity	1.74%
Gas Production & Distribution	0.07%
Wholesale & Retail Trade	3.47%
Finance & Insurance	1.16%
Real Estate	5.86%
Business & Professional Services	0.57%
Waste Management & Remediation Services	0.22%
Other Services	0.55%
Federal Government	0.00%
State & Local Government	0.00%
Value-Added	
Imports	11.29%
Compensation of employees	**43.66%**
Proprietor's income	0.57%
Indirect Business Taxes	0.00%
Other capital costs	**22.42%**
Total	100.00%

*Source: Department of Business, Economic Development, and Tourism, State of Hawaiʻi (2008). The 2005 State Input-Output Study for Hawaiʻi.

In 2005, sugar was a $72.8 million dollar industry with 40,100 acres in production. Within the two sugarcane plantations on Kauai and Maui, with 7,100 and 33,000 acres, respectively, there were a total of 699 jobs paying an average wage and salary of $45,000[34] (DBEDT,

[3] Calculated from the 2005 Input-Output Study: total Wages and Salaries paid in 2005 ($31.8 million) divided by the number of Wage and Salary Jobs (699).

[4] As an agricultural sector characterized by full-time employment, workers in the sugarcane industry made $45,000 on average in 2005. This is in contrast to the average wages of other agricultural workers, such as

2006, 2008). There were also 542 proprietor jobs, representing considerable local ownership of the industry. At a statewide stakeholder summit regarding the future of biofuels, there was considerable discussion whether the cost of labor was a barrier to production or a benefit from production. More specifically, high labor costs are seen as prohibiting market viability, at the same time as wanting to achieve the desired outcome of providing living wage jobs.

It should be noted that a proportion of petroleum manufacturing output is used to produce sugarcane. At least initially, this would also then be true for the ethanol sector. The relative amount is small, however, at 1.24%. In addition, electricity and transportation services are a petroleum-intensive sectors that goes into producing sugarcane (1.74% and 1.1%, respectively). Although the energy-balance for ethanol from sugarcane is shown to be positive elsewhere, a Hawai'i-specific analysis of total energy inputs versus energy output may be illustrative in order to better understand the full life-cycle costs of ethanol production in Hawai'i.[5]

vegetable crops and macadamia nuts/coffee/other fruits who make $25,000 and $28,000 on average, respectively. The primary reason for this difference is the need for more full-time agricultural workers in sugarcane as a good serving an export market. Whether it would remain full-time employment as a bioenergy product is a question of interest.

[5] The question of net energy balance is crucial to understanding whether policy outcomes are achieving their stated goals. For example, a 2002 USDA report on the energy balance for corn ethanol estimates that corn ethanol produces 34% more energy than it takes to produce it (USDA, 2002). Sugarcane is thought to be quite a bit more energy positive, estimated to increase energy output by nearly 80%.

The development of a local bioenergy industry is an economic strategy based on import-substitution. In this case, an in-State ethanol industry would replace imported ethanol into the petroleum manufacturing sector as well as gasoline. Tables 3 and 4 present the production activity (i.e. proportion of necessary inputs) for a local ethanol industry. As a point of comparison, production of petroleum manufacturing is also shown.

Table 3. Energy Sector Production Functions: Petroleum Manufacturing and Ethanol

	Petroleum Manufacturing*	Ethanol Processing**
Sugarcane	0.00%	**52.39%**
Agriculture	0.01%	0.00%
Mining & Construction	0.09%	0.14%
Petroleum Manufacturing	4.62%	0.43%
Other Manufacturing & Processing	0.60%	2.72%
Air Transportation	0.21%	0.11%
Water Transportation	1.51%	0.59%
Other Transportation	0.27%	0.47%
Electricity	2.54%	0.57%
Gas Production & Distribution	0.11%	0.03%
Wholesale & Retail Trade	1.84%	0.00%
Finance & Insurance	1.05%	0.31%
Real Estate	1.33%	0.56%
Business & Professional Services	4.26%	3.08%
Waste Management & Remediation Services	0.69%	0.00%
Other Services	1.87%	1.05%
Federal Government	0.03%	0.15%
State & Local Government	0.34%	0.09%
Imports	**70.44%**	20.03%
Value-Added		
Compensation of employees	3.23%	**12.33%**
Proprietor's income	0.95%	4.37%
Indirect Business Taxes	0.12%	0.34%
Other capital costs	3.90%	0.28%
Total	100.00%	100.00%

*Source: Department of Business, Economic Development, and Tourism, State of Hawai'i (2008). The 2005 State Input-Output Study for Hawai'i.

**Estimated based on the production of sugarcane and the proportion of sugarcane in food processing and other manufacturing.

Sugarcane is the largest input into ethanol production, comprising 52% of total inputs. Other notable inputs include purchases from the petroleum manufacturing industry (i.e. gasoline), other manufacturing and processing inputs, travel in the form of water and ground transportation (of product between and on-island), air transportation (a common operating expense for travel to industry-associated meetings), electricity purchases, wholesale and retail trade, finance and insurance, real estate and rentals, and business and professional services. Wages are also a substantial portion of production inputs, accounting for 12% of the total value of production.

The production function for ethanol was estimated using both a top-down and bottom-up process. It was assumed that sugarcane production is used entirely for ethanol production, where the production of sugarcane is taken directly from the Input-Output dataset. The other inputs into ethanol are estimated as the proportion of sugarcane into the sectors of processing and other manufacturing, excluding non-relevant inputs such as agriculture, wholesale and retail trade, and solid waste disposal.[6]

Table 4 provides an overview of jobs provided in the ethanol and petroleum manufacturing industries, normalized by $ million of output.

Table 4. Jobs per Million Dollars of Output:
Petroleum Manufacturing and Ethanol (Sugarcane and Processing)

	Petroleum Manufacturing*	Ethanol**
Wage & Salary Jobs	0.17	8.09
Proprietor Jobs	0.00	4.59

*Source: Department of Business, Economic Development, and Tourism, State of Hawaiʻi (2008). The 2005 State Input-Output Study for Hawaiʻi. Value normalized by total sector output.
**Estimated based on the production of sugarcane and the proportion of sugarcane in food processing. Value normalized by total sector output.

The ethanol sector, including sugarcane growing and ethanol processing, provides substantially more employment per dollar of activity. The petroleum manufacturing sector provides 0.17 jobs for every million dollars of production, while the ethanol sector is estimated to provide 8 jobs and 4.6 proprietors for every million dollars of production. For ethanol sector, 64% of the jobs created are estimated to be in sugarcane growth and 36% in processing.

3. Hawaiʻi Bioenergy Model

Hawaiʻi is an excellent case study for CGE modeling because it truly is a small, open economy. Hawaiʻi producers are modeled as world price takers, including the world price of oil. Representing a classic Walrasian system, goods are produced under perfect competition and constant returns to scale using intermediate commodities, imports, labor, and capital. Households supply labor, and final demand is generated by households, visitors, various government entities, and exports (Shoven & Whalley, 1984, 1992). The model is estimated using GAMS (General Algebraic Modeling Systems) and MPSGE (Mathematical Programming System for General Equilibrium Analysis). For a more detailed presentation of the model, see Appendix I.

[6] As a confirmation of the top-down estimates, results were compared to previous estimates for Hawaii done by Stillwater Associates (2003) and BBI International (2003) on ethanol production in Hawaii. The Stillwater Associates and BBI International approaches to estimating the cost of ethanol production was very specific to the ethanol plant, including the cost of capital, feedstock expenses, chemicals, fuel oil and electricity inputs, and labor costs. Combining the top-down and bottom-up vantage points allows for a more comprehensive view of the inputs into ethanol processing, including expenses such as on-island and between-island transportation of product. Many of the overall results are quite similar. For example, Stillwater Associates (2003) estimate 40.5% of the value of inputs is from sugarcane feedstock while BBI International (2003) estimate 48%. More recently, a 2006 USDA study of the viability of ethanol from sugarcane in the United States estimated that feedstock costs comprising 62% of the cost of production. For labor inputs, BBI International (2003) estimates roughly 11% of the total value of ethanol production will be accounted for in labor compensation. On the other hand, Stillwater Associates (2003) estimates less than 1% of the value of production will be accounted for in labor compensation, at $753,000 annually with direct employees. This translates to an average annual salary of $24,000 including benefits. Given that the average salary of manufacturing workers in Hawaii is $41,000, this is seen to be too low a wage to draw workers from other sectors. Thus the initial estimates, generally consistent with BBI International (2003), are used.

The model is calibrated to the economic activity of Hawai'i in the year 2005. The year 2005 is an appropriate year in which to calibrate the model because oil prices were similar to current prices, roughly $40/barrel. Table I shows an overview of data used to calibrate the Hawai'i Bioenergy Model.

Table I. Overview of Hawai'i's Economy

	Total Output	Inter-Industry Demand	Imports	Labor Income	Proprietor Income	Other Value-Added	Jobs
	$ 2005 Billion						#
Total	**$90.3**	**$23.5**	**$11.8**	**$32.5**	**$3.0**	**$19.6**	**838,588**
Sugarcane	0.08%	0.31%	0.07%	0.10%	0.01%	0.08%	0.15%
Agriculture	0.72%	1.06%	0.83%	0.70%	0.39%	0.56%	1.72%
Mining & Construction	8.09%	4.16%	15.31%	7.12%	12.87%	2.94%	5.35%
Petroleum Manufacturing	2.69%	5.35%	14.53%	0.24%	0.78%	0.50%	0.05%
Other Manufacturing & Processing	3.03%	5.35%	8.61%	1.91%	7.42%	0.16%	2.16%
Air Transportation	2.38%	0.62%	3.98%	1.73%	0.14%	0.73%	1.22%
Water Transportation	1.86%	1.47%	4.46%	0.53%	0.01%	0.47%	0.42%
Other Transportation	1.56%	2.35%	0.83%	1.90%	4.14%	1.41%	2.13%
Electricity	2.14%	4.48%	2.01%	0.88%	0.08%	2.95%	0.34%
Gas Production & Distribution	0.09%	0.24%	0.08%	0.04%	0.00%	0.13%	0.02%
Wholesale & Retail Trade	10.00%	9.25%	9.27%	9.40%	9.45%	12.91%	13.19%
Finance & Insurance	4.87%	8.28%	4.07%	3.56%	3.26%	5.88%	3.01%
Real Estate	15.52%	17.64%	4.45%	1.86%	15.36%	43.39%	5.05%
Business & Professional Services	10.91%	27.86%	8.81%	12.69%	22.79%	7.20%	13.88%
Waste Management & Remediation Services	0.28%	1.00%	0.13%	0.25%	0.19%	0.34%	0.20%
Other Services	21.05%	7.75%	19.59%	22.58%	23.10%	14.16%	30.53%
Federal Government	8.43%	1.12%	0.63%	20.92%	0.00%	3.08%	10.06%
State & Local Government	6.31%	1.72%	2.34%	13.60%	0.00%	3.10%	10.51%

Source: Department of Business, Economic Development, and Tourism, State of Hawai'i (2008). The 2005 State Input-Output Study for Hawai'i.

Hawai'i produces over $90 billion of output annually. There are 838,588 jobs, with the largest employment in the service sector, including wholesale and retail trade (13% of jobs), and other services (30%). The state and local government is also a large employer, with 11% of jobs and 14% of wages paid. Sugarcane production accounts for less than 0.01% of Hawai'i's overall economic activity, and agriculture as a whole is less than 0.1%. Petroleum manufacturing accounts for nearly 3% of economic output and other energy-intensive sectors like air transportation, electricity production, water transportation and other transportation account for nearly 8% of economic activity.

3. <u>Key Findings</u>

In the baseline calibration of the model, bioenergy does not exist as a sector. Simulations are run to build ethanol as an industry to meet 10% of Hawai'i's motor fuel needs: 1) under current economic conditions, and 2) with a 50% increase in the world crude oil price (i.e.

from $40 per barrel to $60 per barrel).[7] To make the local ethanol supply competitive with ethanol imports, it is assumed that the State supports (and, ultimately, residents) the difference in price. This assumption is consistent with current State policies to subsidize ethanol production. The question of price volatility, however, is not addressed.

To meet 10% of Hawai'i's motor fuel demand with locally produced ethanol, it is assumed that roughly 55,100 acres of land will be committed to sugarcane growth (or similar energy cane varieties). From various conversations with potential ethanol producers, it seems there is a minimum scale of contiguous land of roughly 20,000 acres in order to make production feasible. Thus this would likely to be broken into two different sites and would require commitment of agricultural lands into sugarcane production. Assuming the land is irrigated, this results in 55 million gallons of ethanol.[8]

The following results provide an insight into the economic impacts of making the switch to locally produced ethanol. From this baseline scenario, a discussion is then provided of what market forces will affect the outcome of that scenario including 1) the price crude oil, 2) the price of imported ethanol, and 2) potential greenhouse gas emissions regulations.

Impacts Along the Production Chain

From an economic perspective, feedstock production and logistics are captured in the activity of growing and transporting sugarcane, described in Table 2. Conversion of sugarcane to ethanol and elements of distribution of final ethanol product are described in Table 3. Because the scenario presented here focuses solely on ethanol, end-use is very similar to current practices.

Resurrecting the sugarcane industry to achieve local supply of the 10% ethanol blending mandate means not only recommitting lands into production but also increasing industries that support agriculture (such as water services, trucking, insurance and legal services) by $35 million. In addition, labor costs increase by $32 million. Labor is the largest input into sugarcane production. While this has historically been true, labor costs might be reduced by increased mechanization in harvesting practices. Because sugarcane is harvested with frequent rotations, between 12 to 18 months, however, labor regardless remains a key input into production. The question of tradeoffs between labor and capital nonetheless is an important inquiry, particularly for crops with longer periods between harvests.

The production of ethanol uses sugarcane as its primary input. About 50% of the value of inputs into ethanol production comes from the value of raw sugarcane (see Table 3). The total value of the ethanol industry is estimated to be $186 million in order to meet the 10% ethanol-blending mandate with local sources, producing 55 million gallons of ethanol. This equates to $3.32 per gallon (without subsidies). It is possible for costs to be brought down with integration of byproducts, particularly with the electric sector. For comparison, a recent

[7] In 2005, world crude oil prices fluctuated between $42 and $58/bbl. In 2008, they skyrocketed to $125/bbl and today are back to roughly $40/bbl (Source: EIA, http://tonto.eia.doe.gov/dnav/pet/hist/wtotworldw.htm). The volatility in oil prices has historically made it difficult for countries to foster bioenergy and renewable energy markets and thus a vital part of this analysis.

[8] Conversions of raw sugarcane to ethanol taken from Keffer et al. 2008.

report on the feasibility of sugarcane for ethanol production in the U.S. estimates costs to amount to $2.40 per gallon (USDA, 2006).

In terms of distribution to end-use, ethanol would likely continue to be blended with petroleum-based motor fuel at the sites of the two refineries located on Oahu. The federal blending credit would remain relevant, regardless of whether the ethanol is imported or produced locally. Thus the refineries would continue to capture the support of the federal government. Given that it's likely for sugarcane and ethanol to be produced on islands other than Oahu, there would be considerable transportation costs (both financial and environmental) of bringing the final product to Oahu for final processing.[9]

The Economic Impacts of Local Ethanol Production

Substituting imported ethanol with locally-produced product has a net positive economic outcome for the State. Table 5, Key Macroeconomic Indicators, shows impacts to real gross state product, real household expenditures, and labor demand.

Table 5. Key Macroeconomic Indicators

	Baseline Scenario	Ethanol Scenario	Difference
Gross State Product ($2005 million)	$55,072	$55,234	$162
Household Expenditures ($2005 million)	$36,386	$36,415	$29
Labor Force (# of Jobs)	838,588	839,371	730

Gross State Product is a measure of overall economic productivity, taking into account the balance of trade (exports less imports). The simulation shows that introducing the $186 million ethanol industry leads to a $162 million increase in overall State productivity. Both because the magnitude of the ethanol "shock" scenario is relatively modest and because locally-produced ethanol is more expensive than imports, the overall impact is also relatively modest – increasing productivity by 0.3%. Nonetheless, it is a positive outcome, which shows net economic benefit to the State economy.

Household Expenditures serves as a proxy for resident welfare. It represents the value of goods and services that households are able to purchase. A result of increased proprietor and employee compensation (i.e. income) due to the ethanol industry, residents are then able spend that money within the economy (i.e. induced impacts). Employee compensation increases by $14.8 million and proprietor income increases by $9.3 million. Total household expenditures increase by $29 million.

In addition, 1,009 new jobs are created. Because demand for the ethanol sector draws activity away from other sectors, this new demand for labor also pulls workers away from other sectors. An estimated 279 workers shift employment from other sectors, resulting in a net increase of 730 jobs. Of the 1,009 jobs created in the ethanol industry, 646 are estimated

[9] On the other hand, if more alternative fuel vehicles enter the market, it is also possible that ethanol could be offered without blending and thus would not need to be transported to Oahu for final processing. This may, however, be a more likely scenario for biodiesel.

to be in the sugarcane industry and 364 in ethanol processing. These estimates include both direct employment (i.e. field workers, machinery operators, agricultural specialists, and engineers) as well as indirect employment (i.e. truck drivers, lawyers, and marketing specialists).

While the Statewide economic impacts are diffuse, the impacts to communities with agricultural lands chosen as suitable for biofuel production may be quite pronounced. For example, job creation and increased wages will occur in relatively small geographic regions. Community suitability and assessment studies will be needed in order to determine region-specific impacts. In particular, analysis should determine whether the labor demand could be met within the community (i.e. assessing indicators such as local unemployment rates and available housing), address potential negative spillover effects such as the additional use of roads, and assess alignment with regional plans including zoning and other infrastructure.

Project Financing – Managing Uncertainty

There are substantial capital investments that need to be made in order to develop a local ethanol industry. There is, however, a large range in cost estimates. For example, BBI International (2003) estimates that the construction cost of a 15 MMGY Molasses Plant on Maui would cost nearly $34 million. Stillwater Associates (2003) estimates that a 30 MMGY plant would cost nearly $32 million for a stand-alone plant and $43 million for a plant integrated with electricity production. For an out-of-state comparison, an estimate for a 32 MMGY sugarcane-to-ethanol plant in Louisiana is $41 million (USDA, 2006). There is large variation in capital expenditure projections because costs are often associated with unique region-specific circumstances (USDA, 2006, 32).

Given the varying estimates of start-up construction costs and relatively high per gallon operating costs, there is likely to be difficulty in financing ethanol projects. In various discussions with potential ethanol producers, a theme of uncertainty and inconsistency arose. In particular, this pertained to inconsistent tax incentives, uncertainty about the longevity of tax incentives, and relatively cheap alternatives (i.e. fossil fuels and imported biofuels). Thus, if financing were available, it could amount to an increase in a dollar to two dollars per gallon in the first year. Although, costs are manageable when amortized across multiple years of operation, it is the risk associated with investment that has likely precluded development of the industry to date.

4. Discussion

Impacts of Rising Crude Oil Prices

An increase in the world price of oil makes ethanol more attractive – particularly ethanol sources that have a high net energy output (i.e. relatively fewer fossil fuels are needed to make the ethanol product). To better understand the pressures on locally-produced ethanol, a 50% increase in the world price of oil is simulated and global prices for ethanol are discussed.

Locally, if the world price oil increases by 50% (i.e. from $40/barrel to $60/barrel), then there is a market shift away from petroleum-intensive goods (Coffman, 2008). Nonetheless, the demand for many petroleum-intensive goods is quite inelastic, particularly in the short-run. For example, the demand for electricity and transportation are not highly sensitive to changes in price (inelastic) in the short-run and more sensitive (elastic) in the long-run as people are able to purchase energy-efficient appliances and more fuel-efficient vehicles. Ethanol (and other biofuels) provides a market substitute for crude oil – both at the level of the refineries and other downstream industries such as the electric utilities.

A 50% increase in the world price of oil leads to a 43% increase in the price of refined petroleum products in Hawai'i, i.e. gasoline. Thus, there would be a 43% increase in the price of gasoline, bringing the price of gasoline roughly comparable to that of ethanol: $3.43 per gallon.

Competition with Imported Ethanol

When local ethanol is made more attractive from an increase in the world price of oil, the same goes for imported ethanol.

Corn-based ethanol is selling on the U.S. mainland for an average of $1.72 per gallon (*Ethanol Market Weekly News*, 2009). For ethanol imported into the U.S., there is a 54-cent import tariff per gallon. The largest international producer of ethanol is Brazil, where the feedstock is primarily sugarcane. In terms of cost comparisons, the costs of sugarcane production in Brazil are 2.5 to 3 times less than the U.S. (USDA, 2007a). In 2006, Brazil produced 4 billion gallons of ethanol, representing nearly 38% of the world total (USDA, 2007). In 2007, ethanol was produced in Brazil for roughly $1.10 per gallon (USDA, 2007b). Hawai'i sources are estimated to be more expensive than either the continental U.S. or imported sources.

The competitiveness of imported ethanol is likely the primary barrier to local production. When oil prices soared in 2008, over a 300% increase from today's price levels, it seemed possible for local ethanol to penetrate the market. Announcements for ethanol plants were made and land consortiums were developed. But that is a limited view in comparison to oil alone – the world market for ethanol is developing and imported sources will be the primary competition for local ethanol production. This is particularly the case with a blending mandate without preference for local product.

Greenhouse Gas Emissions Legislation

In the absence of federal legislation, States have pioneered climate change mitigation policies and over half of all U.S. states have committed to meeting greenhouse gas reduction targets and many more are participating as observers. The State of Hawai'i has committed to reducing its greenhouse gas emissions footprint to 1990 levels by the year 2020. In addition, the Obama Administration campaigned on the platform that he would help to put in place a national cap-and-trade system that would achieve 1990 levels by the year 2020 and 80% below 1990 levels by the year 2050 (Zeleny, 2007).

The form of future national legislation will greatly affect the status of State greenhouse gas emissions mitigation strategies. In general, however, greenhouse gas emissions policy aims to reduce the use of fossil fuels and promote renewable and alternative energy technologies. Most policies, including the Hawai'i-based law, emphasize the use of market-based mechanisms to achieve these goals. It remains unclear, however, how biofuels will be treated within a State or Federal greenhouse gas emissions reduction system. There is early evidence that the combustion of bioenergy will be omitted from regulation. For example, the Environmental Protection Agency released a draft of the federal mandatory emissions reporting guidelines to the Federal Register in April 2009. Within this draft, the combustion of biofuels is excluded from the facility's inventory (Federal Register, 2009). This means that the gases emitted from biofuel combustion will not be subject to mandatory reporting and, presumably, from future regulation. The logic is that the feedstock itself is carbon neutral. Nonetheless, the increase in price for fossil-based fuel will thus differentiate the cost of inputs between biofuels with a relatively low or high net energy return.

5. Conclusions

In 1994, a 10% ethanol-blending requirement for motor fuel was introduced and was later implemented in 2006. Although plans for a number of local ethanol production facilities have been introduced, none have materialized. This study uses Input-Output data to estimate the inputs into local production of ethanol. In addition, a computable general equilibrium model of the State's economy is created to understand the economic impacts of substituting imported ethanol with in-State production. This study assess ethanol industry-level operation, including production costs, labor demand, and compensation to employees. In addition, macroeconomic impacts are estimated including impact to gross state product, resident welfare, and shifts in sector-level demand.

To move to locally-produced ethanol, over 55,000 acres of agricultural land would have to be committed to sugarcane production, resulting in roughly 55 million gallons of ethanol produced. Key findings include:

1) Ethanol can be produced locally at $3.39 per gallon – although costs may be brought down with integration of byproducts, particularly with the electric sector.

2) There would be an increase in Gross State Product of $162 million annually.

3) The ethanol sector would create roughly 1,000 new jobs, both in agricultural production and processing.

Although the switch from imported to locally produced ethanol within the State has positive economic implications – they are relatively small (0.3% of real gross state product). The region-specific impacts, however, may be sizeable and merit further study. For example, the benefits in compensation to employees and increased household expenditures would likely be concentrated in the communities in which sugarcane and ethanol produced. Moreover, region-specific studies should be conducted to better understand the availability of labor. While the State unemployment rate is currently high, over 7%, Hawai'i's unemployment rate was close to 3% just a year ago (BLS, 2009). It is unclear whether the demand of labor can be met within specific communities. In addition, the non-monetized impacts to communities may also be persuasive – particularly in increasing demand for agricultural lands with zoning-consistent use, maintaining open space and promoting rural lifestyles. On the other hand, stakeholder input also voiced that locating ethanol-processing facilities may be difficult and it is important to involved specific communities through all steps of the process.

The reasons for supporting a local industry are primarily environmental in nature. In particular, deforestation practices, net energy inputs, and transportation emissions are all considerations in choosing to support a local ethanol industry. In the face of potential national and international greenhouse gas emissions commitments, environmental consequences may eventually have financial impacts as well. As such, the role of biofuels should be assessed in comparison to other renewable energy technologies. In particular, the ways in which biofuels can complement the implementation other renewable energy sources, particularly intermittent sources for electricity, merits further analysis. This could then further inform whether promoting a biofuels industry is an appropriate use of public resources.

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Appendix I. Detailed Model Overview

Hawai'i is a small open economy and thus producers are modeled as world price takers. Representing a classic Walrasian system, goods are produced under perfect competition and constant returns to scale using intermediate commodities, imports, labor, and capital. Households supply labor, and final demand is generated by households, visitors, various government entities, and exports (Shoven & Whalley, 1984, 1992). The model is estimated using GAMS (General Algebraic Modeling Systems) and MPSGE (Mathematical Programming System for General Equilibrium Analysis). For more information on these modeling platforms, refer to Brooke et al., 1988, and Rutherford, 1987 and 1999, respectively.

Production

Production in the economy is represented through a nested-Leontief function. This means that commodities are a set of complementary inputs into each sector's output, both intermediate inputs and value added activities. The nested structure comes into play through allowing substitution within factors of production (i.e. capital and labor are flexible in producing a specified level of value added).

At the first level, a Leontief production function represents final output (Y_j) in sector $j = 1,..,$ n as made up of intermediate inputs (Z_{ij}) of commodity i, and value-added (V_j):

$$Y_j = \min[Z_{1j} / a_{1j}, ...Z_{nj} / a_{nj}, V_j / a_{vj}] \tag{1}$$

where a_{ij}, a_{vj} are unit input coefficients for intermediates and value-added respectively.

At the second level, intermediate inputs consist of flexible domestically-produced and importable commodities represented through an Armington[10] constant elasticity of substitution (CES) production nest:

$$Z_{ij} = [\theta_{Dij} D_{ij}^{(\varepsilon_{ijm}-1)/\varepsilon_{ijm}} + \theta_{Mi} M_i^{(\varepsilon_{ijm}-1)/\varepsilon_{ijm}}]^{\varepsilon_{ijm}/(\varepsilon_{ijm}-1)} \tag{2}$$

where ε_{ijm} is the CES substitution between domestically-produced good i and imports by producer j. D_{ij} is sector i demands by producer j for domestically-produced goods and M_i is the composite import good demand in sector i. The parameter shares are represented by θ_{Dij} and θ_{Mi}, respectively.

Value-added (V_j) consists of capital (K_j), wage labor (L_j), and proprietor income (R_j):

$$V_j = [\alpha_{Lj} L_j^{(\sigma_j-1)/\sigma_j} + \alpha_{Kj} K_j^{(\sigma_j-1)/\sigma_j} + \alpha_{Rj} R_j^{(\sigma_j-1)/\sigma_j}]^{\sigma_j/(\sigma_j-1)} \tag{3}$$

[10] The "Armington assumption" states that goods are differentiated by country of origin and is often used in regional CGE models to account for cross-hauling in trade data and to preclude unrealistic extreme specialization within countries. See Armington, 1969.

where σ_j is the CES among value-added variables and α_{Lj}, α_{Kj} are the respective parameter shares.

The initial endowment of wage labor, proprietor income, and capital ($\bar{L}_0, \bar{R}_0, \bar{K}_0$) are given within the baseline dataset. In calibration, the value of the initial endowment of wage labor, proprietor income and other value-added must equal the sum of each factor over all j=1,..,n industries (a baseline full employment assumption).

$$L \equiv \bar{L}_0 = \sum_j L_j \tag{4}$$

$$R \equiv \bar{R}_0 = \sum_j R_j \tag{5}$$

$$K \equiv \bar{K}_0 = \sum_j K_j \tag{6}$$

Output commodity Y_j can either be consumed domestically or exported and, under the Armington assumption, is differentiated for those markets using a constant elasticity of transformation (CET) function between domestic (D_j) sales and exports (X_j):

$$Y_j = [\beta_{Dj} D_j^{(\varepsilon_j - 1)/\varepsilon_j} + \beta_{Xj} X_j^{(\varepsilon_j - 1)/\varepsilon_j}]^{\varepsilon_j/(\varepsilon_j - 1)} \tag{7}$$

where ε_j is the elasticity of transformation and β_{Dj}, β_{Xj} are parameter shares.

Ethanol Production

In the baseline calibration, because the production of ethanol costs more than the production of other refined petroleum products, no ethanol is produced (Bohringer, 1998). In the scenario, the production of ethanol (as outlined in Table 3), is introduced into the economy to a level that it can offset 10% of motor fuel consumption in order to meet the blending mandate.

Consumption

On the demand side, the model reflects the behavior of Hawai'i residents (r) and visitors (v). Although both agents follow a utility-maximizing behavior, the structure of visitor utility differs because visitors must purchase air transportation before all other commodities.

Consumption demand is represented through a CES utility function:

$$U_r = [\sum_i \rho_{ri} C_{ri}^{\sigma_{ri}-1/\sigma_{ri}}]^{\sigma_{ri}/\sigma_{ri}-1} \tag{8}$$

where U is a utility level, C_{ri} is consumption and ρ_{ri} is the resident income expenditure share of i= 1,..,n,m (where n are the number of domestically-produced commodities and m is the imported composite good). σ_{rN} is the CES between all goods.

Consumers flexibly demand both domestically-produced goods (i=1,…,n) and an imported composite good (m):

$$C_{ri} = [\theta_{Dri} D_{ri}^{(\varepsilon_{rim}-1)/\varepsilon_{rim}} + \theta_{Mr} M_r^{(\varepsilon_{rim}-1)/\varepsilon_{rim}}]^{\varepsilon_{rim}/(\varepsilon_{rim}-1)} \tag{9}$$

where ε_{rim} is the Armington CES for residents between domestically-produced good i and imports m, taking a Cobb-Douglas form. D_{ri} is sector i demands for domestically-produced goods and M_r is imported demand. The parameter shares are represented by θ_{Dri} and θ_{Mr}, respectively.

A representative consumer's expenditure constraint can be written as:

$$\sum_i p_i C_{ri} = p_L L + P_R R + P_K K + \overline{p}_{fx} BP - T_r \tag{10}$$

where prices p_i represent the market prices for imports and commodities i = 1,..n, m. The resident derives income from factors of production including labor (L), proprietor income (R), and capital (K), where p_L, p_R, p_K are the market price of the respective factors. The resident pays a lump-sum tax (T_r), net of transfer payments, to the State and Local Government. The resident also receives foreign exchange ($\overline{p}_{fx} BP$) from a balance of payment deficit, described below in equation (18).

Government

Government activity is represented through three branches – the State and Local Government (SL), the Federal Military Government (FM), and the Federal Civilian Government (FC). Each government type purchases domestic commodities (G_{gi}) and imports (G_{gm}) according to a Leontief utility function to assure a constant level of public provision:

$$U_g = \min[G_{g1},..,G_{gn},G_{gm}] \tag{11}$$

where g = SL, FM, FC.[11]

The State and Local Government depends entirely on the economy for the tax base:

$$\sum_i p_i G_{SLi} + p_m G_{SLm} = \sum_i p_i Y_i \tau_i + T_r \tag{12}$$

where p_i and p_m are the price of commodities i=1,..,n and imports, respectively. Thus the left-hand side represents the cost of public expenditures. These expenditures are funded primarily through the State's general excise tax (τ_i) on producer output (Y_i) of commodity

[11] The specification for government utility follows Kim and Konan (2005).

i.[12] The State and Local Government also impose a variety of taxes (T_r), such as property and income taxes on residents.[13]

The market clearing conditions must hold such that the cost of public expenditures balances government income.

$$\sum_i p_i G_{gi} + p_m G_{gm} = I_{g0} \equiv I_g \tag{13}$$

Balance of Payments

A balance of external payments (*BP*) is maintained under the assumption of a fixed exchange rate ($\overline{p}_{fx}$), where $\overline{p}_{fx}$ is the exchange rate with the "rest of the world." This assumption is made because Hawai'i uses the U.S. dollar as a means of exchange and, as a small economy, has no effect on the exchange rate. The quantity of imports (*M*) are constrained by the inflow of dollars obtained from visitor expenditures (I_v), Federal Government expenditures (I_{FM}, I_{FC}), and Hawai'i exports (X_j). Because Hawai'i is a price taker, import and export prices are perfectly inelastic.

$$\overline{p}_{fx} BP = \overline{p}_m M - I_v - I_{FM} - I_{FC} - \sum_j \overline{p}_{xj} X_j \tag{14}$$

Market Clearing

Constant returns to scale and perfect competition ensure that the producer price (p_j) equals the marginal cost of output in each sector *j*. In addition, the State and Local Government collects a general excise tax (τ_j) on sales. This implies that the value of total output (supply) equals producer costs, where p_L, p_K, p_R, equal the market price of labor, capital, and proprietor income respectively.

$$p_j Y_j (1+\tau_j) = \sum_{l=1,..,n} p_l Z_{lj} + P_L L_j + p_k K_j + p_R R_j + p_m M_{Yj} \tag{15}$$

In addition, sector *j* output, which supplied to the domestic market (D_j), is demanded by consumers $a \in \{r,v\}$, government agencies $g \in \{SL,FC,FM\}$, and industries Z_i $i = 1,..,n$.

$$D_j = \sum_a C_{aj} + \sum_g G_{gj} + \sum_i Z_i \tag{16}$$

In equilibrium, the value of output balances the value of inter-industry, consumer, and government agencies demand.

[12] Shown in the 2005 I-O table as "indirect taxes" for each commodity.

[13] Shown in the 2005 I-O table as "indirect taxes" for final demand.