Hawaii Clean Energy Initiative Scenario Analysis

Quantitative Estimates Used to Facilitate Working Group Discussions (2008–2010)

R. Braccio, P. Finch, and R. Frazier
Booz Allen Hamilton
McLean, Virginia

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Subcontract Report
NREL/SR- 7A40-52442
March 2012

Contract No. DE-AC36-08GO28308

Hawaii Clean Energy Initiative Scenario Analysis

Quantitative Estimates Used to Facilitate Working Group Discussions (2008–2010)

R. Braccio, P. Finch, and R. Frazier
Booz Allen Hamilton
McLean, Virginia

NREL Technical Monitor: Ken Kelly

Prepared under Subcontract No. LGJ-0-40279-01

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401
303-275-3000 • www.nrel.gov

Subcontract Report
NREL/SR-7A40-52442
March 2012

Contract No. DE-AC36-08GO28308

This publication received minimal editorial review at NREL.

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mreports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/ordermethods.aspx

Cover Photos: (left to right) PIX 16416, PIX 17423, PIX 16560, PIX 17613, PIX 17436, PIX 17721

Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.

Acknowledgments

Booz Allen Hamilton would like to thank the Hawaii Clean Energy Initiative and its working group members; the State of Hawaii Department of Business, Economic Development and Tourism; and the U.S. Department of Energy (Office of Energy Efficiency and Renewable Energy and Office of Electricity Delivery and Energy Reliability) for their insight and assistance in this scenario analysis. Booz Allen Hamilton would also like to thank the National Renewable Energy Laboratory for its efforts throughout the process. Without these organizations' significant contributions, the analysis described in this report would not have been possible.

Acronyms and Abbreviations

BAU	business as usual
bbl	Barrel
CAFE	Corporate Average Fuel Economy
CO_2	carbon dioxide
DBEDT	State of Hawaii Department of Business, Economic Development and Tourism
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EEPS	Energy Efficiency Portfolio Standard
EERE	Office of Energy Efficiency and Renewable Energy
EIA	U.S. Energy Information Administration
EPRI	Electric Power Research Institute
GHG	greenhouse gas
GWh	gigawatt-hour
HADA	Hawaii Automobile Dealers Association
HARC	Hawaii Agriculture Research Center
HCEI	Hawaii Clean Energy Initiative
HECO	Hawaii Electric Company
HELCO	Hawaii Electric Light Company
HEV	hybrid electric vehicle
HNEI	Hawaii Natural Energy Institute
HVAC	heating, ventilating, and air conditioning
IRP	integrated resource plan
KIUC	Kauai Island Utility Cooperative
kWh	kilowatt-hour

MECO	Maui Electric Company
MGY	million gallons per year
MPG	miles per gallon
MSW	municipal solid waste
MW	megawatt
MWh	megawatt-hour
NGO	nongovernmental organization
NPV	net present value
NREL	National Renewable Energy Laboratory
NRC	National Research Council
PHEV	plug-in hybrid electric vehicle
PV	photovoltaic
RFS	renewable fuels standard
VMT	vehicle miles traveled

Executive Summary

In January 2008, the U.S. Department of Energy (DOE) and the governor of the state of Hawaii signed a memorandum of understanding launching the Hawaii Clean Energy Initiative (HCEI) to transform the energy sector in Hawaii by achieving 70% clean energy by 2030.

The HCEI was set up to be an ongoing, collaborative effort, one that was to serve as the foundation of a long-term clean energy strategy for the state. To ensure that the solutions developed through the HCEI endured, and that the initiative would eventually transition to one that was owned wholly by the people of Hawaii, working groups composed of government, nongovernmental organization (NGO), university, and business leaders from Hawaii were formed to collaborate with DOE in analyzing various strategies for the state to employ. The working groups were structured to be managed via a collaborative effort between the state of Hawaii's Department of Business, Economic Development and Tourism (DBEDT) and DOE, with much of the day-to-day work of organizing and generating feedback from the working groups falling upon their respective DBEDT/DOE co-chairs.

> *The HCEI was designed to be a partnership—a collaboration among key stakeholders in the state of Hawaii, including the government, NGOs, the private sector, and universities.*

The first of the major outputs from the working group process was a request from the stakeholders for Booz Allen Hamilton to develop a high-level analysis of how 70% could be achieved—work that eventually became known as the scenario or "wedge" analysis. Although the wedge analysis is the basis upon which much of the additional follow-on work was conducted, it was only the first of many different studies undertaken on behalf of the working groups. A rough timeline of these analyses is incorporated in Figure 1, below:

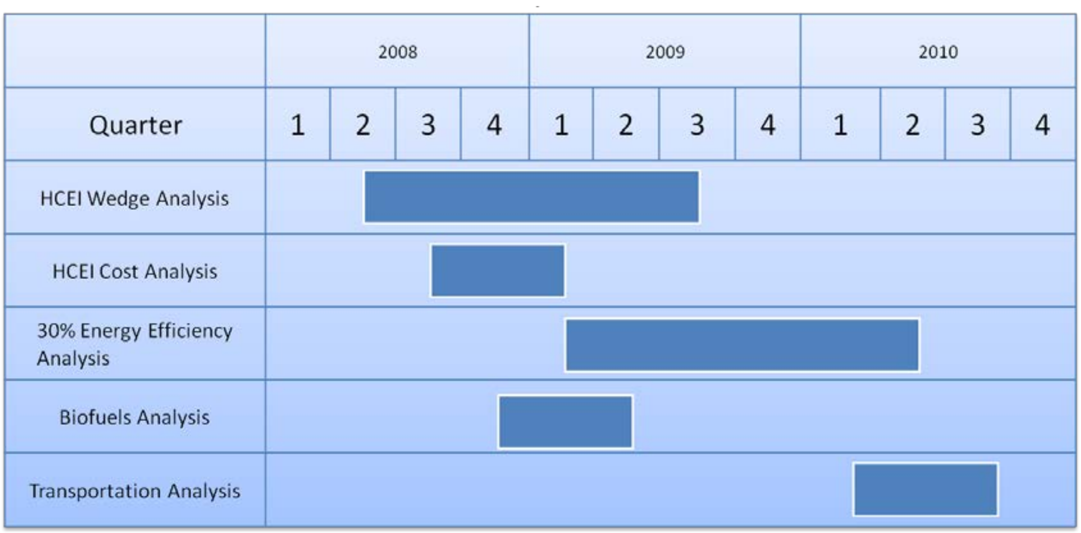


Figure 1.HCEI analysis timeline

This report was prepared as an account of work sponsored by DOE. The actual work was conducted by Booz Allen Hamilton under a subcontract to the National Renewable Energy Laboratory, a national laboratory of DOE.

The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

The scenario analysis was designed to determine what the key decision points for the state would be in seeking to attain its goal of 70% clean energy by 2030.

This work reflects a high-level analysis of how the HCEI's 70% goals could be achieved. The actually work was conducted during 2008 and 2009. Since that time other analyses and options have been considered and are still to be further evaluated in the future.

The scenario analysis was meant to:

- Facilitate an interactive discussion of the working groups
- Identify potential policy options and evaluate their impact on reaching the 70% goal
- Present possible pathways to attain the goal based on currently available technology, with an eye to initiatives under way in Hawaii
- Provide an "order-of-magnitude" cost estimate
- Provide a jump-start to action that would be adjusted with a better understanding of the technologies and market.

The scenario analysis was <u>not</u> meant to:

- Evaluate the 70% clean energy goal or calculate an alternative target
- Determine how much of each type of renewable energy is possible in Hawaii
- Optimize potential scenarios based on cost, or any other metric
- Be an in-depth technical or economic evaluation of alternatives
- Conclude with a "definitive pathway" or suite of technologies/investments to reach the 70% goal.

Policy options were used to develop scenarios and focused on the expected penetration of energy-efficiency technologies, transportation alternatives, Corporate Average Fuel Economy (CAFE) standards/renewable fuel standards (RFS), and a decision whether to build an undersea electric cable.

A variety of academic, governmental, and business-sponsored studies were reviewed to determine the potential for energy efficiency, renewable energy resources, and market penetration of alternative fuel vehicles.

The three primary variables around which this scenario analysis revolve were chosen based on critical strategic "break-points" identified by state decision makers as priorities to the state of Hawaii. These included cost (lower-cost resources such as wind were deemed higher priorities than more expensive measures), technical viability (the inter-island cable and large-scale electric vehicle viability were both considered to be of reasonable technical risk at the time), and price volatility (imported biofuels were considered to be an equivalent price risk to maintaining the status quo). As such, these scenarios were structured to present the most strategically viable range of outcomes possible based on the knowledge available to HCEI management at that point in time. For example, without knowing whether the cost and technical viability of an inter-island cable would be acceptable to state decision makers, it made sense to develop scenarios that projected potential futures for the state both with and without such a cable.

For the transportation sector, the potential for locally produced biofuels indicated that there would be insufficient local supply to cover state demand for both electricity and transportation needs. As the 70% clean energy goal for electricity was more easily met through a combination of renewable sources and energy efficiency than the 70% clean energy goal for transportation, it was determined that the optimal use of these biofuels would be in the transportation sector. By using domestic biofuels to meet transportation goals to the extent possible, HCEI as a whole could go further toward meeting its goals without resorting to importing external fuels. Based on these strategic considerations, the scenarios presented here reflect the range of potential outcomes that best highlight key decision points for state decision makers to consider.

The initial results indicated that only the most aggressive scenario—called Scenario 8 throughout this document (including the appendices, under separate cover)—would come closest to reaching 70% for both electricity and ground transportation. Scenario 8 includes aggressive energy-efficiency goals, high deployment of wind and solar resources, and an inter-island cable bringing wind-based energy from Molokai and Lanai to Oahu, among other elements See Table 1 and Figure 2 below.

Table 1. Summary of 2030 Generation End State for Each Scenario (Installed Capacity)[a]

	Scenarios							
	1	2	3	4	5	6	7	8
Efficiency	220	220	220	220	495	495	495	495
Biomass - direct firing	93	93	120	120	56	56	83	83
Wind	276	1076	276	1076	223	1023	260	1060
Geothermal	102	102	102	102	102	102	102	102
Hydro	36	36	40	40	24	24	24	24
Solar (residential roofs)	182	182	205	205	166	67	179	179
Solar (commercial roofs)	633	633	712	712	578	232	622	622
Solar (utility scale)	29	29	29	29	22	22	29	29
MSW	77	77	79	79	77	77	77	77
Ocean energy	53	53	53	53	53	3	53	53
Dispatchable	271	271	301	301	235	235	261	261
Nondispatchable	1209	2009	1316	2116	1065	1370	1167	1967
Electricity Sector Clean Energy %	**46%**	**65%**	**46%**	**63%**	**58%**	**70%**	**57%**	**70%**
Oil reduction (million bbls in 2030)	10.0	14.0	11.5	15.5	12.5	15.1	14.0	17.3
CO_2 avoided (million tons in 2030)	5.1	7.2	5.9	7.9	6.4	7.7	7.2	8.8
Transportation Sector Clean Energy %	**30%**	**30%**	**57%**	**57%**	**30%**	**30%**	**57%**	**63%**
Oil reduction (million bbls in 2030)	4.7	4.7	9.0	9.0	4.7	4.7	9.0	9.9
CO_2 avoided (million tons in 2030)	2.0	2.0	3.8	3.8	2.0	2.0	3.8	4.2

Based on the installed capacities presented in Table 1 above, a schedule of deployment dates and dispatching renewable resources (by island), in order of relative cost, was determined and used to create the graphical representation of the potential path toward the HCEI's goals.

[a] Numbers reflect installed capacity needed. The initial scenarios assumed 800 MW installed capacity for the Big Wind project, but these are revised to 400 MW in the most recent analysis.

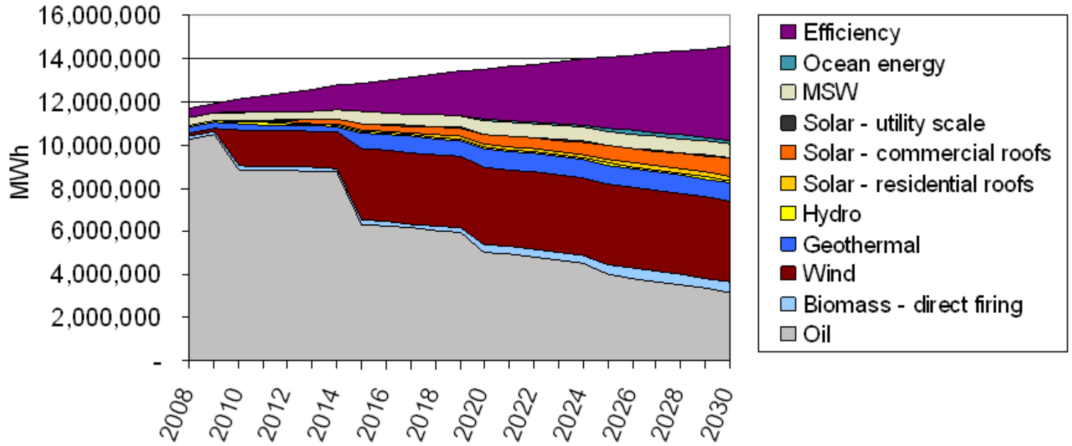


Figure 2.Initial statewide electricity generation results

The Scenario 8 analysis indicates that the 70% goal is, in fact, attainable for the state, but that all types of resources and aggressive policies (e.g., high energy-efficiency targets) will be needed.

Booz Allen next developed an "order-of-magnitude" cost model to understand the net present value of these energy investments as they relate to the revenue generated through displacing the purchase of oil. Cost ranges, shown in Table 2 below, were used in a Monte Carlo simulation to develop an understanding of each scenario's potential capital requirements.

Table 2.Scenario Capital Installation Requirements and Cost Ranges[a]

	1 Scenario 7	2 Scenario 8	3 Capital Cost (a)
Solid Biomass ($ / kWh)	83 MW	83 MW	Range: $2,000 - $6,000, $4,000 most likely
Wind ($ / kWh)	260 MW	1,060 MW	Range: $2,400 - $2,800, $2,600 most likely
Geothermal ($ / kWh)	102 MW	102 MW	Range: $3,000 - $5,000, $4,000 most likely
Small Hydro ($ / kWh)	24 MW	24 MW	Range: $2,500 - $4,000, $3,250 most likely
Solar - Residential Roofs ($ / kWh)	179 MW	179 MW	Range: $8,125 - $9,375, $8,750 most likely
Solar PV (lg roof/utility scale) ($ / kWh)	651 MW	651 MW	Range: $6,500 - $7,500, $7,000 most likely
MSW/Landfill Gas ($ / kWh)	77 MW	77 MW	Range: $2,100 - $3,500, $2,800 most likely
Ocean Energy (wave) ($ / kWh)	53 MW	53 MW	Range: $2,000 - $7,600, $6,000 most likely
Energy Efficiency ($ / MWh)	495 MW	495 MW	Range: $70 - $100, $75 most likely

The resulting net present value of capital expenditures is approximately $16 billion for Scenario 8. Figure 3 below shows the impact of these results. Given the range of costs above, and the deployment and timing of investments outlined in Scenario 8, the "break-even" value of this investment would be a long-term average cost of oil from $65 to $85 per barrel (bbl).

[a] See Appendix C for detailed stakeholder inputs, sources, and ranges.

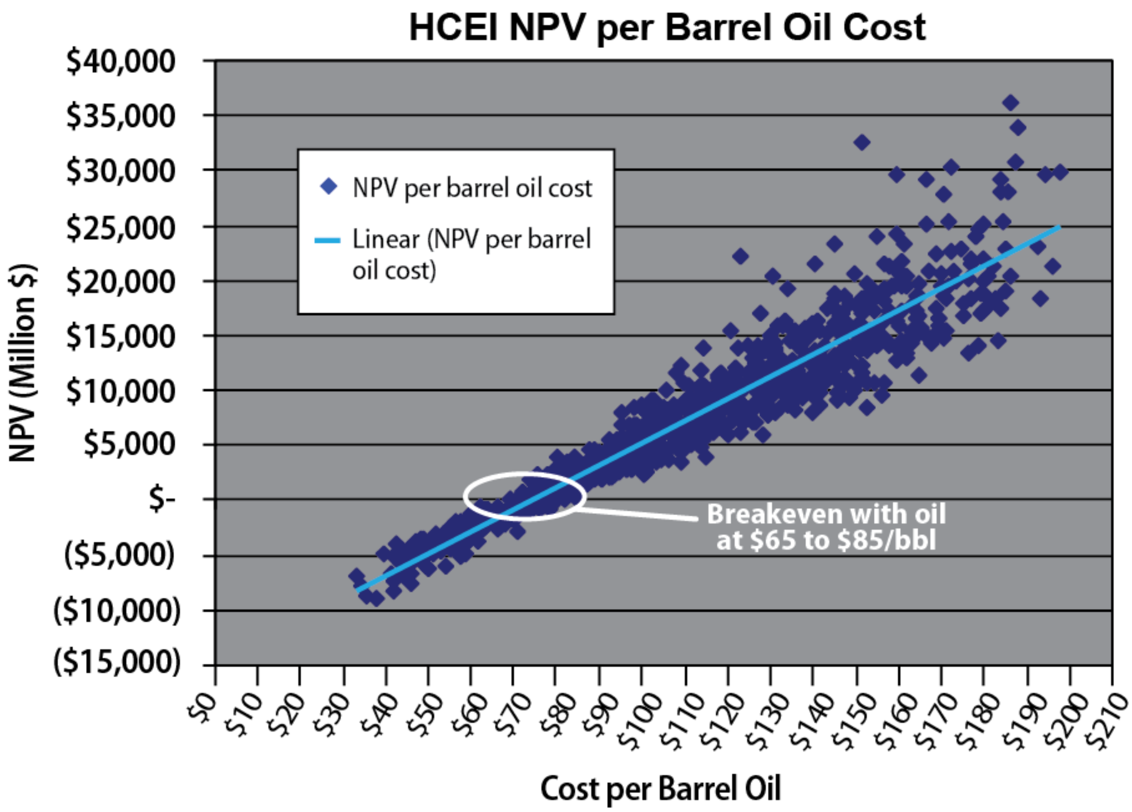


Figure 3.Scenario 8: NPV break-even with cable[1]

Upon completion of the original high-level scenario analysis for the HCEI, Booz Allen collaborated with HCEI working group members to identify potential areas for more detailed study. Three areas of specific interest were identified: understanding the biofuel potential within the state of Hawaii, creating a more detailed breakdown of the State's energy-efficiency goal, and performing an analysis of Hawaii's alternative transportation options.

Given that any forecast of the cost of oil from 2008 to 2030 will have a high margin of error, the break-even point for the HCEI to attain 70% clean energy under Scenario 8 was shown to be within the range of $65-$85/bbl for long-term average price of oil. This indicates a high probability that the HCEI would be a better long-term investment for the state than business as usual based on historical oil price trends.

[1] Simulations based on 1,000 runs.

Table of Contents

List of Figures

List of Tables

Introduction and Purpose

In January 2008, the U.S. Department of Energy (DOE) and the governor of the state of Hawaii signed a memorandum of understanding launching the Hawaii Clean Energy Initiative (HCEI). The essence of the HCEI was and is to transform the energy sector in Hawaii such that clean energy—both renewable energy and energy efficiency—would by 2030 provide 70% of Hawaii's energy needs in the electricity and ground transportation sectors.

In February 2008, the initial stakeholder working groups were formed to develop solutions based around Hawaii-specific data and local feedback. The HCEI Scenario Analysis was the first product of these working group efforts.

HCEI was set up to be an ongoing, collaborative effort, and one of the first steps was the creation of working groups, composed of leaders from Hawaii, nongovernment organizations (NGO), universities, businesses, and DOE. The purpose was to ensure that changes to the energy sector were based on the best thinking from both Hawaii and the rest of the United States. The purpose was also to ensure that the solutions recommended were vigorously debated by the working groups and not developed elsewhere.

The first set of working group meetings was held in February 2008. There were five working groups: electricity generation, electric delivery, energy efficiency, fuels and transportation, and an Integration Working Group to review the work of all other groups. In February 2008, the working groups requested that Booz Allen Hamilton develop a high-level analysis of how 70% could be achieved—this is referred to as the scenario or "wedge" analysis. This report summarizes the work undertaken on behalf of the working groups. Booz Allen developed the scenario analysis from March to June 2008; presented the preliminary findings to the working groups in June 2008; and incorporated feedback from the meetings, revised the analysis, and presented the revisions to the working groups in September 2008 (three targeted, deeper analyses were conducted in 2009 and 2010 for specific working groups and are presented separately in Section 4 of this report).

The scenario analysis was meant to:

- Facilitate an interactive discussion of the working groups by quantifying aspects of proposed policies (the overall agenda for the working groups was to draft suggested legislative and regulatory changes in time for the January 2009 − May 2009 legislative session; thus, discussions based on the scenario analysis were to take place in June and September 2008. Presentations were developed and used to keep the discussions interactive; no reports were written)
- Identify potential policy options and evaluate their impact on reaching the 70% goal
- Present a possible pathway based on currently available technology, with an eye to initiatives underway in Hawaii (e.g., ocean energy technology)
- Provide an "order-of-magnitude" cost estimate of a possible pathway for reaching 70% clean energy and evaluate savings that come from avoided oil costs.

The scenario analysis was <u>not</u> meant to:

- Examine the 70% clean energy goal or calculate an alternative target
- Determine how much of each type of renewable energy is possible in Hawaii, relying instead on studies already published from state of Hawaii sources
- Optimize potential scenarios based on cost (or any other metric), although the analysis was mindful of cost when creating scenarios and focused on lower-cost technologies to the extent feasible
- Conclude with the definite or "only pathway" or suite of technologies/investments to reach the 70% goal. The scenario analysis presented a pathway for reaching the 70% target based on available technology. To the extent that future developments create technologies that are cheaper or more efficient, then a different scenario would provide greater benefit to the state of Hawaii.

Scenario Analysis

Meeting Hawaii's clean energy goal is an ambitious undertaking that will require a transformation in how the state's energy is produced and consumed. A wide range of possible solutions exists, with outcomes dependent on an array of assumptions about the state's resource potential and economic future.

The three primary variables around which this scenario analysis revolve were chosen based on critical strategic "break-points" identified by state decision makers as priorities to the state of Hawaii. These included cost (lower-cost resources such as wind were deemed higher priorities than more expensive measures), technical viability (the inter-island cable and large-scale electric vehicle viability were both considered to be of reasonable technical risk at the time), and price volatility (imported biofuels were considered to be an equivalent price risk to maintaining the status quo). As such, these scenarios were structured to present the most strategically viable range of outcomes possible based on the knowledge available to HCEI management at that point in time. For example, without knowing whether the cost and technical viability of an inter-island cable would be acceptable to state decision makers, it made sense to develop scenarios that projected potential futures for the state both with and without such a cable.

For the transportation sector, the potential for locally produced biofuels indicated that there would be insufficient local supply to cover state demand for electricity and transportation needs. As the 70% clean energy goal for electricity was more easily met through a combination of renewable sources and energy efficiency than the 70% clean energy goal for transportation, it was determined that the optimal use of these biofuels would ultimately be in the transportation sector, although long term utility contracts could be an important first step in development of in-state production capacity. By using domestic biofuels to meet transportation goals to the extent possible, HCEI as a whole could go further toward meeting its goals without resorting to importing external fuels. Based on these strategic considerations, the scenarios presented here reflect the range of potential outcomes that best highlight key decision points for state decision makers to consider.

To identify potential clean energy adoption strategies, Booz Allen developed a series of interdependent models that forecast expected progress toward Hawaii's 70% clean energy goal. Each model was tested against a range of scenarios that made basic assumptions about Hawaii's future in energy efficiency, electricity generation, and transportation infrastructure and demand.

The scenarios assessed in the models are based on an evaluation of Hawaii's baseline energy demand as well as its electricity generation and biofuel production resource potential. This information was collected in conjunction with an analysis of variables such as plug-in hybrid electric vehicle (PHEV) penetration, grid upgrades, and commercial and residential efficiency gains.

Measuring Baseline Energy Demand

To measure progress toward the 70% clean energy goal, it was first necessary to have a thorough understanding of Hawaii's baseline electricity and transportation demand.

The state utilities' integrated resource plans (IRPs) provided a comprehensive study of how the islands use electricity and the ways in which demographics and geography are expected to affect long-term demand. Integrated resource planning is a public process required by state law to serve as the utilities' guide for how they will adjust to the state's future electricity needs (note: this process has subsequently been replaced by a new reporting requirement called "Clean Energy Scenario Planning"). Hawaii is served by four main utility companies: Hawaiian Electric Company (HECO), which serves Oahu; Hawaii Electric Light Company (HELCO), which serves Hawaii Island; Maui Electric Company (MECO); and Kauai Island Utility Cooperative (KIUC).[2] Their most recent IRPs were published between 2006 and 2008 and forecast demand through 2025. When HECO released an updated IRP in 2008, the scenarios were revised to reflect the changes.

If no material changes occur in Hawaiian electricity usage patterns, demand in the state will grow to approximately 1,661 MW by 2030, driven largely by increasing demand on Oahu.

The IRP demand forecasts account for factors such as past sales, state-level economic forecasts, population growth, the need for new generation infrastructure, and fuel prices. The IRP forecasts end in 2025, so they were extrapolated to form a baseline electricity demand estimate that reaches to 2030, the HCEI goal completion target date. Absent any policy interventions, the forecasts predict statewide demand growing more than 20%, to 1,661 megawatts (MW), by 2030.

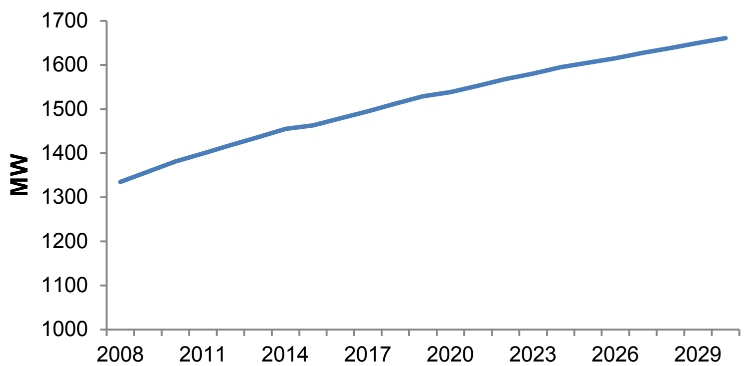


Figure 4.Expected baseline state electricity demand[3]

Oahu is expected to continue to have the state's largest electricity demand—currently about 74% of the state total—growing to 1,164 MW by 2030. Whereas Oahu has the highest level of demand, Maui, Hawaii, and Kauai are expected to grow at a much faster pace, increasing demand 38% to 48% by 2030.

The utility companies' demand estimates for each year are included in Booz Allen's model of electricity generation scenarios and aggregated to create a statewide business-as-usual case.

Fuel demand in the ground transportation sector is also expected to continue recent growth. Hawaii currently uses more than 60% of its energy for transportation. Just as with electricity

[2]Maui Electric Company (MECO), 2007; Hawaiian Electric Company (HECO), 2005; Hawaii Electric Light Company (HELCO), 2007; Kauai Island Utility Cooperative (KIUC), 2007.
[3]Hawaii utilities' integrated resource plans.

generation, Booz Allen established a baseline demand level against which the clean energy adoption scenario impact could be modeled.

In 2006, Hawaii residents drove an average 9,206 miles per year and owned 1.2 million vehicles, including a sizable rental fleet.[4] In 2008, Hawaii drivers used approximately 500 million gallons of fuel.[5]

Based on Hawaii's recent 1.02% average annual population growth rate (from 2000 to 2006) and a ratio of 0.9 cars per person, the state's vehicle fleet is expected to grow 0.92% per year.[6] The initial demand, average fuel economy, and growth rate in the number of vehicles were used to forecast total fuel demand over time. The model of transportation scenarios establishes a baseline fuel demand for each year through 2030.

Ground transportation fuel usage in the state is forecast to increase to as much as 750 million gallons per year by 2030, barring any significant change in Hawaii's vehicle choice and driving patterns.

Given the growth in fuel demand, by 2030 Hawaii will use approximately 747 million gallons of fuel per year for ground transportation, with nearly three-quarters in gasoline and the remainder in diesel. Without tightened Corporate Average Fuel Economy (CAFE) standards, higher PHEV market penetration, or other policy interventions, this business-as-usual case represents a nearly 25% increase in vehicle fuel demand over a 20-year period.

Maritime, aviation, and military demand are also components of the state's transportation sector, but only ground transportation was considered in the initial model, as options for replacing maritime and aviation fuel are still under technological development, and the analysis chose instead to focus only on those technologies that were (or were close to) commercially viable as of 2008.

These demand figures represent the business-as-usual case, where demand growth factors into current economic and demographic trends but not additional policy interventions. With both the electricity and transportation sectors, the models created for this analysis measure these initial demand figures against potential clean energy adoption scenarios, designed to either reduce overall demand (e.g., through energy efficiency programs and PHEVs), or to meet it through the use of cleaner generation and fuel technologies.

Scenario Development

Once a baseline case was established for electricity and ground transportation demand, Booz Allen developed a series of scenarios through which to compare the impact of different strategies for improving clean energy adoption. The scenarios include assumptions about future electricity and transportation demand as well as the existence of an undersea transmission cable providing wind power to Oahu. The objective of the analysis was to facilitate discussion within the working groups and to identify scenarios that would allow Hawaii to reach the 70% clean energy goal, both for individual islands and statewide.

---

[4]Hawaii Department of Business, Economic Development, and Tourism. (2006). *Hawaii Databook*. http://hawaii.gov/dbedt/info/economic/databook/db2006 (accessed March 21, 2011).
[5] http://www6.hawaii.gov/tax/monthly/2008cy-fuels-base_rev.pdf
[6]*ibid.*

Summary

Table 3, below, summarizes the initial set of eight scenarios, though only Scenarios 7 and 8 were considered in the revised follow-on analysis. The sections that follow explain the basis of their assumptions.

Table 3.Summary of Initial Eight scenarios with Assumptions Regarding Efficiency, Generation, and Transportation[a]

	Transportation: Low PHEV Penetration	Transportation: High PHEV Penetration
Moderate Efficiency ("Maximum Achievable Potential" from utility IRPs)	1 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics – no cable Low PHEV	3 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics – no cable High PHEV
	2 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics – cable from Lanai, Molokai Low PHEV	4 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics – cable from Lanai, Molokai High PHEV

[a] Grey boxes are scenarios that employ an inter-island cable. Economic "loading" indicates that lowest-cost resources were assumed to be deployed first, with more expensive resources being added later as needed.

	Transportation: Low PHEV Penetration	Transportation: High PHEV Penetration
High Efficiency	5 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics – no cable Low PHEV	7 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics – no cable High PHEV
	6 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics – cable from Lanai, Molokai Low PHEV	8 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics – cable from Lanai, Molokai High PHEV

Energy Efficiency

Energy-efficiency gains, which are expected to cover 30% of the progress toward the goal, were a key component in developing the scenarios. Booz Allen modeled both a moderate- and high-efficiency case to determine potential energy savings for each island from 2004 to 2030. The primary distinction between the moderate- and high-efficiency cases is the difference in savings achievable by either retrofitting an existing building or constructing a new, more efficient one.

To quantify these potential savings, the model drew on a 2004 HECO study that examined Hawaii's "maximum achievable potential efficiency" gains given current technology.[7] Those savings are represented as a percentage reduction in a new or retrofitted building's electricity demand as compared to an unmodified, existing home or office (Table 4).

---

[7]Global Energy Partners LLC (2004). *Assessment of Energy Efficiency and Demand Response Potential*. Prepared for HECO.

Table 4.Maximum Achievable Efficiency Potential Savings[a]

Building Type	Potential Savings
Residential New Construction	36%
Residential Retrofit	34%
Commercial New Construction	30%
Commercial Retrofit	19%

Source: "Maximum Achievable Potential Efficiency Case" as described in Assessment of Energy Efficiency and Demand Response Potential, a 2004 report prepared by Global Energy Partners for HECO.

In the moderate efficiency scenario, these potential savings remain constant over time, lowering aggregate demand as customers adopt energy management systems; install high-efficiency heating, ventilating, and air conditioning (HVAC), lighting, and appliances; and construct buildings with newer materials. The moderate case supposes that adoption of the potential efficiency savings shown above will continue apace through 2030, yielding a 13% reduction over business-as-usual consumption.

By contrast, a high-efficiency case yielded a 30% decrease in electricity consumption by 2030 compared with the business-as-usual case. Based on technical analysis by the National Renewable Energy Laboratory (NREL) and the End-Use Efficiency Working Group, the high-efficiency case makes aggressive assumptions about the availability of net-zero energy commercial and residential buildings. Under this case, all new construction would be net-zero energy by 2015 and half of existing buildings would be retrofitted to net-zero energy status by 2030. Approximately half of a building's progress toward net-zero energy status would come from rooftop photovoltaic (PV) solar. The remainder would be achieved through efficiency gains.[8]

Attaining a very high deployment of efficiency is essential to reach the state's goals. The highest efficiency scenario possible for the state is a savings of approximately 4,300 gigawatt-hours (GWh) (30% of forecast demand in 2030).

To calculate energy savings in the high-efficiency case, the maximum achievable potential gains discussed above were escalated by 1%–2% per year through 2015. This annual growth rate accounts for the progress that would need to take place for Hawaii to meet the net-zero building scenario. After 2015, the potential efficiency gains stay constant through 2030. In addition, the model assumes that 1% of the building stock will be replaced each year, with an additional 2.5% retrofitted. The turnover rates were based on an analysis of the age of the islands' building stock over time.[9]

[a] The percentages reflect a potential reduction in electricity use in a new or retrofitted building versus a comparable, unmodified building.

[8] Rooftop PV solar's potential value in a net-zero building was evaluated based on data from DOE's Builders Challenge, which examined the effect of efficient home building practices in warm, humid climates.

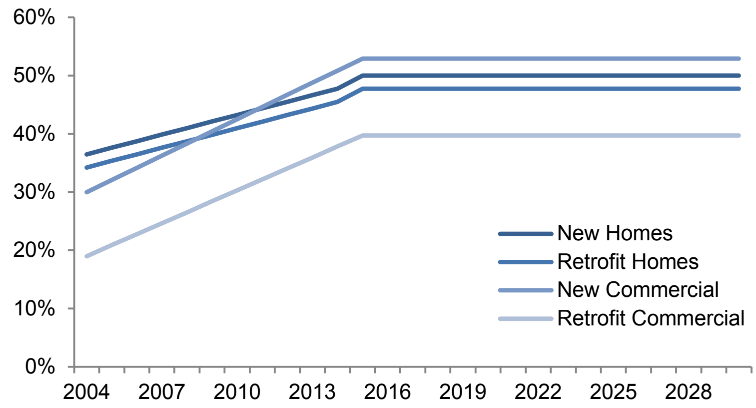


Figure 5.High efficiency potential savings[10]

Source: Booz Allen analysis

Using the average potential savings for a high-efficiency building and accounting for turnover in the building stock, the end-use efficiency model calculated expected electricity savings for each island in each year. These were aggregated to measure a total, statewide amount by which one could expect to reduce electricity demand each year. By 2030, the high-efficiency case lowers demand by 355 MW—a significant decrease compared with the business-as-usual and moderate cases (Figure 6).

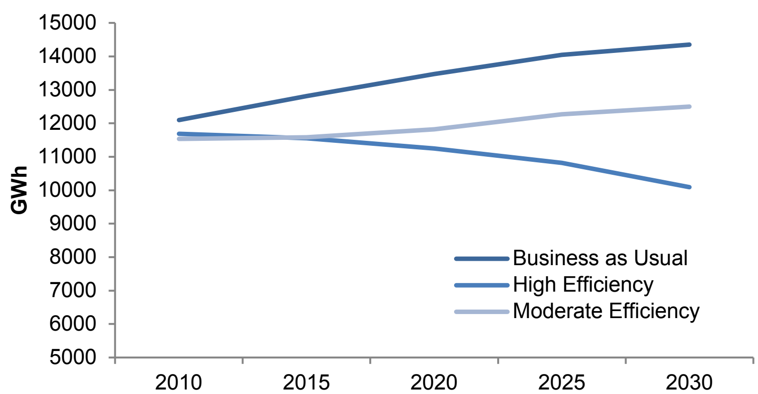


Figure 6.Comparison of demand across efficiency cases

Source: Booz Allen analysis

Underlying the high-efficiency case is the principle that continued technological innovation will drive down the cost of adding efficiency improvements, increasing their prevalence and accelerating the pace of efficiency gains over time. These improvements facilitate the continued replacement and retrofitting of the building stock that would allow the state to meet the net-zero energy portion of the high-efficiency case.

[9]Building age data from the 2000 census was used to establish the rate at which buildings are replaced or retrofitted.

[10]The percentages reflect a potential reduction in electricity use in a new or retrofitted building versus an unmodified building.

PHEV Market Penetration

Beyond building efficiency measures, assumptions about electricity consumption also depend on Hawaii's adoption of plug-in hybrid vehicles (PHEV), which will likely place upward pressure on electricity demand. PHEVs have a dual effect, however, because they can significantly decrease fuel demand even as they consume moderately more electricity. The effect of PHEVs on electricity generation and transportation fuel demand is considered in the scenario analysis.

Initial scenarios varied in the extent to which PHEVs will penetrate Hawaii's automobile market. In a low-PHEV case, only 15% of vehicles sold in 2030 use plug-in hybrid technology. The lower adoption level, based on an Argonne/Electric Power Research Institute (EPRI) estimate, would increase electricity demand by 62 MW.[11] A high-PHEV case, based on a Pacific Northwest National Laboratory study, assumes significantly higher market penetration, where 69% of vehicles sold in 2030 are PHEVs, increasing electricity demand by 314 MW (Figure 7).[12]

The resource potential estimates used in the Booz Allen analysis were an aggregation of multiple local data sources, including resource studies and planned projects.

Updated scenarios modified the timeline over which PHEVs are deployed. PHEVs still reach 69% of new car sales by 2030, but their sales begin in 2012 instead of 2008 and accelerate on a delayed timeline. As a result, in the updated scenario, PHEVs add only 202 MW of demand because there are fewer of them on the road.

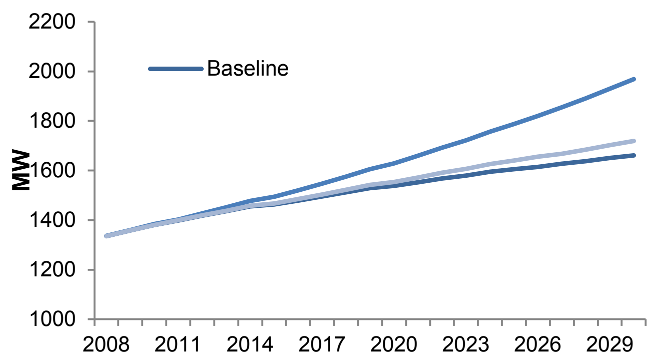


Figure 7.Expected state electricity demand

Source: Hawaii utilities' integrated resource plans, Argonne National Laboratory, Pacific Northwest National Laboratory

Vehicle Efficiency and Biofuels for Transportation

The scenarios make several assumptions about fuel economy and the availability of biofuels for the transportation sector.

---

[11] Winkel, R.; van Mieghem, R. (2006). "Global Prospects of Plug-in Hybrids." EVS-22 Conference. Argonne National Laboratory, Electric Power Research Institute. http://transportation.anl.gov/pdfs/HV/393.pdf (accessed March 22, 2011).

[12] Kintner-Meyer, M.; Schneider, K.; Pratt, R. (November 2007). Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids. Pacific Northwest National Laboratory.

The scenarios assume that CAFE standards will tighten over time, ultimately raising fuel economy to 35 MPG by 2022.[13] The improved fuel economy reduces demand by 33 million gallons per year (MGY) in 2030. In addition, the scenarios assume that a proposed RFS escalates to 20% by 2020, offsetting 98 million gallons of petroleum per year with biofuels by 2030. As the current RFS is a 10% ethanol standard, it was thought that doubling the RFS by 2020 could serve as a high-end but reasonable assumption. Half of the land technically available for biofuels would be used, and any remaining amount needed to meet a proposed RFS would be imported.

In each scenario, both ethanol and biodiesel support transportation demand, with the ratio of ethanol to biodiesel produced determined based on the amount of ethanol needed to meet a proposed 20% RFS over the full life of HCEI.

Renewable Energy Resource Potential

After measuring baseline demand and developing a set of clean energy adoption scenarios, the next step in the analysis was to evaluate the biofuel and electricity generation resources Hawaii has at its disposal. This includes both current infrastructure as well as potential capacity. The total resource potential was ultimately determined based on the parameters in the scenarios (e.g., whether an undersea cable is employed), set against adjusted demand levels (e.g., moderate versus high efficiency), and used to determine the impact of the scenarios on the 70% clean energy goal. The existence of an undersea cable facilitating wind generation on Lanai and Molokai is a key difference among the scenarios.

In measuring potential resource capacity, multiple sources of data were provided and built into the analysis accordingly. To capture resource potential for a range of clean energy generation sources across each island, Booz Allen examined relevant literature, investigated planned projects that will add generation infrastructure, and sought feedback from HCEI working groups and other local stakeholders.[14] The models were also updated as new data became available. Since the analysis, developers have conducted other studies of specific project sites, which have sharpened overall estimates of potential over time.

The result was an island-by-island snapshot of Hawaii's potential to generate clean energy in 2030—3,816 MW in total. Much of the data used for measuring resource potential were available in a 2007 NREL assessment of Hawaii's oil dependence that was mandated by Section 355 of the Energy Policy Act (see Table 5).[15] Proposed projects, existing infrastructure, and local stakeholders' data were used instead of NREL's assessments in cases where those estimates of resource potential were greater.

---

[13] Energy Independence and Security Act of 2007.

[14] See Table 5 for detailed data and sources.

[15] Arent, D.; Barnett, J.; Mosey, G.; Wise, A. (2009). "The Potential of Renewable Energy to Reduce the Dependence of the State of Hawaii on Oil." 42nd Hawaii International Conference on System Sciences. Produced in compliance with EPAct Section 355: National Renewable Energy Laboratory (NREL), Golden, Colorado. http://www.hawaiicleanenergyinitiative.org/storage/potential_of_renewable_energy.pdf (accessed March 22, 2011).

Table 5.Matrix of Unadjusted Generation Capacity by Island and Technology (MW)[a]

	Source	Oahu	Kauai	Maui	Hawaii	Lanai	Molokai	Total
Biomass	355 Report[b]	7	20	8	20	No data	6	
	KIUC Renewable Energy Technology Assessment[c]		20					
	Hawaii Energy Strategy 2000[d]	25	25	25	50			
	Value used for Booz Allen model	25	25	25	50	0	0	125
Wind	355 Report	At least 50	At least 40	At least 40	At least 10	No data	No data	
	Proposed Projects[e,f]			97		400	400	
	Hawaii Energy Strategy 2000	65			85			
	Value used for Booz Allen model	65	40	97	85	400	400	1,087
Geothermal	355 Report (from GeothermEx 2005)			140	750	n/a	n/a	
	Value used for Booz Allen model	0	0	140	750	0	0	890
Hydro	355 Report	No data	No data	3	20	20	No data	
	KIUC RETA		21					
	Hawaii Energy Strategy 2000		7					

[a] The resource potentials in this table represent nominal technical capacity and do not take into account cost, transmission issues, or other factors that would decrease actual available resource potential. These factors and their effect on resource potential are discussed in detail in the section. Proposed projects, existing plants, KIUC RETA, HES 2000, and county energy staff estimates were used whenever greater than those in the 355 Report.
[b] Arent, D.; Barnett, J.; Mosey, G.; Wise, A. (2009). "The Potential of Renewable Energy to Reduce the Dependence of the State of Hawaii on Oil."
[c] Kauai Island Utility Cooperative. (March 2005). *Renewable Energy Technology Assessments.*
[d] Hawaii Department of Business, Economic Development, and Tourism. (January 2000). *Hawaii Energy Strategy 2000*.
[e] Hao, S. (6 June 2007). "Lanai could get $750-million windfarm." *Honolulu Advertiser*.
[f] Ibid.

	Source	Oahu	Kauai	Maui	Hawaii	Lanai	Molokai	Total
	Value used for Booz Allen model	0	21	3	20	0	0	44
Solar – rooftop	Residential roof analysis[g]	416	35	80	94			
	Commercial roof analysis[h]	576	48	111	130			
	Value used for Booz Allen model	992	83	191	224	0	0	1,490
Solar – utility scale	NREL Estimate	8	8	8	8			
	355 Report		285					
	Value used for Booz Allen model	8	14	8	8	0	0	37
MSW (including landfill gas)	Hawaii Energy Strategy 2000		25					
	KIUC RETA / County Energy Staff	57	8	8	10			
	Existing plant (H-POWER)	46						
	Value used for Booz Allen model	57	8	8	10	0	0	83
Ocean energy	Estimates / proposed projects	50		10				
	Value used for Booz Allen model	50		10		0	0	60
Total	Value used for Booz Allen model	1,196	192	481	1,147	400	400	3,816

[g] NREL estimates 2.5 kW per house and assumes that half of Hawaii's 500,036 houses (as of 2006 census) are available for rooftop PV. (National Renewable Energy Laboratory. [2006]). *Number of Home Electricity Needs Met Calculation.*

[h] In 2003, Hawaii had approximately 173 million ft² of office space, according to HECO, with 0.01 kW per ft² (which is the figure for the 309 kW, 31,000 ft² Ford Array). According to NREL, it is assumed commercial buildings are proportional to residential ones when seeking an island-by-island estimate, with half of commercial buildings available for rooftop PV.

The majority of generation potential is on the islands of Oahu and Hawaii, each of which can produce nearly 1,200 MW. The NREL assessment identifies 750 MW of geothermal potential for the Island of Hawaii, whereas Oahu has 992 MW of potential output that can be achieved with rooftop solar on residential and commercial buildings. Oahu's solar potential is based on NREL data estimating that half of homes are suitable for rooftop PV, with each producing 2.5 kW. This estimate was assumed to hold for offices, which it was estimated can output 0.01 kW per ft^2.[16] As detailed in subsequent sections, however, the scenarios assume that the lowest cost resources are used first. Because rooftop solar carries one of the highest costs, Oahu's adjusted resource capacity is relatively low.

Lanai and Molokai were not modeled in the scenario analysis, but their resource potential is included because of their large potential for wind generation that could be exported to their neighboring islands. The proposed projects were assumed to have a combined output of 800 MW for consumption on Oahu. An undersea cable is necessary to tap into this potential resource, so its availability is the key difference among the scenarios. Whereas energy-efficiency measures and PHEV market penetration affect the levels of electricity demand in the scenarios, the installation of an undersea transmission cable broadens available supply.

Scenarios with an undersea cable allow for greater wind generation potential, whereas the alternate scenarios that assume no transmission cable is in place rely primarily on solar power. Oahu's geography and dense population, however, limit commercial-scale solar generation capacity, and even with deployment of rooftop PV on half the buildings in Oahu, solar alone cannot fully compensate for the loss of the wind capacity that would be brought to Oahu by the undersea transmission cable. NREL's Technical Review Committee and *Oahu Wind Integration and Transmission Study* (OWITS) have recently provided detailed analyses of the Big Wind project's technical feasibility.[17]

Although large-scale wind generation involving an undersea cable would provide a major source of renewable energy for the state, it is just one of the scenarios evaluated by HCEI.

These resource potentials represent a maximum possible output by 2030. When modeled, the availability of these resources is scaled up in 5-year increments and adjusted for capacity factors. Capacity factors take into account variables that may keep a generation source from operating at full capacity, such as maintenance downtime and weather. The adjustments are discussed below.

For the transportation sector, land available for biofuel production is the key metric when measuring resource potential. Two recent studies provide insight into the amount of arable land for energy crops. The scenarios assume that half of the potential identified in a 2006 ethanol study by the Hawaii Natural Energy Institute (HNEI) is actually available for ethanol and that half of the potential identified in the Hawaii Agriculture Research Center (HARC) biodiesel

[16] Estimate based on conversations with NREL staff. The 2006 census showed Hawaii had 500,000 homes, and a 2003 DBEDT assessment reported 173 million ft^2 of office space.
[17] National Renewable Energy Laboratory. (2010). *Oahu Wind Integration and Transmission Study*. http://www1.eere.energy.gov/deployment/pdfs/48632.pdf (accessed December 25, 2011).

study is actually available for biodiesel; the rest of the land is assumed to be dedicated to some other use, such as food production.[18] [19]

Together, 135,340 acres are technically available for either biodiesel or ethanol production. As discussed above, the ratio of ethanol produced to biodiesel produced is determined based on the amount of ethanol needed to meet a proposed 20% RFS over the full life of the HCEI. The goal was to maximize the amount of locally produced biofuels in order to limit import costs.

Together, these parameters formed the basis for an evaluation of progress toward the 70% clean energy goal. The scenarios reflect potential futures for the state of Hawaii, with varying success in promoting energy efficiency, adopting PHEVs, and upgrading the electric grid. Initially, eight scenarios were established using the assumptions described above, but the analysis ultimately focused on two specific scenarios, Scenarios 7 and 8, that vary only with respect to an undersea cable. The evolution of these scenarios and their results are discussed in subsequent sections.

Modeling Scenarios

After establishing baseline demand, a set of underlying assumptions, and data on Hawaii's resource potential, Booz Allen used two models that draw on this information to measure the ability of each scenario to meet the 70% clean energy goal.

Generation Model

To measure outcomes in the electricity sector, Booz Allen developed a generation model that estimates the state's clean energy output, island by island, each year through 2030. This output is also broken down by generation source, depicting how much capacity each source is expected to deliver relative to the state's demand. The model uses this information to calculate the percentage of the state's generation output that comes from clean sources, thereby comparing each clean energy adoption scenario to the 70% goal. It also measures the amount of oil use and carbon dioxide (CO_2) output that can be avoided each year.

To calculate clean energy progress, baseline demand for each island was modified based on the parameters in the scenarios. As discussed above, electricity demand was adjusted to account for future efficiency gains, and it was increased to account for greater use of PHEVs.

The adjusted demand was then compared to the available supply of clean energy. To calculate supply, the resource potential for each renewable generation source was adjusted for capacity factors. Capacity factors take into account variables that may keep a generation source from operating at full capacity, such as maintenance downtime and weather. They were established using data gathered by NREL and DOE's Office of Energy Efficiency and Renewable Energy (EERE) (Table 4).[20] [21]

[18]Hawaii Natural Energy Institute, University of Hawaii. (2006). *Potential for Ethanol Production in Hawaii*. http://hawaii.gov/DBEDT/info/energy/publications/ethanol-hnei-06.pdf (accessed March 22, 2011).
[19]Poteet, M.D. (2006*). Biodiesel Crop Implementation for Hawaii*. Hawaii Agriculture Research Center. https://www.eere-pmc.energy.gov/states/Hawaii_Docs/biodiesel_report-revised.pdf (accessed March 22, 2011).
[20]National Renewable Energy Laboratory. (2006). *Number of Home Electricity Needs Met Calculation*. http://www.nrel.gov/analysis/power_databook/docs/pdf/db_chapter12_2.pdf (accessed March 23, 2011, from Power Databook).

Table 6.Average Capacity Factors

Energy Source	Capacity Factor
Biomass—direct firing	80%
Wind	35%–45%
Geothermal	95.5%
Hydro	44.2%
Solar−residential roofs	22.5%
Solar−commercial roofs	22.5%
Solar−utility scale	24.4%
Municipal solid waste	95%
Ocean energy	35%

Source: NREL and DOE Office of Energy Efficiency and Renewable Energy (EERE)
Note: Additional wind industry information was provided by Maui and West Maui counties. Wind includes a range of capacity factors because Lanai and Molokai are more optimally suited for wind generation than other islands, so they offer a higher capacity factor.

Delivered capacity was loaded into the model over time to account for the planning and capital needed to bring a generation project to scale. Rooftop solar capacity was added continuously, whereas other energy sources were scaled up in 5-year increments.

An important assumption of the analysis is that each island has a 70% clean energy goal, so not all of an island's potential generation sources are necessarily needed. Renewable energy technologies were added based on their relative cost, with the least expensive sources fully utilized by 2030 (Table 5). For example, even though Hawaii and Kauai islands have ocean energy capacity available, this capacity is not fully loaded into the model because they can reach the 70% goal without it. In addition, ocean energy technology has not yet been proven to be commercially viable, though future developments may improve its viability.

[21]Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. (no date). *Geothermal Hydrothermal* and *Biomass (Direct Firing).* http://www1.eere.energy.gov/ba/pba/ pdfs/geo_hydro.pdf and /direct_fire_bio.pdf (accessed March 23, 2011).

Table 7.Basis for Renewable Energy Cost Ranking[a]

Source	Merchant	IOU	POU
Geothermal	$0.07	$0.06	$0.07
Municipal solid waste (MSW)		$0.07	
Wind	$0.08	$0.07	$0.06
Biomass	$0.12	$0.11	$0.12
Small hydro	$0.14	$0.12	$0.09
Utility-scale solar	$0.28	$0.28	$0.20
Rooftop PV solar	$0.71	$0.70	$0.47
Ocean	$1.03	$0.84	$0.62

Source: California Energy Commission, 2007. MSW costs are based on a 2007 Black & Veatch Renewable Energy Transmission Initiative report

The model, however, also accounts for Hawaii-specific considerations, such as currently planned projects. Maui's geothermal output was capped at 30% of its 140 MW capacity (42 MW), and Maui has 30% of its 10 MW ocean energy potential (3 MW) deployed in each scenario because of a planned project. Development of utility-scale solar on Kauai is also capped at 5% of its 285 MW potential (14 MW) due to land availability and current development constraints.

In addition, the model considers the availability of wind generation capacity on Lanai and Molokai. The updated scenarios differ on whether an undersea cable is available to supply electricity from the proposed project to consumers on Oahu. If a cable is employed, Oahu is assumed to have an additional 320 MW of wind power (adjusted for capacity factors) available by 2030. The availability of the cable is the only differentiator between Scenarios 7 and 8.

Finally, any demand unmet by clean energy sources is assumed to be met with oil—the status quo. Initially, the scenarios assumed that any shortfalls in an island's attempt to reach its 70% goal would be met using imported biodiesel. The updated scenarios assume biofuels will only be devoted to meeting demand in the transportation sector, with only enough imports to meet a proposed RFS.

The model's result is a detailed snapshot of island-by-island supply and demand for each year through 2030 (see Appendix D for a sample of results for each particular island and scenario; given eight scenarios and four islands, including one statewide roll-up, there are 40 pages of results for the electricity model). The model computes the percentage of demand that can be met with clean energy for each scenario and island. Comparing results from the scenarios allows one to measure the added impact of a cable connecting Lanai and Molokai to Oahu.

[a] Costs are per kWh. Except for MSW, costs represent those paid by merchants reselling power, investor-owned utilities, and public-owned utilities.

The initial scenarios included both moderate and high-efficiency gains and low and high PHEV market penetration (Figure 7). It was clear from this analysis that scenarios with moderate efficiency gains would fall well short of the 70% goal (Scenarios 1–4, Table 8).

Table 8.Summary of 2030 Generation End State for Each Scenario (Installed Capacity)[a]

	Scenarios							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Efficiency	220	220	220	220	495	495	495	495
Biomass - direct firing	93	93	120	120	56	56	83	83
Wind	276	1076	276	1076	223	1023	260	1060
Geothermal	102	102	102	102	102	102	102	102
Hydro	36	36	40	40	24	24	24	24
Solar (residential roofs)	182	182	205	205	166	67	179	179
Solar (commercial roofs)	633	633	712	712	578	232	622	622
Solar (utility scale)	29	29	29	29	22	22	29	29
MSW	77	77	79	79	77	77	77	77
Ocean energy	53	53	53	53	53	3	53	53
Dispatchable	271	271	301	301	235	235	261	261
Nondispatchable	1209	2009	1316	2116	1065	1370	1167	1967
Electricity Sector Clean Energy %	**46%**	**65%**	**46%**	**63%**	**58%**	**70%**	**57%**	**70%**
Oil reduction (million bbls in 2030)	10.0	14.0	11.5	15.5	12.5	15.1	14.0	17.3
CO_2 avoided (million tons in 2030)	5.1	7.2	5.9	7.9	6.4	7.7	7.2	8.8

Source: Booz Allen analysis

[a] Numbers reflect installed capacity needed. The initial scenarios assumed 800 MW installed capacity for the Big Wind project for those scenarios highlighted in grey. These are revised to 400 MW installed capacity in the most recent analysis. Scenarios 1-4 are low efficiency, whereas 5-8 are high efficiency. Scenarios 1, 2, 6, and 7 are low PHEV, whereas scenarios 3, 4, 7, and 8 have higher PHEV penetration.

Scenarios 6 and 8 achieve the 70% goal, whereas others either come close (Scenarios 2 and 4) or fall well short (Scenarios 1, 3, 5, and 7). Several conclusions can be drawn from comparing the initial scenarios. Every scenario relies on the deployment of the full range of electricity generation technologies. Those scenarios that met or approached the goal all rely on the high-efficiency case and heavy use of wind power, made possible by an undersea transmission cable connecting wind generation on Lanai and Molokai to Oahu.

The results also indicate that the 70% goal can be met only by employing an undersea cable. Scenarios 2 and 6 show similar results, but Scenario 2 relies more heavily on commercial solar, whereas Scenario 6 assumes larger efficiency gains than Scenario 2 (both have low PHEV penetration levels, which correspondingly hurts their viability as clean transportation options).

After discussing the full range of possible strategies with the HCEI working groups, Booz Allen presented revised models in September 2008, completing a focused analysis of Scenarios 7 and 8, which were deemed the most likely options for attaining success in both generation and transportation, and updating some of the models' underlying assumptions (see Appendices A and C for the material presented at the working group meetings). Scenarios 7 and 8 differ over whether a cable is available to connect wind generation on Lanai and Molokai to Oahu, yet both assume high PHEV penetration and high-efficiency gains. Their results are discussed in the next section.

By converting the supply and demand figures from units of electrical output to barrels of oil and tons of CO_2, the model also estimates the amount of oil and CO_2 reduction under each scenario as compared to the business-as-usual case. Assuming the heat content in a barrel of oil is 6.3 million BTU, and the average system rate heat content per unit of electrical consumption is 11 million BTU per megawatt-hour (MWh), Booz Allen estimated a barrel of oil could output 0.00057 GWh.[22] Using this equivalency factor, both the baseline demand and delivered clean energy capacity were converted to barrels of oil. The result was an estimate of the volume of oil foregone under each scenario by using clean energy (these calculations did not account for oil still needed for spinning reserve).

This total volume foregone was also broken down by the type of fuel, based on data of which fuels Hawaii uses for generation purposes (65% residual, 30% diesel, 2% jet fuel, and 4% other).[23] Emission coefficients for each fuel type converted oil foregone to greenhouse gas (GHG) emissions avoided.[24]

Transportation Model

Booz Allen also developed a model that measures the impact of transportation technology adoption rates on the clean energy goal in the transportation sector. This model uses principles similar to those employed in the generation model except that it was not developed island by island. It adjusts baseline fuel demand using parameters outlined in the scenarios and measuring the extent to which biofuels can meet it.

[22]Heat rate content figures were provided by DBEDT.
[23]Current oil usage breakdown provided by DBEDT.
[24]Energy Information Administration. (April 2007). *Voluntary Reporting of Greenhouse Gases Program*. http://www.eia.doe.gov/oiaf/1605/coefficients.html (accessed March 23, 2011).

With respect to demand, the updated scenarios assume high PHEV usage (69% of all new vehicles sold in 2030) and CAFE standards escalating to 35 MPG by 2020. These assumptions are discussed in greater detail in previous sections. PHEVs reduce fuel use by 158 MGY by 2030. The improved fuel economy from CAFE reduces demand by 33 MGY by 2030.

To calculate the effect of PHEVs, the number of electric vehicles was established by setting the market penetration rate against the total number of vehicles in Hawaii, both of which escalate over time. Assuming PHEVs meet 70% of their energy use with electricity, achieve 0.32 miles per kilowatt-hour (kWh), and have a 30-mile electric range,[25] Booz Allen calculated total electricity demand added and fuel use avoided in a given year.

Similarly, the fuel saved through tightened CAFE standards can be determined by comparing fuel use under CAFE to the status quo. Expected fuel savings were calculated using the number of vehicles on the road, average miles driven per year, and escalating fuel economy standards.

Although electric vehicles are important to Hawaii's transportation goal, increased adoption of biofuels in standard vehicles and improved vehicle efficiency are also critical elements to a comprehensive transportation plan.

In addition, potential savings from increased use of mass transit were examined initially but were not used as a scenario option because even a significant increase in public transportation demand would have a negligible effect on the state's demand for fossil fuels. This is due largely to the very high levels of ridership on the current mass transit system in the greater Honolulu area, the major population center for the state. Incremental increases in ridership are, therefore, unlikely to result in a significant new source of petroleum savings above the current baseline. Mass transit options may offer other important public benefits, such as reducing congestion, but this analysis focused on potential petroleum savings.

Under this initial scenario analysis, biofuels are the primary source of clean energy in the transportation sector. The amount of arable land available for energy crop production (discussed above) is scaled up over time, from 10% of technically arable land in 2010 to 50% in 2030. In addition, the scenarios assume a proposed RFS that increases to 20% by 2020. The model measures how much fuel would be needed to meet the RFS, compared with production capacity, and calculates whether surplus biofuel is available and to what extent fuel imports would be necessary.

Together, the adjusted supply and demand figures can be compared to determine what percentage of demand could be met with biofuels. The model also breaks down how the baseline demand is either met or reduced over time by different components of the scenarios (e.g., PHEVs reduce fuel consumption, whereas biodiesel and ethanol offset the need for petroleum). By using the same method as in the generation scenario, the model also calculates the amount of CO_2 avoided.

---

[25]Winkel, R.; van Mieghem, R. (2006). "Global Prospects of Plug-in Hybrids." EVS-22 Conference. Argonne National Laboratory, Electric Power Research Institute. http://transportation.anl.gov/pdfs/HV/393.pdf (accessed March 22, 2011).

The scenarios show that PHEVs add modest electric power demand (202 MW in the high penetration case), but they can have a significant effect on reducing demand for gasoline–158 million gallons by 2030. As seen in Table 9, although none of the initial scenarios achieves the 70% goal, only those scenarios with a high PHEV market penetration (scenarios 3, 4, 7, and 8) even approach it.

Table 9.Summary of 2030 Transportation End State for Each Scenario[a]

	Scenarios							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Transportation Sector Clean Energy %	**30%**	**30%**	**57%**	**57%**	**30%**	**30%**	**57%**	**63%**
Oil reduction (million bbls in 2030)	4.7	4.7	9.0	9.0	4.7	4.7	9.0	9.9
CO_2 avoided (million tons in 2030)	2.0	2.0	3.8	3.8	2.0	2.0	3.8	4.2

Source: Booz Allen analysis

Scenario Results

After discussing the full range of potential clean energy adoption strategies with the HCEI working groups and reviewing initial results, Booz Allen presented revised models in September 2008, completing a focused analysis on Scenarios 7 and 8 (see Appendix C). The results, the underlying assumptions of which are discussed above, differ over whether a cable is available to connect wind generation on Lanai and Molokai to Oahu.[26] Key findings from the analysis included the following.

Key Findings

- Generation
  - Those scenarios that met or approached the 70% goal all rely on high-efficiency levels and heavy use of wind power, made possible by an undersea transmission cable connecting wind generation on Lanai and Molokai to Oahu.
- Transportation
  - The scenarios show that PHEVs add modest electric power demand (202 MW in the high penetration case), but they can have a significant effect on reducing demand for gasoline—158 million gallons by 2030. Initial scenarios that did not include high PHEV adoption rates did not approach the 70% clean transport goal.
  - None of the transportation scenarios achieved the 70% goal. Hawaii is facing a significant level of future transportation demand that would be difficult to

[a] The revised scenarios count on a mixture of ethanol and biodiesel produced in Hawaii. Once production capacity has been met, biofuels would be imported at levels needed to meet a proposed 20% RFS. Any demand unmet by biofuels beyond that mandated by the RFS is assumed to be met with petroleum.

[26] See Appendices A and C for details of the wedge analysis presented to the working groups.

meet even with aggressive fuel economy measures, widespread adoption of new vehicle technologies, and increased biofuel production and imports.

In the scenario without a cable, Scenario 7 (Figure 8), Hawaii's electricity sector would reach 55% clean energy, saving 15.7 million barrels of oil and avoiding 8 million tons of CO_2 per year by 2030. Geothermal, wind, commercial rooftop solar, MSW, and efficiency improvements would all be core components of a noncable scenario.

With a cable connecting Lanai and Molokai to Oahu, the electricity sector would meet the 70% goal, saving 20 million barrels of oil and avoiding 10.1 million tons of CO_2 by 2030. Although commercial solar and geothermal continue to play significant roles, the ability to produce wind on Lanai and Molokai for Oahu electricity consumers adds 2.8 million MWh in delivered capacity from wind (Figure 9) and allows the state to reach its 70% goal in entirety.

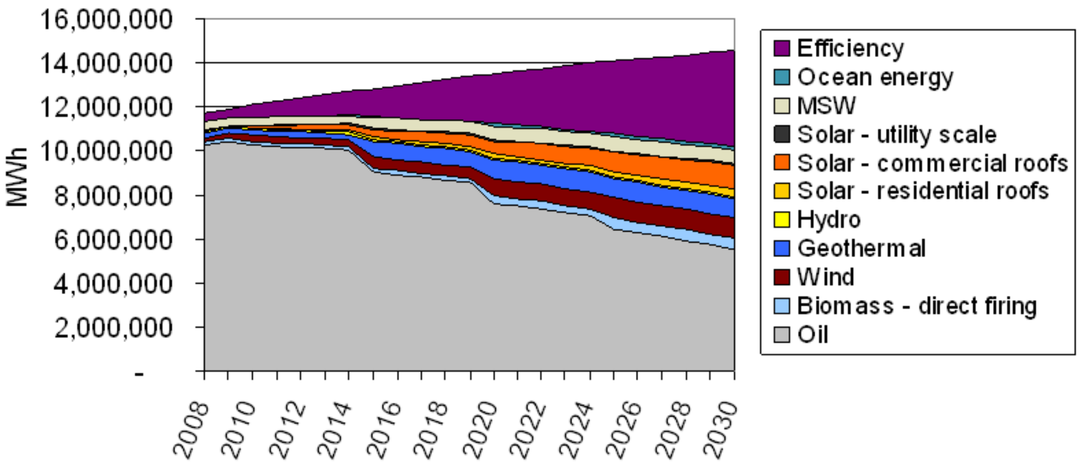


Figure 8.Statewide generation results—Scenario 7 (delivered capacity, no cable)

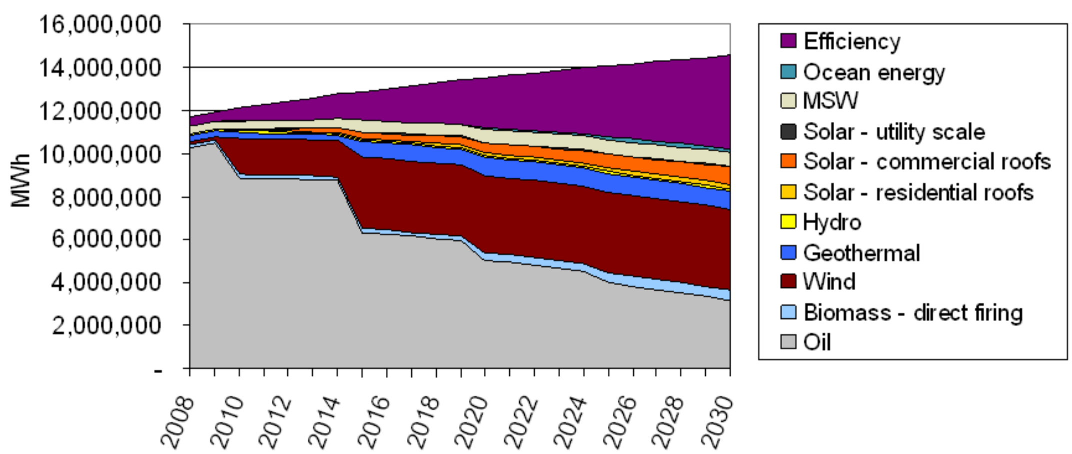


Figure 9.Statewide generation results—Scenario 8 (delivered capacity, with cable)

Because the scenarios differ only with respect to the availability of wind capacity from Lanai and Molokai, the transportation results are the same for both scenarios. Under the scenarios outlined above, Hawaii would be able to achieve 45% clean energy by 2030 in the transportation sector, reducing oil consumption by 7.9 million barrels per year and avoiding 2.7 million tons of CO_2.

Even with all domestic clean transportation options included, significant imports of biofuels will be needed to attain the state's 70% transportation goal.

Initial results indicated a slightly higher level of progress toward the clean energy goal, but those results supposed that any unmet progress toward the clean energy goal would be met with imported biofuel. The revised model further integrates the role of imports, assuming biofuels will be imported only at levels needed to meet a proposed 20% RFS. Imports, therefore, are directly factored into the state's clean energy level, and any unmet progress is assumed to be met with petroleum.

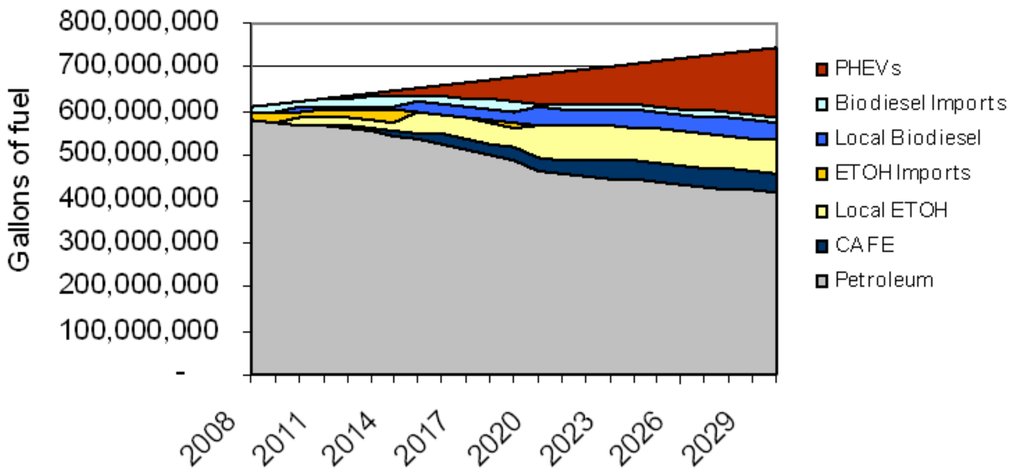


Figure 10.Transportation results

Source: Booz Allen analysis

The model results show that PHEVs add modest electric power demand (202 MW), but they can have a significant effect on reducing demand for gasoline–158 million gallons by 2030. Nevertheless, the results demonstrate that Hawaii is facing a significant level of future transportation demand that would be difficult to meet even with aggressive fuel economy measures, widespread adoption of new vehicle technologies, and increased biofuel production and imports.

Cost Analysis

After establishing the scenarios, Booz Allen developed a cost model to determine the net present value (NPV) of each scenario under different long-run oil price expectations. The intention was to provide an "order-of-magnitude" cost estimate. The cost model essentially uses the present value of the avoided oil expenditures to offset the present value of capital costs of each scenario. Since oil prices are the main variable in the "revenue" side of the NPV calculation (i.e., the avoided expenditure on oil is essentially a revenue to the NPV calculation), this analysis was run at a variety of different oil prices, which helps illustrate the approximate break-even price of oil that would justify the capital expenditure on renewable technologies. Key findings from that analysis are summarized below.

Key Findings

- Break-even oil prices are within a reasonable range, suggesting further investigation of specific investments is appropriate
- With undersea cable
  - $16 billion estimated capital costs
  - $65 to $85 per barrel break-even oil price
  - Fully attain 70% generation goal
- Without undersea cable
  - $14 billion estimated capital costs
  - $65 to $75 per barrel break-even oil price
  - Do not fully attain 70% generation goal (only reach 55% clean energy).

The initial NPV analyses used capital costs from a California Regional Energy Transmission Initiative study that presented installed capital costs, on a $/kW basis, for the state of California,[27] then multiplied by the amount of capacity of each technology needed in each scenario (see Appendix B). Based on conversations with HCEI stakeholders, these capital costs were revised in the second version of the model to present a more Hawaii-specific view. Additionally, the functionality of the model was improved to accept a range of capital cost estimates to account for the relative uncertainty of using emerging technologies. The details on capital costs by technology are presented below.

[27]See http://www.energy.ca.gov/2008publications/RETI-1000-2008-002/RETI-1000-2008-002-F.PDF, pages 1-8 for detailed table.

Table 10.Capital Costs by Technology

Renewable Type:	Installed Capital Costs ($/kW)	
	Original Model Assumptions	Revised Model Assumptions after Stakeholder Input[a]
Solid Biomass	$4,000 [b]	Range: $2,000 –$6,000; $4,000 = most likely
Wind	$2,150 [b]	Range: $2,400 –$2,800; $2,600 = most likely
Geothermal	$4,000 [b]	Range:$3,000 –$5,000; $4,000 = most likely
Small Hydro	$3,250 [b]	Range:$2,500 –$4,000; $3,250 = most likely
Solar – Residential Roofs	$8,750 [b]	Range:$8,125–$9,375; $8,750 = most likely
Solar PV Large Roof/Utility Scale	$7,000 [b]	Range:$6,500–$7,500; $7,000 = most likely
MSW/Landfill Gas	$1,600 [b]	Range:$2,100–$3,500; $2,800 = most likely
Ocean Energy (wave)	$4,000 [b]	Range:$2,000 –$7,600; $6,000 = most likely
Energy Efficiency	$75–$100 [c]	Range:$75–$100; $75 = most likely
Biorefinery Capex ($/gal. nameplate)	$5.00 [d]	Range:$4–$7; $5 = most likely
Cable Costs ($ millions)	$600 [e]	Range:$480–$720; $600 = most likely
Grid Capex ($/MWh intermittent generation)	$32 [f, d]	Range: 41% to 50% of levelized cost of intermittent generation; 45% = most likely

Booz Allen used the revised capital cost inputs and a Monte Carlo simulation to further refine the total capital cost estimate (see Appendix C). The result of this modeling is a capital cost estimate of $14 billion for the scenario with no undersea cable and $16 billion for the scenario with an undersea cable, as seen in Figure 11.

[a] See Appendix C for detailed stakeholder inputs and ranges.
[b] California RETI Coordinating Committee. Renewable Energy Transmission Initiative, Phase 1A (April 2008).
[c] Rogers, C.; Messenger, M.; Bender, S. (2005). Funding and Savings for Energy Efficiency Programs for 2000-2004. California Energy Commission.
[d] Capital cost estimated from Jacobsen, Inc. “Biodiesel Production Cost Worksheet,” http://www.thejacobsen.com/ (accessed June 2008).
[e] NREL estimate.
[f] According to NREL, grid CAPEX are 45% of levelized cost of intermittent generation above 20% clean energy.

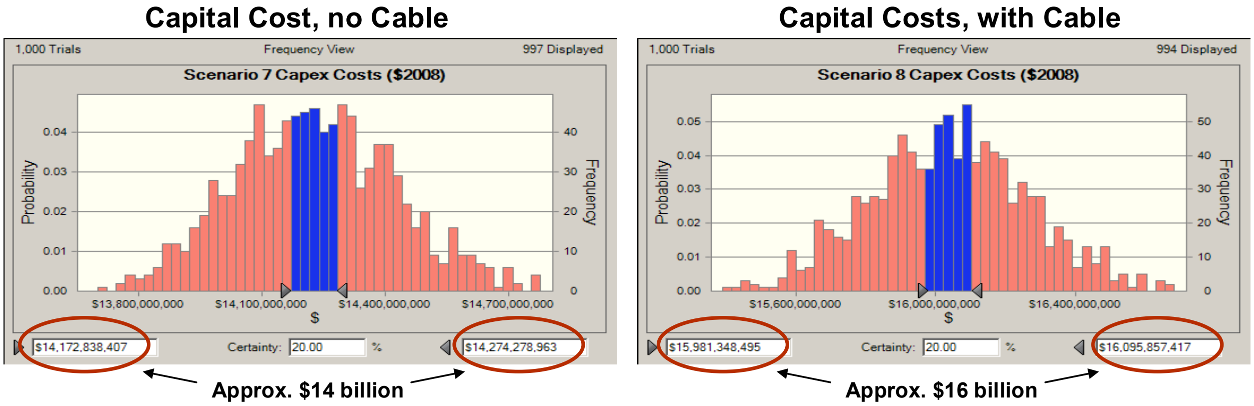


Figure 11.Capital cost estimates by scenario

These capital costs invest in technologies that either produced electricity instead of oil-fired generation, avoided the use of electricity (i.e., energy-efficiency investments), or provided transportation fuels in place of petroleum products. The number of kWh generated by each technology is a function of the amount of installed capacity and the capacity factors (i.e., percentage of time a generation asset is available or able to generate electricity) or the number of kWh saved (in the case of energy-efficiency investments). Each of these variables has been discussed in previous sections of this report. The revenue generated by these capital investments is then the avoided expense in terms of oil imports. Since oil prices are inherently unpredictable, Booz Allen employed a range of oil prices, from a minimum of $30 per barrel to a maximum of $200 per barrel, with a most likely value of $100 per barrel and a triangular distribution. The oil price distribution is shown below in Figure 12.

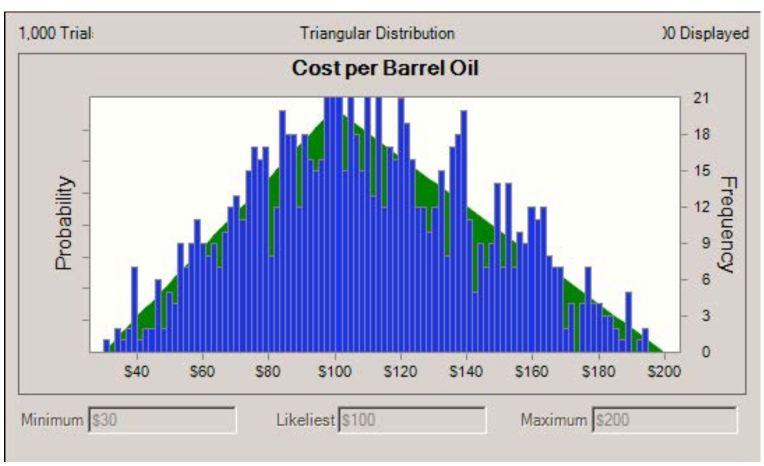


Figure 12.Oil price distribution

Source: Booz Allen analysis

Similarly, the discount rate was varied, with a minimum of 5.0%, a maximum of 9.0%, and a most likely value of 7.0%.

The model was then run as a Monte Carlo simulation with capital costs for each technology, oil prices, and discount rate each varying within their specified ranges. The graphs below illustrate how the net present value of the scenarios shows a largely linear relationship with the price of oil—this is to be expected, as the price of oil generates the revenue in the NPV model. The interesting point of the analysis is the x-intercept, which illustrates the long-term average price of oil that would create a positive (or negative) net present value of investing in the capital necessary for each scenario.

For the scenario without an undersea cable, the long-term average oil price needs to be approximately $60 to $75 per barrel. Above that point, the NPV is consistently positive. As expected, for the scenario with an undersea cable the long-term average oil price needs to be slightly higher to consistently provide a positive NPV, approximately $65 to $85 per barrel. This slightly higher range is understandable based on additional capital costs for the undersea cable, but additionally provides for a higher penetration of clean energy (55% clean energy versus 70% clean energy, as noted in the Scenario Results section of this report).

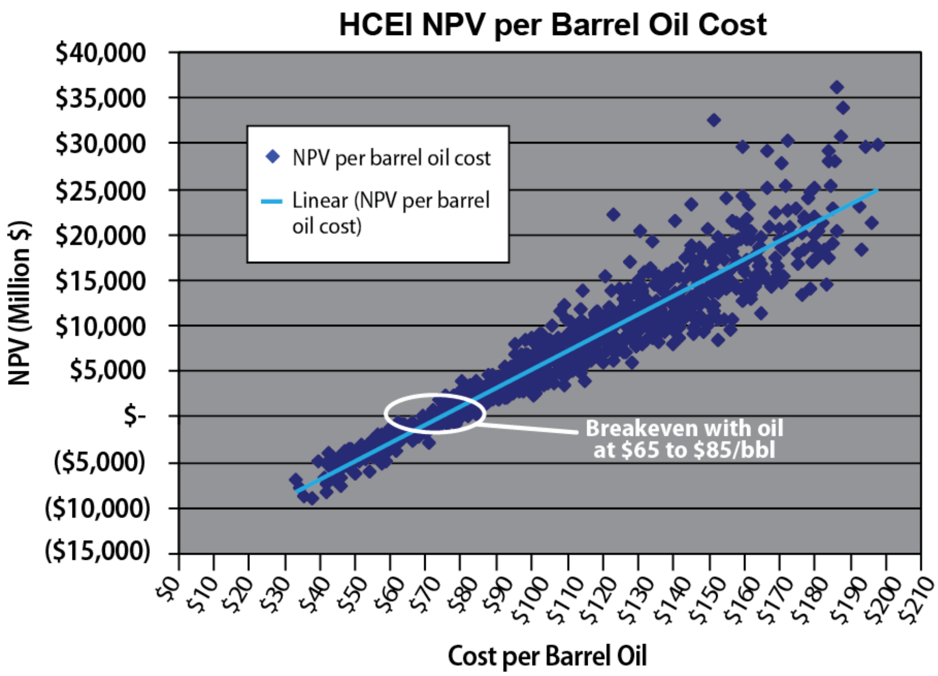


Figure 13.NPV break-even point based on oil price[28]

Source: Booz Allen analysis

At a high level, the results of the cost modeling show that both scenarios (with and without an undersea cable) are viable within a reasonable range of oil price expectations. That is, if the results of the analysis had determined that an average $200 per barrel oil price was necessary to create a break-even NPV, the scenarios as currently developed may not be attractive. The analysis results show a need for average oil prices between $65 and $85 per barrel, which, in light of recent years' average oil prices, appears to be in the reasonable range of forward projections. This test of reasonableness was used to conclude that the specific investments warranted further examination.

[28] Simulation based on 1,000 runs.

In-Depth Analysis

Upon completion of the original high-level scenario analysis for the HCEI working groups, Booz Allen collaborated with the working groups to identify potential areas for more detailed study. Over the course of 2008, three areas of specific interest were identified. These included biofuel potential within the state of Hawaii, a more detailed breakdown of the state's energy-efficiency goal, and an analysis of Hawaii's alternative transportation options. These works were conducted in sequence, with the biofuels analysis completed in April 2009, energy efficiency in November 2009, and transportation in October 2010.

The results of the biofuels model were considered in conjunction with HNEI's Bioenergy Master Plan to help the local biofuels industry evaluate potential options moving forward. The results of the energy-efficiency analysis were used to inform the interveners in the Energy Efficiency Portfolio Standard (EEPS) docket as to the viability of attaining the stated goal of reducing demand 4,300 GWh by 2030, whereas the results of the transportation analysis were used to outline strategies and goals for the state in the HCEI Road Map in December 2010.

This section will take an in-depth look at these three areas and outline how the conclusions reached by each analysis affected the results of the original scenario analysis for HCEI. All results were presented to the HCEI working groups to help them identify key decision points that required evaluation in each of the respective areas.

Biofuels

Booz Allen's biofuels analysis was undertaken on behalf of the HCEI Fuels Working Group beginning in November 2008 (see Appendix E). The task was outlined in two stages:

Stage 1: Develop an integrated framework of current biofuels activities (reports, projects, and plans) and sort the information by component of the supply chain and gaps identified

Stage 2: Conduct an analysis of the biofuels supply chain supply, demand, and cost and identification of key scenarios:

- Electricity and transportation demand trade-offs
- Comparison with business as usual.

Key Findings

- A clean energy scenario with higher usage of biofuels (60% renewable combustion technologies) would generate demand as high as 480 MGY of ethanol and 280 MGY of biodiesel.
- Booz Allen filtered available data to construct an "aggressive yet reasonable" supply scenario, which states that Hawaii could produce 93 MGY of ethanol and 73 MGY of biodiesel.
- Increasing crop acreage and yields could increase supply, but significant imports would be needed in almost every scenario.
- The cost of a higher level of biofuel imports is significantly higher than the capital costs of adding renewable generation capacity.

- The economic risk of fuel price volatility due to use of biofuels for generation is likely to be higher than the economic risk of grid impacts due to the intermittence of renewable generation.
- An analysis of means to promote both food and fuel crops in an integrated manner is necessary to identify optimal fuel production solutions that do not displace current agricultural land users.

Stage 1:
To start, Booz Allen identified all prior Hawaii-specific studies and activities in the area of biofuels. The primary sources used in this analysis were:

- Poteet, Michael. (2006). *Biodiesel Crop Implementation for Hawaii.* Hawaii Agriculture Research Center (HARC)
- Hawaii Natural Energy Institute, University of Hawaii. (2006). *Potential for Ethanol Production in Hawaii*.

It is critical to note that this round of analysis focused primarily on existing, commercially viable technologies for biofuel production in Hawaii. The potential for use of cellulosic materials for the production of ethanol, however, was also evaluated, as the authors of the *Potential for Ethanol Production in Hawaii* report deemed cellulosic ethanol to be the most likely of the second-generation refining technologies to be commercially viable in the near future.

Stage 2:
Demand
To begin, Booz Allen identified two likely demand scenarios for fuels. The first is based on the prior Scenario 8 analysis. Details are outlined below in Figure 14.

HCEI Scenario 8

- Focused on attaining a 70% clean energy goal for generation through:
  - High levels of intermittent renewable energy generation technologies (wind, solar);
  - Firm renewable energy generation technologies (geothermal, hydropower, ocean);
  - Renewable combustion technologies (MSW, biomass); and
  - High levels of energy efficiency
- Reaches 70% clean energy for transportation through:
  - Improved CAFE standards;
  - Higher PHEVs; and

Figure 14.HCEI Scenario 8

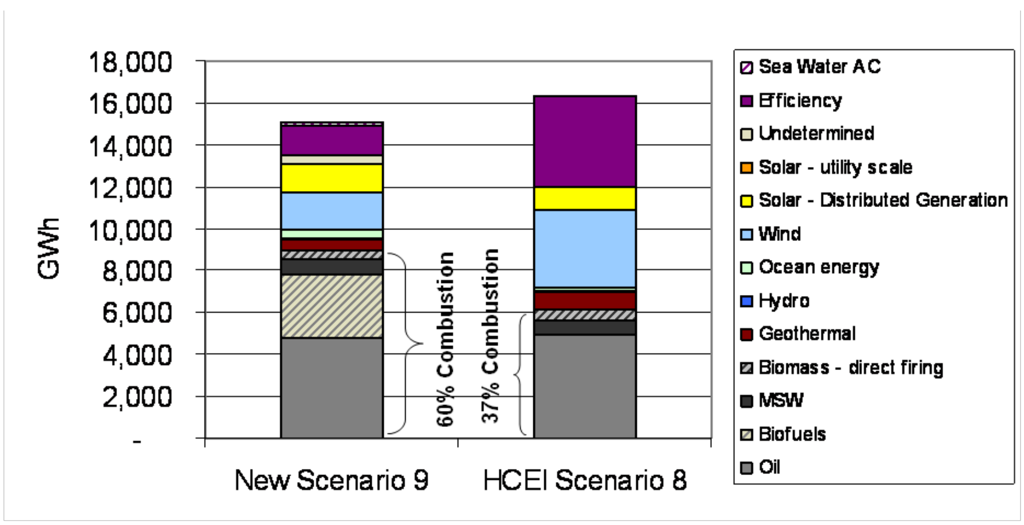
The second scenario was created to illustrate a higher usage of biofuels for generation, as opposed to Scenario 8 where biofuels were reserved primarily for ground transportation. The new scenario was labeled Scenario 9. Details are outlined below in Figure 15.

New Scenario 9

- Focused on attaining a 70% clean energy goal for generation through:
  - High levels of renewable combustion technologies (biofuels, MSW, biomass);
  - Firm renewable energy generation technologies (geothermal, hydropower, ocean);
  - Moderate levels of intermittent renewable energy generation technologies (wind, solar); and
  - Low levels of energy efficiency
- Reaches 70% clean energy for transportation through:
  - Improved CAFE standards;
  - Lower PHEVs; and
  - Higher biofuel usage

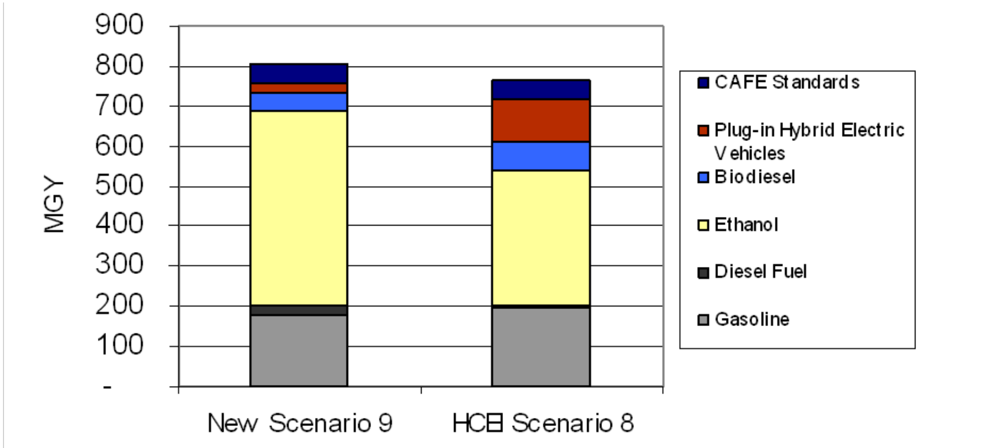
Figure 15.New Scenario 9

A comparison of fuel mix for each scenario, both generation and transportation, is outlined in Figures 16 and 17 below.



Note: The difference in magnitude of total generation is due to different assumptions for PHEV/ electric vehicle deployment and resulting electricity demand

Figure 16.Scenario 8 versus New Scenario 9 − generation/energy efficiency mix (2030)



Note: the difference in magnitude between the two scenarios in terms of overall gallons used is due to heat content adjustments between gasoline and ethanol. The scenario with the slightly higher ethanol use (New Scenario 9), will use a relatively higher number of gallons of fuel to generate the same amount of energy

Figure 17.Scenario 8 versus New Scenario 9 – transportation fuel mix (2030)

Source: Booz Allen analysis

These graphs show that Hawaii's overall demand for fuels would range from 77 MGY of biodiesel in Scenario 8, where electricity demand is met primarily from other sources of energy, to 283 MGY of biodiesel in Scenario 9, where an additional 206 MGY is used to power diesel generators (corresponding to the commitments outlined in the voluntary energy agreement between HECO and the state of Hawaii signed in October 2008). Likewise, ethanol demand is forecast to range from 338 MGY in Scenario 8 to 486 MGY in Scenario 9. This increase is due to the fact that lower plug-in hybrid numbers were assumed in Scenario 9, corresponding with the levels of PHEVs forecast in the energy agreement.

The potential local supply of biofuels was forecast based on the use of only those lands and crops that would not materially alter current land- and water-use patterns.

Supply

To create a viable supply scenario, Booz Allen leveraged the Hawaii Agriculture Research Center (HARC) and HNEI reports to identify the total pool of agricultural land eligible for the growth of biofuel feedstock crops. Once the total pool of agricultural lands was determined, Booz Allen applied a series of screens to the total pool to narrow it down to a more aggressive but realistic scenario. These screens are outlined in Figure 18 below.

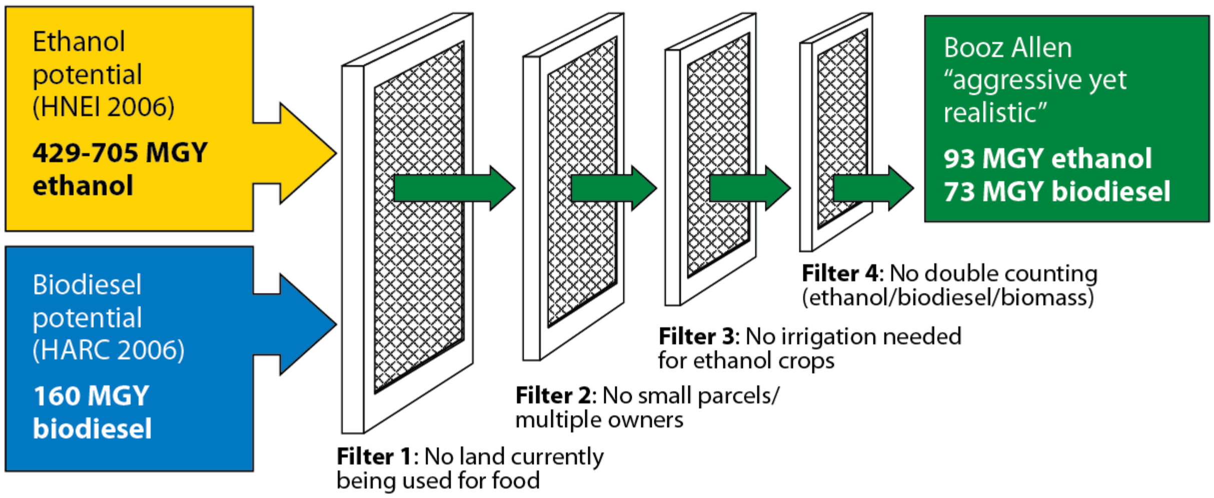


Figure 18.Booz Allen fuel supply analysis methodology

Source: Booz Allen analysis

Booz Allen also accounted for those crops that were eligible for use as feedstock in straightforward biomass generation. After subtracting the lands already being used for these purposes from the total pool, Booz Allen leveraged gallons-to-acre conversions from each report to convert the total land put into each feedstock into corresponding gallons of biofuel produced per year. This resulted in the following supply scenario:

- Ethanol: 93 MGY from 77,000 acres (65 million gallons of gasoline equivalent)
- Biodiesel: 73 MGY from 106,000 acres (including 2.5 MGY from waste oil)
- Biomass: 420 million kWh of biomass electricity from 23,000 acres

This production scenario would require 12% (206,000 acres) of Hawaii's agricultural land, a total that Booz Allen deemed reasonable for the state, particularly given that the competing uses for which this land could be used (such as food production) would also require significant tracts of land. Ethanol feedstock would be grown on Maui, Kauai, and Hawaii, with biodiesel feedstock being grown on Oahu, Maui, Kauai, and Hawaii. Biomass feedstock would be grown on Hawaii, Maui, and Kauai. By island, the total production figures are presented in Figure 19.

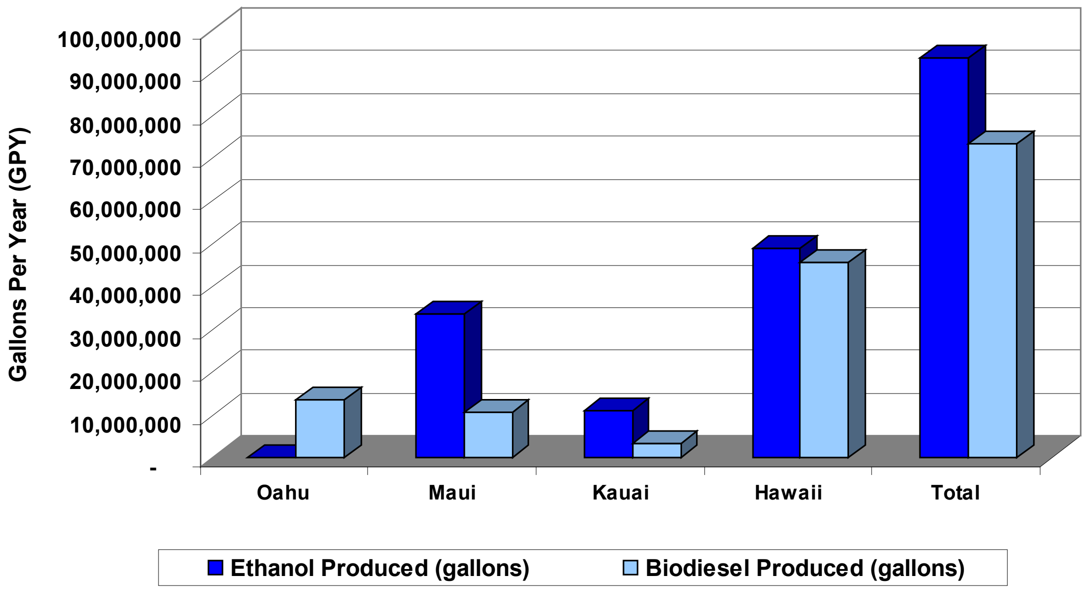


Figure 19.Local liquid fuel production – Booz Allen supply scenario

Finally, these islands' specific supply scenarios were compared to scale limitations in the refining step of the supply chain. After looking at the scale of existing biorefineries worldwide, it was determined that the levels of feedstock produced on each island would be large enough to economically support one small-scale refinery.

Table 11.Biofuels Production Capacity

	Hawaii <u>ethanol</u> plants required	Existing ethanol plants – for comparison
Oahu	None	
Hawaii	50 MGY cellulosic ethanol plant	No commercial-scale cellulosic ethanol plants are currently in operation, but the NREL design report for thermochemical and biochemical cellulosic processes assume plant sizes around 60 MGY production capacity[a, b]
Maui	35 MGY fermentation plant	In the U.S. the average capacity of the 172 existing ethanol plants is 62 MGY and the average capacity of the 23 under construction is 77 MGY.[b] In Brazil the average output of an ethanol distillery is approximately 53 MGY[c]
Kauai	10 MGY fermentation plant	
	Hawaii <u>biodiesel</u> plants required	**Existing biodiesel plants – for comparison**
Oahu	15 MGY biorefinery	In the U.S. the average capacity of existing biodiesel plants is 9.5 MGY; newer plants average 19 MGY.[b]
Hawaii	50 MGY biorefining capacity (potentially 2 or 3 refineries)	
Maui	10 MGY biorefinery	
Kauai	5 MGY biorefinery (alternatively the feedstock could be sent to another island for refining)	

[a] Phillips, S.; Aden, A.; Jechura, J.; Dayton, D. *Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass.* NREL/TP-510-41168. Golden, CO: National Renewable Energy Laboratory. April 2007.

[b] Data from the Renewable Fuels Association and Biodiesel.org.

[c] Goldemburg,J.. "The Brazilian Biofuels Industry." *Biotechnology for Biofuels* 1:6. SP 05508-101. Sao Paulo, Brazil: University of Sao Paulo, Institute of Electrotechnics and Energy. May 2008.

Sensitivity Analysis
In comparing potential island-by-island supply against demand, Booz Allen found that, for both scenarios, domestic supply alone would be insufficient (see Figure 20).

2030 Demand / Total=% met by local production in 2030	Biodiesel for Electricity	Biodiesel for Transportation	Ethanol for Transportation
HCEI Scenario 8 (70% clean energy set for the transportation sector as a whole)	0 / **N/A**	77 MGY / **73 MGY = 95%**	338 MGY / **93 MGY = 28%**
New Scenario 9 (electricity demand for biodiesel met first)	233 MGY / **73 MGY = 31%**	50 MGY / **0%**	486 MGY / **93 MGY = 19%**
New Scenario 9 (transportation demand for biodiesel met first)	233 MGY / **23 MGY = 10%**	50 MGY / **50 MGY = 100%**	486 MGY / **93 MGY = 19%**

Figure 20.Sensitivity analysis

This is particularly true in the case of Scenario 9, in which the overall demand for biofuels is higher.

This result indicated that other alternatives should be considered for increasing the overall supply of domestic fuels. As part of its analysis, Booz Allen identified three possible levers for bridging the gap between supply and demand.

Lever 1: Increase the land in production for bioenergy.

Booz Allen looked at a range of possible options based on an evaluation that included additional agricultural lands not currently in use as part of the supply mix, as well as the potential addition of algae-based oil to the total supply. The results of this sensitivity analysis are summarized in Figure 21, below. They indicate that only the most aggressive possible scenario, which is contingent on the development of second-generation algae-based technology, could fully meet the demand of Hawaii under Scenario 8, and even this scenario could not fully meet the demand under Scenario 9.

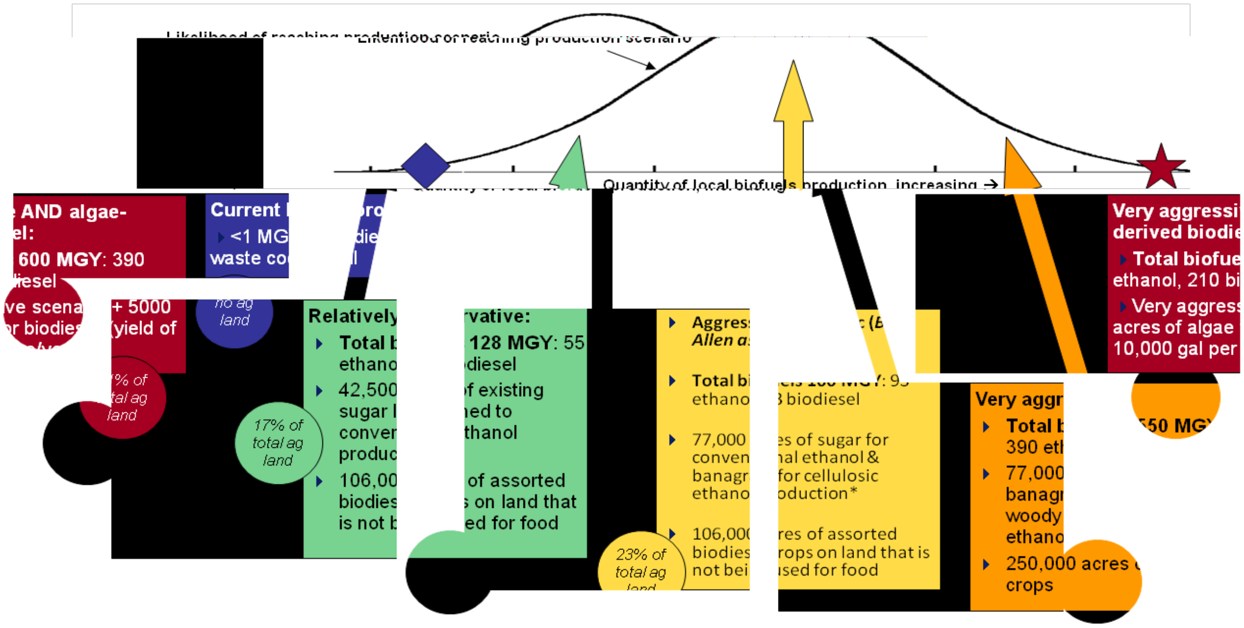


Figure 21.Likelihood of meeting production scenarios

Sources: Hawaii Natural Energy Institute, University of Hawaii. (2006). *Potential for Ethanol Production in Hawaii*. http://hawaii.gov/DBEDT/info/energy/publications/ethanol-hnei-06.pdf (accessed March 22, 2011); Poteet, M.D. (2006). Biodiesel Crop Implementation for Hawaii. Hawaii Agriculture Research Center. https://www.eere-pmc.energy.gov/states/Hawaii_Docs/biodiesel_report-revised.pdf (accessed March 22, 2011).

Lever 2: Increase the yield of bioenergy crops.

If increasing the total land in production is not going to meet demand on its own, the second option to consider is increasing the yield of the lands put into feedstock. Holding total demand constant, Booz Allen determined that yields would need to increase three to four times above current yield levels assumed by HARC and HNEI (see Table 12 and Figure 22).

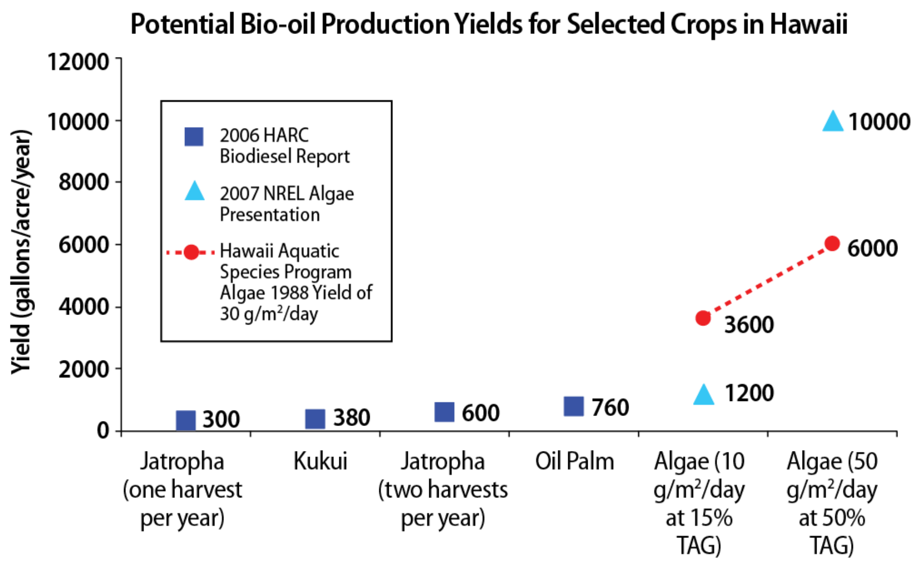
Table 12. Domestic Yields[a, b, c]

Values in gallons per acre per year	Current Domestic Yield Assumed	Yield Required to Meet Domestic Demand	
		New Scenario 9	HCEI Scenario 8
Ethanol Yield	1,500	6,335	4,411
Biodiesel Yield	667	2,871	670

[a] New Scenario 9 requires the use of biodiesel for generation. HCEI Scenario 8 requires biodiesel usage only for transportation purposes.
[b] PHEV penetration across scenarios differs: HCEI Scenario 8 assumes a much higher level of PHEV usage that for New Scenario 9.
[c] Yield assumed is a weighted average of the feedstock yields chosen for this analysis, including cellulosic ethanol, but not algae biodiesel.

Although improvements in technology may increase yields over time, it seems unlikely that the efficiencies that result would be on this order of magnitude.

Comparing current yields for biofuel crops to those necessary to meet demand (holding all other variables constant) indicates that crop yields would have to increase at least two times over for all nonalgae crops to fully meet demand.



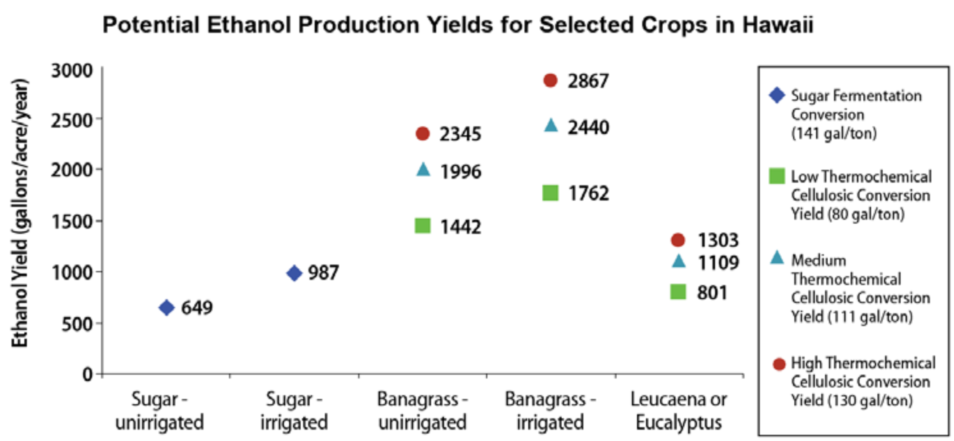


Figure 22.Biodiesel and ethanol potential production yields by crop

Sources: Poteet, M.D. (2006). Biodiesel Crop Implementation for Hawaii. Hawaii Agriculture Research Center. https://www.eere-pmc.energy.gov/states/Hawaii_Docs/biodiesel_report-revised.pdf (accessed March 22, 2011); Pienkos, P. (November 2007) "The Potential for Biofuels from Algae." NREL; Hawaii Natural Energy Institute, University of Hawaii. (2006). *Potential for Ethanol Production in Hawaii*. http://hawaii.gov/DBEDT/info/energy/publications/ethanol-hnei-06.pdf (accessed March 22, 2011); ARPS Project in Hawaii. "A Look Back at the U.S. Department of Energy's Aquatic Species Program: Biodiesel from Algae."

In looking at the current versus projected yields of next-generation technologies, it seems clear that only algae fuels would meet this yield requirement for biodiesel, whereas no future ethanol crop would reach the level of yield necessary to fully meet demand.

Lever 3: Increase the amount of biofuel imports.

Although it is certainly possible to increase the amount of land and the yield per feedstock, the total shortfall using current technologies indicates that, even in the best case scenario, the use of imported biofuels will also be necessary to meet the overall demand. These levels are outlined in Table 13.

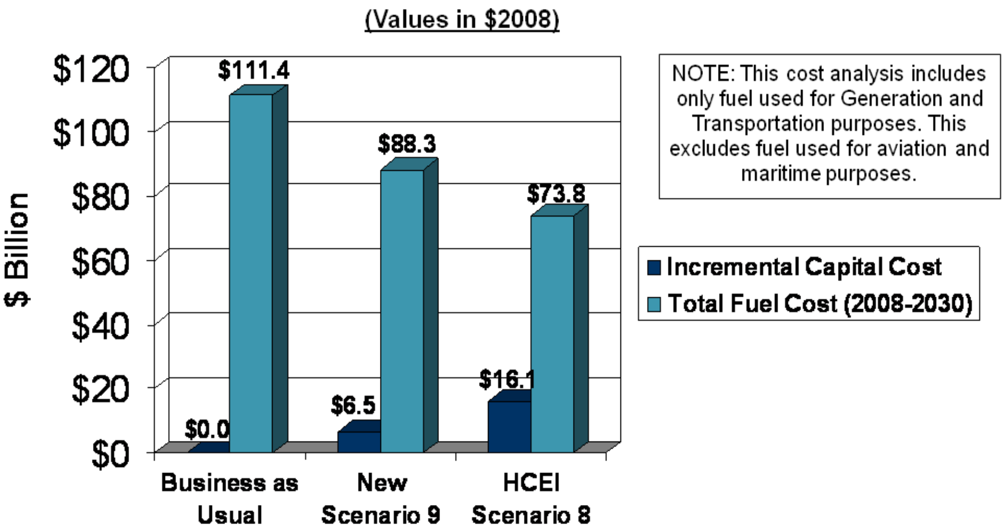
Table 13.Biofuels Needed by Scenario

	New Scenario 9	HCEI Scenario 8	Description
Cumulative Biofuel Imports, 2008-2030 (million gal.)	7,762	2,553	The total number of gallons of imported combustion fuels needed to meet both generation and transportation demand over the 2008-2030 time period
Percentage of Total Electric Generation Met Through Oil & Biofuel Imports in 2030	45%	30%	Percent of baseline generation demand met from imported combustion fuels in 2030 (excludes electricity generated from domestically produced biodiesel)
Percentage of Total Transportation Fuel Demand Met Through Oil & Biofuel Imports in 2030	79%	56%	Percent of baseline transport fuel demand met from imported combustion fuels in 2030 (excludes domestic biofuel usage)

Source: Booz Allen analysis

Costs and Risks

In comparing the costs of the various scenarios (see Figure 23), it becomes evident that the cost of the extra imports necessary for Scenario 9 vastly outweighs the additional capital costs necessary for the additional renewable energy generation in Scenario 8.



Fuel costs are based on an assumed range of prices: $3/gal gasoline, $4/gal diesel fuel for transport, $3.50/gal diesel fuel for generation, $2.60/gal residual fuel for generation, $2.10/gal ethanol, $4/gal biodiesel (Source: EIA Historical Wholesale Fuel Price Trends)

Capital Costs drawn from previous HCEI Scenario analysis, with additional transportation infrastructure costs based on Booz Allen Hamilton Intellectual Capital included as necessary

Figure 23.New Scenario 9 versus Scenario 8 total costs (2008–2030)

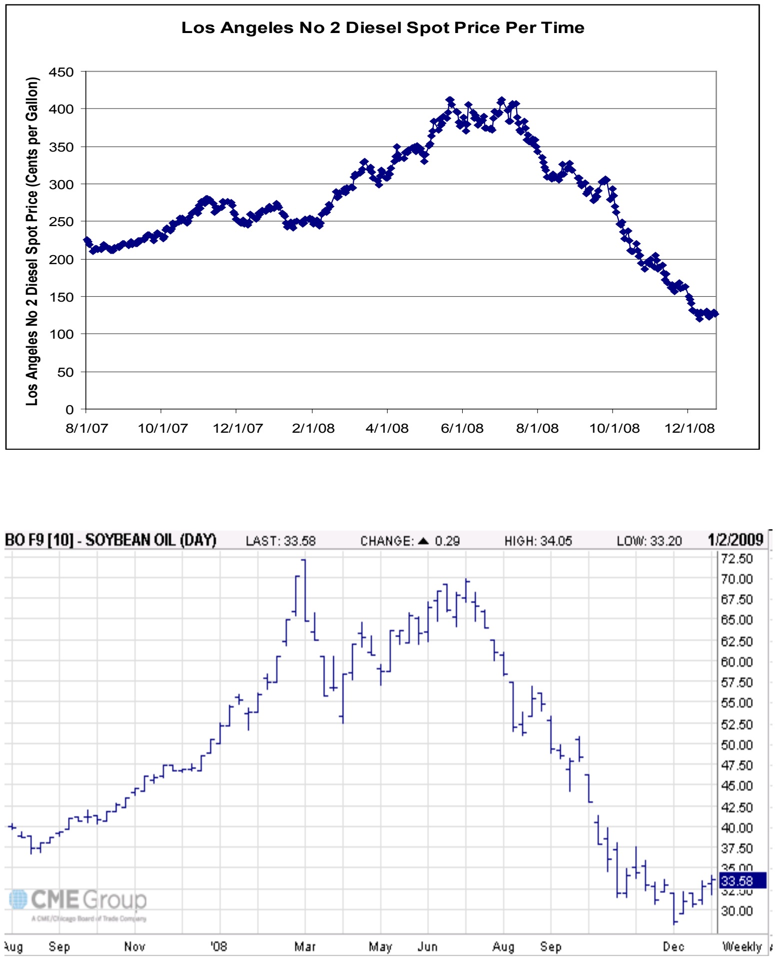
Although the extra $10 billion in capital costs of Scenario 8 above those of Scenario 9 are incurred up front, in the long run, the investment will save the state of Hawaii approximately $4 billion in avoided liquid fuel imports (and approximately $11 billion over the business-as-usual scenario, which includes no renewable energy, alternative transport, or biofuels).

In terms of risk, the critical element to look at is the volatility of fuel prices versus the increase in intermittence on the electrical grid associated with an investment in high levels of variable generation technologies such as solar and wind energy.

Table 14. Price Volatility, Efficiency, and Intermittence by Scenario

	New Scenario 9	HCEI Scenario 8	Description
Price Volatility Index	60%	37%	Percent of generation tied to oil prices in the long term, including petroleum products, ethanol, and biodiesel
Intermittence as a Percent of Delivered Capacity	23%	29%	Intermittent technologies (e.g., wind and solar) put more stress on grid operations than combustion or other firm generation types
Energy-Efficiency Level Reached in 2030 (GWh)	1,607	4,336	Energy-efficiency figures for New Scenario 9 are based on IRP forecasts for each utility. Efficiency figures for Scenario 8 are based on NREL efficiency technology curves and DOE goals

As the correlation between oil prices and biofuel prices is very high (see Figure 24), any significant reliance on imported fuels carries with it a high risk of price fluctuations to the state.



The Booz Allen piece of the efficiency analysis focused solely on existing buildings; the National Renewable Energy Laboratory conducted the new construction efficiency analysis.

Figure 24.Correlation between oil and biofuel prices

Source: Energy Information Administration (EIA)

On the other hand, the intermittence associated with renewable energies at high levels carries with it a risk corresponding to the reliability of electricity supply and may result in significant costs to the utility companies (and by extension, the ratepayers) in the form of increasing storage or reserve generation capacity.

When these risks are compared to one another, it becomes clear that an increase in price volatility in moving from Scenario 8 to Scenario 9 is 23%, relative to the 6% increase in intermittence.

The final risk associated with a large-scale shift to local biofuel production relates to current land use patterns. This analysis was careful not to assign land currently in use for food to the potential production of biofuels; in the future, however, additional analysis is recommended for finding complementary means of promoting both food and fuel crops, such as:

- **Intercropping**—growing food and fuel crops in alternating rows to help reduce fertilizer needs and/or grow the energy needed to harvest the fields
- **Alternating crops**—exploiting the seasonality of crops to allow farmers to increase the number of months they can harvest
- **Sharing infrastructure**—sharing food and fuel crop harvesting and/or processing equipment (i.e., coffee and jatropha or sugarcane and banagrass) to help reduce the capital costs for farmers by allowing for expanded use of equipment
- **Avoiding cattle land conversion**—assuming the conversion of cattle land to farmland for biofuel purposes is not necessary to achieve a significant level of biofuel production; through careful future land use analysis, a working agreement that satisfies both farmers and ranchers should be possible**.**

In summary, domestic biofuels provide farmers the opportunity to diversify the markets they can serve as well as increase their self-sufficiency and reduce their exposure to fluctuations in the price of fuels. Nevertheless, an overly biofuel-dependent strategy may end up exposing the state to the same cost, price volatility, and supply risks that it currently faces through the use of imported petroleum fuels.

Energy Efficiency

This section is adapted from the Executive Summary and recommendations of a 43-page report prepared by Booz Allen. The full report can be found in Appendix H.

Key Findings

- Booz Allen's analysis of Hawaii's existing building stock focused on six building categories, that when combined, account for 62% of the state's electricity demand.
- Even if only current commercially available technologies are used, attainment of EEPS is technically possible.
- Total potential electricity savings by 2030 are estimated at between 2,100 and 3,100 GWh (15% and 22%, respectively, of 2030 business-as-usual electricity use).
- Estimated investment needed to attain required EEPS savings is ~$4.1 billion by 2030, or $196 million per year (based on total cost to society of measures, which includes both program and building owner funds).
- Attaining efficiency goals will require building retrofits on the order of 80% of the current building stock in the state, as well as building retirements and new construction equal to approximately 20% of the current building stock.
- Significant outreach and education, investment, and public-private cooperation will be necessary to reach such a large portion of the population.

Although many issues are associated with land use in the state, the benefits of growing local biofuels over importing fuel are substantial, and compromise solutions for land use should be worked out wherever possible.

In June 2009, the state of Hawaii enacted an EEPS with a target of 4,300 GWh by 2030. Upon setting this goal, the Hawaii Clean Energy Initiative, Booz Allen, and NREL, working with select local stakeholders, partnered to execute the first key step toward attaining the EEPS goal: the creation of a high-resolution road map outlining key areas of potential electricity savings. This road map was divided into two core elements: savings from new construction and savings from existing buildings. After the stakeholders provided feedback, it was determined that Booz Allen would focus primarily on the existing building analysis, whereas NREL would focus on new construction forecasting. The Booz Allen report[29] presented the results of a review of the existing building stock of Hawaii, along with conclusions on the key drivers of potential energy-efficiency savings and the steps necessary to attain them.

In deconstructing the various types of buildings in the state along with their respective energy footprints, Booz Allen relied heavily on contributions from various stakeholders, including HECO, KIUC, DBEDT, and The Gas Company, among others. Combining the data received from these parties, Booz Allen determined that the highest areas of energy intensity among all building usage categories were concentrated in six specific sectors: (1) offices, (2) hospitality, (3) retail on the commercial side, (4) single family homes, (5) multi-family homes, and (6) high rises on the residential side. The stakeholders' input suggested that, given resource and time constraints, any analysis of potential existing building efficiency savings must begin with these key sectors, which account for 62% of the overall electricity usage in the state.

Once the dominant energy users were identified, Booz Allen evaluated existing state data to determine where best to supplement them with national building technologies and building operation studies. Booz Allen identified a need for additional state data and worked with the HECO companies and KIUC to administer a limited appliance saturation survey for the Hawaii commercial sector.[30] Aggregating these data by building type, Booz Allen developed building profiles representing both average baseline buildings and efficient buildings based on the most efficient currently available technologies.[31] Electricity savings by building type and end use were calculated as the difference in the electricity use between the building profiles. Booz Allen then adjusted these savings estimates to include the full building stock for each of the six building types.

[29] The sources and data underlying this analysis can be found in the report on the NREL/Booz Allen analysis of Hawaii's existing building efficiency. (Finch, P.; Potes, A. (June 2010). *Hawaii Clean Energy Initiative Existing Building Energy Efficiency Analysis.* Honolulu: National Renewable Energy Laboratory, NREL). The report is included as Appendix H.

[30] "Commercial Efficiency Survey." Booz Allen Hamilton, HECO, and KIUC. October 2009.

[31] The commercial baseline and efficiency building profiles include technologies for the following end uses: cooling, lighting, water heating, fans and motors, building controls, building envelope, and computers. For the residential sector, we model cooling, lighting, water heating, building envelope refrigeration, and other major appliances. Some combination of these applies to all building types. Full details of calculations and assumptions are available in the appendix of the building efficiency analysis included as Appendix H.

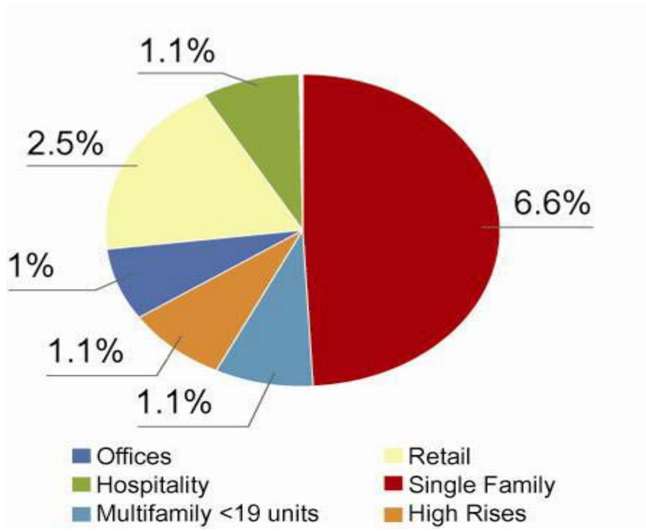


Figure 25.Electricity savings as a percentage of 2007 Hawaii electricity usage

Source: Finch, P.; Potes, A. (June 2010) *Hawaii Clean Energy Initiative Existing Building Energy Efficiency Analysis*. Honolulu: National Renewable Energy Laboratory, NREL. The report is included as Appendix H.

Ultimately, the study determined that the estimated potential savings from the six modeled building types (single-family, multi-family below 20 units, high-rises above 20 units, offices, retail, and hospitality) are approximately 1,300 GWh per year, or 13.5% of 2007 Hawaii electricity use (Figure 25). HECO projects annual energy use to increase to 14,300 GWh per year by 2030, and the state energy-efficiency target is 30% of this amount, or 4,300 GWh.[32] Since Booz Allen's model is limited to six building types and based on current energy use, the results were adjusted to account for the entire building stock, the growth of existing building loads, and building stock turnover through 2030.

After these adjustments, it is estimated that potential electricity savings from existing buildings in 2030 would be between 2,100 GWh (15% of 2030 electricity use) and 3,100 GWh (22% of 2030 electricity use). These savings account for approximately one-half to three-quarters of the 30% state efficiency target.[33] Assuming a levelized cost of $83 per MWh saved,[34] the estimated investment needed to attain required EEPS savings is approximately $4.1 billion by 2030, or $196 million per year. This figure is counted as a total cost to society, which includes both program incentives as well as the total cost to the building owner. To succeed in attainment of the goal, any public moneys spent will need to leverage much higher levels of private spending,

[32]Hawaiian Electric Company. (28 October 2005). *Integrated Resource Plan, 2006-2026*. http://www.heco.com/vcmcontent/FileScan/PDFContent/HECO_IRP3_Final_Report.pdf (accessed March 20, 2011).

[33]The exact value depends on the contribution of additional loads from existing buildings to electricity growth compared to that of new construction.

[34]Due to the extremely high levels of efficiency being targeted by the state, this figure represents a premium over the figure noted in the Rogers, Messenger, and Bender California program study. The first 10% of efficiency attained per building is assumed to cost $50 per MWh, with the per MWh price increasing incrementally as one approaches what is technically achievable. This results in an average of $83 per MWh of efficiency for buildings attaining an average electricity use reduction of 25%.

as it is unreasonable to assume that the state's current budgets for efficiency will extend far enough to cover the full cost of the necessary building improvements.

Table 15.Top Five Individual Efficiency Measure Savings by Building Type and End Use

	GWh Savings Potential	% of 2007 Electricity Use[a]
Single Family Water Heating	250 GWh	2.5%
Single Family Lighting	194 GWh	2%
Retail Lighting	85 GWh	1%
Office Cooling	72 GWh	1%
Single Family Refrigeration	69 GWh	1%

Source: HECO; Rogers, C., Messenger, M.; Bender, S. (2005). "Funding and Savings for Energy Efficiency Programs for Program Years 2000 Through 2004."; California Energy Commission. (July 2005); Booz Allen analysis

Conclusions

Attaining the efficiency goals will require building retrofits on the order of 80% of the current building stock in the state, as well as building retirements and new construction equal to approximately 20% of the current building stock. To successfully meet these goals, extensive collaboration between the public and private sectors (including state agencies, utility companies, private businesses, and building owners) will be needed across a wide range of issues, including identifying and testing new technologies, capital fund raising and investment, public education, and refining existing programs.

Given the significant projected cost of achieving the EEPS target and constraints on the state efficiency budget, it is anticipated that finding additional sources of private investment for efficiency efforts in the state will be critical. In addition, those buildings least viable for retrofit should be identified, retired, and replaced with new, more efficient buildings.

Understanding that not all technologies will be cost effective for every building type, a continued focus on next-generation technologies to fill in key efficiency gaps will be essential for long-term success. As such, pilot programs for new technologies can help identify and verify the performance of promising new technologies.

In addition, with less than 20% of building owners enrolling voluntarily in retrofit programs, more than 60% of the existing building stock is currently left unaccounted for in trying to reach the EEPS target. Outreach and education programs on the benefits of efficiency should be a key area of focus in persuading building owners to improve the efficiency of their buildings. Beyond educating owners, attention to building commissioning and education of building operators on operations and maintenance will allow buildings to realize the full impact of a retrofit.

Transportation

Booz Allen was engaged by the Transportation Working Group to assist in the construction of possible alternative vehicle scenarios and goals for the state. This analysis began in February 2010 and concluded in October 2010. The goals and conclusions outlined in this section were

[a] Because of the uncertain nature of how load growth and efficiency by category type will fluctuate, projections of what each efficiency measure savings will be as a fraction of 2030 energy usage is outlined here.

subsequently incorporated into the HCEI Road Map document in December 2010 as a comprehensive energy plan for the state.[35]

The process adopted by Booz Allen in conducting this analysis can be summarized in four steps:

- Construct business-as-usual case
- Develop likely alternative vehicles scenarios
- Conduct sensitivity analysis to identify key trade-offs
- Identify optimal vehicle adoption pathways to 70% transportation savings.

Booz Allen and NREL worked in conjunction with the stakeholders in the HCEI Transportation Working Group, including (but not limited to) the Hawaii Automobile Dealers Association (HADA), the State Department of Transportation, Project Better Place, University of Hawaii, HNEI, and DBEDT, to gather all existing data on Hawaii transportation patterns, outline alternative scenario options, and conduct focused analysis on what various scenarios could mean to Hawaii, from both a clean energy and an economic standpoint (see Appendices F and G).

Business as Usual

Using figures provided by DBEDT and HADA on the current configuration of the Hawaii vehicle stock, Booz Allen constructed a baseline for vehicle fuel usage and projected sales moving forward. Currently, Hawaii's vehicle stock is composed of passenger vehicles, including cars and light trucks.

[35]Additional information and sources are available in the HCEI Vehicle Analysis, included as Appendix G.

Table 16.Overview of Hawaii's Vehicle Stock, 2007

Type of Vehicle	State Total	City and County of Honolulu	County of Hawaii	County of Kauai	County of Maui
All Vehicles	1,160,643	735,509	184,202	77,989	162,943
Motor Vehicles	1,127,567	719,640	175,166	74,344	158,417
Passenger Vehicles[a]	903,518	595,825	133,722	52,722	121,249
Ambulances	57	36	5	1	15
Buses	2,213	1,735	268	11	199
Trucks[a]	191,459	101,690	36,933	19,826	33,010
Truck Tractors	799	511	186	13	89
Truck Cranes	1,074	879	105	6	84
Motorcycles and motorscooters[b]	28,447	15,869	3,947	1,765	3,771
Trailers and Semi-Trailers	33,076	15,869	9,036	3,645	4,526

Source: Hawaii Department of Transportation, Motor Vehicle Safety Office

As the vast majority of the vehicles in the state are passenger vehicles such as cars and sport utility vehicles, it was determined that this would be the state's primary focus. In looking at vehicle sales patterns moving forward, however, an even stronger limitation to the deployment of alternative vehicle patterns in the state was determined: the relatively low turnover of vehicles year to year (see Table 17).

[a] Vans, pickups, and other trucks under 6,500 lbs in person use, legally classified as passenger vehicles, are included in the totals for trucks.
[b] Excludes mopeds (1.5 HP or less), which are legally classified as bicycles.

Table 17.New Retail Car and Light Truck (van) Registrations: 1989 to 2009[a]

Year	Number	Year	Number	Year	Number
1989	57,456	1996	41,480	2003	62,712
1990	54,544	1997	42,487	2004	65,882
1991	47,783	1998	40,673	2005	70,268
1992	44,865	1999	45,054	2006	67,224
1993	45,249	2000	51,500	2007	57,526
1994	44,175	2001	51,388	2008	42,804
1995	41,083	2002	53,314	2009	33,639

Source: Hawaii Automobile Dealers Association (HADA), "Hawaii Dealer 2010 First Quarter"

Based on these patterns, it's clear that average annual vehicle turnover in the state is strikingly low: about 50,000 vehicles were purchased or replaced per year, indicating that the average vehicle life of a car in Hawaii was on the order of 20 years (approximately one million vehicles in the state/50,000 vehicles replaced/year = 20 years for a complete turnover of the fleet), seriously limiting the state's ability to get older, less efficient vehicles off the road and replace them with newer, more sustainable models. These figures are based on HADA-identified trends indicating that the overall fleet of vehicles in Hawaii is not growing at a rapid pace, which limits another possible source of deploying alternative vehicles into the fleet. Likewise, the number of standard hybrid electric vehicles (HEVs) on the road currently in the state is also low, although in basic alignment with the national hybrid adoption average of 2% of annual sales (see Table 13).

Table 18.Prius and Total Hybrid New Vehicle Registrations in Hawaii

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Prius	0	31	85	56	113	442	661	686	648	646	516
Total Hybrid	0	46	113	141	261	625	971	1235	1127	1155	1047

Source: R.L. Polk and Company

It is also critical to note that the business-as-usual scenario includes extremely high ridership of the public bus system in the state, as well as an E-10 (10% ethanol) blending standard (both in place prior to the start of HCEI). Assuming current increases in vehicle efficiency due to the natural progression of CAFE standards in the Energy Independence and Security Act of (EISA) 2007 as part of the baseline as well, the business-as-usual fuel savings projected from simply maintaining the 2007 status quo total approximately 160 million gallons of fuel saved in 2030 (Figure 26, below.)

[a] Excludes U-drive/fleet sales; revised from previous year's DBEDT Databook.

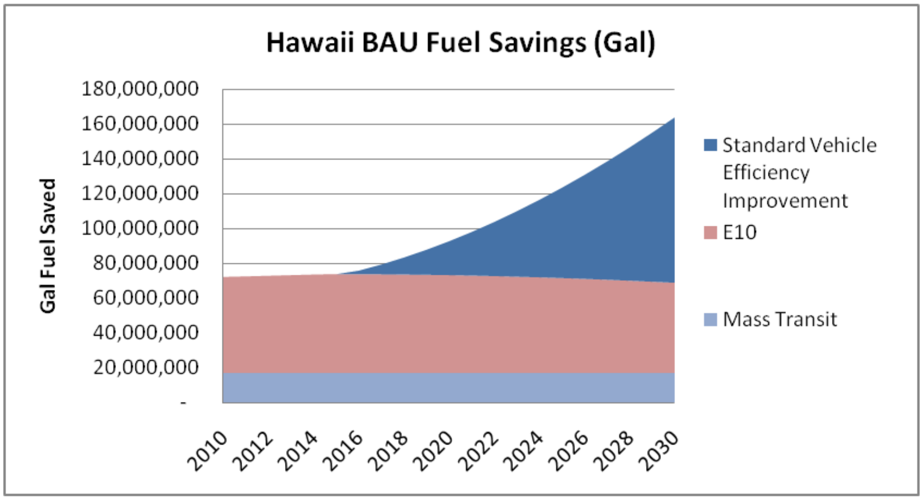


Figure 26.Hawaii business-as-usual fuel savings

These projections are based on the bus ridership, fleet efficiency, and overall ground transportation demand figures outlined in Table 13, below.

In summary, the Business-as-Usual Scenario indicated that alternatives considered would have to focus not just on the deployment of new vehicles but also on overall reduction in the number of vehicle miles traveled per year and one-for-one fuel switch-outs (e.g., via drop-in replacement biofuels) for existing vehicles that may remain in the fleet for years to come. For the purposes of this analysis, drop-in fuels were considered as those biofuels that have chemical structures similar to standard petroleum products, allowing them to be blended with petroleum-based counterparts without causing operational difficulties. This is particularly essential for attainment of the transportation goals, as low vehicle turnover means that many of the existing vehicles on the road will not be eligible for infrastructure switch-outs for quite some time. Without the ability to utilize the current vehicle infrastructure fully through a simple fuel swap-out, many of the existing vehicles on the road will be unable to use biofuels as an alternative energy solution.

As the efficiency of an average vehicle in the business-as-usual case is assumed to improve over time, the projected per-vehicle savings estimates from switching to an electric vehicle or riding public transport decline.

Alternative Scenarios

Booz Allen then outlined several possible alternatives for consideration, including:

- Improved vehicle efficiency (e.g., CAFE improvement, adoption of more efficient alternative vehicles such as HEVs, and/or diesel engines)
- Electric vehicles (e.g., PHEVs, battery electric vehicles)
- Alternative fuels (e.g., biofuels, hydrogen)
- Reduction in vehicle miles traveled (VMT) (e.g., telecommuting, public transportation).

In evaluating these four alternatives, Booz Allen looked at several possible scenarios. These are outlined in the table below.

Table 19.Summary of Possible Futures by Scenario Component

	Business as Usual	Probable	Optimistic
Vehicle Efficiency	Fleet performance stays at 4/5 of EISA CAFE Standard levels (Hawaii's measured fleet fuel economy performance relative to the EISA mandate)	Fleet performance attains level of EISA CAFE Standard **(weighted average of all vehicles on road, including electric)** through standard vehicle improvements, HEV adoption, and diesel fuel switching	Fleet performance attains level of EISA CAFE for all standard vehicles including HEVs and diesel-fueled vehicles **(excluding electric vehicles from weighted average)**
Mass Transit	Standard ridership (198,000 weekday riders, 4 MPG per bus, 40 riders per bus ride)[a]	Bus 27% ridership increase by 2030	Light Rail + Bus Ridership Increase – 1A Light Rail + Bus Ridership Increase + Alternative VMT Reduction measures implemented – 1B
PHEV/BEV	Minimal adoption	5% adoption	13% adoption – 1A 20% adoption – 1B
Alternative Fuels[b]	E10 Standard 10% of total annual demand for gasoline (~55 MGY in 2010, based on DBEDT vehicle registration/avg. fuel economy standards)	E10 plus domestic biofuel production	Remainder of alternative fuel needed to meet 70% goal

Source: Booz Allen analysis

In total, Booz Allen evaluated four scenarios as the basis of this analysis. These scenarios were Business as Usual (BAU), Probable, Optimistic 1A (13% EV adoption, only light rail/bus expansion implemented), and Optimistic 1B (20% EV adoption, enhanced VMT reduction strategy implemented). These scenarios were based on a range of available data sources, including conservative (National Academies of Science[36]) and more optimistic (Deutsche Bank[37]) electric vehicle technology development forecasts.

[a] Source: www.theBus.com.

[b] No separate scenarios were created for biofuels as a part of this analysis. Biofuels simply represent the option implemented after all other alternative transportation options were exhausted. Conditionally, in a scenario where imports are not assumed, such as the Probable Scenario, the 70% clean energy goal for transportation is not reached.

[36]National Research Council. (2009). "Transitions to Alternative Transportation Technologies−Plug-In Hybrid Electric Vehicles." The National Academies Press.

[37]Deutsche Bank Securities, Inc. (2010). "Vehicle Electrification: More Rapid Growth; Steeper Price Declines for Batteries."

A common theme across three of the four options evaluated for this analysis is the progression of vehicle efficiency in the conventional vehicle fleet compared with that of alternative transportation options. This is important for forecasting conventional vehicle efficiency savings above BAU, as well as PHEV and VMT reduction savings over a standard vehicle. Savings are calculated by looking at the difference in MPG as new vehicles are integrated into the overall fleet year to year. The per-mile savings above a standard alternative are then aggregated across total miles driven by each vehicle type to generate total savings to the state. The MPG for various vehicle types and scenarios used throughout this analysis is summarized in Figure 27, below:

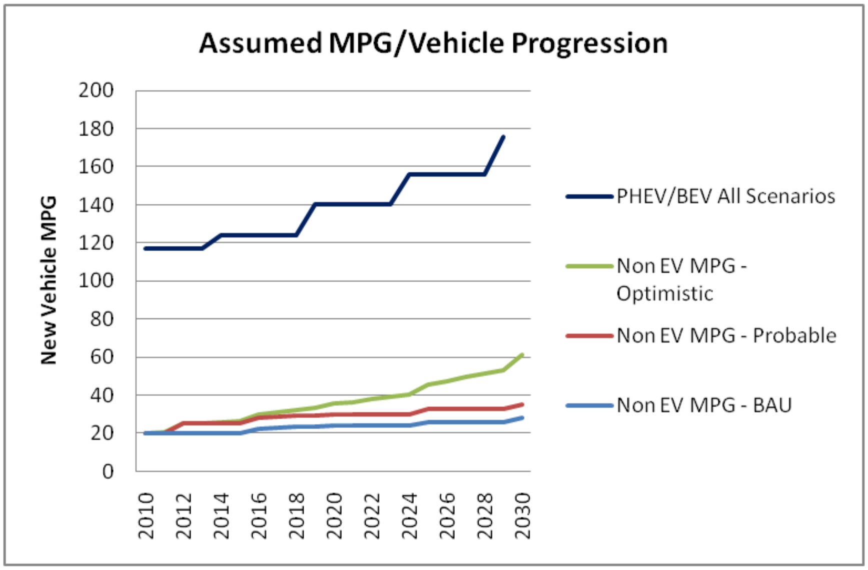


Figure 27.Assumed MPG/vehicle progression

The basis for each scenario is outlined in the section below.

Improved Vehicle Efficiency

The vehicle efficiencies mandated in EISA 2007 form the basis of the various improved efficiency scenarios. The BAU Scenario represents the measured performance of Hawaii's fleet in comparison to the mandate. As the mandate is written to impact the tested fuel economy of all vehicles produced by manufacturers, the actual fleet performance (e.g., the actual measured average MPG of all vehicles in the Hawaiian fleet), is unlikely to match manufacturer standards in real life performance. As of 2007, the measured performance of the Hawaiian fleet was four-fifths of the standards' requirements. The EISA mandate is structured as a weighted average of all vehicles sold by individual manufacturers, which would include hybrid electric, plug-in electric, and battery electric vehicles, as well as more efficient diesel engine vehicles. The Probable Scenario, therefore, is aligned directly to the EISA mandate (25 MPG in 2012, 30 MPG in 2020, 35 MPG in 2030), which represents a fleet performance improvement of 20% over the BAU Scenario. Due to the discrepancy in real-world performance over manufacturer standards noted above, to attain this scenario, consumer purchasing patterns would need to notably shift toward vehicles that are, on average, 20% better than standard. To form an even more optimistic scenario, the working group chose to present a case in which all nonelectric vehicles sold in the state attain the full performance level equivalent to that mandated by the EISA, which would require an improvement in the overall standard fleet performance of approximately 60% by 2030. This means that all nonelectric vehicles sold in 2030 would need to perform at a 61 MPG level, and that consumers would need to materially improve their purchasing choices starting in 2011 to reach the overall standard fleet MPG average of 37 MPG (excluding EVs) necessary to attain this optimistic standard.[38] Clearly, a massive shift in consumer purchasing behavior will be necessary to attain the Optimistic Efficiency Scenario (under BAU, with no change in consumer behavior, the average fleet efficiency will only reach a level of 23.5 MPG by 2030).

The savings from improved fleet efficiency are driven largely by changes in consumer purchasing behavior.

Finally, it should be noted that the vehicle efficiency standards used as a reference point for Hawaii's fleet are mandated by the federal government nationwide and, as such, are outside of Hawaii's control. Therefore, the working group focused primarily on in-state programs that could help encourage the purchases of more efficient vehicles, such as cash-for-clunkers incentives. No actual changes to the federal mandate were considered as part of this analysis.

In terms of calculating the savings from vehicle efficiency, the progression of the mandated fleet efficiency over time was mapped, and savings above the BAU level of efficiency were calculated across the entire fleet of existing vehicles. A growth rate for the entire fleet consistent with that outlined in the transportation wedge analysis was assumed, with 1/20 of the vehicle stock assumed to turn over per year.[39] The vehicles assumed sold reflect the fuel economy requirements of the EISA for that year, depending on the scenario (the Probable Scenario weighted the average of all vehicles in the fleet; Optimistic Scenario 1A and Optimistic Scenario 1B averaged all standard vehicles in the fleet, including hybrids and diesels but excluding electric vehicles). The exact levels assumed for each scenario are outlined in Figure 27 above. The variation in fuel economy of the new vehicles versus the fleet[40] was then divided into total miles driven per year to determine the ultimate gallon savings from efficiency for a given year.

Electric Vehicles

The electric vehicle adoption scenarios outlined in this analysis are based on several projections identified by the Transportation Working Group members. These projections range in optimism surrounding the projected costs of EV over time and corresponding adoption due to increasing cost parity. The most conservative of these studies, the National Academies of Science forecast,[41] forecasts a 5% adoption of EVs by 2030 in its Probable case, and a 13% adoption of EVs by 2030 in its more Optimistic case (both figures calculated as a fraction of all vehicles on the road in 2030). This 13% adoption level forms the basis of the Optimistic 1A Scenario. The

[38]By excluding electric vehicle MPGs from the weighted average in the standard, the real overall fuel efficiency of the fleet would climb to 26 MPG in 2015, 35 MPG in 2020, and 60 MPG in 2030, based on the EV adoption levels in the Optimistic 1B case.
[39]Hawaii Automobile Dealers Association, HADA; Hawaii Department of Business, Economic Development, and Tourism, DBEDT, 2008 (Table 16). 50,000 vehicles are replaced on average each year per 1 million total vehicles.
[40]Hawaii Department of Business, Economic Development, and Tourism. (2008). *Hawaii Databook 2008*. http://hawaii.gov/dbedt/info/economic/databook/db2008 (accessed March 21, 2011).
[41]National Research Council. (2009). "Transitions to Alternative Transportation Technologies—Plug-In Hybrid Electric Vehicles," National Research Council, The National Academies Press.

most optimistic scenario, based on projections by Deutsche Bank,[42] puts EV adoption as a percentage of the total fleet at 20% by 2030. This forms the basis of the Optimistic 1B Scenario.

Most important, all of these levels were chosen, and vehicle adoption curves developed, based on their ability to remain within the 50,000 vehicles sold per year limitation noted in the base case, as it is unlikely that vehicle purchasing patterns in the state will change materially moving forward vis-à-vis their historic trends. These adoption curves are outlined in Figure 28, below.

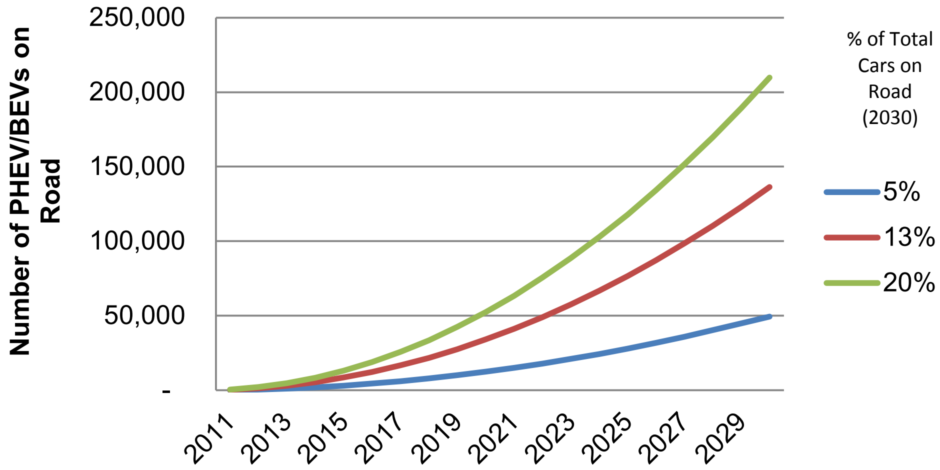


Figure 28.Battery and plug-in electric vehicle adoption curves (2011−2030)

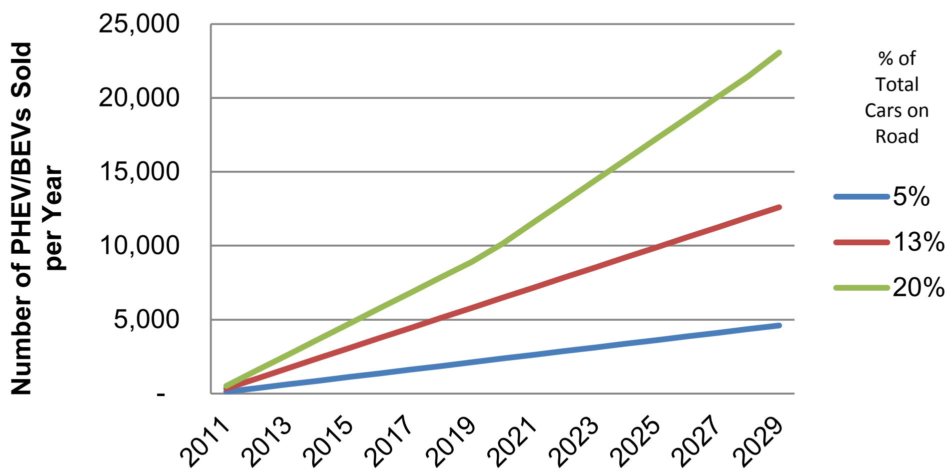


Figure 29.Battery and plug-in electric vehicle annual sales (2011−2030)

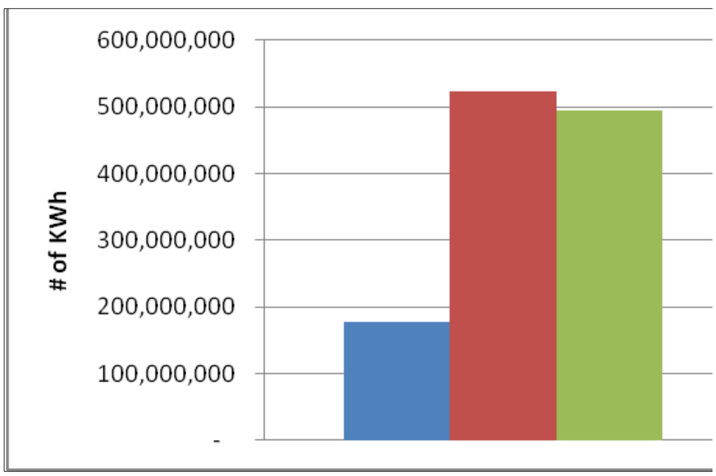
Source: National Research Council. (2009) "Transitions to Alternative Transportation Technologies—Plug-In Hybrid Electric Vehicles."; The National Academies Press; Deutsche Bank Securities Inc. (2010) "Vehicle Electrification: More Rapid Growth; Steeper Price Declines for Batteries."

,

[42]Deutsche Bank Securities, Inc. "Vehicle Electrification: More Rapid Growth; Steeper Price Declines for Batteries." (2010).

These curves were derived by taking the national adoption curves predicted in the National Research Council (NRC) and Deutsche Bank studies and projecting them across the full Hawaii passenger vehicle stock. They reflect the likely technology development, cost, and purchasing patterns of consumers over time. Note that a slow start-up pace will cost the state significant potential fuel savings, as each vehicle purchased in years 1 to 5 will still be on the road in 2030 due to the long life of vehicles in Hawaii. The more inefficient vehicles purchased in years 1 to 5, the greater the eventual opportunity cost to the state down the road.

Also note that any potential petroleum fuel savings associated with electric vehicles will correspond directly to the amount of renewable energy in the generation mix for the state (as petroleum is the primary source of generation fuel at present, the state would still be powering its electric vehicles with petroleum in the absence of renewable energy). The mix of renewables assumed for all scenarios in this analysis is the level of the mandated Renewable Portfolio Standard,[43] which increases to 40% of delivered generation capacity by 2030. An overview of the total projected electricity demand associated with the different electric vehicle scenarios is included in Figure 30, below.



Although the adoption of electric vehicles will correspondingly increase electricity demand, the impact is relatively small as a fraction of overall electricity usage in the state: just 2% to 5% by 2030.

Figure 30.Total additional generation needed for vehicles in 2030 (kWh)[44]

Source: Based on total miles driven in EVs (per scenarios outlined above, assumed conversion rate of 0.32 kWh/mi [EPRI/Argonne])

Once the vehicle adoption curves were developed, they were compared against the limit of total vehicles sold in the state per year to ensure that they remained within the bounds of what was possible for Hawaii to use. After verifying this, petroleum usage was calculated based on a 0.32 kWh/mi rate[45] and aggregated across all of the miles driven by EVs for a given year. This kWh figure was first adjusted for any renewable energy in the mix (per the RPS mandated levels) and converted to gasoline equivalent using the BTU ratio of electricity to gasoline. This MPG figure was then compared against the standard fleet efficiency for each given year (adjusted according

[43]ACT 155 (09), HB 1464, signed June 25, 2009.

[44] These figures represent a range of 2%–5% of total projected demand for electricity by 2030 (per HECO, MECO, HELCO, and KIUC IRP-3 figures).

[45]Winkel, R.; van Mieghem, R. (2006). "Global Prospects of Plug-in Hybrids." EVS-22 Conference. Argonne National Laboratory, Electric Power Research Institute. http://transportation.anl.gov/pdfs/HV/393.pdf (accessed March 22, 2011).

to the methodology outlined in the Vehicle Efficiency Improvement section above, with the PHEV MPG equivalents per year highlighted in Figure 30, above) to determine EV MPG savings above the standard fleet. This per vehicle savings was then divided into the total miles driven by EVs in the fleet (total number of EVs from adoption curve x average miles traveled per year) to calculate total gallons saved by EVs above the standard fleet efficiency.

Reduced Vehicle Miles Traveled

The analysis of reducing vehicle miles traveled initially focused on quantifying potential savings by expanding the public transit system in Oahu. Later, this area was expanded to include estimated savings from other areas of reducing average miles driven per year per person (8,400 miles per year[46] as of 2008). Although no quantifiable data were available to build a full analysis around the alternative methods of reducing vehicle miles, this area was indicated as a clear area of savings potential and one of future analytical need for HCEI.

The goals created as an end result of this analysis represent significantly aggressive outcomes that will take a long-term dedicated commitment on behalf of both the government and the people of Hawaii to attain.

The forecasts for the expanded public transit program were drawn primarily from an analysis done through the Light Rail project's Environmental Impact Statement scenario analysis.[47] The probable scenario is based on an expansion of the bus system, leading to increased ridership of 17%. The Optimistic Scenario includes the implementation of a rail transit system and an expansion of the bus system, which would increase overall ridership of public transportation by 60% (or 116,300 people, per TheBus.com).

These increases in ridership were then converted to savings by estimating the average distance per trip,[48] the average MPG for both the bus and light rail, the number of trips offset per transit measure (per the EIS scenario analysis), and the average vehicle efficiency of the fleet for each given year (outlined for each scenario in Figure 20, pg. 35). The average gallons per passenger was calculated by multiplying the MPG per bus/rail by the average miles per trip, then dividing the number of passengers per bus/rail trip (per the bus and light rail Environmental Impact Statement scenario analysis). This "public transit" MPG was then compared to the average MPG per standard vehicle for that scenario, and the difference was divided into the total miles offset by bus/rail in a given year to determine the total gallons saved by public transit. This forms the core of the VMT reduction savings strategy, although it is enhanced in the Optimistic 1B Scenario by other assumed reductions in commuter travel (such as increased telecommuting).

Alternative Fuels

Alternative fuels are the final option considered as a possible petroleum fuel reduction strategy for transportation. For the purposes of this analysis, Booz Allen assumed that only drop-in replacement fuels (e.g., biodiesel and green gasoline) would be useful to the state as a possible transportation option. This is because ethanol would require specific flex-fuel vehicle and

---

[46]Hawaii Department of Business, Economic Development, and Tourism. (2008). *Hawaii Databook 2008*. http://hawaii.gov/dbedt/info/economic/databook/db2008 (accessed March 21, 2011).
[47]Honolulu Transit. *Light Rail Alternatives Analysis*. http://www.honolulutransit.org/document-library/eis.aspx, (accessed September 10, 2010).
[48]Data provided by Hawaii Department of Transportation (TheBus.com).

refueling infrastructure for fuels beyond current blended levels of 10%. Given the extreme limitations on the total number of vehicles replaced year to year, for truly large impacts to be made in alternative fuels, drop-in replacements, which could be used in all existing standard vehicles without concern, would be necessary. Given that these fuels are not commercially viable at present, a time frame for their deployment was set for the period of 2015 and beyond.

For this analysis, it is assumed that upon their commercialization, the amount of drop-in biofuels the state will use corresponds to the remaining alternative transport fuel necessary to meet the 70% goal by 2030 (after all other fuel saving options have been implemented). This is a large figure in all scenarios, but even using the most Optimistic one (1B), the order-of-magnitude demand for biofuels for the transportation sector alone is equivalent to 150 MGY by 2030. Given that the competing demand for biofuels for use in the generation and aviation sectors is projected to be equivalent in size to that of the ground transportation sector, obtaining the levels of replacement fuel required to meet the transport goal is going to be a primary challenge for the state moving forward.

Results

The final results of the analysis were a series of goals for the state to shoot for across the four transportation categories. These goals are highly aggressive across the board and represent our best estimate as to how the 70% transportation goal will need to be attained:

Table 20.Fuel Displacement Measures and Goals

Fuel Displacement Measure	2030 Goal	Equivalent Fuel Displaced (2030)
Vehicle Efficiency (MPG)	35 MPG−All new cars 28 MPG−All new trucks	120 MGY
Reduced Vehicle Miles Traveled	8% VMT reduction over 2010 miles traveled	40 MGY
EVs	30K EVs/year being sold = 20% of fleet	75 MGY
Biofuels	150 MGY of green fuels	150 MGY

Figure 31, below, shows the interim goals for the scenario adopted into the goals (Optimistic 1B[49]) and the overall distribution of savings by alternative over time. Savings for the Probable and Optimistic 1A Scenarios fall well short of these levels and require even more extensive use of biofuels to meet the goal.

[49]Specifics for the transport goals incorporated into the HCEI Road Map document are outlined in Appendix G.

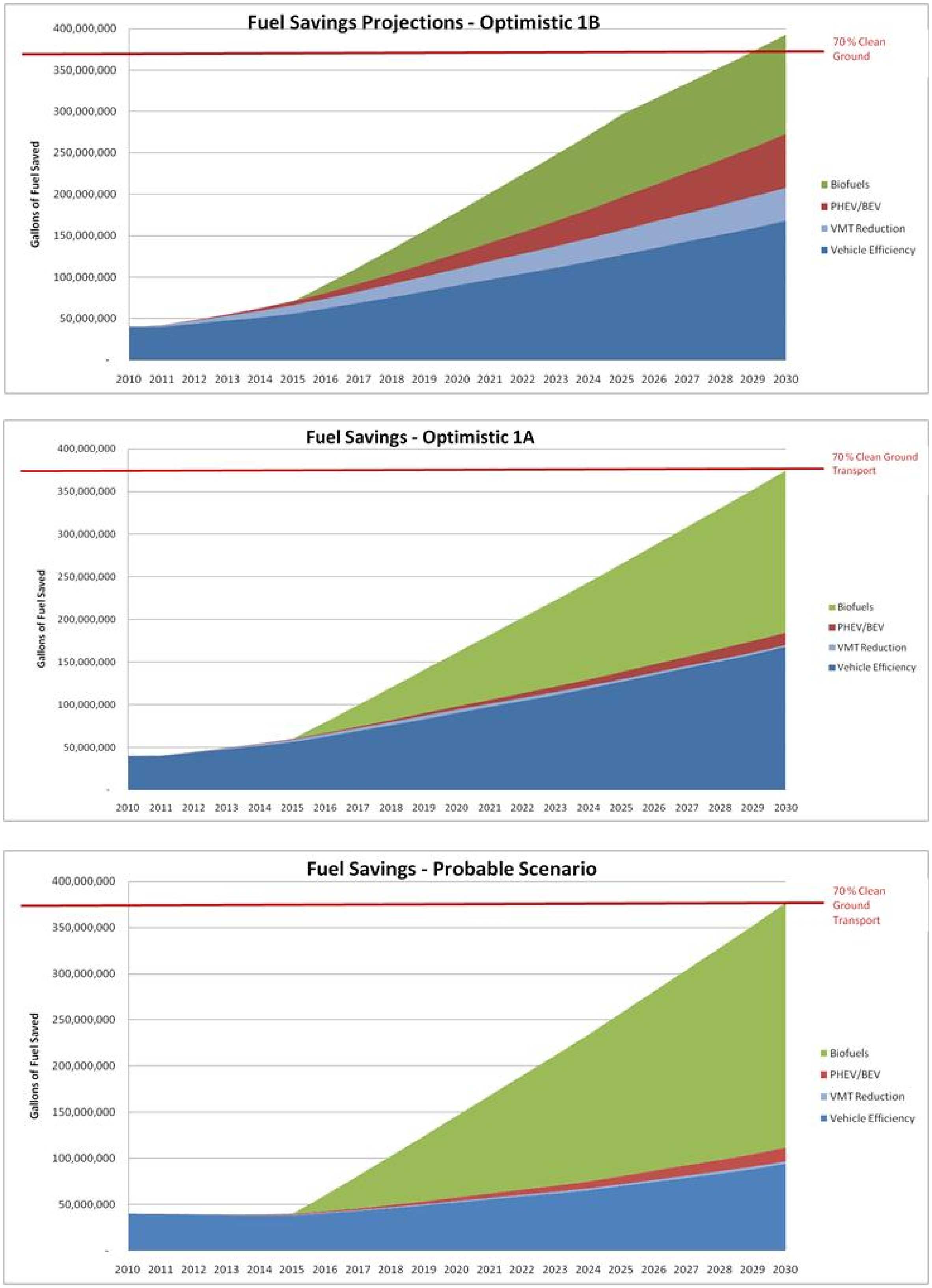


Figure 31.HCEI transportation goals: fuel savings projections

Note: VMT Reduction estimates for the Optimistic 1B Scenario include additional estimated savings from the implementation of telecommuting and mixed-use zoning strategies in addition to savings from increased use of public transportation. As such, this wedge is largely notional in nature, as existing data to support it are required to make a definitive statement as to the exact potential levels associated with the full suite of strategies. Savings using public transport expansion options only may seem small because the existing public transport system in Honolulu is quite extensive and is not included as part of the HCEI goal because it predates the goal itself and cannot be considered an additional "reduction" above business as usual.

Based on the overall analysis, it is possible to generate several key conclusions:

- As vehicle turnover is currently low (approximately 50,000 vehicles sold per year out of a fleet of 1.1 million), accelerating vehicle turnover to get inefficient vehicles off the road more quickly is the fastest way to increase savings, as long as new vehicles being adopted are more efficient standard or electric vehicles.
- Accelerating the adoption of PHEVs and BEVs in the market starting as soon as possible will help "front-load" the adoption of alternative vehicles, increasing total savings.
- By increasing the amount of renewable energy in the generation mix, savings from each individual electric vehicle on the road can be increased.
- The impact of increasing vehicle efficiency in the optimistic scenarios tends to diminish prospective savings from enhanced public transit and electric vehicles significantly.
- Simply enhancing the public transport system without including holistic measures to reduce average commuting distance does not result in high savings because the existing public transport system already has high ridership.

A significant amount of biofuels will be needed regardless of which scenario actually occurs. This makes the production of domestic biofuels of significant importance to the transportation sector. It must also be mentioned that there are many barriers to attaining each of the goals outlined above. First, each policy option associated with these measures will bear some up-front cost to the state, which will be significant in some cases. Although this analysis does not quantify this amount, unless battery costs for electric vehicles fall drastically, the range of forecasts considered in this analysis indicates an extra "premium" to the purchaser of $5,200–$10,000 per vehicle. Thus, the premiums associated with just the purchase of electric vehicles alone to the state could be as high as $2 billion by 2030, in a scenario where 20% of the fleet goes electric.

Whereas alternative fuels and improved vehicle efficiency do not bear significant costs above the status quo, reducing vehicle miles traveled could result in a large cost to Hawaii taxpayers should the public transportation system be expanded per the Optimistic Scenario requirements. Ultimately, all of these measures will pay for themselves in terms of petroleum fuel costs avoided and lowered exposure to oil price volatility, but in the meantime it must be acknowledged that this should be considered a long-term investment in the state's future.

Second, each outcome identified above relies heavily on either significant changes in consumer behavior, which are difficult to predict and even harder to influence, or significant changes in technology over today's levels. To this end, this analysis should be updated periodically to reflect new information, new technologies, and new trends in consumer behavior to ensure that the goals and milestones forecast in this report remain relevant. Even so, attainment of all of the measures in this analysis will remain a difficult challenge given the constrained resources, competition for renewable liquid fuels, and the other barriers outlined throughout this analysis.

References

Arent, D.; Barnett, J.; Mosey, G.; Wise, A. (2009). "The Potential of Renewable Energy to Reduce the Dependence of the State of Hawaii on Oil." 42nd Hawaii International Conference on System Sciences, 2009. Produced in compliance with EPAct Section 355. Golden, CO: National Renewable Energy Laboratory (NREL). http://www.hawaiicleanenergyinitiative.org/storage/potential_of_renewable_energy.pdf (accessed March 22, 2011).

California Energy Commission. (2007). *California Solar Resources Report*. http://energy.ca.gov/2007publications/ (accessed June 8, 2008).

California RETI Coordinating Committee. (April 2008). *Renewable Energy Transmission Initiative, Phase 1A*. http://www.energy.ca.gov/2008publications/RETI-1000-2008-002/RETI-1000-2008-002-F.pdf (accessed June 2008).

Chicago Board of Trade. "Cost of Biodiesel Feedstock." http://www.cbot.com/cbot/pub/page/0,3181,959,00.html (accessed June 2008).

Corbus, D.; Schuerger, M.; Roose, L.; Strickler, J.; Surles, T.; Manz, D.; Burlingame, D.; Woodford, D. (2010). *Oahu Wind Integration and Transmission Study*. NREL/TP 5500-48632. Golden, CO: National Renewable Energy Laboratory.

Deutsche Bank Securities Inc. (2010) "Vehicle Electrification: More Rapid Growth; Steeper Price Declines for Batteries." http://gm-volt.com/files/DB_EV_Growth.pdf (accessed December 24, 2011).

[DBEDT] Hawaii Department of Business, Economic Development, and Tourism. (2006). *Hawaii Databook 2006*. http://hawaii.gov/dbedt/info/economic/databook/db2006 (accessed March 21, 2011).

[DBEDT] Hawaii Department of Business, Economic Development, and Tourism. (2008). *Hawaii Databook 2008*. http://hawaii.gov/dbedt/info/economic/databook/db2008 (accessed March 21, 2011).

[DBEDT] Hawaii Department of Business, Economic Development, and Tourism. (January 2000). *Hawaii Energy Strategy 2000*. http://hawaii.gov/dbedt/info/energy/publications/hes2000.pdf (accessed March 21, 2011).

[DOE] Department of Energy. *Builders' Challenge—Builders Option Program (Hot, Humid Climates)*.

[EERE] Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. (no date). *Geothermal Hydrothermal* and *Biomass (Direct Firing)*. http://www1.eere.energy.gov/ba/pba/ pdfs/geo_hydro.pdf and /direct_fire_bio.pdf (accessed March 23, 2011).

[EIA] Energy Information Administration. (April 2007). *Voluntary Reporting of Greenhouse Gases Program*. http://www.eia.doe.gov/oiaf/1605/coefficients.html (accessed March 23, 2011).

Energy Independence and Security Act of 2007, Section 102.

[EPA] Environmental Protection Agency. (2010). "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 to 2010." http://epa.gov/otaq/fetrends.htm (accessed March 21, 2011).

Finch, P.; Potes, A. (June 2010) *Hawaii Clean Energy Initiative Existing Building Energy Efficiency Analysis.* NREL/SR-7A2-48318. Work performed by Booz Allen Hamilton, Honolulu, HI. Golden, CO: National Renewable Energy Laboratory.

Global Energy Partners LLC (2004). *Assessment of Energy Efficiency and Demand Response Potential.* Prepared for HECO.

Hao, S. (6 June 2007). "Lanai could get $750-million windfarm." *Honolulu Advertiser*. http://the.honoluluadvertiser.com/article/2007/Jun/06/ln/FP706060405.html (accessed December 25, 2011).

Hart Energy Publishing. "Ethanol Market Spot Prices." http://ethanolmarket.com (accessed June 2008).

Hawaii Department of Transportation. *Ridership Data*. http://www.thebus.com (accessed September 10, 2010).

[HECO] Hawaiian Electric Company. (28 October 2005). *Integrated Resource Plan, 2006-2026.* http://www.heco.com/vcmcontent/FileScan/PDFContent/HECO_IRP3_Final_Report.pdf (accessed March 20, 2011).

[HELCO] Hawaii Electric Light Company. (May 2007). *Integrated Resource Plan, 2007-2026.* http://www.heco.com/vcmcontent/HELCO/RenewableEnergy/IRP/HELCO_IRP3_Report_Final.pdf (accessed March 20, 2011).

[HNEI] Hawaii Natural Energy Institute, University of Hawaii. (2006). *Potential for Ethanol Production in Hawaii*. http://hawaii.gov/DBEDT/info/energy/publications/ethanol-hnei-06.pdf (accessed March 22, 2011).

Hawaii Star-Bulletin. (8 November 2007). "Wind farm vows $50M for Molokai bid."

Honolulu Transit. *Light Rail Alternatives Analysis.* http://www.honolulutransit.org/document-library/eis.aspx (accessed September 10, 2010).

Jacobs, J. (2006). "Ethanol from Sugar." U.S. Department of Agriculture. http://www.rurdev.usda.gov/rbs/pub/sep06/ethanol.htm (accessed June 2008).

Jacobsen, Inc. “Biodiesel Production Cost Worksheet.” http://www.thejacobsen.com/ (accessed June 2008).

Kintner-Meyer, M.; Schneider, K.; Pratt, R. (November 2007). *Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids.* Pacific Northwest National Laboratory.

[KIUC] Kauai Island Utility Cooperative. (16 February 2007). *Integrated Resource Plan.* http://www.kiuc.coop/IRP/Tariff/2006%20IRP%20Update%20(Final)%20(2-16-07).pdf (accessed March 20, 2011).

[KIUC] Kauai Island Utility Cooperative. (March 2005). *Renewable Energy Technology Assessments.* http://www.kiuc.coop/About_RE.htm (accessed March 22, 2011).

[MECO] Maui Electric Company. (30 April 2007). *Integrated Resource Plan, 2006-2026.* http://www.heco.com/vcmcontent/MECO/RenewableEnergy/IRP/MECO_IRP3_Report_Complete.pdf (accessed March 20, 2011).

[NRC] National Research Council. (2010). “Assessment of Fuel Economy Technologies for Light-Duty Vehicles.” The National Academies Press.

[NRC] National Research Council. (2009). “Transitions to Alternative Transportation Technologies—Plug-In Hybrid Electric Vehicles.” The National Academies Press.

[NREL] National Renewable Energy Laboratory. (2006). *Number of Home Electricity Needs Met Calculation.* http://www.nrel.gov/analysis/power_databook/docs/pdf/db_chapter12_2.pdf (accessed March 23, 2011, from Power Databook).

Rogers, C.; Messenger, M.; Bender, S. (2005). *Funding and Savings for Energy Efficiency Programs for Program Years 2000 through 2004*. California Energy Commission. http://www.fypower.org/pdf/CEC%20_Trends2000-04.pdf (accessed June 2008).

Pienkos, P. (November 2007) “The Potential for Biofuels from Algae.” National Renewable Energy Laboratory. www.nrel.gov/docs/fy08osti/42414.pdf (accessed March 2011).

Poteet, M.D. (2006). *Biodiesel Crop Implementation for Hawaii.* Hawaii Agriculture Research Center. https://www.eere-pmc.energy.gov/states/Hawaii_Docs/biodiesel_report-revised.pdf (accessed March 22, 2011).

Winkel, R.; van Mieghem, R. (2006). “Global Prospects of Plug-in Hybrids.” *EVS-22 Conference.* Argonne National Laboratory, Electric Power Research Institute. http://transportation.anl.gov/pdfs/HV/393.pdf (accessed March 22, 2011).

Hawaii Clean Energy Initiative Scenario Analysis:

Appendices

Prepared for U.S. Department of Energy

June 30, 2011

Booz | Allen | Hamilton

Appendices

* Appendix G was created in October 2010 as an update to Appendix F, the Transportation Scenario Analysis.

Appendix A: Electricity and Transportation Wedge Analysis (June 2008)

Hawaii Clean Energy Initiative

Electricity and Transportation Wedge Analysis

Scenarios to illuminate policy needs and inform technical working groups

Washington D.C.
June 11, 2008

Contents

The purpose of the analysis is to show various ways that Hawaii's resources can be deployed to reach the 70% clean energy goal

- The analysis illuminates various ways that Hawaii's supply and demand side resources can be used to reach 70% clean energy (Note: this is not an optimization exercise; it does not pick the best scenario based on lowest cost, lowest greenhouse gas emissions, or similar metric)
- The scenarios include efficiency, electric generation, and transportation, but do not analyze energy delivery needs (grid upgrades, energy storage, etc.)
- The working groups will be able to use these scenarios to determine which policy changes will be needed to encourage different types of clean energy investment (e.g., solar PV) at sufficient scale

Key conclusions

- **Renewable resources**: All types of electricity generating technologies need to be deployed to reach 70% (wind, solar, geothermal, biomass, hydro, etc.)
- **Efficiency**: Aggressive energy efficiency measures are likely to be critical to achieving the 70% clean energy goal
- **Cable**: The state is unlikely to reach 70% clean energy for electricity and maintain high levels of clean energy for transportation unless there is a cable to Oahu from the outer islands; the cable explored in this analysis is a shallow cable to Oahu from Lanai and Molokai
- **Electric vehicles**: While the number of electric vehicles on the road in 2030 has only a modest impact on the state's electricity demand, high levels of electric vehicles are needed if the transportation sector is to reach high clean energy goals

The analysis is sensitive to a few important assumptions—which can be further examined

- **Plug-in hybrid electric vehicle (PHEV) efficiency assumptions**
  - 0.32 kWh per mile driven (Source: EPRI/Argonne)
- **Use of biodiesel in generating units**
  - 650,000 gallons per year of petroleum liquids—residual fuel, jet fuel, distillate fuel oil, and kerosene (roughly energy equivalent to biodiesel) are needed to produce 1 MW over a year (Source: DOE/EIA)
- **Level of in-state biodiesel and ethanol production**
  - A maximum achievable potential of 50% of the 428 MGY ethanol potential and 50% of the 161 MGY biodiesel potential, given constraints of food production and other land uses. These lands are assumed to be overlapping, so only ethanol *or* biodiesel can be fully deployed to this 50% level for any one scenario (Source: HARC Biodiesel Crop Implementation for Hawaii, HNEI Potential for Ethanol Production in Hawaii)
- **Solar potential figures for rooftop PV installations**
  - 2 kW per home on 50% of Hawaii's homes, 100 kW per commercial building on 50% of Hawaii's commercial buildings (Source: adopted from California Solar Resources Report)

The analysis explored eight scenarios to test the effect of energy efficiency levels, PHEV penetration, biofuels, and inter-island cabling

	Transportation: Maximize ethanol production and use all biofuels for transportation; low PHEV penetration	Transportation: Maximize biodiesel production and use biodiesel for electricity needs on Oahu; high PHEV penetration
Moderate Efficiency ("Maximum Achievable Potential" from utility IRPs)	**1** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - no cable Biofuels for transportation (only ethanol) Low PHEV	**3** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - no cable Biofuels fill in Oahu electricity to 70% (only biodiesel) High PHEV
	2 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - cable from Lanai, Molokai Biofuels for transportation (only ethanol) Low PHEV	**4** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - cable from Lanai, Molokai Biofuels fill in Oahu electricity to 70% (only biodiesel) High PHEV
High Efficiency	**5** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - no cable Biofuels for transportation (only ethanol) Low PHEV	**7** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - no cable Biofuels fill in Oahu electricity to 70% (only biodiesel) High PHEV
	6 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - cable from Lanai, Molokai Biofuels for transportation (only ethanol) Low PHEV	**8** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - cable from Lanai, Molokai Biofuels fill in Oahu electricity to 70% (only biodiesel); remainder to transportation High PHEV

Note: Grey boxes have an inter-island cable

Summary of results for the eight scenarios

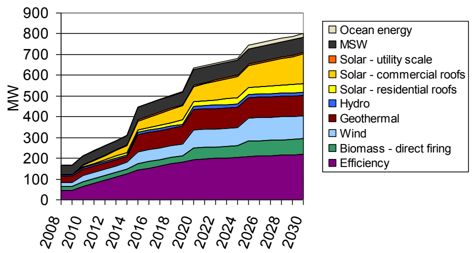
	2030 End-state for Each Scenario (installed capacity)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Efficiency	220	220	220	220	495	495	495	495
Biomass - direct firing	93	93	120	120	56	56	83	83
Wind	276	1076	276	1076	223	1023	260	1060
Geothermal	102	102	102	102	102	102	102	102
Hydro	36	36	40	40	24	24	24	24
Solar (residential roofs)	182	182	205	205	166	67	179	179
Solar (commercial roofs)	633	633	712	712	578	232	622	622
Solar (utility scale)	29	29	29	29	22	22	29	29
MSW	77	77	79	79	77	77	77	77
Ocean energy	53	53	53	53	53	3	53	53
Dispatchable	271	271	301	301	235	235	261	261
Non-dispatchable	1209	2009	1316	2116	1065	1370	1167	1967
Electricity Sector Clean Energy %	**46%**	**65%**	**46%**	**63%**	**58%**	**70%**	**57%**	**70%**
Oil reduction (million bbls in 2030)	10.0	14.0	11.5	15.5	12.5	15.1	14.0	17.3
CO_2 avoided (million tons in 2030)	5.1	7.2	5.9	7.9	6.4	7.7	7.2	8.8
Transportation Sector Clean Energy %	**30%**	**30%**	**57%**	**57%**	**30%**	**30%**	**57%**	**63%**
Oil reduction (million bbls in 2030)	4.7	4.7	9.0	9.0	4.7	4.7	9.0	9.9
CO_2 avoided (million tons in 2030)	2.0	2.0	3.8	3.8	2.0	2.0	3.8	4.2

Note: All electricity sector numbers are in total installed capacity needed; transportation sector includes only ground transportation

***Example observation**: While Scenarios 2 and 6 show similar results, they employ different means. Scenario 2 uses less energy efficiency and requires much more solar capacity; also its ratio of non-dispatchable to dispatchable electricity is 7.4, whereas Scenario 6 relies more on energy efficiency (and is likely to cost less) and has a non-dispatchable to dispatchable ratio of 5.8*

Contents

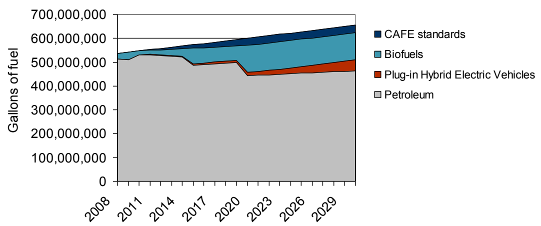
Scenario 1 Electricity - Moderate efficiency, low PHEV penetration, and no cable connecting the islands



Summary of 2030 Electricity Results	
Clean energy achieved	*46%*
Oil reduction (million bbl/yr)	*10.0*
CO2 avoided (million ton/yr)	*5.1*

- **DESCRIPTION:** Energy efficiency to the level of "maximum achievable potential" as defined in the utility Integrated Resource Plans (IRPs); clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (36% without imports); no cable; PHEVs at a low penetration level
- **RESULTS:**
  - Energy Efficiency: Under the "maximum achievable potential" estimates in the utility IRPs, demand side management measures would decrease statewide electricity demand by 220 MW (13% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by commercial and residential rooftop solar (183 MW delivered capacity), as well as geothermal, wind, and biomass. Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 62 MW statewide in 2030

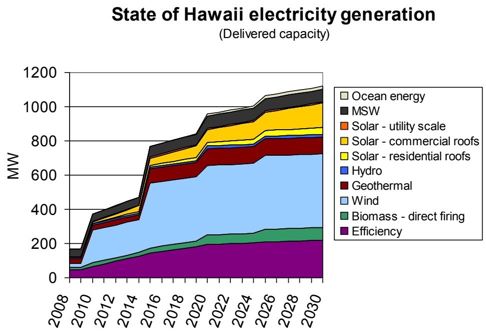
Scenario 1 Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation



Summary of 2030 Transportation Results	
Clean energy achieved	*30%*
Oil reduction (million bbl/yr)	*4.7*
CO2 avoided (million ton/yr)	*2.0*

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a low penetration in 2030 based on an Argonne/EPRI projection (15% of all vehicles sold in 2030 are PHEVs); 50% of technically achievable in-state ethanol is in production by 2020 and is maintained through 2030; biodiesel is imported to meet the RFS
- **RESULTS:**
  - Under this scenario, 30% clean energy is achieved primarily through ethanol production
  - Hawaii would have to import an additional 265 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

Scenario 2 Electricity - Moderate efficiency, low PHEV penetration, and a cable to Oahu from Lanai and Molokai



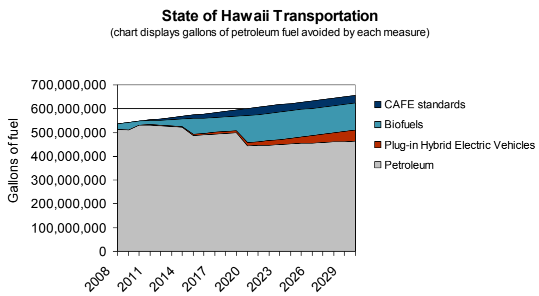
Summary of 2030 Electricity Results	
Clean Energy Achieved	*65%*
Oil reduction (million bbl/yr)	*14.0*
CO2 avoided (million ton/yr)	*7.2*

- **DESCRIPTION:** Energy efficiency to the level of "maximum achievable potential" as defined in the IRPs; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (36% without imports); cable connecting Oahu to Lanai and Molokai; biofuel resources used for transportation fuels; PHEVs at a low penetration level
- **RESULTS:**
  - Energy Efficiency: Under the "maximum achievable potential" estimates in the utility IRPs, demand side management measures would decrease statewide electricity demand by 220 MW (13% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by wind (431 MW delivered capacity). Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 62 MW statewide in 2030

DRAFT: June 11, 2008

Booz | Allen | Hamilton

Scenario 2 Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation



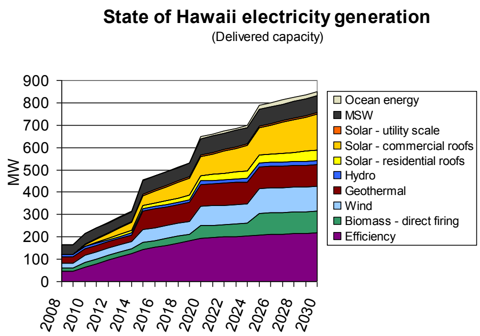
Summary of 2030 Transportation Results	
Clean energy achieved	*30%*
Oil reduction (million bbl/yr)	*4.7*
CO2 avoided (million ton/yr)	*2.0*

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a low penetration in 2030 based on an Argonne/EPRI projection (15% of all vehicles sold in 2030 are PHEVs); 50% of technically achievable in-state ethanol is in production by 2020 and is maintained through 2030; biodiesel is imported to meet the RFS
- **RESULTS:**
  - Under this scenario, 30% clean energy is achieved primarily through ethanol production
  - Hawaii would have to import an additional 265 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

DRAFT: June 11, 2008

Booz | Allen | Hamilton

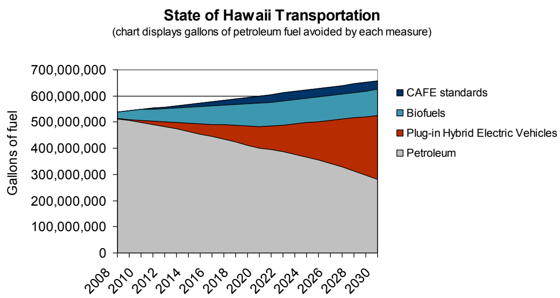
Scenario 3 Electricity - Moderate efficiency, high PHEV penetration with biofuels in electric generation, and no cable



Summary of 2030 Electricity Results	
Clean energy achieved	*46%*
Oil reduction (million bbl/yr)	*11.5*
CO2 avoided (million ton/yr)	*5.9*

- **DESCRIPTION:** Energy efficiency to the level of "maximum achievable potential" as defined in the IRPs; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (32% without imports); no cable; PHEVs at a high penetration level
  - Oahu would require 352 MGY of biodiesel to reach 70% clean energy for electric generation, but since since only 45 MGY can be produced in-state, the state only reaches 46%
- **RESULTS:**
  - Energy Efficiency: Under the "maximum achievable potential" estimates in the utility IRPs, demand side management measures would decrease statewide electricity demand by 220 MW (13% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by rooftop solar (206 MW combined), as well as geothermal, wind, and biomass. Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 314 MW statewide in 2030

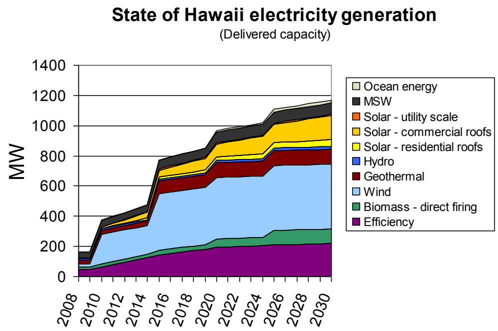
Scenario 3 Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%



Summary of 2030 Transportation Results	
Clean energy achieved	*57%*
Oil reduction (million bbl/yr)	*9.0*
CO2 avoided (million ton/yr)	*3.8*

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a high penetration in 2030 based on a PNNL projection (69% of all vehicles sold in 2030 are PHEVs); land is dedicated to biodiesel production; biodiesel beyond that required to meet the RFS goes to Oahu generating units to generate electricity; ethanol is imported to meet the RFS
- **RESULTS:**
  - Under this scenario, 57% clean energy is achieved primarily through PHEVs
  - Hawaii would have to import 83 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

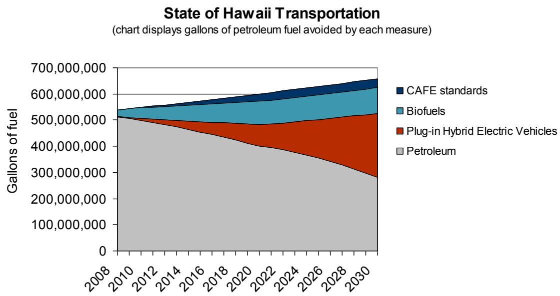
Scenario 4 Electricity - Moderate efficiency, high PHEV penetration with biofuels in electric generation, and a cable to Oahu from Lanai and Molokai



Summary of 2030 Electricity Results	
Clean energy achieved	*63%*
Oil reduction (million bbl/yr)	*15.5*
CO2 avoided (million ton/yr)	*7.9*

- **DESCRIPTION:** Energy efficiency to the level of "maximum achievable potential" as defined in the IRPs; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (32% without imports); cable connecting Oahu to Lanai and Molokai; PHEVs at a high penetration level
  - Oahu would require 139 MGY of biodiesel to reach 70% clean energy for electric generation, but since since only 45 MGY can be produced in-state, the state only reaches 63%
- **RESULTS:**
  - Energy Efficiency: Under the "maximum achievable potential" estimates in the utility IRPs, demand side management measures would decrease statewide electricity demand by 220 MW (13% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by wind (431 MW). Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 314 MW statewide in 2030

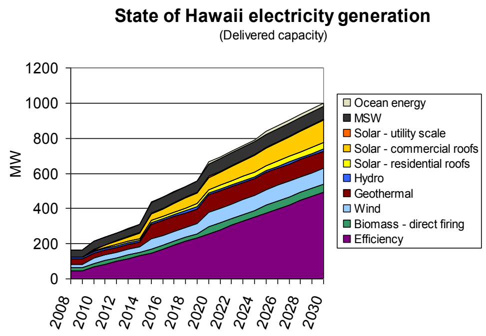
Scenario 4 Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%



Summary of 2030 Transportation Results	
Clean energy achieved	*57%*
Oil reduction (million bbl/yr)	*9.0*
CO2 avoided (million ton/yr)	*3.8*

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a high penetration in 2030 based on a PNNL projection (69% of all vehicles sold in 2030 are PHEVs); land is dedicated to biodiesel production; biodiesel beyond that required to meet the RFS goes to Oahu generating units to generate electricity; ethanol is imported to meet the RFS
- **RESULTS:**
  - Under this scenario, 57% clean energy is achieved primarily through PHEVs
  - Hawaii would have to import 83 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

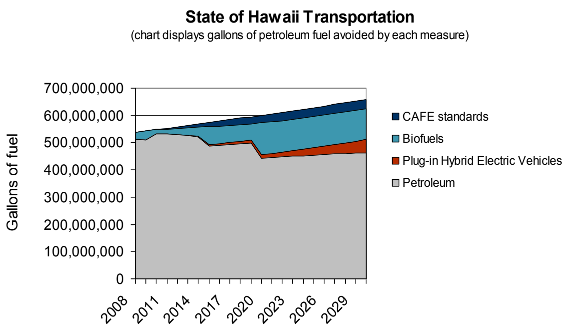
Scenario 5 Electricity- High efficiency, low PHEV penetration, and no cable connecting the islands



Summary of 2030 Electricity Results	
Clean energy achieved	*58%*
Oil reduction (million bbl/yr)	*12.5*
CO2 avoided (million ton/yr)	*6.4*

- **DESCRIPTION:** Energy efficiency to the level of "HCEI high efficiency," which assumes aggressive gains in net zero energy residential buildings and commercial building efficiency; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (53% without imports); no cable; PHEVs at a low penetration level
- **RESULTS:**
  - Energy Efficiency: Under HCEI high efficiency assumptions, demand side management measures would decrease statewide electricity demand by 495 MW (30% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by rooftop solar (165 MW combined), as well as geothermal, wind, and MSW. Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 62 MW statewide in 2030

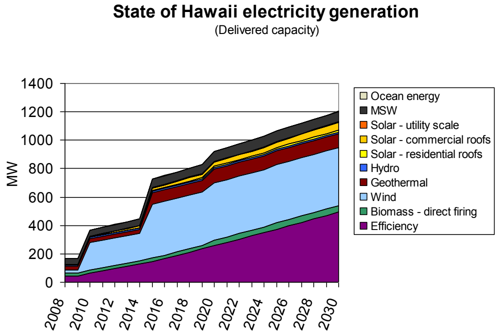
Scenario 5 Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation



Summary of 2030 Transportation Results	
Clean energy achieved	*30%*
Oil reduction (million bbl/yr)	*4.7*
CO2 avoided (million ton/yr)	*2.0*

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a low penetration in 2030 based on an Argonne/EPRI projection (15% of all vehicles sold in 2030 are PHEVs); 50% of technically achievable in-state ethanol is in production by 2020 and is maintained through 2030; biodiesel is imported to meet the RFS
- **RESULTS:**
  - Under this scenario, 30% clean energy is achieved primarily through ethanol production
  - Hawaii would have to import an additional 265 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

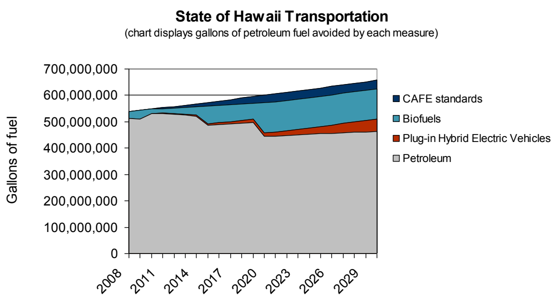
Scenario 6 Electricity - High efficiency, low PHEV penetration, and a cable to Oahu from Lanai and Molokai



Summary of 2030 Electricity Results	
Clean energy achieved	*70%*
Oil reduction (million bbl/yr)	*15.1*
CO2 avoided (million ton/yr)	*7.7*

- **DESCRIPTION:** Energy efficiency to the level of "HCEI high efficiency," which assumes aggressive gains in net zero energy residential buildings and commercial building efficiency; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (53% without imports); cable connecting Oahu to Lanai and Molokai; PHEVs at a low penetration level
- **RESULTS:**
  - Energy Efficiency: Under HCEI high efficiency assumptions, demand side management measures would decrease statewide electricity demand by 495 MW (30% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by wind (409 MW). Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 62 MW statewide in 2030

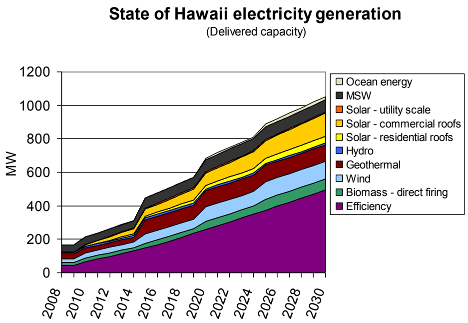
Scenario 6 Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation



Summary of 2030 Transportation Results	
Clean energy achieved	*30%*
Oil reduction (million bbl/yr)	*4.7*
CO2 avoided (million ton/yr)	*2.0*

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a low penetration in 2030 based on an Argonne/EPRI projection (15% of all vehicles sold in 2030 are PHEVs); 50% of technically achievable in-state ethanol is in production by 2020 and is maintained through 2030; biodiesel is imported to meet the RFS
- **RESULTS:**
  - Under this scenario, 30% clean energy is achieved primarily through ethanol production
  - Hawaii would have to import an additional 265 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

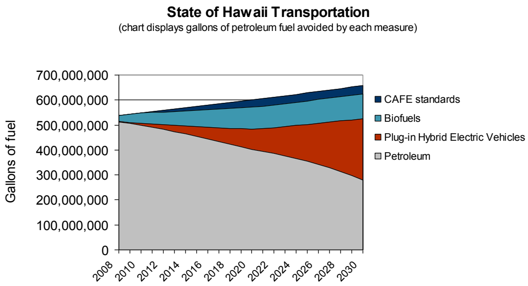
Scenario 7 Electricity - High efficiency, high PHEV penetration with biofuels in electric generation, and no cable



Summary of 2030 Electricity Results	
Clean energy achieved	*57%*
Oil reduction (million bbl/yr)	*14.0*
CO2 avoided (million ton/yr)	*7.2*

- **DESCRIPTION:** Energy efficiency to the level of "HCEI high efficiency," which assumes aggressive gains in net zero energy residential buildings and commercial building efficiency; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (46% without imports); no cable; PHEVs at a high penetration level
  - Oahu would require 220 MGY of biodiesel to reach 70% clean energy for electric generation, but since since only 45 MGY can be produced in-state, the state only reaches 57%
- **RESULTS:**
  - Energy Efficiency: Under HCEI high efficiency assumptions, demand side management measures would decrease statewide electricity demand by 495 MW (30% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by rooftop solar (180 MW combined), as well as geothermal and wind. Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 314 MW statewide in 2030

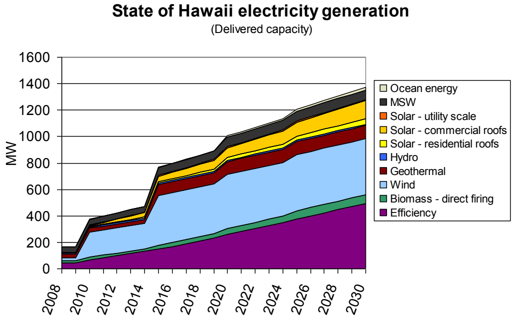
Scenario 7 Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%



Summary of 2030 Transportation Results	
Clean energy achieved	*57%*
Oil reduction (million bbl/yr)	*9.0*
CO2 avoided (million ton/yr)	*3.8*

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a high penetration in 2030 based on a PNNL projection (69% of all vehicles sold in 2030 are PHEVs); land is dedicated to ethanol biodiesel production; biodiesel beyond that required to meet the RFS goes to Oahu generating units to generate electricity
- **RESULTS:**
  - Under this scenario, 57% clean energy is achieved primarily through PHEVs
  - Hawaii would have to import 83 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

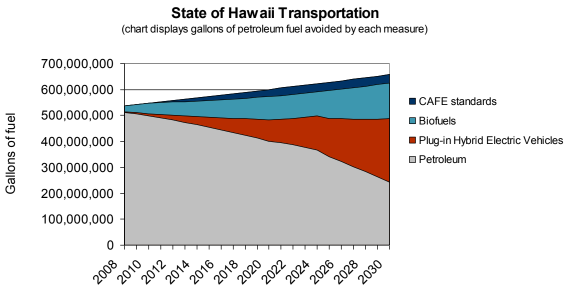
Scenario 8 Electricity - High efficiency, high PHEV penetration, and a cable to Oahu from Lanai and Molokai



Summary of 2030 Electricity Results	
Clean energy achieved	*70%*
Oil reduction (million bbl/yr)	*17.3*
CO2 avoided (million ton/yr)	*8.8*

- **DESCRIPTION:** Energy efficiency to the level of "HCEI high efficiency," which assumes aggressive gains in net zero energy residential buildings and commercial building efficiency; renewable generation of 70% on all islands except Oahu; Oahu renewable generation to the maximum allowed by resources (46% without imports); cable connecting Oahu to Lanai and Molokai; PHEVs at a high penetration level
  - Oahu requires 7 MGY of biodiesel to reach 70% clean energy for electric generation; the remainder of the biodiesel is used for transportation
- **RESULTS:**
  - Energy Efficiency: Under HCEI high efficiency assumptions, demand side management measures would decrease statewide electricity demand by 495 MW (30% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by wind (424 MW). Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 314 MW statewide in 2030

Scenario 8 Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%



Summary of 2030 Transportation Results	
Clean energy achieved	*63%*
Oil reduction (million bbl/yr)	*9.9*
CO2 avoided (million ton/yr)	*4.2*

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a high penetration in 2030 based on a PNNL projection (69% of all vehicles sold in 2030 are PHEVs); land is dedicated to ethanol in sufficient quantity to meet the RFS with locally grown fuels, with the remaining land going to biodiesel production; biodiesel is not needed in Oahu generating units, so all biofuels are used for transportation
- **RESULTS:**
  - Transportation: Under this scenario, 63% clean energy is achieved primarily through PHEVs
  - Under this scenario, Hawaii would have to import 44 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

Next steps for the analysis

- First-order energy delivery and grid upgrade analysis
- Investment analysis and macroeconomic analysis of impacts for the State
- Detailed exploration and costing of a few select scenarios

Appendix

- Assumptions and notes on the analysis
- Island by island summaries for each scenario

Notes on the analysis – electric generation

- Energy demand **baselines** are all taken from utility Integrated Resource Plans (IRPs). Business as usual demand for electricity in 2030 is predicted to grow from the current level of 988 MW to 1,164 MW statewide (This does not include reserve capacity).
- Projected plug-in hybrid electric vehicle (**PHEV**) electricity needs are added onto these numbers
  - In the "Low PHEV" scenarios, PHEVs are 15% of new car sales in 2030 (Argonne/EPRI) and require 62 MW of additional generation capacity
  - In the "High PHEV" scenarios, PHEVs are 69% of new car sales (PNNL) and require 314 MW of additional generation capacity
- Resources were loaded onto each island's system in the following dispatch order, which reflects the cost ranking – least expensive to most expensive – of each resource according to the California Energy Commission, 2007 (the MSW cost figure comes from the Black & Veatch Renewable Energy Transmission Initiative 2008 report)

Renewable energy cost ranking	
1	Geothermal
3	Wind
4	Biomass
5	Small Hydro
6	Utility scale solar
7	Solar PV
8	Ocean

2: MSW

- Maui geothermal is capped at 30% of its 140 MW capacity (42 MW) as identified in the GeothermEx 2005 and EPACT 355 Reports; the geothermal is used to meet Maui's demand and is not cabled to Oahu
- Maui has 30% of its 10 MW ocean energy potential (30 MW) deployed in all scenarios because of the planned project
- 50 MW potential is used for Oahu's ocean energy
- MSW is dispatched to 75% of its potential on all islands. Landfill gas is counted together with MSW
- Development of utility scale solar (concentrated solar power) on Kauai is capped at to 5% of the 285 MW potential identified in the EPACT 355 Report; this and CSP numbers for the other islands were developed in consultation with NREL and state and county energy officials
- Lanai and Molokai demand are not modeled
- The following **capacity factors**, from NREL and EERE, were used for each resource (for wind, 35% was used for Oahu, Hawaii, and Kauai resources, 40% was used for Molokai and Lanai, and 45% was used for Maui)

Capacity factors	
Biomass - direct firing	80%
Wind	35-45%
Geothermal	95.5%
Hydro	44.2%
Solar - residential roofs	22.5%
Solar - commercial roofs	22.5%
Solar - utility scale	24.4%
MSW	95%
Ocean energy	35%

Notes on the analysis – efficiency and transportation

- **Building efficiency** assumptions:
  - 55% of all existing housing stock will be retrofitted by 2030
  - 1% of building stock each year is demolished and replaced with new construction
  - Max efficiency potential for all residential buildings is 50% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for new commercial buildings is 53% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for existing commercial buildings is 42% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for all new/retrofitted buildings will be reached in the year 2015, and remain constant until 2030
  - Current efficiency potential is 36% for residential new construction, 34% for residential retrofits, 30% for commercial new construction, and 19% for commercial retrofits
- The transportation model assumes that 50% of the potential identified in the 2006 ethanol study by HNEI is actually available for **ethanol** and that 50% of the potential identified in the HARC biodiesel study is actually available for **biodiesel**; the rest of the land is assumed to be dedicated to food production or some other use
  - This would result in about 142,000 acres devoted to crops for ethanol under the max ethanol scenario (Scenarios 1,2,5 and 6) and 124,000 acres devoted to biodiesel under the max biodiesel scenario (Scenarios 3,4,7 and 8). It is assumed that there is a high degree of overlap between these two land areas
  - These acres are either in ethanol or biodiesel production. In scenarios 1,2,5, and 6, ethanol is produced to the exclusion of biodiesel. All ethanol is used only in the transportation sector. Biodiesel is imported to meet the RFS; this cost is included in the cost model
  - In scenarios 3, 4, and 7, biodiesel is produced to the exclusion of ethanol. In these scenarios, biodiesel beyond that required to meet the RFS is provided to the generation sector. Ethanol is imported to meet the RFS; the cost thereof is included in the cost model
  - In Scenario 8, biodiesel is produced to meet the RFS and ethanol is imported. The generation model shows that by the year 2030, only a small quantity of biodiesel (7 million gallons) will be required to achieve 70% clean energy in the electricity sector. This quantity of biodiesel is given to the generation sector and the remainder is used in the transportation sector
  - There are no scenarios under which both ethanol and biodiesel are produced in sufficient volumes to meet the RFS

Resource potential for all Hawaii islands – units are potential of installed capacity

	Source		Oahu	Kauai	Maui	Hawaii	Lanai	Molokai	Total
Biomass	355 Report /1	MW	7	20	8	20	no data	6	
	KIUC Renewable Energy Technology Assessment			20					
	Hawaii Energy Strategy 2000/2	MW	25	25	25	50			
	Value used for BAH model		25	25	25	50	0	0	**125**
Wind	355 Report	MW	At least 50	At least 40	At least 40	At least 10	no data	no data	
	Proposed projects/3	MW			97		400	400	
	Hawaii Energy Strategy 2000	MW	65			85			
	Value used for BAH model		65	40	97	85	400	400	**1087**
Geothermal	355 Report (from GeothermEx 2005)	MW	n/a	n/a	140	750	n/a	n/a	
	Value used for BAH model		0	0	140	750	0	0	**890**
Hydro	355 Report	MW	no data	no data	3	20	20	no data	
	KIUC RETA	MW		21					
	Hawaii Energy Strategy 2000	MW		7					
	Value used for BAH model		0	21	3	20	0	0	**44**
Solar - rooftop	Residential roof analysis /5	MW	416	35	80	94			
	Commercial roof analysis /6	MW	576	48	111	130			
	Value used for BAH model		992	83	191	224	0	0	**1490**
Solar - utility scale	NREL estimate	MW	8	8	8	8			
	355 Report			285					
	Value used for BAH model		8	14	8	8	0	0	**37**
MSW (incl. landfill gas)	Hawaii Energy Strategy 2000	MW		25					
	KIUC RETA / County energy staff	MW	57	8	8	10			
	Existing plant (H-POWER)	MW	46						
	Value used for BAH model		57	8	8	10	0	0	**83**
Ocean energy	Estimates / proposed projects		50		10				
	Value used for BAH model	MW	50		10				**60**
Total	*Value used for BAH model*	**MW**	**1196**	**192**	**481**	**1147**	**400**	**400**	**3816**

1. "Assessment of Dependence of State of Hawaii on Oil" for EPACT Section 355, DOE, 2007.

2. Hawaii Energy Strategy 2000. Prepared by DBEDT

3. Lanai: DBEDT website--Castle and Cooke is investigating a 300 MW wind farm on Lanai; Molokai: Hawaii Star Bulletin, "Wind Power Firm Vows $50M for Molokai Bid."

Maui: DBEDT wesbite: http://hawaii.gov/dbedt/info/energy/renewable/wind

5. NREL estimates 2.5 kW per house, assume that half of Hawaii's 500,036 houses (as of 2006 census) are suitable for PV on the roof

6. In 2003, Hawaii had approx. 173 mil sq feet of commercial buildings, according to HECO (http://hawaii.gov/dbedt/ert/rebuild/minutes/May03Presentations/Benchmarking.pdf), 100 sq ft per kW (which is the figure for the 309 kW, 31,000 sq ft Ford Island array), assume that commercial buildings are proportional to residential buildings on each island to get island by island estimate, then assume that half of Hawaii's commercial buildings are suitable for solar

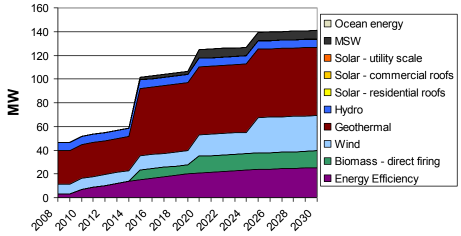
Note: Proposed projects, existing plants, KIUC RETA, HES 2000, and county energy staff estimates are used if they are greater than those listed in 355 Report

Sources

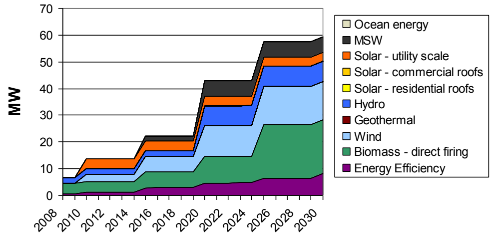
- Utility IRPs (HECO, MECO, HELCO, KIUC)
- NREL, EIA, Pacific Northwest National Lab, Argonne National Lab, EPRI
- California Energy Commission and California Solar Resources Report
- Black & Veatch Renewable Energy Transmission Initiative
- 355 Report: Assessment of Dependence of State of Hawaii on Oil
- KIUC Renewable Energy Technology Assessment
- Catalog of Potential Sites for Renewable Energy in Hawaii
- HARC Biodiesel Crop Implementation for Hawaii
- HNEI Potential for Ethanol Production in Hawaii
- Hawaii Energy Strategy 2000
- Hawaii Databook

Scenario 1 Electricity - Moderate efficiency, low PHEV penetration, and no cable connecting the islands

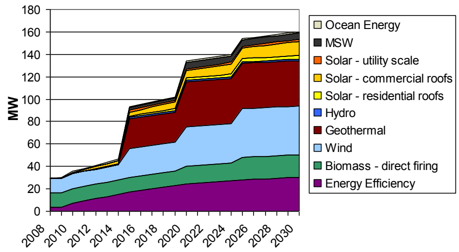
Hawaii



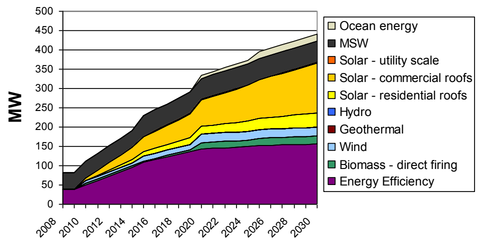
Kauai



Maui

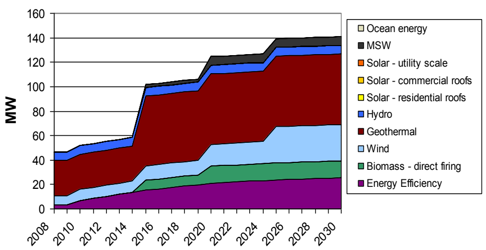


Oahu

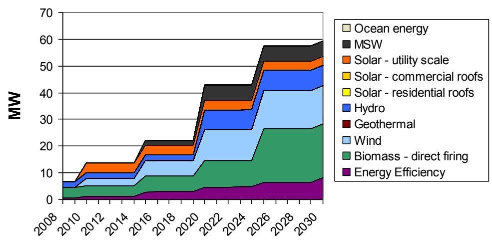


Scenario 2 Electricity - Moderate efficiency, low PHEV penetration, and a cable to Oahu from Lanai and Molokai

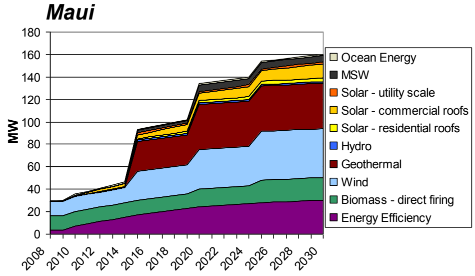
Hawaii



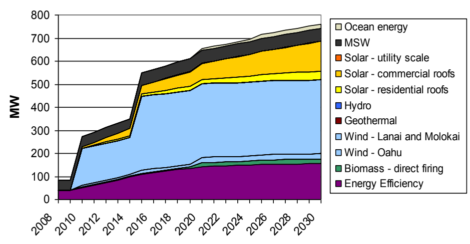
Kauai



Maui

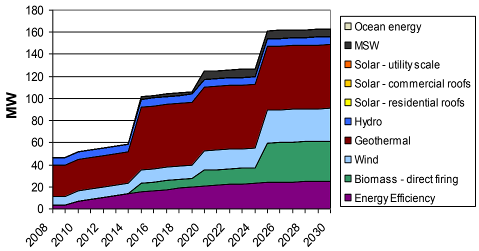


Oahu

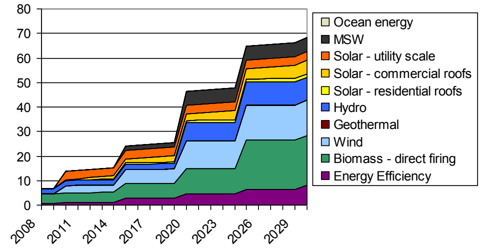


Scenario 3 Electricity - Moderate efficiency, high PHEV penetration with biofuels in electric generation, and no cable

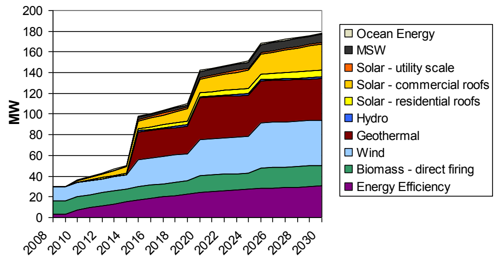
Hawaii



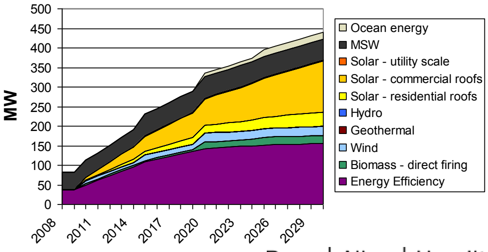
Kauai



Maui

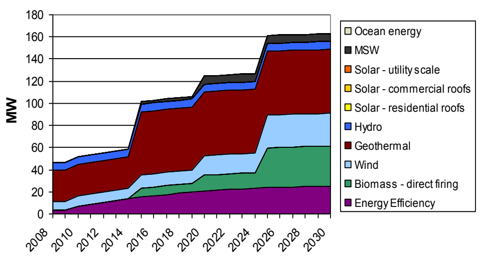


Oahu

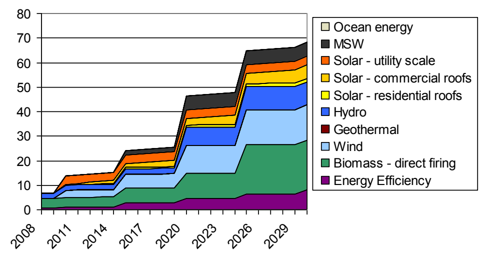


Scenario 4 Electricity - Moderate efficiency, high PHEV penetration with biofuels in electric generation, and a cable to Oahu from Lanai and Molokai

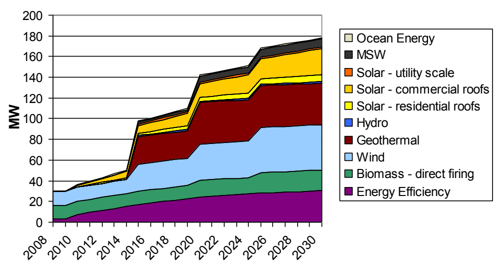
Hawaii



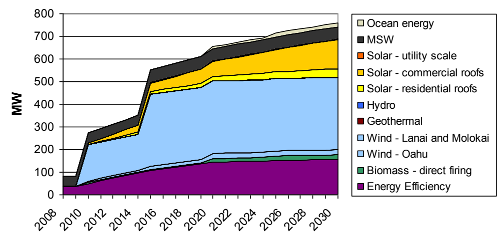
Kauai



Maui

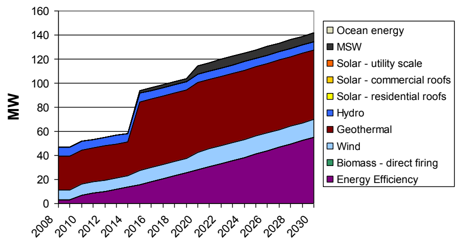


Oahu

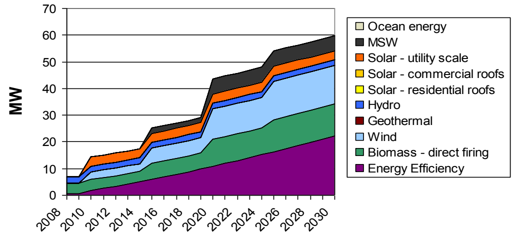


Scenario 5 Electricity - High efficiency, low PHEV penetration, and no cable connecting the islands

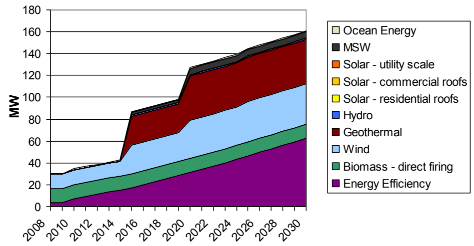
Hawaii



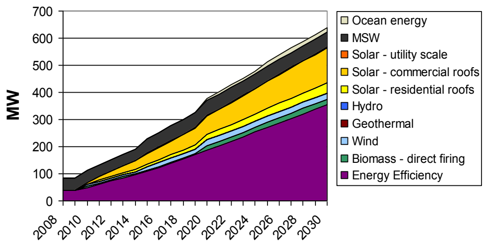
Kauai



Maui

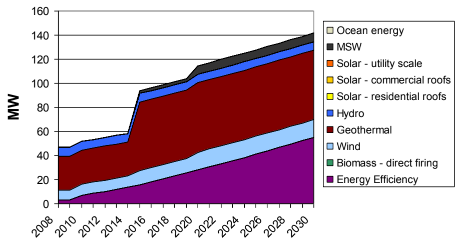


Oahu

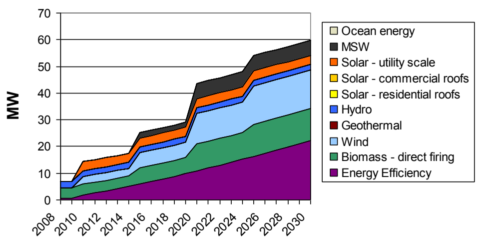


Scenario 6 Electricity - High efficiency, low PHEV penetration, and a cable to Oahu from Lanai and Molokai

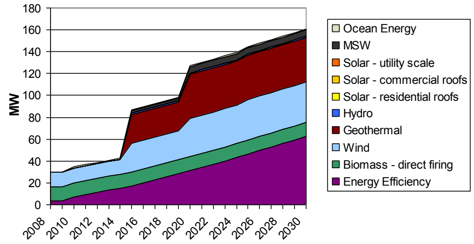
Hawaii



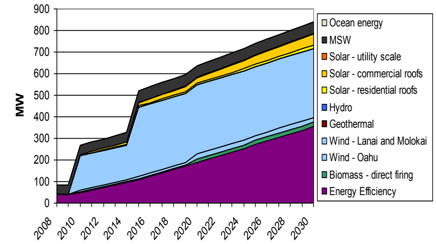
Kauai



Maui

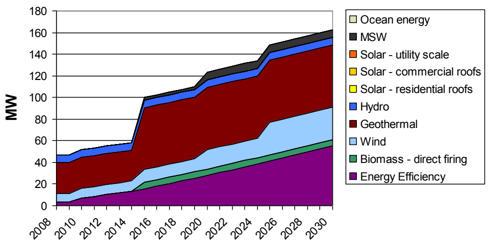


Oahu

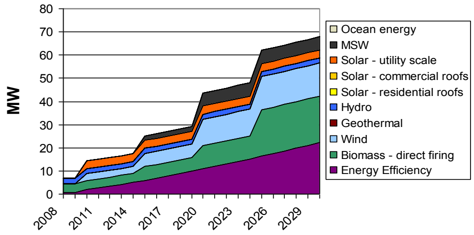


Scenario 7 Electricity - High efficiency, high PHEV penetration with biofuels in electric generation, and no cable

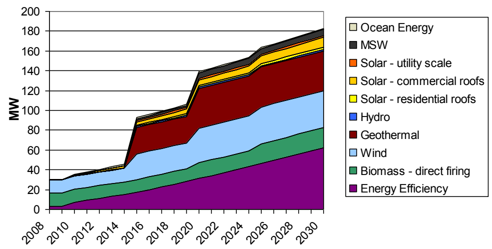
Hawaii



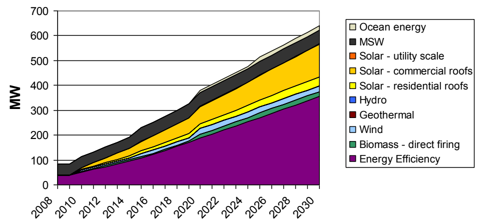
Kauai



Maui



Oahu



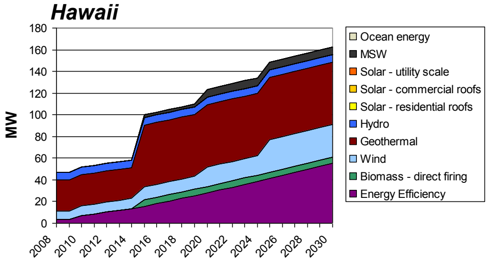
DRAFT: June 11, 2008

36

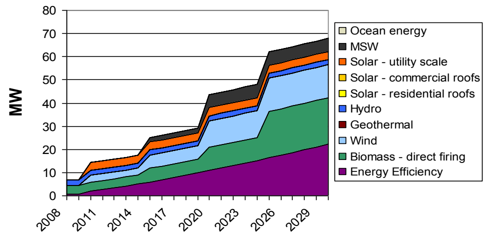
Booz | Allen | Hamilton

Scenario 8 Electricity - High efficiency, high PHEV penetration, and a cable to Oahu from Lanai and Molokai

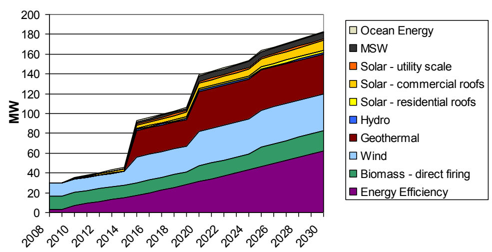
Hawaii



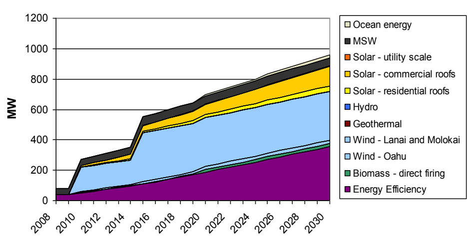
Kauai



Maui



Oahu



DRAFT: June 11, 2008

37

Booz | Allen | Hamilton

Appendix B: Investment Costs and Expected Savings Associated with the HCEI Scenarios (June 2008)

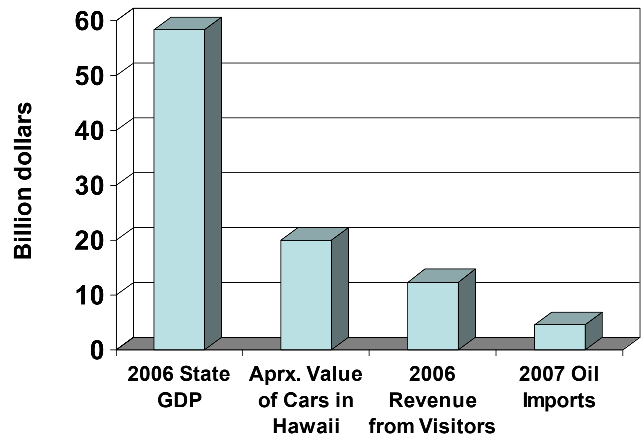
Investment Costs and Expected Savings Associated with the HCEI Scenarios

Honolulu, HI
June 17, 2008

Introduction

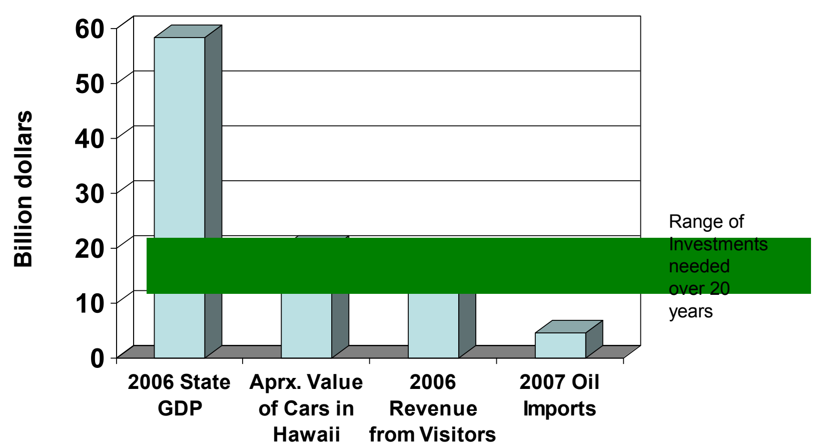
- This analysis provides a first look, first-order calculation of the investment costs and projected savings of key scenarios
- Truly a team effort—multiple sources of information and multiple methodologies (Booz Allen, DBEDT, DOE, NREL)

Scale and Context for Numbers



Sources: Hawaii Databook, DBEDT, other estimates

Scale and Context for Numbers



Sources: Hawaii Databook, DBEDT, other estimates

Summary of the Eight Scenarios

	2030 End-state for Each Scenario (installed capacity)							
	1	2	3	4	5	6	7	8
Efficiency	220	220	220	220	495	495	495	495
Biomass - direct firing	93	93	120	120	56	56	83	83
Wind	276	1076	276	1076	223	1023	260	1060
Geothermal	102	102	102	102	102	102	102	102
Hydro	36	36	40	40	24	24	24	24
Solar (residential roofs)	182	182	205	205	166	67	179	179
Solar (commercial roofs)	633	633	712	712	578	232	622	622
Solar (utility scale)	29	29	29	29	22	22	29	29
MSW	77	77	79	79	77	77	77	77
Ocean energy	53	53	53	53	53	3	53	53
Dispatchable	271	271	301	301	235	235	261	261
Non-dispatchable	1209	2009	1316	2116	1065	1370	1167	1967
Electricity Sector Clean Energy %	**46%**	**65%**	**46%**	**63%**	**58%**	**70%**	**57%**	**70%**
Oil reduction (million bbls in 2030)	10.0	14.0	11.5	15.5	12.5	15.1	14.0	17.3
CO2 avoided (million tons in 2030)	5.1	7.2	5.9	7.9	6.4	7.7	7.2	8.8
Transportation Sector Clean Energy %	**30%**	**30%**	**57%**	**57%**	**30%**	**30%**	**57%**	**63%**
Oil reduction (million bbls in 2030)	4.7	4.7	9.0	9.0	4.7	4.7	9.0	9.9
CO2 avoided (million tons in 2030)	2.0	2.0	3.8	3.8	2.0	2.0	3.8	4.2

Note: All electricity sector numbers are in total installed capacity needed; transportation sector includes only ground transportation

Summary of the Eight Scenarios

	2030 End-state for Each Scenario (installed capacity)							
	1	2	3	4	5	6	7	8
Efficiency		220	220	220	495	495		
Biomass - direct firing		93	120	120	56	56		
Wind		1076	276	1076	223	1023		
Geothermal		102	102	102	102	102		
Hydro		36	40	40	24	24		
Solar (residential roofs)		182	205	205	166	67		
Solar (commercial roofs)		633	712	712	578	232		
Solar (utility scale)		29	29	29	22	22		
MSW		77	79	79	77	77		
Ocean energy		53	53	53	53	3		
Dispatchable		271	301	301	235	235		
Non-dispatchable		2009	1316	2116	1065	1370		
Electricity Sector Clean Energy %		**65%**	**46%**	**63%**	**58%**	**70%**		
Oil reduction (million bbls in 2030)		14.0	11.5	15.5	12.5	15.1		
CO2 avoided (million tons in 2030)		7.2	5.9	7.9	6.4	7.7		
Transportation Sector Clean Energy %		**30%**	**57%**	**57%**	**30%**	**30%**		
Oil reduction (million bbls in 2030)		4.7	9.0	9.0	4.7	4.7		
CO2 avoided (million tons in 2030)		2.0	3.8	3.8	2.0	2.0		

Note: All electricity sector numbers are in total installed capacity needed; transportation sector includes only ground transportation

Basis of Investment Cost Information

RETI Stakeholder Steering Committee
Renewable Energy Transmission Initiative Phase 1A

Appendix A. Appendix A Here

Table 1-1. Renewable Technologies Performance and Cost Summary.

	Net Plant Capacity, MW	Net Plant Heat Rate, Btu/kWh	Capacity Factor	[redacted]	Fixed O&M, $/kW-yr	Variable O&M, $/MWh	Fuel Cost, $/MBtu	Levelized Cost, $/MWh
Solid Biomass	35	14500	80		83	11	0 to 3	67 to 150
Cofired Biomass	35	10000	85		5 to 15		-0.5 to 1	-1 to 22
An. Digestion	0.15	13000	80			17	1 to 3	100 to 168
Landfill Gas	5	13500	80			17	1 to 2	50 to 80
Solar Thermal	200		26-29		66			137 to 176
Solar Photovoltaic	20		25-30		35			201 to 276
New Hydroelectric	<50		40 to 60		5 to 25	5 to 6		57 to 136
Inc. Hydroelectric	1 to 600		40 to 60		5 to 25	3.5 to 6		10 to 98
Wind	100		25 to 40		50			59 to 128
Offshore Wind	200		35 to 45		75-100			142 to 232
Geothermal	30		70 to 90			25 to 30		54 to 107
Marine Current	100		25 to 45		90 to 255			97 to 410
Wave	100		25 to 45		150 to 270	11		135 to 445

Notes:
Levelized Cost includes applicable incentives, subsidies, etc.

Scenario 1 Recap

- Electricity - Moderate efficiency, low PHEV penetration, and no cable connecting the islands—clean energy achieved 46%
- Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation—clean energy achieved 30%

Scenario 1: Investments and Projected Savings (2008 through 2030)

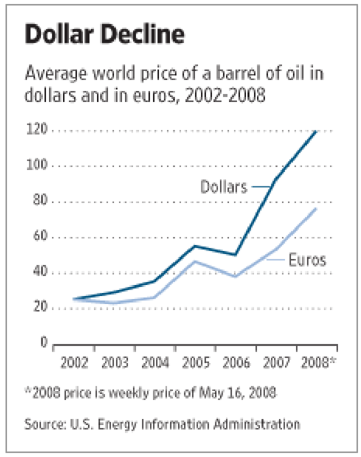
Avg. Crude Oil Price (2008-2030) per Barrel	Investment Cost	PV of Investment Cost	Savings from Oil Displaced	PV of Savings from Oil Displaced
$40	$ 10.3	$ 5.0	$ 11.8	$ 4.9
$50	$ 10.3	$ 5.0	$ 14.7	$ 6.1
$60	$ 10.3	$ 5.0	$ 17.7	$ 7.4
$70	$ 10.3	$ 5.0	$ 20.6	$ 8.6
$80	$ 10.3	$ 5.0	$ 23.6	$ 9.8
$90	$ 10.3	$ 5.0	$ 26.5	$ 11.0
$100	$ 10.3	$ 5.0	$ 29.5	$ 12.3
$110	$ 10.3	$ 5.0	$ 32.4	$ 13.5
$120	$ 10.3	$ 5.0	$ 35.4	$ 14.7
$130	$ 10.3	$ 5.0	$ 38.3	$ 15.9
$140	$ 10.3	$ 5.0	$ 41.3	$ 17.2

Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

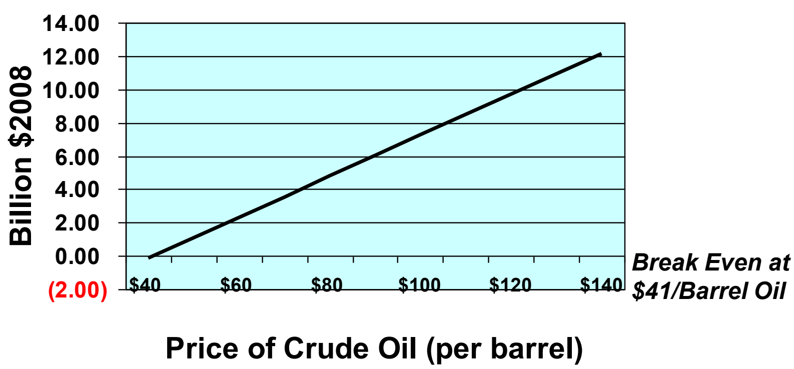
Scenario 1: Investments and Projected Savings (2008 through 2030)

Avg. Crude Oil Price (2008-2030) per Barrel	Investment Cost	PV of Investment Cost	Savings from Oil Displaced	PV of Savings from Oil Displaced
$40	$ 10.3	$ 5.0	$ 11.8	$ 4.9
$50	$ 10.3	$ 5.0	$ 14.7	$ 6.1
$60	$ 10.3	$ 5.0	$ 17.7	$ 7.4
$70	$ 10.3	$ 5.0	$ 20.6	$ 8.6
$80	$ 10.3	$ 5.0	$ 23.6	$ 9.8
$90	$ 10.3	$ 5.0	$ 26.5	$ 11.0
[redacted]				
$110	$ 10.3	$ 5.0	$ 32.4	$ 13.5
$120	$ 10.3	$ 5.0	$ 35.4	$ 14.7
$130	$ 10.3	$ 5.0	$ 38.3	$ 15.9
$140	$ 10.3	$ 5.0	$ 41.3	$ 17.2

Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%



Scenario 1: Net Present Value of Projected Savings Less Investments for 2008 through 2030



Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

Basis of Levelized Cost Information

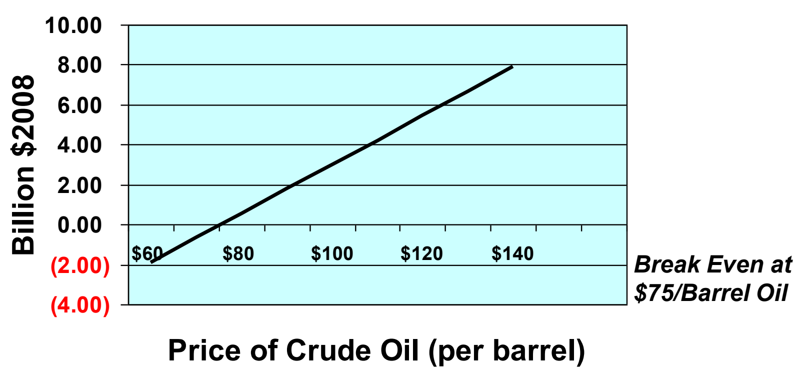
RETI Stakeholder Steering Committee
Renewable Energy Transmission Initiative Phase 1A — Appendix A. Appendix A Here

Table 1-1. Renewable Technologies Performance and Cost Summary.

	Net Plant Capacity, MW	Net Plant Heat Rate, Btu/kWh	Capacity Factor	Capital Cost, $/kW	Fixed O&M, $/kW-yr	Variable O&M, $/MWh	Fuel Cost, $/MBtu
Solid Biomass	35	14500	80	3000 to 5000	83	11	0 to 3
Cofired Biomass	35	10000	85	300 to 500	5 to 15		-0.5 to 1
An. Digestion	0.15	13000	80	4000 to 6000		17	1 to 3
Landfill Gas	5	13500	80	1200 to 2000		17	1 to 2
Solar Thermal	200		26-29	3600 to 4200	66		
Solar Photovoltaic	20		25-30	6500 to 7500	35		
New Hydroelectric	<50		40 to 60	2500 to 4000	5 to 25	5 to 6	
Inc. Hydroelectric	1 to 600		40 to 60	600 to 3000	5 to 25	3.5 to 6	
Wind	100		25 to 40	1900 to 2400	50		
Offshore Wind	200		35 to 45	5000 to 6000	75-100		
Geothermal	30		70 to 90	3000 to 5000		25 to 30	
Marine Current	100		25 to 45	2200 to 4725	90 to 255		
Wave	100		25 to 45	2800 to 5200	150 to 270	11	

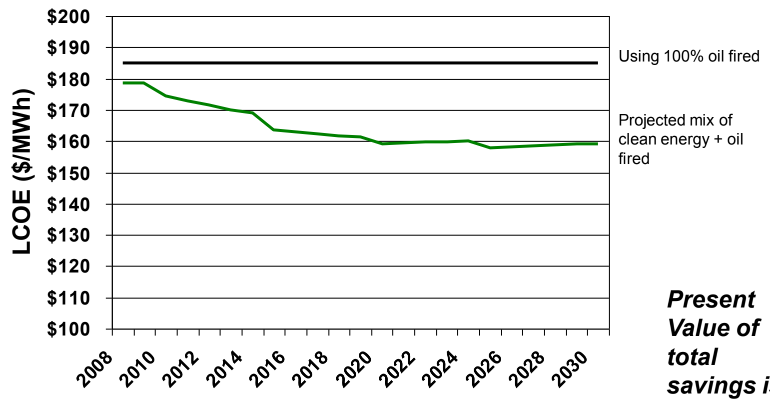
Notes:

Scenario 1: Net Present Value of Projected Savings Less Total of Levelized Costs for 2008 - 2030



Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

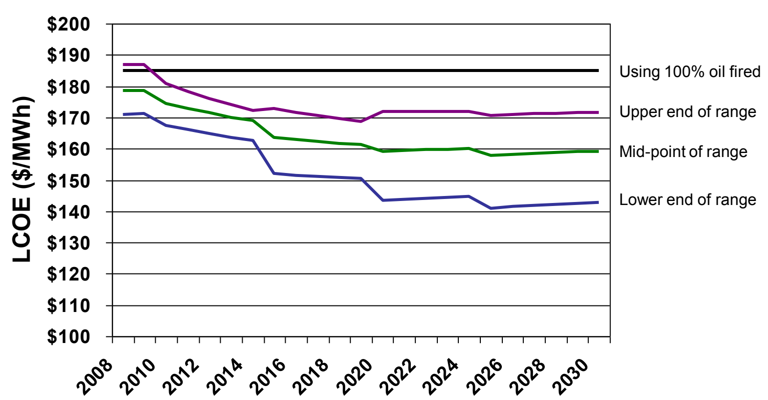
Scenario 1: LCOE (Electricity) and Savings Over Time $100/Barrel Oil



Present Value of total savings is $2.9 billion

Figures in 2008 dollars
PV figures based on discount rate of 7%

Scenario 1: LCOE (Electricity) and Savings Over Time $100/Barrel Oil



Figures in 2008 dollars

Scenario 7 Recap

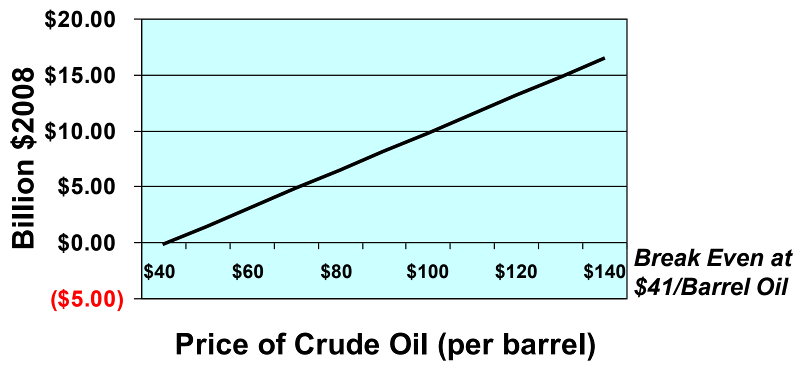
- Electricity - High efficiency, high PHEV penetration with biofuels in electric generation, and no cable—clean energy achieved 57%
- Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%—clean energy achieved 57%

Scenario 7: Investments and Projected Savings (2008 through 2030)

Avg. Crude Oil Price (2008-2030) per Barrel	Investment Cost	PV of Investment Cost	Savings from Oil Displaced	PV of Savings from Oil Displaced
$40	$ 14.9	$ 6.9	$ 16.8	$ 6.7
$50	$ 14.9	$ 6.9	$ 21.0	$ 8.3
$60	$ 14.9	$ 6.9	$ 25.1	$ 10.0
$70	$ 14.9	$ 6.9	$ 29.4	$ 11.7
$80	$ 14.9	$ 6.9	$ 33.6	$ 13.3
$90	$ 14.9	$ 6.9	$ 37.8	$ 15.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$110	$ 14.9	$ 6.9	$ 46.1	$ 18.3
$120	$ 14.9	$ 6.9	$ 50.3	$ 20.0
$130	$ 14.9	$ 6.9	$ 54.5	$ 21.7
$140	$ 14.9	$ 6.9	$ 58.7	$ 23.3

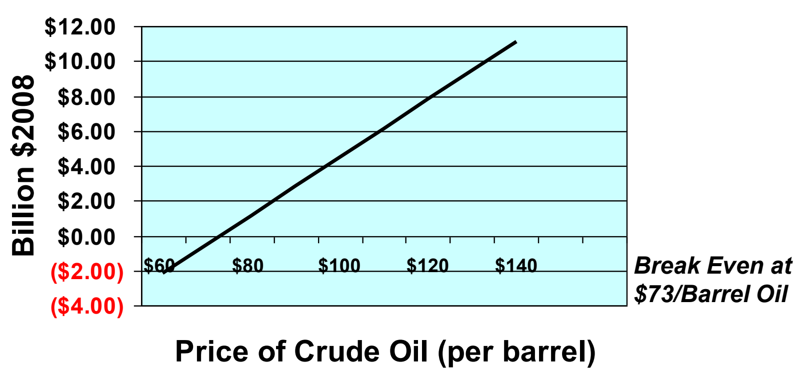
Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

Scenario 7: Net Present Value of Projected Savings Less Investments for 2008 through 2030



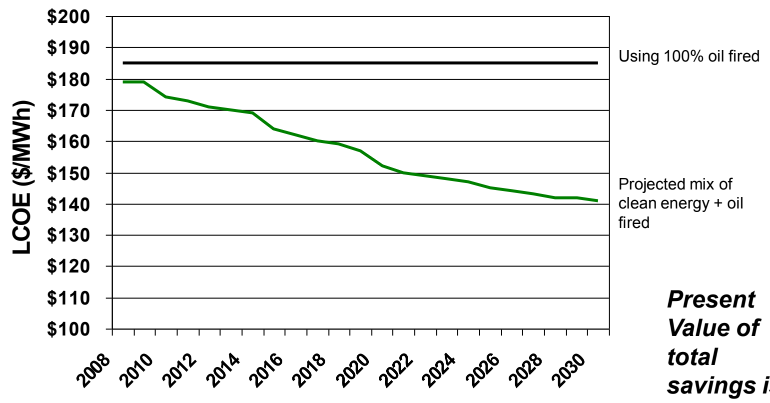
Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

Scenario 7: Net Present Value of Projected Savings Less Total of Levelized Costs for 2008 - 2030



Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

Scenario 7: LCOE (Electricity) and Savings Over Time $100/Barrel Oil



Present Value of total savings is $3.8 billion

Figures in 2008 dollars
PV figures based on discount rate of 7%

Scenario 8 Recap

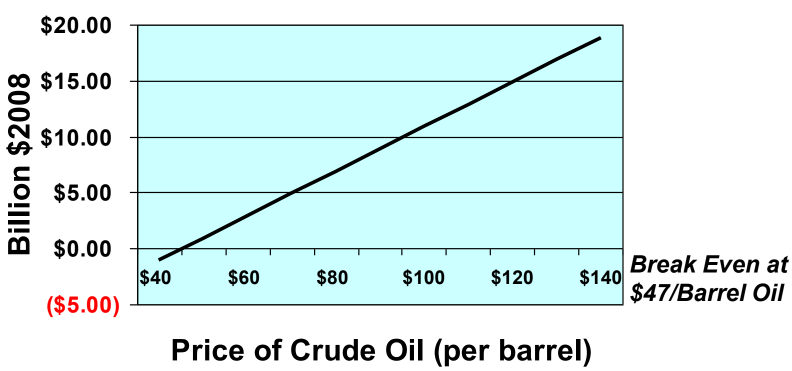
- Electricity - High efficiency, high PHEV penetration, and a cable to Oahu from Lanai and Molokai—clean energy achieved 70%
- Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70% —clean energy achieved 63%

Scenario 8: Investments and Projected Savings (2008 through 2030)

Avg. Crude Oil Price (2008-2030) per Barrel	Investment Cost	PV of Investment Cost	Savings from Oil Displaced	PV of Savings from Oil Displaced
$40	$ 18.1	$ 9.1	$ 19.7	$ 8.0
$50	$ 18.1	$ 9.1	$ 24.7	$ 10.0
$60	$ 18.1	$ 9.1	$ 29.6	$ 12.0
$70	$ 18.1	$ 9.1	$ 34.5	$ 14.0
$80	$ 18.1	$ 9.1	$ 39.5	$ 16.0
$90	$ 18.1	$ 9.1	$ 44.4	$ 18.0
$110	$ 18.1	$ 9.1	$ 54.3	$ 21.9
$120	$ 18.1	$ 9.1	$ 59.2	$ 23.9
$130	$ 18.1	$ 9.1	$ 64.2	$ 25.9
$140	$ 18.1	$ 9.1	$ 69.1	$ 27.9

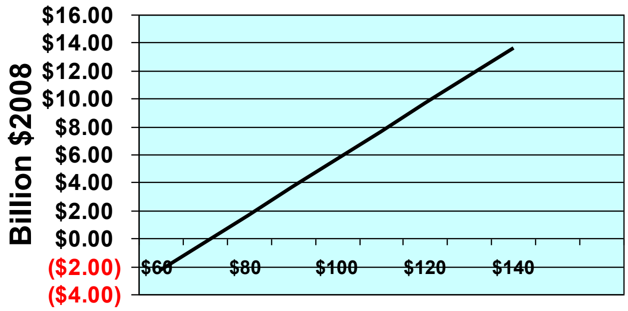
Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

Scenario 8: Net Present Value of Projected Savings Less Investments for 2008 through 2030



Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

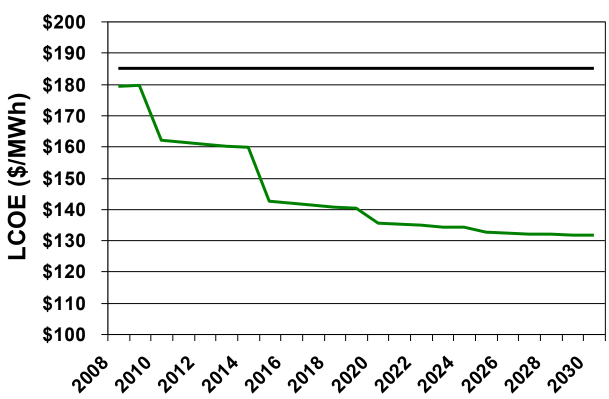
Scenario 8: Net Present Value of Projected Savings Less Total of Levelized Costs for 2008 - 2030



Break Even at $72/Barrel Oil

Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

Scenario 8: LCOE (Electricity) and Savings Over Time $100/Barrel Oil



Present Value of total savings is $5.7 billion

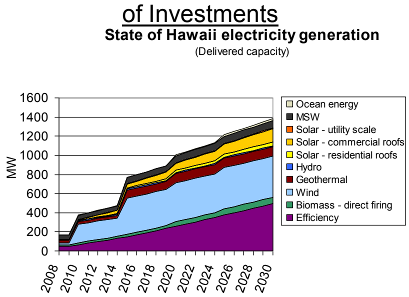
Figures in 2008 dollars
PV figures based on discount rate of 7%

The Importance of Early Action

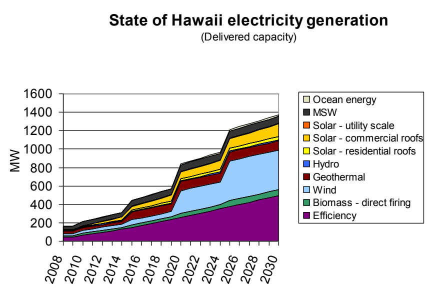
- All of our scenarios assume early investment (with most between 2008 and 2015) reaping savings for a long time
- Scenario 8 is used to model what delays in investment in could mean for potential savings
- The modified Scenario 8 has a more uniform loading of investments and the cable installation delayed until 2020

Scenario 8: Comparison Accelerated vs. Delayed Investment

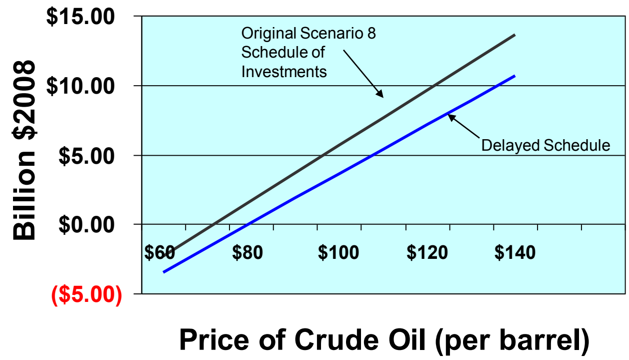
Original Scenario 8 Schedule of Investments



Delayed Investment Schedule



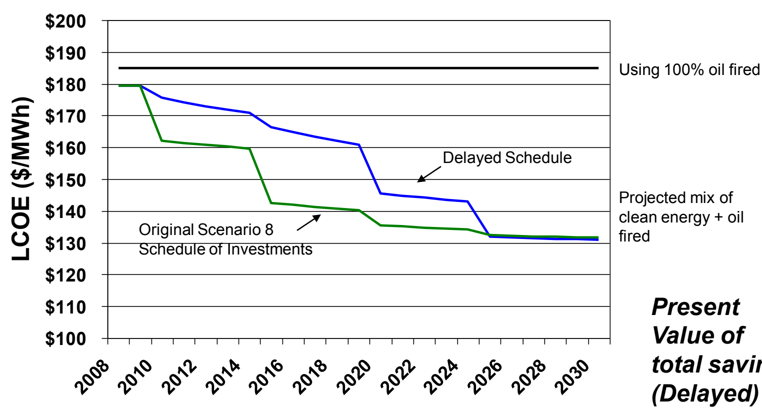
Scenario 8: Net Present Value of Projected Savings Less Total of Levelized Costs for 2008 – 2030, Delayed Investment Schedule



Break Even at $80/Barrel Oil

Figures in Billion 2008 dollars (except per barrel cost).
PV figures based on discount rate of 7%

Scenario 8: LCOE (Electricity) and Savings Over Time $100/Barrel Oil, Delayed Investment Schedule



Present Value of total savings (Delayed) is $4.0 billion

Figures in 2008 dollars
PV figures based on discount rate of 7%

Conclusions & Next Steps

- At a first-order level, each scenario seems economical with long-term oil at $80-100/bbl

Scenario	Achievement	Investment Cost (billion 2008$)	Breakeven point with Crude Oil Range (2008$/bbl)
1	Electric Generation Clean Energy 46% Transportation Clean Energy 30%	10	$41 to $75
7	Electric Generation Clean Energy 57% Transportation Clean Energy 57%	15	$41 to $73
8	Electric Generation Clean Energy 70% Transportation Clean Energy 63%	18	$47 to $72

- Early action on investments is crucial to the overall economics/savings
- NEXT: An in depth analysis on one scenario with Hawaii specific cost factors & an economic analysis (e.g., impact on jobs, rates, GDP)

Sources

- Levelized Renewable Energy Cost Estimates and Capex Estimates
  - RETI Study: http://www.energy.ca.gov/2008publications/RETI-1000-2008-002/RETI-1000-2008-002-F.PDF
- PHEV Infrastructure Costs/Premiums per Vehicle:
  - NREL: http://www.nrel.gov/docs/fy07osti/41410.pdf
- Ethanol Estimates
  - Price per gallon ETOH: http://ethanolmarket.aghost.net
  - Gallons Gas per Barrel Oil: www.gravmag.com/oil.html
  - Gallons Fuel Oil per Barrel Oil: www.gravmag.com/oil.html
  - BTU content of fuels: http://www.nafa.org/Content/NavigationMenu/Resource_Center/Alternative_Fuels/Energy_Equivalents/Energy_Equivalent
- Biodiesel Estimates:
  - http://www.biodiesel.org/buyingbiodiesel/retailfuelingsites/showstate.asp?st=VA
- Cost of Biodiesel Capex:
  - Capital Cost estimated from "Biodiesel Production Cost" worksheet from Jacobsen and Testimony from Ray Stultz, Director of NREL: http://energy.senate.gov/public/_files/StultsTestimony110607.doc
- Cost of Biodiesel Feedstock:
  - http://www.cbot.com/cbot/pub/page/0,3181,959,00.html
- Energy Efficiency Cost Estimate ($/kWh):
  - California Energy Commission: http://www.fypower.org/pdf/CEC%20_Trends2000-04.pdf
- Wholesale Fuel Prices:
  - www.nymex.com
  - http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp

Appendix C: Update to Electricity and Transportation Wedge Analysis (September 2008)

Hawaii Clean Energy Initiative

Update to Electricity and Transportation Wedge Analysis

Scenarios to illuminate policy needs and inform technical working groups

Honolulu, HI
Sept 30, 2008

Contents

Based on comments during the June 2008 Working Group meetings, Booz Allen updated the electricity, transportation, and cost models

- Electricity changes:
  - Biofuels: For the purposes of this analysis, which does not include imports, biofuels are a limited resource. Therefore for this analysis, all biofuels are used in the transportation sector because fuels provide the only pathway to approach 70% clean energy in the transportation sector even with very aggressive plug-in hybrid electric vehicle projections
  - Geothermal: Maintain assumptions (60 MW Hawaii; 42 MW Maui)
  - Efficiency: Maintain assumption of slow ramping up of efficiency because of the capital and skilled labor needed to complete each transaction
  - Oil usage baseline adjusted to match Hawaii-specific heat rates

Changes to transportation model. . .

- Transportation changes
  - Baseline: Revise the baseline to be consistent with the April 2008 version of the section 355 report
  - BTU content: Change the energy equivalency of ethanol to gasoline based on Hawaii-specific BTU content figures for gasoline
  - Biodiesel/ethanol mix: Assume a mix of ethanol and biodiesel in the scenario (goal is to use information from the Biofuels Assessment Phase II due out July 2008)
  - Plug-in hybrid electric vehicles: Refine assumptions and deploy PHEVs starting in 2012 instead of 2008

Changes to cost model. . .

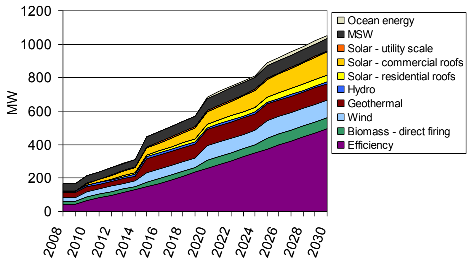
- Cost changes
  - Revise costs to be Hawaii-specific, based on survey input from Hawaii Working Group members
  - Grid integration: Use refined cost estimate from NREL
  - Timescale: All costs will be assumed to remain constant from 2008-2030
  - Use Crystal Ball Software to put likely ranges around uncertain costs and assumptions

Contents

Scenario 7 Electricity - high efficiency, high PHEV penetration with biofuels in electric generation, and no cable

PREVIOUS GENERATION RESULTS

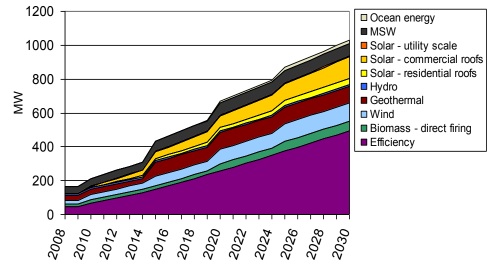
State of Hawaii electricity generation
(Delivered capacity)



Summary of 2030 Electricity Results	
Clean energy achieved	*57%*
Oil reduction (million bbl/yr)	*14.0*
CO2 avoided (million ton/yr)	*7.2*

NEW GENERATION RESULTS

State of Hawaii electricity generation
(Delivered capacity)

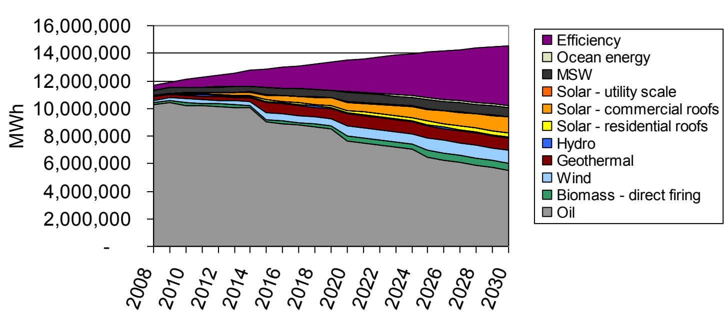


Summary of 2030 Electricity Results	
Clean energy achieved	*55%*
Oil reduction (million bbl/yr)	*15.7*
CO2 avoided (million ton/yr)	*8.0*

Booz | Allen | Hamilton

Under Scenario 7, Hawaii would reach 55% clean energy in the electricity sector and reduce oil imports by 16 MM bbl/year by 2030

State of Hawaii electricity generation
(Delivered capacity)



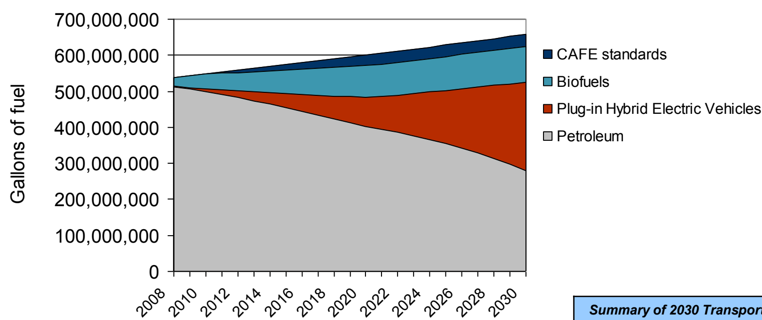
Booz | Allen | Hamilton

Scenario 7 Transportation - high PHEV penetration, local biodiesel and ethanol production

PREVIOUS TRANSPORT RESULTS

State of Hawaii Transportation

(chart displays gallons of petroleum fuel avoided by each measure)



Summary of 2030 Transportation Results	
Clean energy achieved	*57%*
Oil reduction (million bbl/yr)	*9.0*
CO2 avoided (million ton/yr)	*3.8*

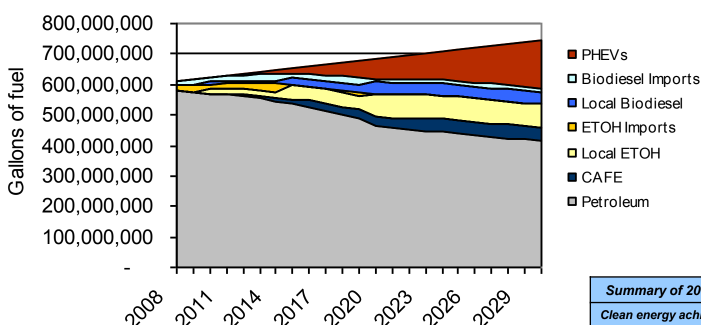
Booz | Allen | Hamilton

Scenario 7 Transportation - high PHEV penetration, local biodiesel and ethanol production

NEW TRANSPORT RESULTS

State of Hawaii Transportation

(chart displays gallons of petroleum fuel avoided by each measure)

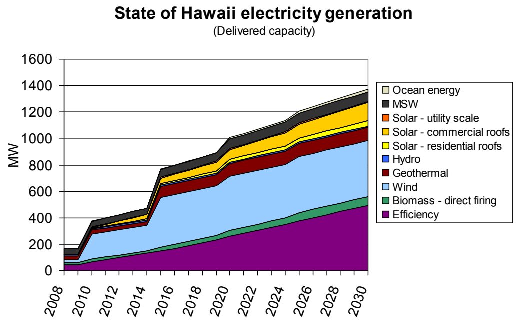


Summary of 2030 Transportation Results	
Clean energy achieved	*45%*
Oil reduction (million bbl/yr)	*7.9*
CO2 avoided (million ton/yr)	*2.7*

Booz | Allen | Hamilton

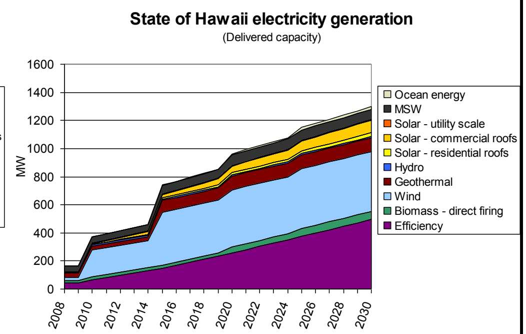
Scenario 8 Electricity - high efficiency, high PHEV penetration, and a cable to Oahu from Lanai and Molokai

PREVIOUS GENERATION RESULTS



Summary of 2030 Electricity Results	
Clean energy achieved	*70%*
Oil reduction (million bbl/yr)	*17.3*
CO2 avoided (million ton/yr)	*8.8*

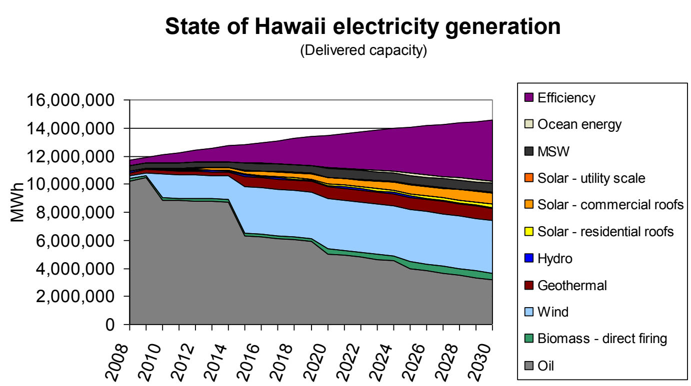
NEW GENERATION RESULTS



Summary of 2030 Electricity Results	
Clean energy achieved	*70%*
Oil reduction (million bbl/yr)	*19.9*
CO2 avoided (million ton/yr)	*10.1*

Booz | Allen | Hamilton

Under Scenario 8, Hawaii would reach 70% clean energy in the electricity sector and reduce oil imports by 20 MM bbl/year by 2030



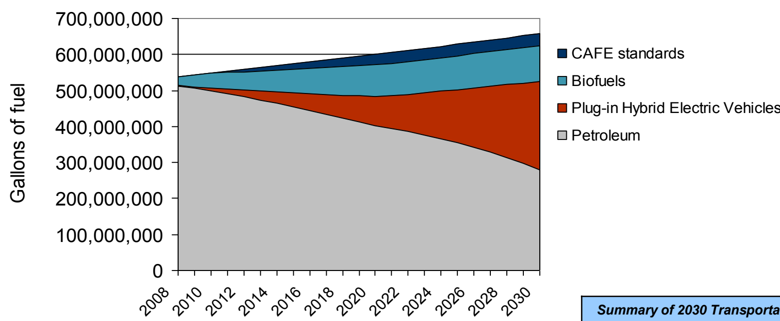
Booz | Allen | Hamilton

Scenario 8 Transportation - high PHEV penetration, local biodiesel and ethanol production (same as Scenario 7)

PREVIOUS TRANSPORT RESULTS

State of Hawaii Transportation

(chart displays gallons of petroleum fuel avoided by each measure)



Summary of 2030 Transportation Results	
Clean energy achieved	*57%*
Oil reduction (million bbl/yr)	*9.0*
CO2 avoided (million ton/yr)	*3.8*

12

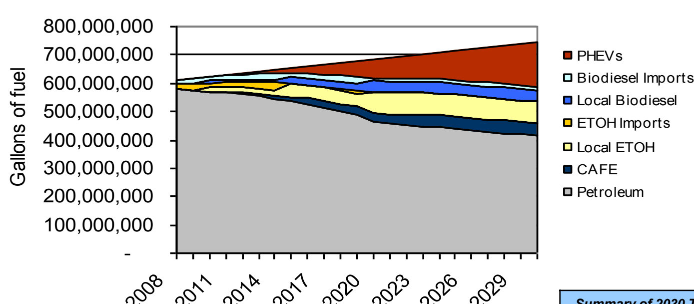
Booz | Allen | Hamilton

Scenario 8 Transportation - high PHEV penetration, local biodiesel and ethanol production (same as Scenario 7)

NEW TRANSPORT RESULTS

State of Hawaii Transportation

(chart displays gallons of petroleum fuel avoided by each measure)



Summary of 2030 Transportation Results	
Clean energy achieved	*45%*
Oil reduction (million bbl/yr)	*7.9*
CO2 avoided (million ton/yr)	*2.7*

13

Booz | Allen | Hamilton

Contents

Booz | Allen | Hamilton

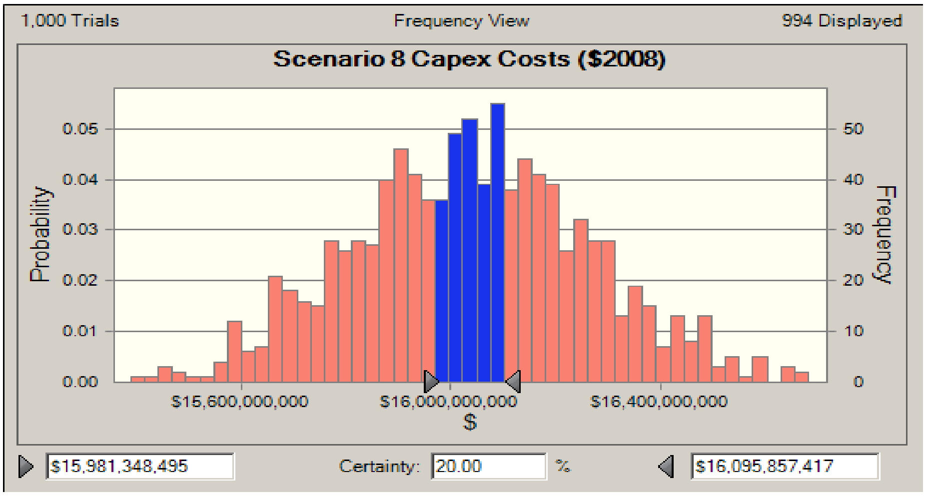
To address uncertainty, the updated cost inputs for Scenarios 7 and 8 are expressed in ranges

Renewable Type:	LCOE ($/MWh)		
	June Model Assumptions	Source	August Model Assumptions after Stakeholder Input*
Solid Biomass	$108.50	http://www.energy.ca.gov/2008publications/RETI-1000-2008-002/RETI-1000-2008-002-F.PDF	Range: $67-150, $108.50 = most likely
Wind	$93.50		Range: $69-156, $113 = most likely
Geothermal	$80.50		Range: $67-86, $77 = most likely
Small Hydro	$96.50		Range: $57-137, $96.50 = most likely
Solar - residential roofs	$298.13		Range: 200-345, most likely = $272.50
Solar PV (Lg Roof/Utility Scale)	$238.50		Range: $190-276, most likely = $228.50
MSW/Landfill Gas	$65		Range: $50-80, most likely = $65
Ocean Energy (Wave)	$290		Range: $135-445, $290 = most likely
Energy Efficiency	$50 (low scenario), $75 (high scenario)	http://www.fypower.org/pdf/CEC%20_Trends2000-04.pdf	Range: $50-100, most likely = $75

****See appendix for detailed cost sources from HI Stakeholders***

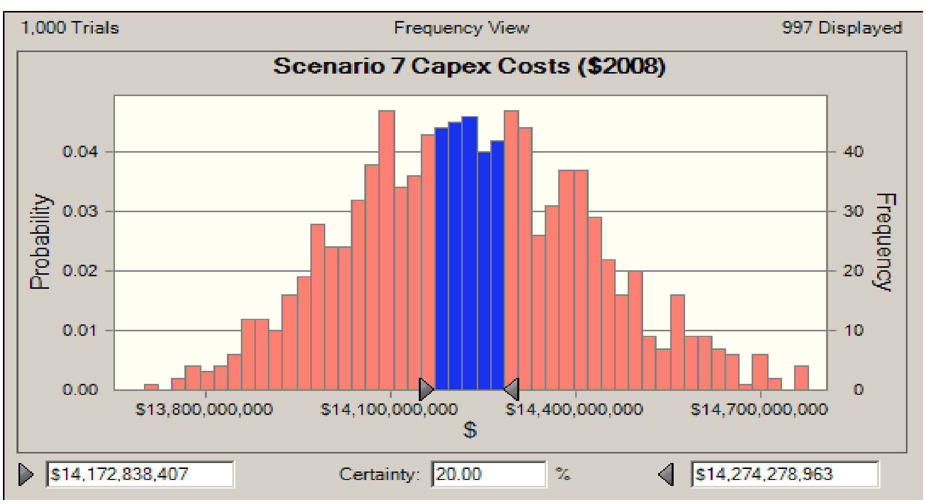
Booz | Allen | Hamilton

Scenario 8—Total investment cost is approximately $16 billion (lower than $18 billion reported in June)



Booz | Allen | Hamilton

Scenario 7—Total investment cost is approximately $14 billion

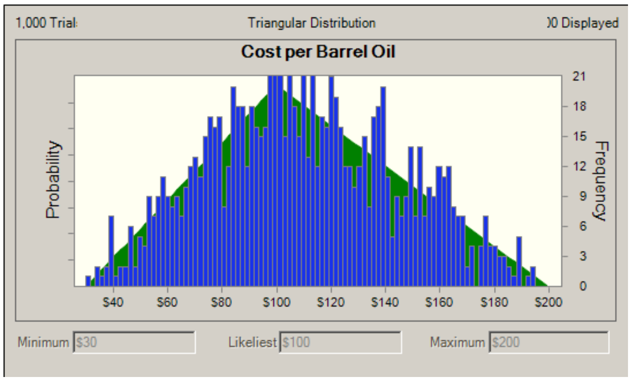


Neither in inter-island cable nor grid upgrades are included

Booz | Allen | Hamilton

To generate the Net Present Value of the overall HCEI investment & savings, cost ranges were considered

General Assumptions:	Min	Most likely	Max
Cost per barrel Oil	$ 30	$100	$200
Real Discount Rate	5%	7%	9%



Booz | Allen | Hamilton

Cost input ranges - Generation

Levelized Cost of Electricity (per Technology):	Min	Most Likely	Max
Biomass - direct firing ($/MWh)	$ 67	$ 109	$ 150
Wind - ($/MWh)	$ 69	$ 113	$ 156
Geothermal ($/MWh)	$ 67	$ 77	$ 86
Hydro ($/MWh)	$ 57	$ 97	$ 136
Solar - residential roofs ($/MWh)	$ 200	$ 273	$ 345
Solar - commercial roofs ($/MWh)	$ 190	$ 233	$ 276
Solar - utility scale ($/MWh)	$ 190	$ 233	$ 276
MSW - ($/MWh)	$ 50	$ 65	$ 80
Ocean energy - ($/MWh)	$ 135	$ 290	$ 445

Capital Expenditures (per Technology):			
Biomass - direct firing ($/MW)	$ 2,000,000	$ 4,000,000	$ 6,000,000
Wind - ($/MW)	$ 2,400,000	$ 2,600,000	$ 2,800,000
Geothermal ($/MW)	$ 3,000,000	$ 4,000,000	$ 5,000,000
Hydro ($/MW)	$ 2,500,000	$ 3,250,000	$ 4,000,000
Solar - residential roofs ($/MW)	$ 8,125,000	$ 8,750,000	$ 9,375,000
Solar - commercial roofs ($/MW)	$ 6,500,000	$ 7,000,000	$ 7,500,000
Solar - utility scale ($/MW)	$ 6,500,000	$ 7,000,000	$ 7,500,000
MSW - ($/MW)	$ 2,100,000	$ 2,800,000	$ 3,500,000
Ocean energy - ($/MW)	$ 2,000,000	$ 6,000,000	$ 7,600,000

Energy Efficiency Costs:				
End Use Efficiency (High Scen):	$ 70	$75	$100	$/MWh

Grid

Note: Grid upgrades not implemented until 20% Clean Energy is reached

Grid LCOE %:	41%	45%	50%	% of levelized cost of intermittent generation tech
Grid LCOE:		$ 32		per MWh Intermittance

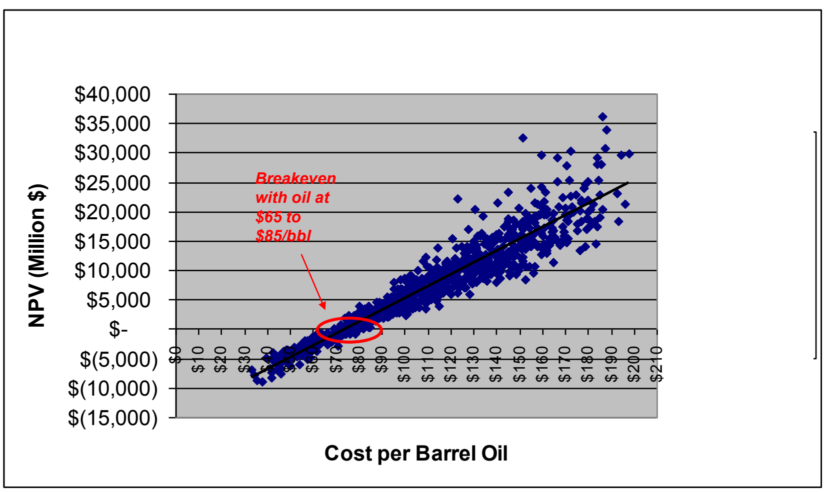
Booz | Allen | Hamilton

Cost input ranges – transportation & shallow water cable

Transport Costs:	Min	Most Likely	Max	
Sugar Cane Ethanol Production LC:	$ 2.00	$2.40	$ 3.00	per gallon
Cellulosic Ethanol Production LC:	$ 0.90	$1.10	$ 1.50	per gallon
Biodiesel Production Cost:	$ 3.00	$3.60	$ 4.20	per gallon
Biorefinery Capex	$ 4.00	$5.00	$ 7.00	per gallon nameplate
Cost per Gallon ETOH	$ 2.97	$3.30	$ 3.63	
Cost per Gallon Biodiesel	$ 4.00	$6	$ 8.00	
Cable Costs				
Shallow Water Cable CapexCosts:	$ 480,000,000	$600,000,000	$720,000,000	

Booz | Allen | Hamilton

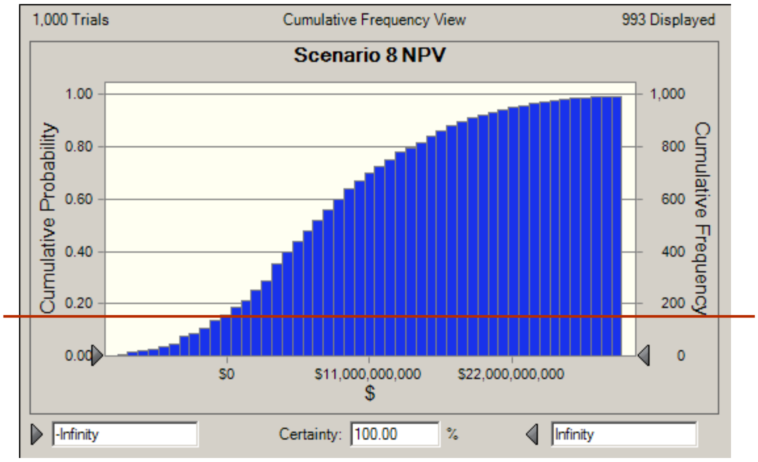
Scenario 8 – NPV outcomes based on Monte Carlo simulation of levelized costs and savings



Simulation based on 1,000 runs

Booz | Allen | Hamilton

Scenario 8—The chance of a negative NPV is less than 20%

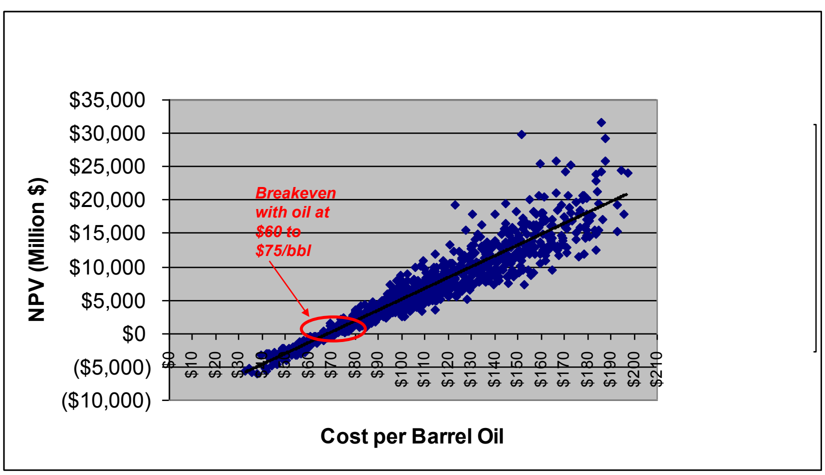


- *Approx. 18% probability of a negative NPV result*

Simulation based on 1,000 runs

Booz | Allen | Hamilton

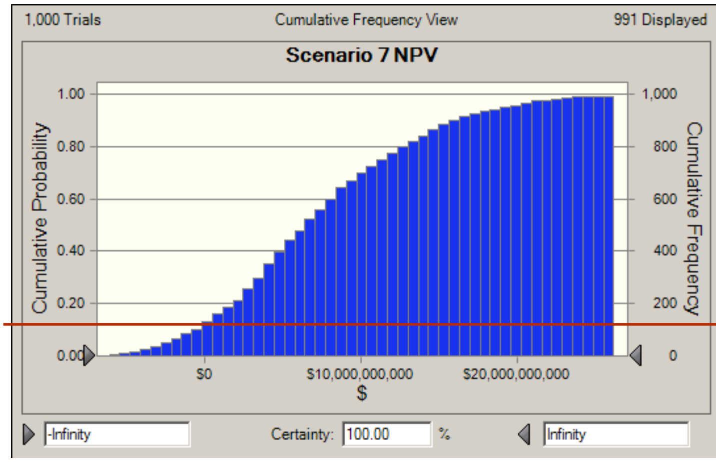
Scenario 7 – NPV outcomes based on Monte Carlo simulation of levelized costs and savings



Simulation based on 1,000 runs

Booz | Allen | Hamilton

Scenario 7— The chance of a negative NPV is less than 20%



- ***Approx. 16% probability of a negative NPV result***

Simulation based on 1,000 runs

Booz | Allen | Hamilton

Contents

Booz | Allen | Hamilton

Notes on the analysis – electric generation

- Energy demand **baselines** are all taken from utility Integrated Resource Plans (IRPs). Business as usual demand for electricity in 2030 is predicted to grow from the current level of 988 MW to 1,164 MW statewide (This does not include reserve capacity).
- Projected plug-in hybrid electric vehicle (**PHEV**) electricity needs are added onto these numbers
  - In the "Low PHEV" scenarios, PHEVs are 15% of new car sales in 2030 (Argonne/EPRI) and require 62 MW of additional generation capacity
  - In the "High PHEV" scenarios, PHEVs are 69% of new car sales (PNNL) and require 314 MW of additional generation capacity
  - NOTE: In updated scenarios 7 & 8, PHEVs still reach 69% of new car sales by 2030, however, they now deploy later and ramp up later, thus, only 202 MW of additional generation capacity is needed (total cars on the road are fewer)
- Resources were loaded onto each island's system in the following dispatch order, which reflects the <u>cost</u> ranking – least expensive to most expensive – of each resource according to the California Energy Commission, 2007 (the MSW cost figure comes from the Black & Veatch Renewable Energy Transmission Initiative 2008 report)

Renewable energy cost ranking	
1	Geothermal
3	Wind
4	Biomass
5	Small Hydro
6	Utility scale solar
7	Solar PV
8	Ocean

2: MSW

- Maui geothermal is capped at 30% of its 140 MW capacity (42 MW) as identified in the GeothermEx 2005 and EPACT 355 Reports; the geothermal is used to meet Maui's demand and is not cabled to Oahu
- Maui has 30% of its 10 MW ocean energy potential (30 MW) deployed in all scenarios because of the planned project
- 50 MW potential is used for Oahu's ocean energy
- MSW is dispatched to 75% of its potential on all islands. Landfill gas is counted together with MSW
- Development of utility scale solar (concentrated solar power) on Kauai is capped at to 5% of the 285 MW potential identified in the EPACT 355 Report; this and CSP numbers for the other islands were developed in consultation with NREL and state and county energy officials
- Lanai and Molokai demand are not modeled
- The following **capacity factors**, from NREL and EERE, were used for each resource (for wind, 35% was used for Oahu, Hawaii, and Kauai resources, 40% was used for Molokai and Lanai, and 45% was used for Maui)

Capacity factors	
Biomass - direct firing	80%
Wind	35-45%
Geothermal	95.5%
Hydro	44.2%
Solar - residential roofs	22.5%
Solar - commercial roofs	22.5%
Solar - utility scale	24.4%
MSW	95%
Ocean energy	35%

Notes on the analysis – efficiency and transportation

- **Building efficiency** assumptions:
  - 55% of all existing housing stock will be retrofitted by 2030
  - 1% of building stock each year is demolished and replaced with new construction
  - Max efficiency potential for all residential buildings is 50% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for new commercial buildings is 53% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for existing commercial buildings is 42% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for all new/retrofitted buildings will be reached in the year 2015, and remain constant until 2030
  - Current efficiency potential is 36% for residential new construction, 34% for residential retrofits, 30% for commercial new construction, and 19% for commercial retrofits
- The transportation model assumes that 50% of the potential identified in the 2006 ethanol study by HNEI is actually available for **ethanol** and that 50% of the potential identified in the HARC biodiesel study is actually available for **biodiesel**; the rest of the land is assumed to be dedicated to food production or some other use
  - This would result in about 142,000 acres (135,340 total acres for either ethanol or biodiesel production in updated Scenarios) devoted to crops for ethanol under the max ethanol scenario (Scenarios 1,2,5 and 6) and 124,000 acres devoted to biodiesel under the max biodiesel scenario (Scenarios 3,4,7 and 8). It is assumed that there is a high degree of overlap between these two land areas
  - These acres are <u>either</u> in ethanol or biodiesel production. In scenarios 1,2,5, and 6, ethanol is produced to the exclusion of biodiesel. All ethanol is used only in the transportation sector. Biodiesel is imported to meet the RFS; this cost is included in the cost model
  - In scenarios 3, 4, and 7, biodiesel is produced to the exclusion of ethanol. In these scenarios, biodiesel beyond that required to meet the RFS is provided to the generation sector. Ethanol is imported to meet the RFS; the cost thereof is included in the cost model
  - In Scenario 8, biodiesel is produced to meet the RFS and ethanol is imported. The generation model shows that by the year 2030, only a small quantity of biodiesel (7 million gallons) will be required to achieve 70% clean energy in the electricity sector. This quantity of biodiesel is given to the generation sector and the remainder is used in the transportation sector
  - There are no scenarios under which both ethanol and biodiesel are produced in sufficient volumes to meet the RFS
  - NOTE: In new transportation scenarios, a blend of ethanol and biodiesel is assumed to be produced. Ratio of ethanol produced to biodiesel produced is determined based on the amount of ethanol needed to meet a renewable fuels standard over the full life of HCEI
- Also in new transportation scenarios:
  - Improved CAFE standards are assumed to result in a net reduction of transportation fuels of 43,782,138 gallons petrofuel by 2030
  - A Renewable Fuel Standard (RFS) ramping up to 20% of all liquid fuels used for transport by 2020 is assumed
  - If domestic production cannot meet the RFS, biofuels (both ethanol and biodiesel, where applicable) in the deficient amount are assumed to be imported in order to comply with the standard
  - PHEV usage is now assumed to start in 2012, although the 69% of new cars purchased in the year 2030 rate set by PNNL is still assumed to hold

Resource potential for all Hawaii islands – units are potential of installed capacity

	Source		Oahu	Kauai	Maui	Hawaii	Lanai	Molokai	Total
Biomass	355 Report /1	MW	7	20	8	20	no data	6	
	KIUC Renewable Energy Technology Assessment			20					
	Hawaii Energy Strategy 2000/2	MW	25	25	25	50			
	Value used for BAH model		25	25	25	50	0	0	**125**
Wind	355 Report	MW	At least 50	At least 40	At least 40	At least 10	no data	no data	
	Proposed projects/3	MW			97		400	400	
	Hawaii Energy Strategy 2000	MW	65			85			
	Value used for BAH model		65	40	97	85	400	400	**1087**
Geothermal	355 Report (from GeothermEx 2005)	MW	n/a	n/a	140	750	n/a	n/a	
	Value used for BAH model		0	0	140	750	0	0	**890**
Hydro	355 Report	MW	no data	no data	3	20	20	no data	
	KIUC RETA	MW		21					
	Hawaii Energy Strategy 2000	MW		7					
	Value used for BAH model		0	21	3	20	0	0	**44**
Solar - rooftop	Residential roof analysis /5	MW	416	35	80	94			
	Commercial roof analysis /6	MW	576	48	111	130			
	Value used for BAH model		992	83	191	224	0	0	**1490**
Solar - utility scale	NREL estimate	MW	8	8	8	8			
	355 Report			285					
	Value used for BAH model		8	14	8	8	0	0	**37**
MSW (incl. landfill gas)	Hawaii Energy Strategy 2000	MW		25					
	KIUC RETA / County energy staff	MW	57	8	8	10			
	Existing plant (H-POWER)	MW	46						
	Value used for BAH model		57	8	8	10	0	0	**83**
Ocean energy	Estimates / proposed projects		50		10				
	Value used for BAH model	MW	50		10				**60**
Total	*Value used for BAH model*	**MW**	**1196**	**192**	**481**	**1147**	**400**	**400**	**3816**

1. "Assessment of Dependence of State of Hawaii on Oil" for EPACT Section 355, DOE, 2007.

2. Hawaii Energy Strategy 2000. Prepared by DBEDT

3. Lanai: DBEDT website--Castle and Cooke is investigating a 300 MW wind farm on Lanai; Molokai: Hawaii Star Bulletin, "Wind Power Firm Vows $50M for Molokai Bid."

Maui: DBEDT wesbite: http://hawaii.gov/dbedt/info/energy/renewable/wind

5. NREL estimates 2.5 kW per house, assume that half of Hawaii's 500,036 houses (as of 2006 census) are suitable for PV on the roof

6. In 2003, Hawaii had approx. 173 mil sq feet of commercial buildings, according to HECO (http://hawaii.gov/dbedt/ert/rebuild/minutes/May03Presentations/Benchmarking.pdf), 100 sq ft per kW (which is the figure for the 309 kW, 31,000 sq ft Ford Island array), assume that commercial buildings are proportional to residential buildings on each island to get island by island estimate, then assume that half of Hawaii's commercial buildings are suitable for solar

Note: Proposed projects, existing plants, KIUC RETA, HES 2000, and county energy staff estimates are used if they are greater than those listed in 355 Report

Resource Potential Sources

- Utility IRPs (HECO, MECO, HELCO, KIUC)
- NREL, EIA, Pacific Northwest National Lab, Argonne National Lab, EPRI
- California Energy Commission and California Solar Resources Report
- Black & Veatch Renewable Energy Transmission Initiative
- 355 Report: Assessment of Dependence of State of Hawaii on Oil
- KIUC Renewable Energy Technology Assessment
- Catalog of Potential Sites for Renewable Energy in Hawaii
- HARC Biodiesel Crop Implementation for Hawaii
- HNEI Potential for Ethanol Production in Hawaii
- Hawaii Energy Strategy 2000
- Hawaii Databook

Cost Sources

- Levelized Renewable Energy Cost Estimates and Capex Estimates
  - Source: http://www.energy.ca.gov/2008publications/RETI-1000-2008-002/RETI-1000-2008-002-F.PDF
- Ethanol Estimates
  - Price per gallon ETOH: http://ethanolmarket.aghost.net
  - Gallons Gas per Barrel Oil: www.gravmag.com/oil.html
  - Gallons Fuel Oil per Barrel Oil: www.gravmag.com/oil.html
- BTU content of fuels: http://www.nafa.org/Content/NavigationMenu/Resource_Center/Alternative_Fuels/Energy_Equivalents/Energy_Equivalents.htm
- Sugarcane ETOH Production Cost: http://www.rurdev.usda.gov/rbs/pub/sep06/ethanol.htm
- Biodiesel Estimates: http://www.biodiesel.org/buyingbiodiesel/retailfuelingsites/showstate.asp?st=VA
  - Cost of Biodiesel Capex: Capital Cost estimated from "Biodiesel Production Cost" worksheet from Jacobsen
  - Cost of Biodiesel Feedstock: http://www.cbot.com/cbot/pub/page/0,3181,959,00.html
- Energy Efficiency Cost Estimate ($/kWh): http://www.fypower.org/pdf/CEC%20_Trends2000-04.pdf
- Wholesale Fuel Prices: www.nymex.com, http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp
- PHEV Estimates
  - Price per Plug: Project Betterplace
  - Premium per car (today): Oak Ridge National Laboratory
  - Premium per car (2030): Oak Ridge National Laboratory
- Note: Hawaii Specific costs generated from cost survey process of relevant stakeholders (see following two slides for details)

Booz | Allen | Hamilton

Hawaii Stakeholder Cost Data Points

Renewable Type:	LCOE ($/MWh)					
	Cost 2	Source	Cost 3	Source	Cost 4	Source
Solid Biomass	Biomass Cofiring: $3-37. Biomass Direct: $50-94	Blunden SunPower Presentation, 07/08				
Wind	$44-91	Blunden SunPower Presentation, 07/08	$50-75	Financing of Renewable Energy – Lessons Learned, Milbank, Tweed, Hadley & McCloy LLP		
Geothermal	$67-86	Sentech/USDOE, 2006	$67-75	Robbie Alm, PGV	$42-69	Blunden SunPower Presentation, 07/08

Booz | Allen | Hamilton

Hawaii Stakeholder Cost Data Points (Cont'd)

Renewable Type:	LCOE ($/MWh) Cost 2	Source	Cost 3	Source	Cost 4	Source
Solar - residential roofs	$200-300	DBEDT, Photovoltaic Electricity in Hawaii, Jan, 06	PV Crystalline: $109-154, PV Thin Film: $79-124	Blunden SunPower Presentation, 07/08		
Solar PV (Lg Roof/Utility Scale)	$190.0	Ward Station PV		Blunden SunPower Presentation, 07/08	$220	Financing of Renewable Energy – Lessons Learned, Milbank, Tweed, Hadley & McCloy LLP
MSW/Landfill Gas	$50-81	Blunden SunPower Presentation, 07/08				
Ocean Energy (Wave)	$50-150	Ocean Power Technologies*	$100-140	Andy Walker, NREL	$250-400	Financing of Renewable Energy – Lessons Learned, Milbank, Tweed, Hadley & McCloy LLP

Booz | Allen | Hamilton

Appendix D: Example Run of Generation Model, Maui, Scenario 8 (September 2008)

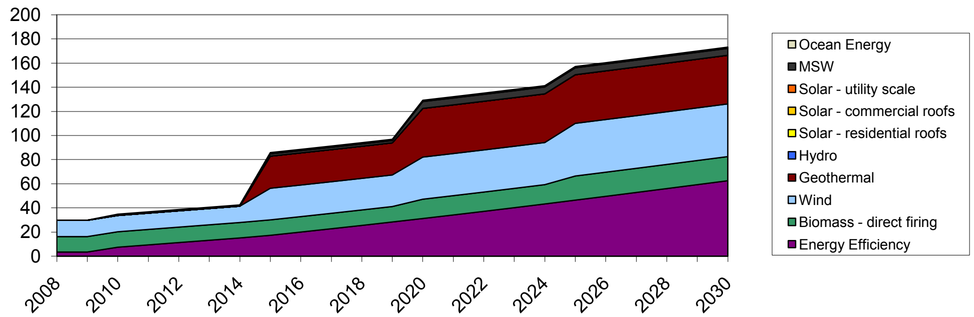
MAUI ELECTRIC GENERATION

Scenario:	HCEI High Efficiency High PHEV Penetration	Clean energy % for Maui: 70%

Energy Source	Data Source	Resource Potential (MW)	Annual MWh	Current installed capacity (MW)	Loading % for each resource 2010 to 2015	2015 to 2020	2020 to 2025	2025 to 2030	
Energy Efficiency		**63**	547,694	n/a	HCEI High Efficiency				
Biomass - direct firing	355 Report	8							
	HES 2000	25							
	BAH Input	**25**	175,200	16	64%	64%	80%	100%	
Wind	355 Report	40							
	Proposed projec	90							
	BAH Input	**97**	382,374	30	31%	60%	80%	100%	
Geothermal	355 Report	140							Note:
	BAH Input	**140**	1,165,080	0	0%	20%	30%	30%	Capped at 30%
Hydro	355 Report	3							
	BAH Input	**3**	11,616	0	0%	0%	0%	0%	
Solar (residential roofs)*	BAH Input	**32**	62,700	0	2030 target -->			0%	
Solar (commercial roofs)*	BAH Input	**110**	217,005	0	2030 target -->			0%	
Solar (utility scale)	BAH Input	**7.5**	16030.8	0	0%	0%	0%	0%	
MSW	BAH Input	**8**	66576	0	0%	25%	75%	75%	
Ocean energy	BAH Input	**10**	30660	0	30%	30%	30%	30%	
Total		485	2,644,276	46					

*For the purposes of this analysis, installed capacity is considered zero, even though there is currently some solar installed

MAUI ELECTRICITY SYSTEM (Delivered capacity)
HCEI High Efficiency High PHEV Penetration



CLEAN ENERGY INSTALLED CAPACITY : NOT ADJUSTED FOR CAPACITY FACTORS

Energy Source	Resource potential	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	63	3	3	7	9	11	13	15	17	20	23	25	28	31	34	37	40	43	46	50	53	56	59	63
Biomass - direct firing	25	16	16	16	16	16	16	16	16	16	16	16	16	20	20	20	20	20	25	25	25	25	25	25
Wind (installed capacity)	97	30	30	30	30	30	30	30	58	58	58	58	58	78	78	78	78	78	97	97	97	97	97	97
Geothermal	140	0	0	0	0	0	0	0	28	28	28	28	28	42	42	42	42	42	42	42	42	42	42	42
Hydro	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar - residential roofs (installed capacity)	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar - commercial roofs (installed capacity)	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar - utility scale (installed capacity)	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MSW (installed capacity)	8	0	0	0	0	0	0	0	2	2	2	2	2	6	6	6	6	6	6	6	6	6	6	6
Ocean energy (installed capacity)	10	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total Clean Energy (installed capacity)		49	50	56	58	60	62	64	124	127	130	133	136	180	183	186	189	192	219	223	226	229	232	236
Total dispatchable generation (installed capacity)		16	16	16	16	16	16	16	46	46	46	46	46	68	68	68	68	68	73	73	73	73	73	73
Total non-dispatchable generation (installed capacity)		30	30	30	30	30	30	30	58	58	58	58	58	78	78	78	78	78	97	97	97	97	97	97
Total energy efficiency		3	3	7	9	11	13	15	17	20	23	25	28	31	34	37	40	43	46	50	53	56	59	63

VALUES FOR THE CHART : CLEAN ENERGY ADJUSTED FOR CAPACITY FACTORS

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	3	3	7	9	11	13	15	17	20	23	25	28	31	34	37	40	43	46	50	53	56	59	63
Biomass - direct firing	13	13	13	13	13	13	13	13	13	13	13	13	16	16	16	16	16	20	20	20	20	20	20
Wind	14	14	14	14	14	14	14	26	26	26	26	26	35	35	35	35	35	44	44	44	44	44	44
Geothermal	0	0	0	0	0	0	0	27	27	27	27	27	40	40	40	40	40	40	40	40	40	40	40
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar - residential roofs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar - commercial roofs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar - utility scale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MSW	0	0	0	0	0	0	0	2	2	2	2	2	6	6	6	6	6	6	6	6	6	6	6
Ocean Energy	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total Clean Energy adjusted for capacity factors	30	30	35	37	39	41	42	86	89	91	94	97	129	132	135	138	141	157	160	164	167	170	173

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Island baseline	149	155	161	164	168	172	175	179	182	185	189	192	195	199	203	206	210	214	215	217	218	220	221
High PHEV	0	0	0	0	0	1	1	2	3	4	5	7	9	10	12	14	15	17	19	21	23	24	26
Total Demand (Baseline + PHEV)	149	155	161	164	168	173	176	181	185	189	194	199	204	209	215	220	225	231	234	238	241	244	247
Total Clean Energy adjusted for capacity factors	30	30	35	37	39	41	42	86	89	91	94	97	129	132	135	138	141	157	160	164	167	170	173
Clean energy as % of total	**20%**	**19%**	**22%**	**22%**	**23%**	**24%**	**24%**	**47%**	**48%**	**48%**	**48%**	**49%**	**63%**	**63%**	**63%**	**63%**	**63%**	**68%**	**69%**	**69%**	**69%**	**70%**	**70%**

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Remaining unmet electricity need to get to 70%	75	79	78	78	79	80	81	41	41	41	42	42	13	14	15	16	16	5	3	3	2	1	0
Biodiesel required to meet remaining energy needs (MGY	50	52	52	52	53	53	54	27	27	27	28	28	9	10	10	10	11	3	2	2	1	1	0

MWh Demand	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	30,000	30,000	65,000	81,800	98,600	115,400	132,200	151,394	174,928	198,886	223,267	248,071	273,299	299,006	325,193	351,860	379,007	406,634	434,456	462,473	490,685	519,092	547,694
Biomass - direct firing	112,128	112,128	112,128	112,128	112,128	112,128	112,128	112,128	112,128	112,128	112,128	112,128	140,160	140,160	140,160	140,160	140,160	175,200	175,200	175,200	175,200	175,200	175,200
Wind	118,260	118,260	118,536	118,536	118,536	118,536	118,536	229,424	229,424	229,424	229,424	229,424	305,899	305,899	305,899	305,899	305,899	382,374	382,374	382,374	382,374	382,374	382,374
Geothermal	-	-	-	-	-	-	-	233,016	233,016	233,016	233,016	233,016	353,203	353,203	353,203	353,203	353,203	353,203	353,203	353,203	353,203	353,203	353,203
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solar - residential roofs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solar - commercial roofs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solar - utility scale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MSW	-	-	-	-	-	-	-	16,644	16,644	16,644	16,644	16,644	49,932	49,932	49,932	49,932	49,932	49,932	49,932	49,932	49,932	49,932	49,932
Ocean energy	-	920	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198	9,198
Total	260,388	261,308	304,862	321,662	338,462	355,262	372,062	751,804	775,338	799,296	823,677	848,481	#######	1,157,398	#######	1,210,252	1,237,399	1,376,541	1,404,363	1,432,380	1,460,592	1,488,999	1,517,602

Appendix E: Bioenergy Supply, Demand, Cost, and Risk Analysis (April 2009)

Hawaii Clean Energy Initiative

Bioenergy Supply, Demand, Cost and Risk Analysis

Honolulu, HI
April 13, 2009

Booz Allen Hamilton is assessing the portfolio of clean energy for Hawaii and is advising on policy actions needed to drive results

Legislative Package Scope

For Congressional Year 2009:

A. End-use efficiency

B. Electricity Generation and Delivery

C. Transportation

For Congressional Year 2010:

D. Biofuels

E. Carbon

Booz Allen Activity Scope

Task 1: Integrated framework of biofuels activities (reports, projects and plans) - information sorted by supply chain component and gaps identified

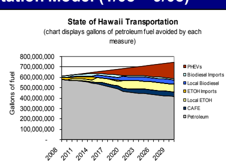
Task 2: Analysis of the biofuels supply chain supply, demand and cost, identification of key scenarios

- Electricity and transportation demand trade-offs
- Comparison with business as usual

Task 3: Decision support for HCEI biofuels policy options

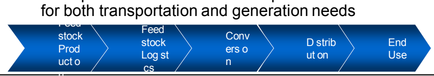
Overall BAH HCEI Transportation Model (1/08 9/08)

- State scale analysis
- Models driven by HCEI goals
  - Example: all biodiesel production allotted to transportation because electricity generation already at 70% CE



Bioenergy Supply Chain Analysis (9/08 1/09)

- Island scale analysis
- In depth analysis of supply/demand across the supply chain
  - Example: assessment of land to produce a mix of biofuels for both transportation and generation needs



Booz Allen's analysis seeks to answer these key questions

- Demand:
  - What are potential demand scenarios for biofuels in Hawaii by 2030?
- Supply:
  - How much biofuel is Hawaii likely to produce by 2030?
  - How does this supply compare with the demand scenarios?
  - What are Hawaii's levers to increase supply?
- Costs and Risks:
  - What costs and risks are associated with biofuels for Hawaii?

To understand the range of Hawaii's bioenergy needs in the context of HCEI 2030 clean energy goals, two demand scenarios were analyzed

New Scenario 9

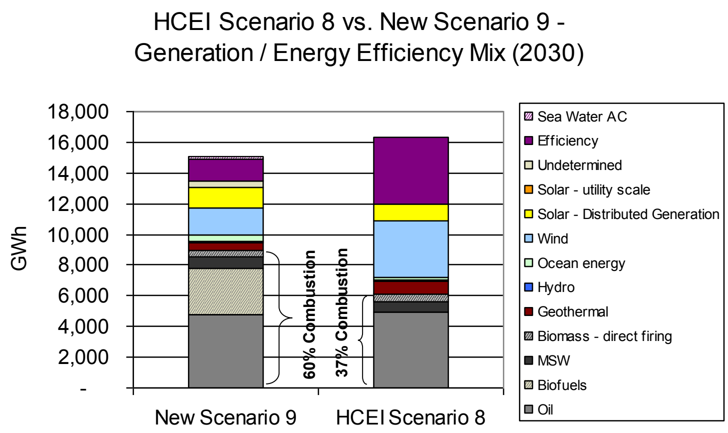
- Focused on attaining a 70% clean energy goal for generation through:
  - High levels of renewable combustion technologies (Biofuels, MSW, Biomass)
  - Firm renewable energy generation technologies (Geothermal, Hydropower, Ocean);
  - Moderate levels of intermittent renewable energy generation technologies (Wind, Solar); and
  - Low levels of energy efficiency
- Reaches 70% clean energy for transportation through:
  - Improved CAFE standards;
  - Lower Plug in Hybrid Electric Vehicles (PHEVs); and
  - Higher Biofuel usage

HCEI Scenario 8

- Focused on attaining a 70% clean energy goal for generation through:
  - High levels of intermittent renewable energy generation technologies (Wind, Solar);
  - Firm renewable energy generation technologies (Geothermal, Hydropower, Ocean);
  - Renewable combustion technologies (MSW, Biomass); and
  - High levels of energy efficiency
- Reaches 70% clean energy for transportation through:
  - Improved CAFE standards;
  - Higher Plug in Hybrid Electric Vehicles (PHEVs); and
  - Lower Biofuel usage

Booz | Allen | Hamilton

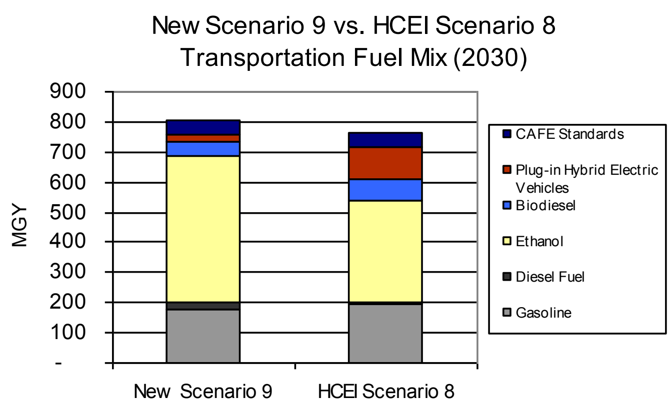
The two scenarios reach 70% clean energy for electricity via different pathways; the primary difference is combustion fuels vs. wind & efficiency



Note: The difference in magnitude of total generation is due to different assumptions for PHEV/ electric vehicle deployment and resulting electricity demand

Booz | Allen | Hamilton

The two scenarios also each reach 70% clean energy for transportation; the primary difference is the number of PHEVs



Note: the difference in magnitude between the two scenarios in terms of overall gallons used is due to heat content adjustments between gasoline and ethanol. The scenario with the slightly higher ethanol use (New Scenario 9), will use a relatively higher number of gallons of fuel to generate the same amount of energy

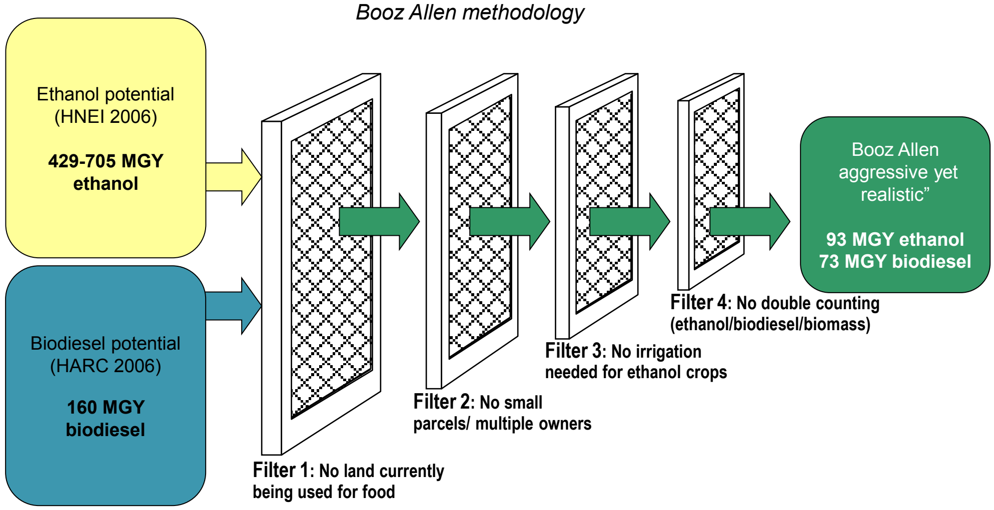
Booz | Allen | Hamilton

Booz Allen’s analysis seeks to answer these key questions

- Demand:
  - What are potential demand scenarios for biofuels in Hawaii by 2030?
- Supply:
  - How much biofuel is Hawaii likely to produce by 2030?
  - How does this supply compare with the demand scenarios?
  - What are Hawaii’s levers to increase supply?
- Costs and Risks:
  - What costs and risks are associated with biofuels for Hawaii?

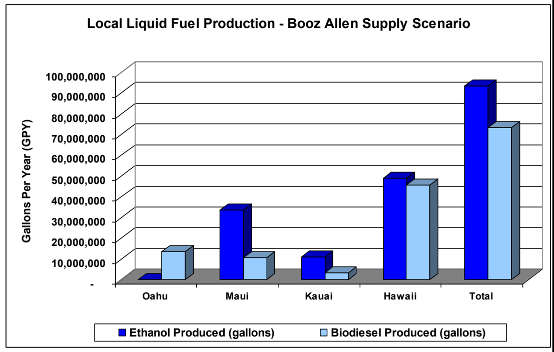
Booz Allen applied a series of filters to publicly available data sources to create a bioenergy production scenario

Booz Allen methodology



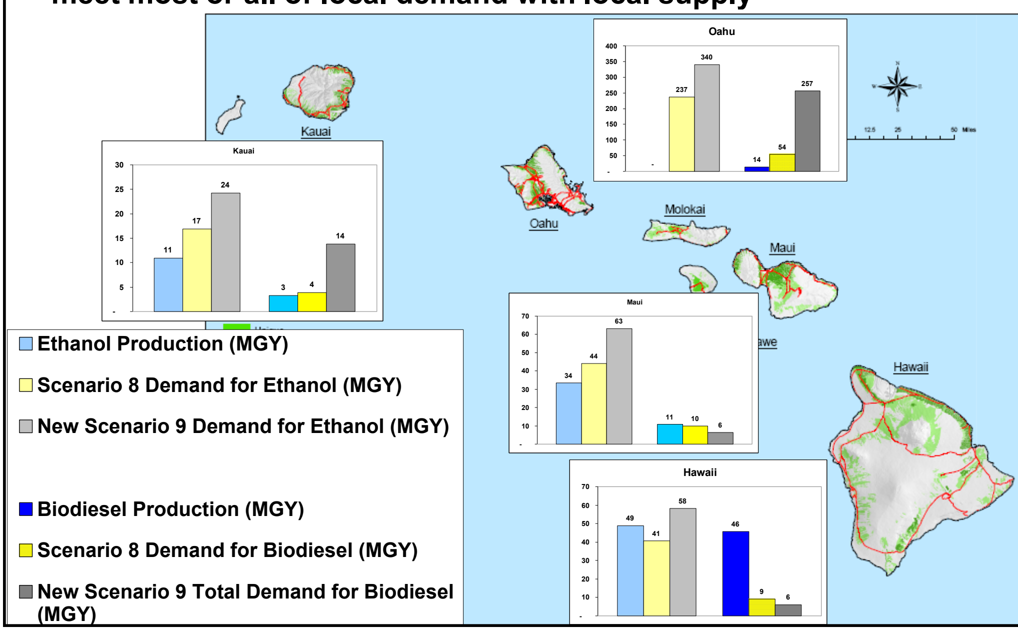
Booz Allen's "aggressive yet realistic" bioenergy production scenario evaluated opportunities island-by-island

- **BAH's production scenario focused on liquid fuels but also took biomass into account**
  - 93 million gallons per year of ethanol from 77,000 acres (65 million gallons of gasoline equivalent)
  - 73 million gallons per year of biodiesel from 106,000 acres (including 2.5 million gallons per year from waste oil)
  - 420 million kiloWatt-hours of biomass electricity from 23,000 acres
- **This production scenario would require 12% (206,000 acres) of Hawaii's agricultural land**
  - Ethanol feedstocks would be grown on on Maui, Kauai and Hawaii
  - Biodiesel feedstocks would be grown on Oahu, Maui, Kauai and Hawaii
  - Biomass feedstocks would be grown on Hawaii, Maui and Kauai



Booz | Allen | Hamilton

Evaluating island-by-island: Hawaii, Kauai and Maui would be able to meet most or all of local demand with local supply



If each island were to refine its own local feedstock, the scale of the biorefineries would be comparable to existing facilities worldwide

Hawaii ethanol plants required		Existing ethanol plants – for comparison
Oahu	None	
Hawaii	50 MGY cellulosic ethanol plant	No commercial-scale cellulosic ethanol plants are currently in operation, but the NREL design report for thermochemical and biochemical cellulosic processes assume plant sizes of around 60 MGY production capacity [1, 2]
Maui	35 MGY fermentation plant	In the U.S. the average capacity of the 172 existing ethanol plants is 62 MGY and the average capacity of the 23 under construction is 77 MGY [3] In Brazil the average output of an ethanol distillery is approximately 53 MGY [4]
Kauai	10 MGY fermentation plant	

Hawaii biodiesel plants required		Existing biodiesel plants for comparison
Oahu	15 MGY biorefinery	In the U.S. the average capacity of existing biodiesel plants is 9.5 MGY; newer plants average 19 MGY [5]
Hawaii	50 MGY biorefining capacity (potentially 2 or 3 refineries)	
Maui	10 MGY biorefinery	
Kauai	5 MGY biorefinery (alternatively the feedstock could be sent to another island for refining)	

1: NREL Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover. June 2002
2: NREL Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass. April 2007
3: Data from the Renewable Fuels Association- these plants are predominantly using corn as a feedstock
4: Data from "The Brazilian Biofuels Industry", *Biotechnology for Biofuels,* Jose Goldemberg, May 2008
5: Data from Biodiesel.org

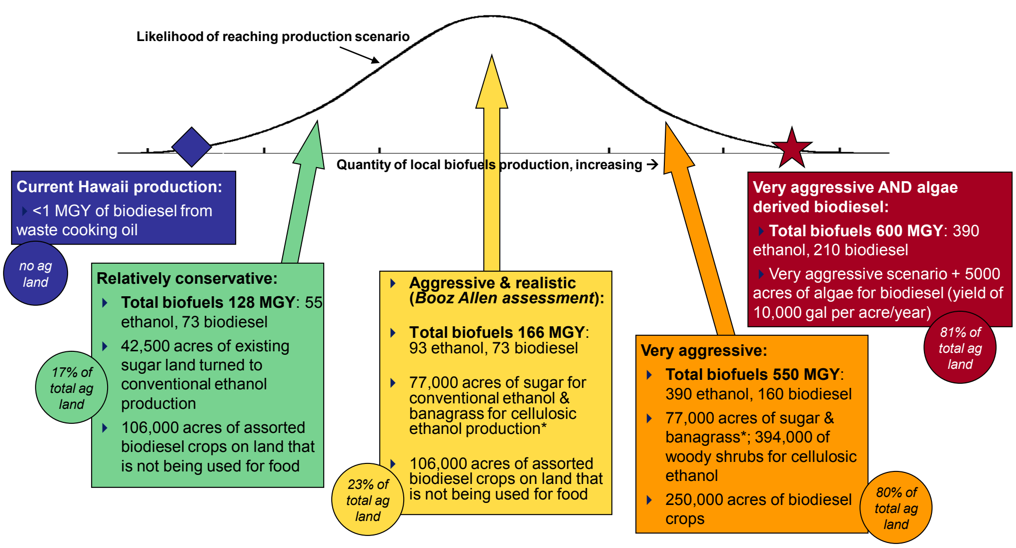
Applying this level of biofuel production to the demand scenarios shows a significant gap between supply and demand

2030 Demand / **Total=% met by local production in 2030**	**Biodiesel for Electricity**	**Biodiesel for Transportation**	**Ethanol for Transportation**
HCEI Scenario 8 (70% clean energy set for the transportation sector as a whole)	0 / **N/A**	77 MGY / **73 MGY = 95%**	338 MGY / **93 MGY = 28%**
New Scenario 9 (electricity demand for biodiesel met first)	233 MGY / **73 MGY = 31%**	50 MGY / **0%**	486 MGY / **93 MGY = 19%**
New Scenario 9 (transportation demand for biodiesel met first)	233 MGY / **23 MGY = 10%**	50 MGY / **50 MGY = 100%**	486 MGY / **93 MGY = 19%**

Booz Allen analyzed three "levers" that represent different opportunities to fill in the gap between local supply and demand

- To assess the impact of each lever, Booz Allen analyzed each one in isolation; however, it is important to recognize that a combination of these strategies ultimately may be employed together
  - **Lever 1**: Increase the land in production for bioenergy
  - **Lever 2**: Increase the yields for bioenergy crops
  - **Lever 3**: Increase the amount of biofuel imports

Lever 1: Increase the land in production for bioenergy



*This is a subset of total ethanol potential that includes land that is owned by the State or large landowners; also, new land for banagrass is only included if it would not need irrigation (>78" rain per year)

Note: In each of these scenarios, land would likely also be dedicated to feedstocks for biomass electricity (in addition to liquid biofuels); those acres are not included

Lever 2: Increase the yields for bioenergy crops

To meet Hawaii's local demand while holding other factors constant, yields would need to increase 3-4x

Values in gallons per acre per year	Current Domestic Yield Assumed	Yield Required to Meet Domestic Demand	
		New Scenario 9	HCEI Scenario 8
Ethanol Yield	1,500	6,335	4,411
Biodiesel Yield	667	2,871	670

Notes:

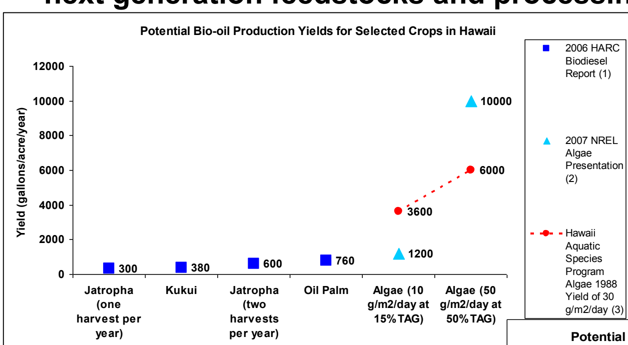
1. New Scenario 9 requires the use of biodiesel for generation. HCEI Scenario 8 requires biodiesel usage only for transportation purposes

2. PHEV penetration across scenarios differs: HCEI Scenario 8 assumes a much higher level of PHEV usage than for New Scenario 9

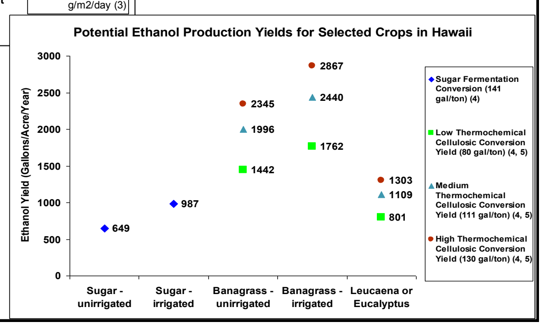
3. Yield assumed is a weighted average of the feedstock yields chosen for this analysis, including cellulosic ethanol but not algae biodiesel.

Booz | Allen | Hamilton

Lever 2 continued: Significant yield increases are likely to require next generation feedstocks and processing



Sources:
(1): "Biodiesel Crop Implementation in Hawaii" report by Michael Poteet of HARC, September 2006
(2): "The Potential for Biofuels from Algae" presentation by Philip T. Pienkos of NREL to the 2007 Algae Biomass Summit, November 15, 2007
(3): "A Look Back at the U.S. Department of Energy's Aquatic Species Program: Biodiesel from Algae", Section III.B.2.g- The ARPS Project in Hawaii, Seventh Year result from a 122 day series of C. cryptica algae
(4): "Potential for Ethanol Production in Hawaii", report by Vhesissu Keffer et al. of HNEI, December 2006
(5): "Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass", technical report by S. Phillips et al. of NREL, April 2007



Lever 3: Increase the amount of biofuel imports

Both scenarios will require that Hawaii import significant amounts of biofuels

	New Scenario 9	HCEI Scenario 8	Description
Cumulative Biofuel Imports 2008-2030 (Million Gal)	7,762	2,553	The total number of gallons of imported combustion fuels needed to meet both generation and transportation demand over the 2008-2030 time period
Percentage of Total Electric Generation Met Through Oil & Biofuels Imports in 2030	45%	30%	Percent of baseline generation demand met from imported combustion fuels in the year 2030 (Note: excludes electricity generated from domestically-produced biodiesel)
Percentage of Total Transportation Fuel Demand Met Through Oil & Biofuel Imports in 2030	79%	56%	Percent of baseline transport fuel demand met from imported combustion fuels in the year 2030 (Note: excludes domestic biofuel usage)

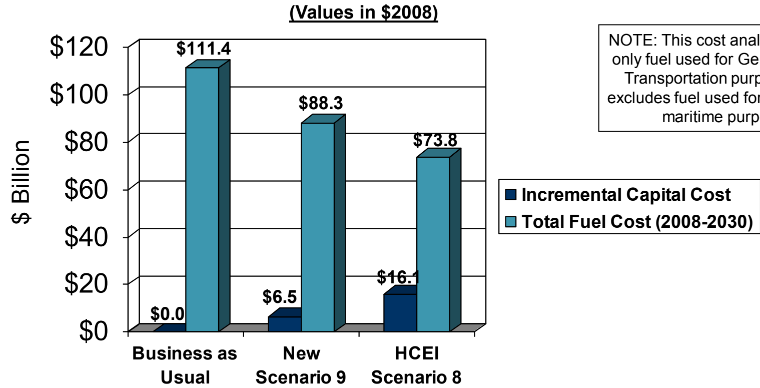
NOTE: For the purposes of Transportation Fuel analysis, increasing electric demand due to PHEVs is considered as a part of the overall generation demand, and accordingly adjusted for as part of the generation fuel usage figure

Booz Allen's analysis seeks to answer these key questions

- Demand:
  - What are potential demand scenarios for biofuels in Hawaii by 2030?
- Supply:
  - How much biofuel is Hawaii likely to produce by 2030?
  - How does this supply compare with the demand scenarios?
  - What are Hawaii's levers to increase supply?
- Costs and Risks:
  - What costs and risks are associated with biofuels for Hawaii?

Using more biofuels for generation would decrease overall capital costs but would raise total fuel costs

New Scenario 9 vs. HCEI Scenario 8
Total Costs (2008-2030)



NOTE: This cost analysis includes only fuel used for Generation and Transportation purposes. This excludes fuel used for aviation and maritime purposes.

Fuel costs are based on an assumed range of prices: $3/gal gasoline, $4/gal diesel fuel for transport, $3.50/gal diesel fuel for generation, $2.60/gal residual fuel for generation, $2.10/gal ethanol, $4/gal biodiesel (Source: EIA Historical Wholesale Fuel Price Trends)

Capital Costs drawn from previous HCEI Scenario analysis, with additional transportation infrastructure costs based on Booz Allen Hamilton Intellectual Capital included as necessary

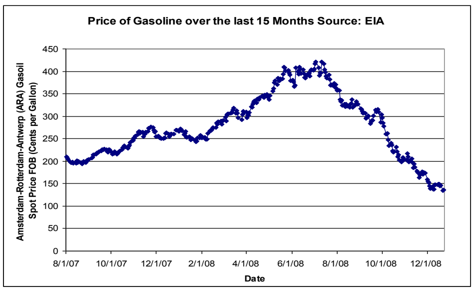
Comparing the two scenarios with risk exposure in mind highlights the tradeoff between price volatility and % of intermittent electricity on the grid

	New Scenario 9	HCEI Scenario 8	Description
Price Volatility Index	60%	37%	Percent of generation tied to oil prices in the long term, including petroleum products, ethanol and biodiesel*
Intermittence as a Percent of Delivered Capacity	23%	29%	Intermittent technologies (i.e., wind, solar) put more stress on grid operations than combustion or other firm generation types
Energy Efficiency Level Reached in 2030 (GWh)	1,607	4,336	Energy efficiency figures for New Scenario 9 are based on IRP forecasts for each utility. Efficiency figures for Scenario 8 are based on NREL efficiency technology curves and DOE goals

*Tracking ethanol feedstock prices during recent years we note that the correlation coefficient, which measures the price association between crude oil and corn prices, rose from 0.04 in 2004 to 0.67 in 2008 as more ethanol was used for transportation fuel. We assume that biodiesel market will also move in coordination with crude oil prices over time. (Robison, Peter, Bloomberg.com, 12/17/2008)

The Price Volatility Index is premised on the correlation between the market price of ethanol and the price of gasoline

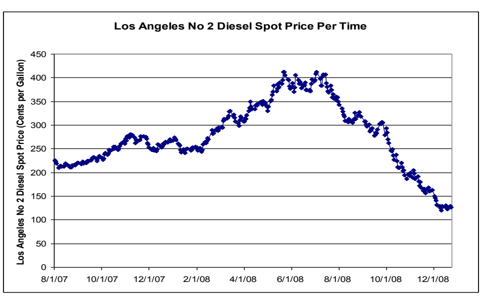
Comparison of Gasoline Prices versus Ethanol Prices - Last 15 Months



Booz | Allen | Hamilton

Likewise, the prices of diesel fuel and biodiesel are correlated

Comparison of Diesel Fuel Prices versus Biodiesel Prices - Last 15 Months



Booz | Allen | Hamilton

In summary, Booz Allen analyzed one supply scenario, two demand scenarios and identified issues needing further consideration

Booz Allen Supply Scenario		
	2030 Production	Acres Required
Ethanol	93 MGY	77,000
Biodiesel	73 MGY	106,000
Biomass	420 kWh	23,000
Demand Scenarios		
	New Scenario 9	HCEI Scenario 8
2030 Demand for Ethanol (MGY)	50	77
2030 Demand for Biodiesel (MGY)	283	338
Cumulative Biofuel Imports in 2030 (MG)	7,762	2,553
% of Total Generation from Oil and Biofuel Imports	45%	30%
% of Total Transportation from Oil and Biofuel Imports	79%	56%
Total Costs	$6.7 B for capital $88.3 B for fuel	$16.3 B for capital $73.8 B for fuel
Price Volatility Index	60%	37%
Percentage of Intermittence of Installed Capacity	23%	29%
Energy Efficiency Level Reached in 2030 (GWh)	1,607	4,336

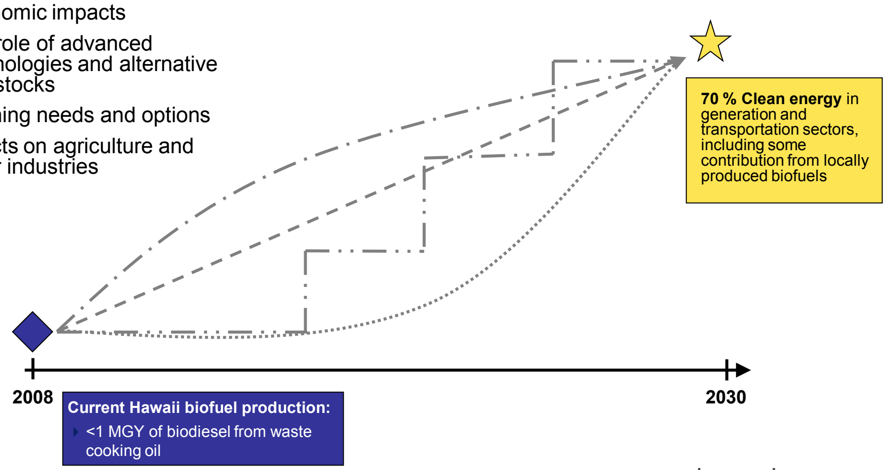
Recognizing that food and fuel needs are both vying for resources, future analysis could explore synergies and areas of mutual benefit

- This analysis was careful not to assign land currently in food to the potential production of biofuels; however, future work could focus on identifying opportunities for the food and fuel industries to help or compliment each other, for example:
  - **Intercropping** - growing food and fuel crops in alternating rows to help reduce fertilizer needs and/or grow the energy needed to harvest the fields
  - **Alternating crops** - exploiting the seasonality of crops to allow farmers to increase the number of months they can harvest
  - **Sharing infrastructure** - there appears to be potential for food and fuel crops to share harvesting and/or processing equipment (i.e. coffee and jatropha or sugarcane and banagrass), this could help reduce the capital costs for farmers by allowing for higher utilization of equipment
  - **Cattle lands** - this analysis was careful to avoid assuming conversion of cattle land to farmland for biofuel purposes, yet still reached a significant level of biofuel production. Through careful future land usage analysis, a working agreement that satisfies both farmers and ranchers should be possible
- Biofuels provide farmers the opportunities to diversify the markets that they can serve as well as increase their self-sufficiency and reduce their exposure to fluctuations in the price of fuels

This analysis focused on identifying likely 2030 supply and demand points; how Hawaii goes from here to there requires further analysis

In order to design effective policy, additional analysis is needed to understand:

- Economic impacts
- The role of advanced technologies and alternative feedstocks
- Refining needs and options
- Effects on agriculture and other industries



Booz | Allen | Hamilton

Appendix – Key Analysis Assumptions and Comparison with Previous Results

Booz | Allen | Hamilton

Island-specific assumptions for realistic, aggressive, 2030 biofuels production were based on published reports from HARC and HNEI

- Ethanol production assumptions
  1. All existing sugar land stays in sugar; no new land is put into sugar; all sugar and molasses is made into ethanol; excess bagasse is NOT put into ethanol
  2. All state-owned sugar soil lands with >78" of rain put into banagrass for ethanol
  3. Half of the “large land owner” owned sugar soil land which gets >78" of rain put into banagrass for ethanol
  4. The data for the land with >78” of rain as well as the rationale and yield for banagrass was taken from the December 2006 HNEI publication “Potential for Ethanol Production in Hawaii”
- Biodiesel production assumptions
  1. The State will maximize waste oil to biodiesel- producing 2.5 million gallons of biodiesel total, data taken from the August 2006 Hawaii Biofuels Summit Briefing book
  2. Land currently producing food (including pasture land for cattle) will not be used for biodiesel
  3. Land currently owned by many small land owners not put into biodiesel
  4. The crop selected for each plot and the yield of that crop in Hawaii was taken from the September 2006 HARC publication “Biodiesel Crop Implementation in Hawaii”
- Biomass production assumptions
  1. Biomass projects were chosen based on the details specified in the most recent HELCO and MECO IRPs and the latest plans of the KIUC

Using published reports, projects were selected with the greatest specificity possible to reduce the chance of double booking land

- **Land selected for ethanol production**
  1. Maui- the existing 35,000 acres currently in sugar would remain
  2. Kauai- the existing 7,500 acres currently in sugar would remain
  3. Kauai- 2,427 acres of state owned sugar soil lands with >78” of rain would grown banagrass[1]
  4. Hawaii- 11,060 acres of state owned sugar soil lands with >78” of rain would grown banagrass[1]
  5. Hawaii- 20,679 (half of the 41,358 total) of large land owner owned sugar soil lands with >78” of rain would grown banagrass[1]
- **Land selected for biodiesel production[2]**
  1. Oahu- 10,000 acres in the Kunia district of soon-to-be-former pineapple land would be used for jatropha
  2. Oahu- 4,000 acres in the leeward region east of Waianae and Nanakuli would be used to grow castor bean
  3. Oahu- 6,500 acres on the North Shore from Haleiwa to Waimea of old sugarcane land would be used for oil palm
  4. Maui- two 10,000 acre sections along the eastern and southern slopes of Mt. Haleakala would be used, one for jatropha and one for kukui
  5. Kauai- 5,500 acres in the Mana Plains on the leeward coast would grow jatropha with two crops per year
  6. Hawaii- 25,000 acres (half of the 50,000 acres identified) along the Hamakua Cost north of Hilo would grow oil palm
  7. Hawaii- 35,000 acres (half of the 70,000 acres identified) in the Puna District would grow oil palm
- **Land selected for biomass production**
  1. Hawaii- per the HELCO IRP-3- 9,800 acres in Ka'u will be planted with banagrass for electricity (20.8 MW)
  2. Maui- per the MECO IRP-3- 8,000 acres in central Maui will be planted with banagrass for electricity (20.8 MW)
  3. Kauai- per the KIUC plan- a 6.4 MW plant will be powered by tree biomass (on approximately 5,000 acres)

References
1: “Potential for Ethanol Production in Hawaii” by UH (HNEI and CTAHR), December 2006
2: “Biodiesel Crop Implementation in Hawaii” by Michael Poteet at HARC, September 2006

Key Analysis Assumptions

Demand Assumptions:			
HI Gasoline Usage (2006)	531,505,000	gal	HI Databook figure. Based on Historical Trend Data. The average from 1992-2008 is 616,000 and that the absolute value of the deviation is typically less than 10%, (negative for nine years, positive for seven) except for 2000, and 2004 (no data avail. for 2007)
Current Avg. HI mpg	20.08	mpg	
Average miles driven per year in HI	9206	mi	DBEDT Databook
Number of vehicles in HI (2006)	1159256	vehicles	DBEDT Databook
Total amount of fuel now used by Hi drivers	531,505,000	Million gal	
Future Avg. mpg (Years 2020-2030):	35	mpg	Energy Independence and Security Act of 2007, Sec. 102
Estimated amount of diesel used	63,780,600	gal	Calculated
Estimated amount of gasoline used	467,724,400	gal	Calculated
% of gasoline usage	88%		HI Databook, 2007
% of diesel fuel usage	12%		HI Databook, 2007
Hawaii Population	1,285,498	ppl	DBEDT Databook
# of passenger vehicles	1,159,256	vehicles	DBEDT Databook
Ratio vehicles/people	0.90		
Hawaii pop. growth rate (2000-2006)	6.10%		DBEDT Databook
Annual population growth	1.02%		
Annual Increase in number of cars Forecast	0.92%		
Plug-in Electric Vehicle kWh/mi	0.32	kWh/mi	EPRI and Agronne NL, Global Prospects for Plug-in Hybrids
Assumed electricity use as a proportion of total PHEV energy use	80%		Per ORNL
Assumed vehicle life	9	yrs	
Turnover rate	11%		
Energy density of ETOH relative to gasoline	70%		Per Hawaii Energy Content Figs
Cafe standard Increase per year (Starting in 2011)	5%		National CAFE Standard
Gallons/bbl	42		
CO2 emissions per gallon of diesel	22.34	lbs	EIA
CO2 emissions per gallon of gasoline	19.564	lbs	EIA
lbs/ton	2000		
Biodiesel for electric generation	1.5	MW/MGY	
Gallons/MW	666,667		
% of E10 Mandated by Statute	85%		
% of Ethanol in E10	10%		
# Gal Diesel = 1 Gal Resid. Fuel	1.15		
Amount of Biodiesel for Generation - HECO IRP	1310	MW	
Amount of Biomass for Generation - HECO IRP	0	MW	
Amount of Biodiesel for Generation - HELCO IRP	0	MW	
Amount of Biomass for Generation - HELCO IRP	25	MW	
Amount of Biodiesel for Generation - MECO IRP	0	MW	
Amount of Biomass for Generation - MECO IRP	25	MW	
Amount of Biodiesel for Generation - Kauai IRP	17	MW	
Amount of Biomass for Generation - Kauai IRP	26.4	MW	
Amount of Biodiesel for Generation - HECO Scenario 9	333	MW	
Amount of Biomass for Generation - HECO Scenario 9	0	MW	
Amount of Biodiesel for Generation - HELCO Scenario 9	0	MW	
Amount of Biomass for Generation - HELCO Scenario 9	25	MW	
Amount of Biodiesel for Generation - MECO Scenario 9	0	MW	
Amount of Biomass for Generation - MECO Scenario 9	6	MW	
Amount of Biodiesel for Generation - Kauai Scenario 9	17	MW	
Discount Rate	7%		

Transport Cost Assumptions			
Cost of Gasoline	$3	gallon	
Cost of Highway Diesel Fuel	$4	gallon	($3.30 wholesale plus $.70 per gallon shipping)
Cost of Wholesale Diesel Fuel	$3.50	gallon	Source: EIA
Sugar Cane Ethanol Production LC:	$ 2.40	per gallon	USDA Report
Cellulosic Ethanol Production LC:	$ 1.10	per gallon	DOE GOAL
Biodiesel Production Cost:	$ 3.60	per gallon	
Residual Fuel Cost	$ 2.60	per gallon	
Biorefinery Capex	$ 5.00	per gallon nameplate	
Biorefinery capacity	0.8		
Biorefinery Adjusted Capex	$ 6.00	per gallon	
Production Capex (pre Conversion)	$ 0.07	per gallon	
Transport Distribution Infrastructure Cost:	$ 0.04	per gallon	
PHEV Premium per car (Today):	$ 10,000	Per Car	
PHEV Premium per car (2030):	$ 4,300	Per Car	
PHEV Transport Infrastructure Capital Cost	$ 500.00	per plug	
Number of PHEV Plugs per vehicle	1.5		
Cost per Gallon ETOH	$ 2.10		
Cost per Gallon Biodiesel	$ 4.00		
Cost per kWh Electricity	$ 0.30	HI Avg. Price	
Conversion rate Gasoline/Barrel Oil	19.5	gallons per barrel	
Conversion rate Diesel Fuel/Barrel Oil	9	gallons per barrel	
Total Gallons per Barrel	42	gallons per barrel	
Energy Content of Ethanol/Gasoline	0.7		
Million BTU per Gallon Gasoline	0.1141	BTU	
Million BTU per Gallon Diesel Fuel	0.1298	BTU	
Million BTU per Gallon Ethanol	0.0761	BTU	

Land Productivity Assumptions		
Irrigated Sugar land yield	9.7	tons/acre/year HC&S
Irrigated Sugar land yield	7	tons/acre/year G&R
Molasses yield	0.276	Tons/(ton of raw sugar)
Fermentable sugar in molasses	48%	sugar content in molasses, by weight
Ethanol yield	141	gallons/ ton of fermentable sugar
Fiber yield	1.5	tons/ ton of fermentable sugar
Electricity Consumption	0.9	tons of fiber/ ton of fermentable sugar
Excess fiber	0.6	tons of fiber/ ton of fermentable sugar
Ethanol yield	70	Gallons/ton of fiber (cellulosic)
Electricity production	8482.6	Tons of biomass per year/MW of electricty

Overall Assumptions and Notes
Neither mass transit nor the ETOH mandate (85% E10) have appreciable impact on fossil fuel use in the state. Rows with data regarding mass transit and the ETOH mandate have been hidden.
CAFÉ
Everyone that replaces a car buys a new, not a used car.
The CAFE of Hawaii will mimic that of the mainland.
Assumed vehicle life is 9 years.

Booz | Allen | Hamilton

A detailed summary of the biodiesel projects proposed in the HARC study including rationale for which were chosen

Summary of the Data in the HARC "Biodiesel Crop Implmenation in Hawaii" Report- Section 7							
Island	**Acreage**	**Yield (gallons per year)**	**Island Totals**	Land Name	BAH Notes	BAH Yield	Poteet Notes
Ni'ihau	25	7,500	**7,500**		island not included		
Kauai	5,500	3,300,000		Mana Plains	used	3,300,000	
	1,400	1,000,000		Koloa	not used- small land owner		
	1,800	1,350,000		Lihue Basin	not used- small land owner		
Kauai other		5,000,000		Other	not used- following Poteet		not included in final analysis
Kauai total			**5,650,000**				
Oahu	25,000	15,000,000		North Shore 1	not used- used for food		
	10,000	6,000,000		Kunia	used	6,000,000	
	4,000	1,100,000		Leeward region	used	1,100,000	
	6,500	4,900,000		North Shore 2	used	4,900,000	
Oahu total			**27,000,000**				
Molokai	15,000	4,500,000	**4,500,000**		island not included		1/2 of max- assumes one crop per year
Lanai	12,000	3,600,000	**3,600,000**		island not included		
Maui	4,000	2,500,000		Lahaina	not used- used for food		
	20,000	12,000,000		Mt. Haleakala	used (different yield calculated)	9,800,000	
Maui total			**14,500,000**				
Hawaii	50,000	38,000,000		Hamakua Coast	used half	19,000,000	
	70,000	53,000,000		Puna district	used half	26,500,000	
	12,500	4,500,000		Ka'u	not used- used for electricity		
	12,500	9,500,000		Ka'u	not used- used for cattle		
Hawaii total			**105,000,000**				

Total Acres Used	**250,225**	**Total Biodiesel Produced**	**160,257,500**

Booz Allen Analysis				
Acres Used	**106,000**	**Biodiesel Produced**	**73,252,000**	including 2.5 MGY biodiesel from waste oil
% of total	**42%**	**% of total**	**46%**	

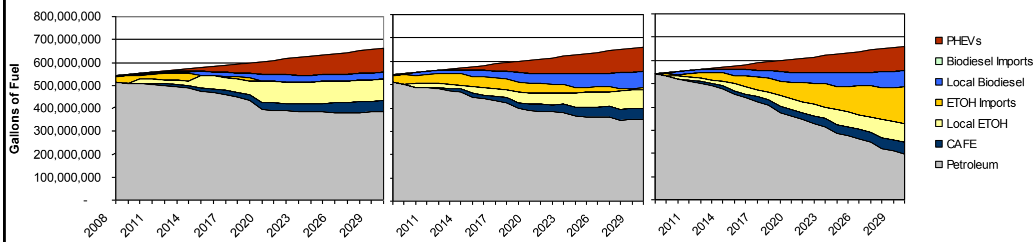
Booz | Allen | Hamilton

Building upon BAH's 2008 HCEI work, the updated bioenergy analysis shows that Hawaii still needs significant ethanol imports to meet the 70% clean energy goal in the transportation sector

State of Hawaii Scenario 8 Transportation Sector Comparison

Gallons of Petroleum Avoided 2008-2030

Previous Analysis Results | *Results updated with new biofuel production #'s* | *Analysis updated with new production #'s and imports to reach 70% goal*



Summary of 2030 Transportation Results	
Amount of agricultural land used	8%
Clean energy achieved	45%

Summary of 2030 Transportation Results	
Amount of agricultural land used	12%
Clean energy achieved	47%

Summary of 2030 Transportation Results	
Amount of agricultural land used	12%
Clean energy achieved	70%

Appendix F: Transportation Scenario Analysis and Key Outcomes (September 2010)

Transportation Scenario Analysis and Key Outcomes

Sept. 10, 2010

Our methodology for the development of Transportation goals is a four step process

STEP 1

Construct "Business as Usual" case

- Outline 2030 projections of transportation fuel usage by current vehicle type, including:
1. Gasoline-powered vehicles (Cars, Light Trucks)
2. Diesel-powered vehicles (Trucks)
3. Standard Hybrid Vehicles (Cars)
4. Public Transport

STEP 2

Develop likely alternative vehicle scenarios

- Identify major vehicle options:

Efficiency/ CAFE	PHEV	Diesel
[redacted]		

- Establish BAU, probable and optimistic adoption projections per each option

STEP 3

Conduct sensitivity analysis to identify key tradeoffs

- Determine key criteria for evaluating best outcomes (e.g., cost, feasibility)

- Analyze outcomes based on criteria and combined impact of multiple options

STEP 4

Determine ideal vehicle pathways to our goal: 70% reduction in ground transport fuel

- Evaluate analysis and establish ideal vehicle type mix for pathway to 70%

- As appropriate, identify multiple scenarios for reaching goal based on different priorities

VEHICLE PROJECTIONS MAPPED TO SPECIFIC ACTION ITEMS

BAU, Probable and Optimistic Alternative Scenarios were then created to highlight a range of potential outcomes

	BAU	Probable	Optimistic
CAFE*	4/5ths of EISA CAFE Standard	Full attainment of EISA CAFE Standard (Weighted Avg.)	100% EISA CAFE for all Standard Vehicles
Mass Transit	Standard ridership	Bus- 27% ridership increase by 2030	Light Rail Installed + Bus Ridership Increase
Hybrid	3% adoption (Standard)	13% adoption	43% adoption
PHEV	Minimal adoption	4% adoption	13% adoption – 1A 25% adoption – 1B
BEV	Minimal adoption	0.6% adoption	5% adoption
FFV	Minimal adoption	9% adoption (Half Domestic)	19% adoption (Full Domestic)
Diesel	No increase over current diesel fuel usage	Half Light Truck Fleet Adoption	Full Light Truck Fleet Adoption

*CAFE Scenarios based on EISA 2007 CAFE levels. To be updated to 2009 EO levels shortly. See Appendix for all scenario sources and additional driving assumptions

Key data points include the makeup of the fleet and total vehicles in use in the state

Type of vehicle	State total	City and County of Honolulu	County of Hawaii	County of Kauai	County of Maui
All vehicles	1,160,643	735,509	184,202	77,989	162,943
Motor vehicles	1,127,567	719,640	175,166	74,344	158,417
Passenger vehicles 1/	903,518	595,825	133,722	52,722	121,249
Ambulances	57	36	5	1	15
Buses	2,213	1,735	268	11	199
Trucks 1/	191,459	101,690	36,933	19,826	33,010
Truck tractors	799	511	186	13	89
Truck cranes	1,074	879	105	6	84
Motorcycles, motorscooters 2/	28,447	18,964	3,947	1,765	3,771
Trailers and semi-trailers	33,076	15,869	9,036	3,645	4,526

1/ Vans, pickups, and other trucks under 6,500 lb. in personal use, legally classified as passenger vehicles, are included in the totals for trucks.
2/ Excluding mopeds (1.5 HP or less), which are legally classified as bicycles.
Source: Hawaii State Department of Transportation, Motor Vehicle Safety Office, records.

See Appendix for study sources

The primary limitation to our savings is the number of new vehicle sales annually

Table 18.12-- NEW RETAIL CAR AND LIGHT TRUCK (VAN) REGISTRATIONS: 1989 TO 2009

[Excludes U-drive/Fleet sales]

Year	Number	Year	Number	Year	Number
1989	57,456	1996	41,480	2003	62,712
1990	54,544	1997	42,487	2004	1/ 65,882
1991	47,783	1998	40,673	2005	70,268
1992	44,865	1999	45,054	2006	67,224
1993	45,249	2000	51,500	2007	57,526
1994	44,175	2001	51,388	2008	42,804
1995	41,083	2002	53,314	2009	33,639

1/ Revised from previous year *Databook* .
Source: Hawaii Automobile Dealers Association, *HawaiiDealer 2010 First Quarter.*

TOTAL AVERAGE ANNUAL SALES (1989-2009): 51,000 Vehicles

Prius and Total Hybrid New Vehicle Registrations in Hawaii

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Prius	0	31	85	56	113	442	661	686	648	646	516
Total Hybrid	0	46	113	141	261	625	971	1235	1127	1155	1047

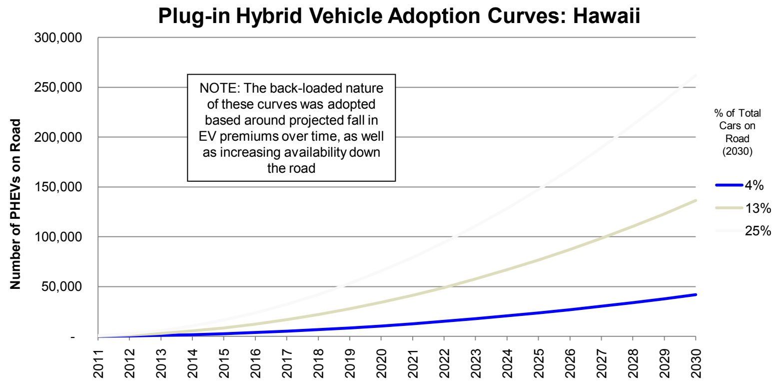
Source: R.L. Polk and Company

HYBRID AVERAGE ANNUAL SALES (2005-2009): 1,100 Vehicles (2% of Total Annual Sales)

Based on the total number of cars sold annually, only certain combinations of outcomes are possible

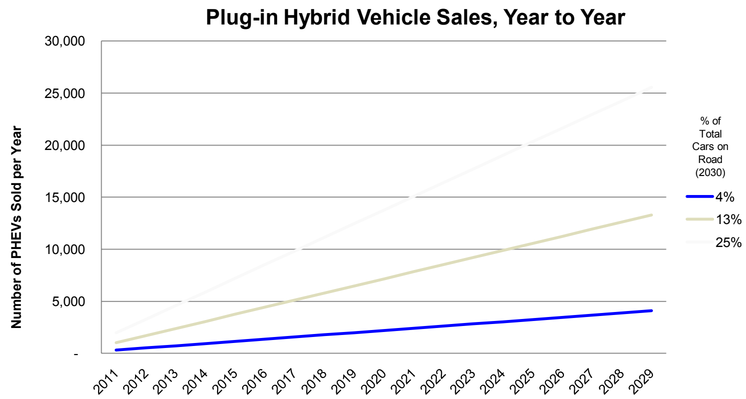
Scenario	Total Alt. (HEV+BEV+PHEV) Vehicles Sold in 2030	Conclusion
BAU – current levels of HEVs	No sales above baseline	Reference point
Probable – 5% PHEV/BEV, 13% HEV	11,000	Represents approximately 1/5 of all vehicle sales in the state in 2030
Optimistic 1A – 18% PHEV/BEV, 13% HEV,	33,000	Represents over ½ of all the vehicles sold in the state in 2030. Aggressive, but possible
Optimistic 1B – 30% PHEV/BEV, 13% HEV	48,000	Represents almost all of the vehicles sold in the state in 2030 (including truck sales, which we assume to be non-electric, this may cross the total sales limit for the year). The rough limit of what is possible unless vehicle sales totals change

PHEV Adoption Curves were then developed to attain target sales levels in 2030



Assumptions:
- PHEV's calculated as a percentage of total motor vehicles (excluding trucks) projected in 2030 per DBEDT 2008 data
- Motor vehicle data taken from DBEDT Data Book 2008 **passenger vehicle** figures
- Trucks (including vans, pickups and other trucks under 6500lb) are excluded from total motor vehicle figure
- Adoption curves assume quadratic increase

These curves are designed to keep the total vehicles sold within the range of actual year to year sales

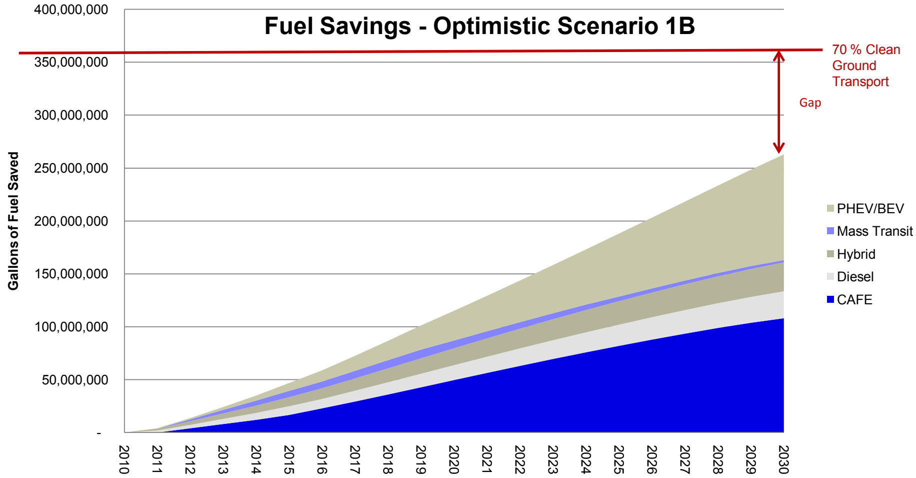


Assumptions:
- PHEV sales calculated from quadratic assumption curves for each scenario
- Number of PHEV's are a function of total motor vehicles (excluding trucks)

	Annual Number of Cars Sold		
Scenario	2015	2020	2025
Probable (4%)	943	1,991	3,039
Optimistic 1A (13%)	3,067	6,817	13,633
Optimistic 1B (25%)	5,899	13,109	26,218

See Appendix for study sources

However, even the most aggressive of these scenarios results in a slight gap in the attainment of the goal



Note: These projected savings are based on an avg. vehicle efficiency of 5 mi/KWh, as opposed to our previous assumption of 3 mi/KWh (due to receipt of new performance data from Nissan.) May not reflect real world driving conditions.

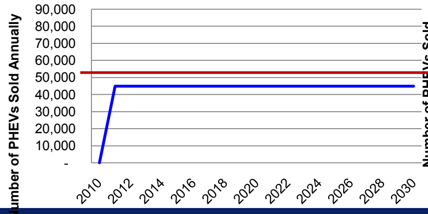
In order to attain the 70% goal, several options are available

- Since vehicle turnover is low (~50K Vehicles sold per year out of a fleet of 1.1M), accelerating it is the fastest way to increase savings, whether they are from improved vehicle efficiency or electric vehicles
- By accelerating the adoption of PHEVs, HEVs, BEVs and flex fuel vehicles to the market, you ensure that a larger portion of the fleet is “Alternative” by 2030, thus increasing savings
- By increasing the amount of renewable energy is in the generation mix, you can increase the savings from each individual electric vehicle on the road
- At the present, no projections involving upping ethanol blending standards for the state have been made (E15 standard currently in review for national deployment)
- It is worth noting that each policy option associated with these measures will bear some cost to the state, in some cases significant

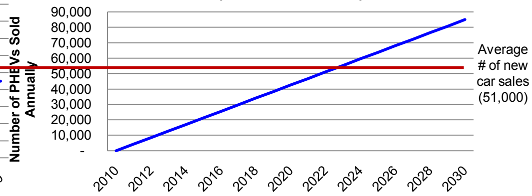
To attain the 70% goal under an "only EV" scenario, 900,000 electric vehicles would need to be on the road in 2030

- This represents 100% of all the cars on the road today (excluding Trucks, which would have to convert fully to diesel fuel for us to reach the goal)
- Primary issue is that CAFE standards cut into projected savings from EVs above a standard vehicle
- Secondary issue is that RPS is only 40% by 2030, which mitigates projected fuel replacement savings from EVs

Annual Electric Vehicle Sales Needed to Attain Goal (Fixed Deployment)



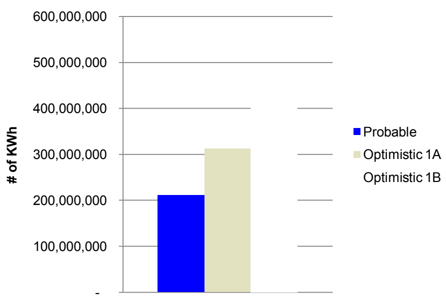
Annual Electric Vehicle Sales Needed to Attain Goal (Linear Increase)



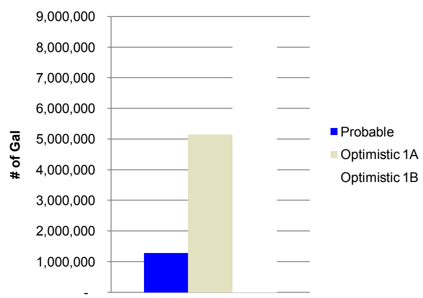
10

Increasing the RPS has potential to lower consumption of fuel at the pump, but will redirect it to the generation sector…

Total Additional Generation Needed For Vehicles in 2030 (KWh)



Total Additional Fuel Needed For Generation in 2030 (Gal)



… but the net impact of doing so is relatively small

	Total Fuel Savings At Pump in 2030 (Excluding New Generation)	Total Fuel Savings in 2030 (Net of New Generation)
Probable	13.4 MGY	12.2 MGY
Optimistic 1A	40.9 MGY	35.9 MGY
Optimistic 1B	83.0 MGY	74.5 MGY

11

Conclusion: CAFE and EVs are central to a comprehensive transportation policy, but may not bring you all the way there

- Any message regarding attainment of the transport goals must focus on these two areas, and policies facilitating them are critical
- Any improvements in vehicle turnover provide an opportunity for additional savings to be gained
- Plug-in vehicles, while a large part of the future savings, cannot get us there on their own
- Cost of accelerating EV adoption and availability of cars must be considered in determining what options are viable
- In short term, may be more productive to focus efforts on promoting purchasing of more efficient vehicles

12

Appendix (Sources)

13

Appendix: Assumptions & Sources

(General Vehicle Assumptions)

- Hawaii population (1.295 million), number of passenger vehicles (1.173 million), average miles traveled (9,059/year) and growth rates (0.60%/year) obtained from 2008 DBEDT Databook
- Hawaii fuel usage projected from DBEDT figure; average mpg calculated at 19.4 for 2010 based off of DBEDT figures for total fuel usage and miles traveled
- Average vehicle life estimated at 9 years (Motor Authority, 2008)
- Commuting habits- average trip length (10 miles) and number of weekday trips (508) taken from Analysis and Recommendations for the Hawaii County Energy Sustainability Plan 2007

(Option Ranges- CAFE)

- CAFE projections based on national CAFE standard from Energy Independence and Security Act of 2007, Section 102
- 80% range built in for "Probable" adoption scenario to reflect current status of HI Vehicle fleet as only 80% of mandated CAFE standard (current CAFE standard- 25.0 mpg)

Appendix: Assumptions & Sources

(Option Ranges- Mass Transit)

- Current bus ridership (238,000) estimated from Hawaii Department of Transportation 2010 figures (www.thebus.com)
- "Probable" bus scenario assumed at 27% increase by 2030 based on Light Rail Alternatives Analysis http://www.honolulutransit.org/library/default.aspx
- Bus efficiency calculated based on MPG estimates from Hawaii County Energy Sustainability Plan, 2007
- Light Rail impact and data drawn from http://www.honolulutransit.org/library/default.aspx

(Option Ranges- Diesel Truck Conversion)

- Diesel 2030 penetration ("Optimistic") estimated at 58% based on full possible adoption of light duty trucks in vehicle fleet (from 2008 DBEDT); 2030 penetration ("Probable") assumed as 29%, half of full possible

Appendix: Assumptions & Sources

(Option Ranges- EVs)

- Hybrid efficiency estimated at 46.0 mpg from Department of Energy Consumer Energy Center
- Hybrid current penetration (“BAU”) estimated at 3% from NREL QAR Q4 Report (12/14/2009)
- Hybrid 2030 penetration (“Probable”) estimated at 13% from NRC study (“Transitions to Alternative Transportation Technologies- Plug-In Hybrid Electric Vehicles”, National Research Council, The National Academies Press, 2009)
- Hybrid 2030 penetration (“Optimistic”) estimated at 43% for 2030 from DOE, as cited in MIT, Cunningham thesis.
- PHEV adoption rates and efficiency assumed based on NRC study (see above)
- BEV adoption rates and efficiency assumed based on MIT, Cunningham thesis

Appendix G: HCEI Transport Road Map (October 2010)

HCEI Transport Road Map
Oct. 19, 2010

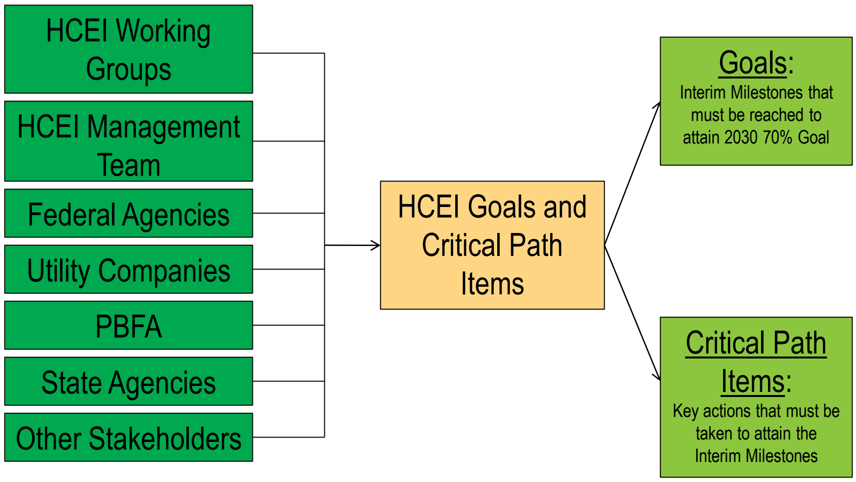
Hawai'i Powered
Hawai'i Clean Energy Initiative

The Road Map is designed to outline interim goals for HCEI, and the critical path items necessary to attain them

- Purposes for the HCEI Road Map include:
  - Foundational document for HCEI
  - Highlight key successes and progress to date
  - Used to brief key outside stakeholders (e.g. next Governor, DOE management, general public)
  - Clearly lay out goals and process for measuring progress against them
  - Outline critical action items and timeframes for achieving them

Hawai'i Powered
Hawai'i Clean Energy Initiative

The development of the Road Map has been a collaborative effort between the many stakeholders of HCEI



The framework of the Road Map is laid out in 5 year increments, with goals and detailed recommendations up front

Interim Milestone 1 Interim Milestone 2 Re-evaluate

2010 | 2015 | 2020 | 2030 → 70% Clean Energy

Year 1-5 Critical Path Items

Electricity:
- Big Wind (400MW of installed capacity)
- 3 medium scale wind projects (72 MW installed capacity)
- 2 medium scale biomass projects (45 MW installed capacity)
- 4 medium scale biofuel generation projects (200+ MW installed capacity)
- Research large-scale energy storage options for use in integrating large scale intermittent renewable into the grid
- Finalize Grid Modeling efforts for Oahu to understand potential impacts of incorporating large scale intermittence
- Identify supply of biofuels necessary (post-delivered intermittent renewable generation) to meet RPS demand (15% of delivered electricity) for consumption in biofuel generation units
- Clarify air-permitting issues for combustion of biofuels for generation

Energy Efficiency
- Retrofit existing building stock to generate 1000 MWh of efficiency savings by 2015
- Improve building codes to IECC 2015 levels, and tighten enforcement of code to generate 365 MWh of efficiency savings by 2015
- Benchmark and identify under-performing building stock to maximize retrofit impact
- Expand outreach and education programs for existing building owners and operators
- Improvement of Transmission/Distribution infrastructure to reduce line loss

Transportation:
- Provide incentives for improving vehicle efficiency (MPG) of fleet to 25 MPG for all new cars and 18 MPG for all new trucks by 2015
- Develop comprehensive VMT reduction policy package, including incentives to businesses for promoting telecommuting and expansion of public transit system
- Install critical infrastructure for EV charging
- Obtain 10,000 electric vehicles for sale in the state by 2015
- Implement incentives to lower cost premiums for EVs
- Maintain current E-10 blending standard

Fuels
- Obtain at least 45 MGY of biofuels to meet RPS generation targets
- Leverage HECO/DoD demand to drive market
- Conduct key refining pilots for production of green drop in replacement fuels
- Conduct key food/feedstock pilots to determine optimal mix of crops vs. bi-products, as well as optimal business model to lower costs as much as possible
- Evaluate logistics and infrastructure costs and structures, focusing on generating economies of scale at the feedstock production, transport, and pre-processing stages of the supply chain
- Identify and preserve as many important agricultural (or potential algae) lands as possible, along with any relevant water rights for future feedstock production
- Train and develop workforce to handle feedstock production and supply chain logistics
- Streamline permitting process for installation biorefineries and/or combustion of biofuels in generation
- Monitor status of biofuel certifications and support blending standard changes as needed

Year 6-10 Critical Path Items

Electricity
- Evaluate future interconnection possibilities between islands (Maui, Oahu, The Big Island)
- Focus on installation of large-scale Solar PV (pending decrease in cost over time)
- Re-evaluate other previously non-commercial generation technologies (OTEC, Wave)
- Finalize installation of any projects previously not completed from year 1-5 list
- Measure progress in installed intermittent renewable vis-à-vis the 2020 RPS goal (25% of delivered electricity) and calibrate the need for additional biofuel generation accordingly

Energy Efficiency
- Retrofit existing building stock to generate an additional 400 MWh of efficiency savings by 2015
- Improve building codes to IECC 2021 levels, and tighten enforcement of code to generate an additional 365 MWh of efficiency savings by 2015
- Re-evaluate previously non-commercial energy efficiency technologies (LEDs, Sea Water AC)
- Identify lessons learned from Net-Zero building pilots

Transportation:
- Ramp up incentives for EV adoption, attain target of 10,000 vehicles sold/year in state by 2020
- Increase blending standards for Green Gasoline with standard gasoline (Target 50 MGY in blend above and beyond E-10 standard by 2020)
- Re-evaluate cost effectiveness of standard vehicle efficiency vs. EVs depending on future CAFE requirements
- Continue incentivizing vehicle efficiency/penalizing vehicle inefficiency to attain target of 30 MPG for all new cars and 20 MPG for all new trucks by 2020
- Continue incentives for reducing VMT in state. Focus on long term location of housing developments near business districts to lower averag commute distance

Fuels:
- Ramp up biocrop production on domestic ag lands. Target is to produce feedstock for at least 150 MGY of domestically produced green drop-in replacement fuels
- Measure results of bio-refinery pilots and determine optimal refining infrastructure for Hawaii
- Work with Tesoro to convert current hydrocracker to at least partial production of blended biofuels (based on pilot results)
- Invest in requisite refining infrastructure outside of Tesoro to meet target demand

Year 11-20 Critical Path Items

All:
- Evaluate current state of energy infrastructure in year 11, status of various technologies, and determine next 10 years of critical path items depending on progress to date

For example, the proposed actions outlined in for Electricity highlight a range of projects/studies needed to attain the RPS

Year 1-5 Critical Path Items

Electricity:

- Big Wind Project Development (400MW of installed capacity)
- 3 medium scale wind projects (72 MW installed capacity)
- 2 medium scale biomass projects (45 MW installed capacity)
- 4 medium scale biofuel generation projects (200+ MW installed capacity)
- Research large-scale energy storage options for use in integrating large scale intermittent renewable into the grid
- Finalize Grid Modeling efforts for Oahu to understand potential impacts of incorporating large scale intermittence
- Identify supply of biofuels necessary (post-delivered intermittent renewable generation) to meet RPS demand (15% of delivered electricity) for consumption in biofuel generation units
- Clarify air-permitting issues for combustion of biofuels for generation

→ Electricity Interim Milestone (2015): 15% RPS

Year 6-10 Critical Path Items

Electricity:

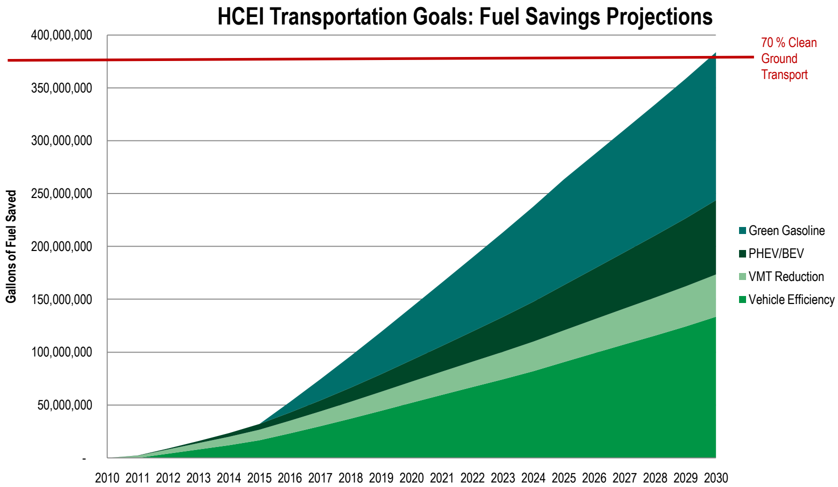
- Evaluate future interconnection possibilities between islands (Maui, Oahu, The Big Island)
- Focus on installation of large-scale Solar PV (pending decrease in cost over time)
- Re-evaluate other previously non-commercial generation technologies (OTEC, Wave)
- Finalize installation of any projects previously not completed from year 1-5 list
- Measure progress in installed intermittent renewable vis-à-vis the 2020 RPS goal (25% of delivered electricity) and calibrate the need for additional biofuel generation accordingly

→ Electricity Interim Milestone (2020): 25% RPS

Next steps include incorporating a full round of working group feedback and presenting a draft to Steering Committee

- Revisions from this round of meetings will be incorporated in the document, with a final review by the Steering Committee in November
- Upon completion will be shared equally with all HCEI stakeholders
- Ultimately, the Road Map is intended to be a living document that will be reviewed annually and revised depending on:
  - Measured progress towards goals
  - The development and commercialization of key technologies
  - Market factors (e.g. price of oil)

The HCEI transport goals were derived through a series of calls with working group members



Hawai'i Powered
Hawai'i Clean Energy Initiative

Vehicle efficiency goals reflect a steady overall improvement in non-EV fleet mileage

Fuel Displacement Measure Savings	Year				Total Fuel Reduction (2030)
	2015	2020	2025	2030	
Vehicle Efficiency (MPG)	25 MPG – All new cars 18 MPG – All new trucks	30 MPG - All new cars 22 MPG - All new trucks	32.5 MPG - All new cars 26 MPG - All new trucks	35 MPG - All new cars 28 MPG - All new trucks	120 MGY

These figures include more efficient standard vehicle options such as Hybrid and Diesel Cars

For reference purposes, EISA 2007 CAFE defined these levels of efficiency to be goal for the overall fleet, *including* electric vehicles

Hawai'i Powered
Hawai'i Clean Energy Initiative

Vehicle Efficiency: Critical Path Items Years 1-5

- Identify options for promoting the purchase of smaller, more efficient vehicles
- Evaluate the potential of current hybrid technologies to assist in the attainment of improved fleet MPG goals
- Evaluate the potential of diesel fuel switching for trucks and other vehicles that may not have clear electric alternatives

Hawai'i Powered
Hawai'i Clean Energy Initiative

8

Vehicle Miles Traveled (VMT) reduction has many other social elements that must be factored in as well

Fuel Displacement Measure Savings	Year				Total Fuel Reduction (2030)
	2015	2020	2025	2030	
Reduced Vehicle Miles Traveled	2% VMT Reduction over 2010 miles traveled	4% VMT Reduction over 2010 miles traveled	6% VMT Reduction over 2010 miles traveled	8% VMT Reduction over 2010 miles traveled	40 MGY

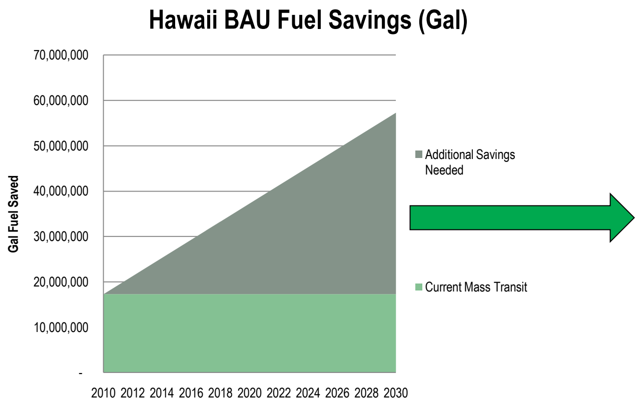
Includes mass transit, biking, carpooling, telecommuting, residential-commercial zoning (etc.)

Ignoring VMT issues will leave HCEI exposed to the risk that mass transit and other socially positive activities will decline or be neglected over time

Hawai'i Powered
Hawai'i Clean Energy Initiative

9

Hawaii's current mass transit system delivers almost 20 MGY of savings, but much more is needed



This wedge reflects the goals for HCEI VMT Reduction. It is equivalent to cutting approx. 600 miles per year off the average driver's vehicle mileage by 2030

VMT Reduction: Critical Action Items Years 1-5

- Identify VMT reduction options, and key stakeholders in each area (e.g., The BUS, State Dept. of Transportation)
- Work with local groups regarding zoning options and localization of work areas with residential areas
- Promote telecommute options for local businesses to reduce the number of miles driven per person per year
- Promote expansion of current car and van pooling options
- Maintain current high levels of bus ridership
- Light rail transport expansion, if cost effective

EV Goals

Fuel Displacement Measure Savings	Year				Total Fuel Reduction (2030)
	2015	2020	2025	2030	
EVs	4K EVs/Year being sold (10,000 total) , and supporting EV infrastructure installed	10K EVs/Year being sold (50,000 total)	20K EVs/Year being sold (110,000 total)	30K EVs/Year being sold (210,000 total)	75 MGY

Hawai'i Powered
Hawai'i Clean Energy Initiative

The primary limitation to our savings is the number of new vehicle sales annually

Table 18.12-- NEW RETAIL CAR AND LIGHT TRUCK (VAN) REGISTRATIONS: 1989 TO 2009

[Excludes U-drive/Fleet sales]

Year	Number	Year	Number	Year	Number
1989	57,456	1996	41,480	2003	62,712
1990	54,544	1997	42,487	2004	1/ 65,882
1991	47,783	1998	40,673	2005	70,268
1992	44,865	1999	45,054	2006	67,224
1993	45,249	2000	51,500	2007	57,526
1994	44,175	2001	51,388	2008	42,804
1995	41,083	2002	53,314	2009	33,639

1/ Revised from previous year *Databook* .
Source: Hawaii Automobile Dealers Association, *HawaiiDealer 2010 First Quarter.*

TOTAL AVERAGE ANNUAL SALES (1989-2009): 51,000 Vehicles

Prius and Total Hybrid New Vehicle Registrations in Hawaii

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Prius	0	31	85	56	113	442	661	686	648	646	516
Total Hybrid	0	46	113	141	261	625	971	1235	1127	1155	1047

Source: R.L. Polk and Company

HYBRID AVERAGE ANNUAL SALES (2005-2009): 1,100 Vehicles (2% of Total Annual Sales)

Hawai'i Powered
Hawai'i Clean Energy Initiative

HCEI EV goals are highly aggressive compared to those of many business estimates

	HCEI Proposed	EC Roadmap	Deutsche Bank	HSBC	Credit Suisse	Merril Lynch
2015	4,000 vehicles sold/year (8% of sales)				1.1% of sales	
2020	10,000 vehicles sold/year (20% of sales)	25% of sales	11% of sales	15% of sales		15% of sales
2025	20,000 vehicles sold/year (40% of sales)					
2030	30,000 vehicles sold/year (60% of sales)	90% of sales			7.9% of sales	

EVs: Critical Path Items Years 1-5

- Identify early adopters for both vehicle and infrastructure (state and county fleets, residential developers)
- Incentivize and install public vehicle charging infrastructure
- Identify EV deployment lessons learned outside of Hawaii (via DOE pilots or other) that may apply in-state
- Implement time of use pricing for vehicle charging (currently approved by PUC)
- Identify creative ways to promote sales of EVs, as well as to increase vehicle turnover in general (e.g., incentives for auto-dealers as well as consumers)
- Negotiate for the acquisition of appropriate quantities of EVs for sale in-state

Misc: Critical Path Items Years 1-5

- Determine best manner in which to leverage large rental fleets
- Monitor the progress of alternative marine and aviation fuel options throughout this period to determine when they might be commercially available
- Evaluate potential for hydrogen vehicles in the state, with a particular eye towards identifying large scale and cost-effective hydrogen sources to power fuel cells

Transportation: 10 year outlook

Certain advanced technologies should be commercially available and may be deployable on a large scale basis from 2016 on. These technologies will form the core of the next generation transport initiative, and include:

- PHEV and BEVs, and associated infrastructure
- Drop-in green gasoline
- Highly efficient standard vehicles

These technologies will be essential to long-term potential savings options for ground transportation, and that deployment of these technologies in the medium-term will ultimately determine the success of HCEI in attaining its ground transportation goal.

Also in this period, HCEI expects a more defined suite of petroleum-offset options will be available for the other two segments of transport fuel: marine and aviation. In this time period, significant research and evaluation of technology options for the diversification of these fuels supplies should have been conducted—or near completion—and the relative merits and costs of each option should be better understood. Currently, HCEI believes that additional action items concerning these areas should be a priority for this 6-10 year timeframe, and recommends that the transportation group expand its focus to include them at this point in time.

Accomplishments to Date:

- ACT 156 of 2009 requires Hawaii government fleets purchase electric, alternative fuel, or highly energy efficient vehicles and that EV parking be designated in all lots with over 100 public parking spaces by December 31, 2011
- Act 186 Expanded existing law where homeowners associations cannot deny solar and energy efficient devices to include EV chargers.
- General Motors and Gas Company announce partnership to develop H2 production, distribution and fueling and bring hydrogen fuel cell Equinox vehicles to Hawaii.
- TheBus took delivery of 20 new HEV buses, bringing the total to 80 HEV transit buses
- The City and County of Honolulu fleet continued use of local produced biodiesel (B20)
- PICTHR Hawaii Renewable Energy Development Venture issued a $2.4M solicitation; awards include 3 transportation projects – more to come in 2nd round solicitation
- Renewable Hydrogen production, refueling, and hydrogen fleet demonstration at Joint Base Pearl Harbor-Hickam established
- Current level of HEV adoption in the state is approximately 2% of annual sales
- Project BetterPlace, the State, and HECO launched a partnership to roll out EVs in Hawaii in 2011 or 2012
- Hawaii EV Ready Program will provide grants and rebates through ARRA funding for the installation of EV chargers and the purchase of new, commercially-available full-speed electric and plug in HEVs by Hawaii businesses, residents, non-profit organizations, and State and County government agencies

Accomplishments to Date: continued

- Nissan North America, Inc. selected Hawaii to be one of its initial U.S. launch markets for its electric car, LEAF, beginning in early 2011
- State signs MOU with Nissan. Nissan announces LEAFs for Hawaii in the first wave of market introduction, and reports 1400 Leaf "hand-raisers" and over 300 reservations.
- CT&T and the state of Hawaii announced the signing of a MOU supporting plans to bring a $200 million EV Regional Assembly and Sales facility

Appendix H: Hawaii Clean Energy Initiative Existing Building Energy Efficiency Analysis, NREL (June 2010)

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

National Renewable Energy Laboratory

Innovation for Our Energy Future

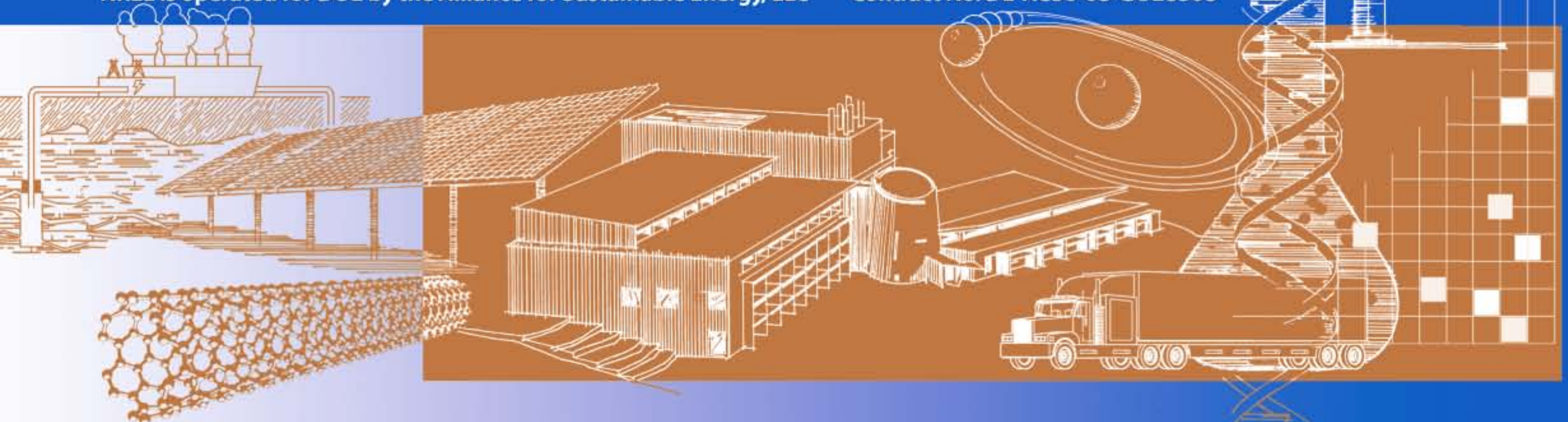
Hawaii Clean Energy Initiative Existing Building Energy Efficiency Analysis

November 17, 2009 – June 30, 2010

P. Finch and A. Potes
Booz Allen Hamilton
Honolulu, Hawaii

Subcontract Report
NREL/SR-7A2-48318
June 2010

NREL is operated for DOE by the Alliance for Sustainable Energy, LLC   Contract No. DE-AC36-08-GO28308



Hawaii Clean Energy Initiative Existing Building Energy Efficiency Analysis

November 17, 2009 – June 30, 2010

P. Finch and A. Potes
Booz Allen Hamilton
Honolulu, Hawaii

NREL Technical Monitor: S. Busche
Prepared under Subcontract No. KLDJ-6-66282-07

Subcontract Report
NREL/SR-7A2-48318
June 2010

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Contract No. DE-AC36-08-GO28308

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

This publication received minimal editorial review at NREL

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

Acknowledgments

Booz Allen Hamilton would like to thank the Hawaiian Electric Company, the Kauai Island Utility Cooperative, the Hawaii Department of Business, Economic Development and Tourism, and The Gas Company for their assistance in the data gathering process. Booz Allen Hamilton would also like to thank the National Renewable Energy Laboratory for all of its work throughout the editing process. Without these significant contributions, the analysis conducted in this report would not have been possible.

List of Acronyms

AC	air-conditioning
ACEEE	American Council for an Energy Efficient Economy
BAH	Booz Allen Hamilton
CFL	compact fluorescent lighting
DBEDT	Hawaiian Department of Business, Economic Development and Tourism
DOE	Department of Energy
DSM	demand side management
EB	existing buildings
EEPS	Energy Efficiency Portfolio Standard
EER	energy efficiency ratio
EMS	energy management system
EPA	Environmental Protection Agency
FEMP	Federal Energy Management Program
GWh	gigawatt-hour
HCEI	Hawaii Clean Energy Initiative
HECO	Hawaiian Electric Company
HELCO	Hawaiian Electric Light Company
IRP	Integrated Resource Plan
KIUC	Kauai Island Utility Cooperative
kWh	kilowatt-hour
LED	light emitting diode
MECO	Maui Electric Company
MWh	megawatt-hour
NAECA	National Appliance Energy Conservation Act
NC	new construction
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
PBF	Public Benefits Fund
SEER	Seasonal Energy Efficiency Rating
SF	square feet
SWAC	seawater air-conditioning
WH	water heating

Executive Summary

In June 2009, the State of Hawaii enacted an Energy Efficiency Portfolio Standard (EEPS) with a target of 4,300 gigawatt-hours (GWh) by 2030 (Hawaii 2009). Upon setting this goal, the Hawaii Clean Energy Initiative, Booz Allen Hamilton (BAH), and the National Renewable Energy Laboratory (NREL), working with select local stakeholders, partnered to execute the first key step toward attaining the EEPS goal: the creation of a high-resolution roadmap outlining key areas of potential electricity savings. This roadmap was divided into two core elements: savings from new construction and savings from existing buildings. After attaining feedback from the stakeholders, it was determined that BAH would focus primarily on the existing building analysis, while NREL would focus on new construction forecasting. This report presents the results of the Booz Allen Hamilton study on the existing building stock of Hawaii, along with conclusions on the key drivers of potential energy efficiency savings and on the steps necessary to attain them.

In deconstructing the various types of buildings in the state along with their respective energy footprints, Booz Allen Hamilton relied heavily on contributions from various stakeholders, including the Hawaiian Electric Company, Inc. (HECO), the Kauai Island Utility Cooperative (KIUC), the Department of Business, Economic Development and Tourism (DBEDT), and The Gas Company, among others. Combining the data received from these parties, we determined that the highest areas of energy intensity among all building usage categories were concentrated in six specific sectors: (1) offices, (2) hospitality, (3) retail on the commercial side, (4) single family homes, (5) multifamily homes, and (6) high-rises on the residential side. It was therefore determined that, given resource and time constraints, any analysis of potential existing building efficiency savings must begin with these key sectors, which combine to total 62% of the electricity usage in the state overall (BAH 2009b).

Once the dominant energy users were identified, Booz Allen Hamilton evaluated existing state data to determine where best to supplement it with national building technologies and building operation studies. We identified a need for additional state data and worked with the HECO companies and KIUC to administer a limited appliance saturation survey for the Hawaii commercial sector (BAH 2009a). Aggregating these data by building type, we developed building profiles representing both "average" baseline buildings and "efficient" buildings based off of the most efficient currently available technologies.[1] Electricity savings by building type and end use were calculated as the difference in the electricity use between the building profiles. These savings estimates were then adjusted to include the full building stock for each of the six building types.

[1] The commercial baseline and efficiency building profiles include technologies for the following end uses: cooling, lighting, water heating, fans and motors, building controls, building envelope and computers. For the residential sector, we model cooling, lighting, water heating, building envelope refrigeration and other major appliances. Some combination of these applies to all building types. Full details of calculations and assumptions are available in Appendix I.

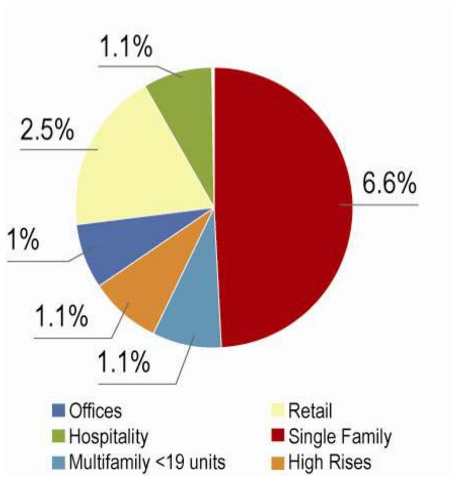


Figure ES-1. Electricity savings as a percent of 2007 Hawaii electricity usage = 13.5%

Ultimately, the study determines that the estimated potential savings from the six modeled building types (single family, multifamily below 20 units, high-rises above 20 units, offices, retail, and hospitality) are approximately 1,300 GWh/yr, or 13.5% of 2007 Hawaii electricity use (**Figure ES-1**). HECO projects annual energy use to increase to 14,300 GWh/yr by 2030, and the state energy efficiency target is 30% of this amount, or 4,300 GWh (HECO 2005). Since our model is limited to six building types and based on current energy use, we adjust our results to account for the entire building stock, the growth of existing building loads, and building stock turnover to 2030.

After these adjustments, we estimate that potential electricity savings from existing buildings in 2030 are between 2,100 GWh (15% of 2030 electricity use) and 3,100 GWh (22% of 2030 electricity use). These savings account for approximately half to three-fourths of the 30% state efficiency target.[2] Assuming a levelized cost of $83 per megawatt-hour (MWh) saved[3] (Rogers, Messenger, and Bender 2005), the estimated investment needed to attain required EEPS savings is approximately $4.1 billion by 2030, or $196 million per year. It is anticipated that the private sector will require incentives to make this investment, but the size of the incentives needed is not known at the present time.

---

[2] The exact value depends on the contribution of additional loads from existing buildings to electricity growth compared to that of new construction.

[3] Due to the extremely high levels of efficiency being targeted by the state, this figure represents a premium over the figure noted in the Rogers, Messenger, and Bender California program study. The first 10% of efficiency attained per building is assumed to cost $50 per MWh, with the per MWh price increasing incrementally as you approach what is technically achievable. This results in an average of $83 per MWh of efficiency for buildings attaining an average electricity use reduction of 25%.

Table ES-1. Top 5 Individual Efficiency Measure Savings

Building Type and End Use	GWh Savings Potential	% of 2007 Electricity Use[4]
Single Family Water Heating	250 GWh	2.5%
Single Family Lighting	194 GWh	2%
Retail Lighting	85 GWh	1%
Office Cooling	72 GWh	1%
Single Family Refrigeration	69 GWh	1%

Given the significant projected cost of attaining the EEPS target and constraints on the state efficiency budget, we anticipate that finding additional sources of private investment for efficiency efforts in the state will be critical to successfully meet the efficiency goals. Additionally, attaining the efficiency goals will require building retrofits on the order of magnitude of 80% of the current building stock in the state, as well as building retirements and new construction equal to approximately 20% of the current building stock. Enrollment in existing efficiency programs lags this 80% estimate by a substantial margin, with below 20% of the existing building stock currently engaged in the state efficiency programs. Therefore, outreach and education programs on the benefits of efficiency to building owners should be another key area of focus for the state to move forward.

[4] Due to the uncertain nature of how load growth and efficiency by category type will fluctuate, projections of what each efficiency measure savings will be as a fraction of 2030 energy usage is outlined here.

Table of Contents

List of Figures

List of Tables

Introduction

The Hawaii Energy Efficiency Portfolio Standard (EEPS) was enacted in bill HB 1464 of the 2009 Hawaii State Legislature (Hawaii 2009). This legislation mandates that by 2030 the state reduce its annual electricity consumption by 4,300 gigawatt-hours (GWh), or 30% of the Hawaiian Electric Company (HECO) forecasted "Business as Usual" 2030 energy consumption of 14,300 GWh/yr (HECO 2008, HELCO 2007, MECO 2007, KIUC 2008). Currently, the state is funding energy efficiency programs through a Public Benefits Fund (PBF) at a rate of approximately $20 million per year to the commercial and residential building sectors, or $21 million total including Kauai Island Utility Cooperative (KIUC) programs, which are administered separately from the PBF's (HCEI 2009, KIUC 2010). To inform future policy initiatives and funding, the Hawaii Clean Energy Initiative created a roadmap to determine how the state is to meet the 2030 EEPS target. For the purposes of this analysis, all savings achieved are assumed to be maintained until the target date of 2030, so that savings from initial investments do not depreciate over time. However, we fully acknowledge that significant operations and maintenance (O&M) and retro/recommissioning costs may accrue over time, and that efforts in this regard are essential to the success of attaining the EEPS.

The roadmap analysis was divided into two components: efficiency savings from new construction and energy savings from existing buildings. When the EEPS goal was set, the projected contribution in efficiency savings from each of these components was estimated to be 73% (3,150 GWh annually in 2030) from existing buildings and 27% (1,150 GWh annually in 2030) from new construction. The National Renewable Energy Laboratory (NREL) undertook new construction modeling, and this study represents Booz Allen Hamilton's (BAH's) analysis (with significant input from local stakeholders) of existing buildings.

Given the limited resources available to the Hawaii PBF and KIUC to devote to efficiency programming to meet the EEPS, a cost-effective distribution of resources that focuses on the building and technology types with the greatest potential electricity savings is essential. The purpose of this study is twofold: to identify the building types and current building technologies with the greatest opportunities for electricity savings, and to estimate potential electricity savings from all existing buildings in 2030. While past estimates of Hawaii efficiency potential exist, they are somewhat dated (HECO 1994, HECO 2004), and they were not conducted in the context of the EEPS. The ultimate goal of this study is to assist program managers in making informed decisions on the optimal building types and end use technologies on which to devote funds to maximize potential electricity savings.[5] See Appendix I for the full list of end use technologies evaluated.

Methodology

In designing our study, BAH followed a six-step process (**Figure 1**). Using data provided from the state's four electrical utilities, the Hawaii Department of Business, Economic Development and Tourism (DBEDT), and The Gas Company, we began by mapping electricity usage across the entire building stock, by building type (Step1). Next, given time and resource restrictions, we screened for the largest efficiency drivers and built electricity use profiles of "average" and "efficient" versions of these buildings and technology types (Steps 2 and 3). We compared these building models to estimate potential electricity savings (Step 4) and scaled up the savings to reflect the potential efficiency available from the entire building stock (Step 5). The goal of the analysis is to identify building types and efficiency measures that will be the primary drivers of electricity savings across the entire building stock and to compare them to the EEPS goal. Once the largest impact areas of focus were identified, we highlighted secondary areas of focus and any behavioral changes that may be necessary to facilitate energy savings to ensure a holistic approach to forecasting potential savings (Step 6).

[5] It is essential to note that, unlike previous Hawaii efficiency studies, cost-effectiveness is **not** emphasized as an essential component of this building technology analysis. Instead, the emphasis is on attainment of the EEPS goal and estimating the amount of funding needed to attain the required level of savings. A quantitative cost-effectiveness screen is not applied because the basis of this study is to identify the building and technology types required to reach the 30% target. While we acknowledge that not all measures necessary to attain the target may currently be cost effective and that omitting these measures would leave the state well short of the necessary goal, we also realize that cost-effectiveness for individual measures varies especially widely on a per-building basis for *existing building* retrofits. Therefore, we do not want to rule out technology types that may end up being cost effective in certain situations. Furthermore, given the long duration of the study period, we expect cost-effectiveness to change over time for various measures. Developing long-term technology cost curves was deemed outside of the scope of this study in its original conception.

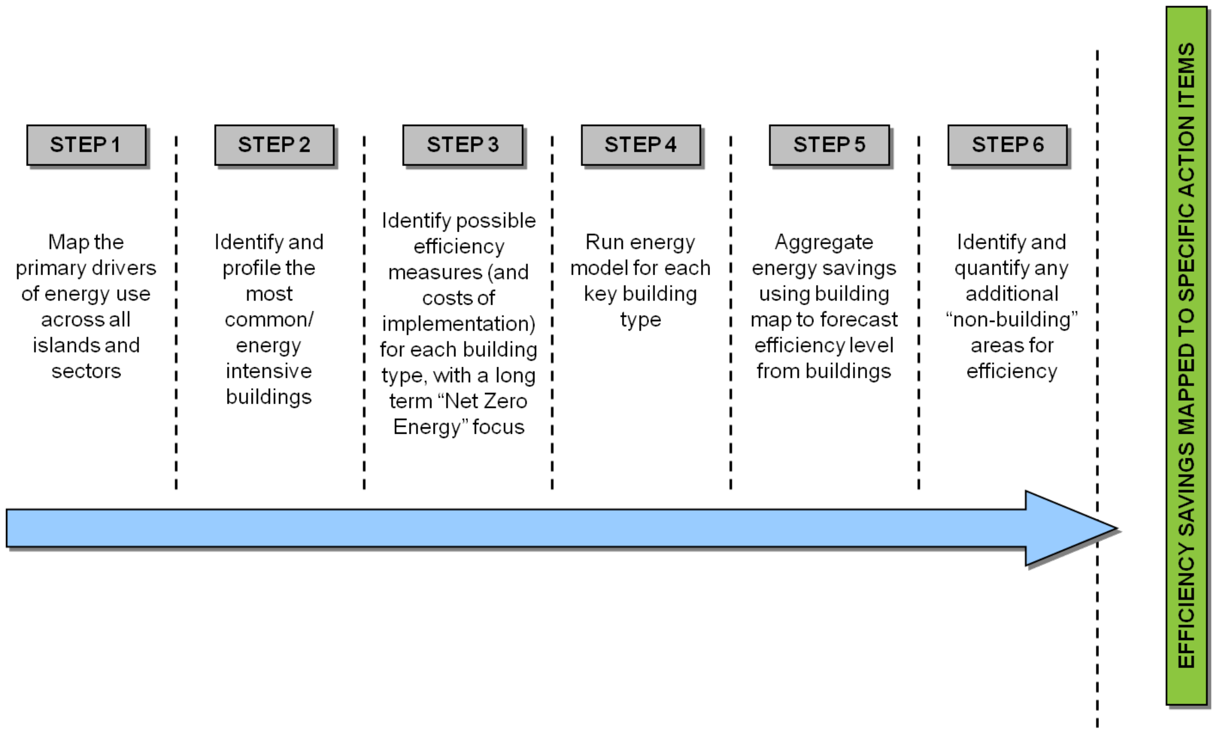


Figure 1. Analysis methodology

Steps 2, 3, and 4 require estimating energy savings potential for selected building types, end use technologies, and efficiency measures. We assembled models of individual buildings for two scenarios: a baseline building and an efficient building. For the commercial sector, we overcame limits on the availability of data by aggregating older, Hawaii-specific building efficiency studies with newer Hawaii building survey data and, where necessary, more recent non-Hawaii data. Assuming that equipment efficiencies, sizes, and saturations are normally distributed across the existing building stock, we used older data as representative of the left side of the efficiency curve and more recent data as representative of the right side of the curve. Thus, the average of these data represents our best estimate of the average building in the existing stock (**Figure 2**). For commercial buildings, we assumed that values from the 1994 HECO Commercial Energy-Use Survey (HECO 1994) and the HECO 2004 Integrated Resource Plan-3 Demand-Side Management Report (HECO 2004) represent the least efficient buildings, or the left side of the building stock efficiency curve. To construct an estimate of the most efficient end of the commercial building efficiency curve, Booz Allen teamed with HECO and KIUC to administer a limited appliance saturation survey (BAH 2009a), which supplied the team with data on the high-performing customers currently enrolled in HECO and KIUC's building efficiency programs.

For residential buildings, appliance sizes and unit energy consumptions were derived from the 2008 HECO Residential Appliance Survey (HECO 2009b). These values were not averaged, since the 2008 appliance survey represents a more recent distribution of equipment in the current building stock, but they were compared to the HECO 2004 residential building profiles (HECO 2004) and the 2005 KIUC energy efficiency study (KEMA 2005) for consistency.

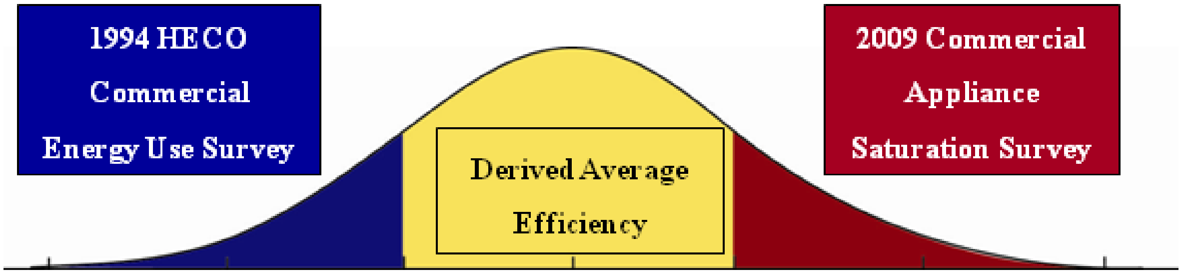


Figure 2. Hawaii commercial existing building efficiency curve and building profile methodology summary

- The area under the left side of the curve represents the saturation and energy usage of technologies for the most inefficient buildings in the state.
- The area under the right side of the curve represents the saturation and energy usage of technologies for the most efficient buildings in the state.
- The goal is to capture the most prevalent and efficient of the full range of technologies in the current building stock by averaging the most and least efficient technology saturations and energy usages for each individual technology type within a given building class.

Once baseline models were built for each building type, efficient building profiles were constructed to calculate electricity savings potential by technology and building type. Values for electricity savings by efficiency measure were taken from a combination of Federal Energy Management Program (FEMP) equipment requirements (FEMP 2010), the 2005 KIUC efficiency study (KEMA 2005), the 2008 study on water heater demand-side programs (KEMA 2008), and the 2004 HECO IRP-3 modeling results (HECO 2004). The calculations and values for each individual baseline and efficient building model (including values for end use efficiencies, sizes, saturations, and efficiency measure savings) are detailed in Appendix I.

To avoid overreliance on future technology development in our forecast, we excluded technologies that are not yet commercially viable from the initial building models. However, given that some future technology adoption is likely, we examined potential savings from second-generation technologies, such as seawater air-conditioning (SWAC) and Light-emitting diodes (LEDs), as an addendum to the initial analysis, to project the possible impact of future technologies.

Once the per-building efficiency potential was calculated by building type, we scaled up from individual buildings to the entire existing building stock by multiplying electricity savings by the number of buildings for each building type. The number of buildings for each building type is calculated by dividing the total 2007 electricity use per building type (BAH 2009) by electricity use per baseline building profile developed in this analysis. To correct for building retirement, the model assumes a 1% per year building retirement rate (equivalent to that assumed by the

EEPS[6]). As values for energy use are available by island, we also calculated aggregate savings by island and building type.

Next, as the modeled building sectors represent only 62% of the electricity used by the existing building stock, we scaled up the aggregated results to estimate the potential efficiency savings available from the entire existing building stock. We assumed that the modeled buildings are representative of the entire building stock and that energy savings will be available at the same rate for the entire excluded building stock. The largest portion of the remaining 38% of the building stock electricity use consists of military residential and office buildings (12% of 2007 electricity use), which is largely similar to the sectors included in this analysis. While we realize that there may be some deviation in savings across the remaining 26%, we believe that the six sectors evaluated in this report, plus the military sector, strongly correlate with the end results. While building-specific differences may alter the end numbers slightly, we do not believe the differences are significant to directionally alter the outcomes of this study.

Finally, we adjusted for existing building load growth from 2010 to 2030. As technology saturations change into the future (i.e., more buildings have cooling equipment) and some technologies become more energy intensive (e.g., some television models and added entertainment systems), the efficiency savings potential from existing buildings will increase. Because it is difficult to accurately estimate the increase in existing building load growth from the expected growth in overall energy usage, we estimated a range of potential savings (and potential contribution to the EEPS goal) in 2030 **(Figure 3)**. The lower bound of the range represents zero existing building load growth and the upper bound of the range represents electrical load growth at a ratio of 30% from new construction and 70% from existing buildings.[7]

[6] Based on 2000 U.S Census building age data, average lifespan of a building in the United States is 70 years; over 20 years approximately two-sevenths of the building stock would turn over, or ~1% per year, [CENSUS 2000a].

[7] Based on historical population growth figures (DBEDT 2008b), utility IRP forecasted energy demand (HECO 2008, KIUC 2008, MECO 2007, HELCO 2007), and BAH-estimated building energy usage (Appendix I)

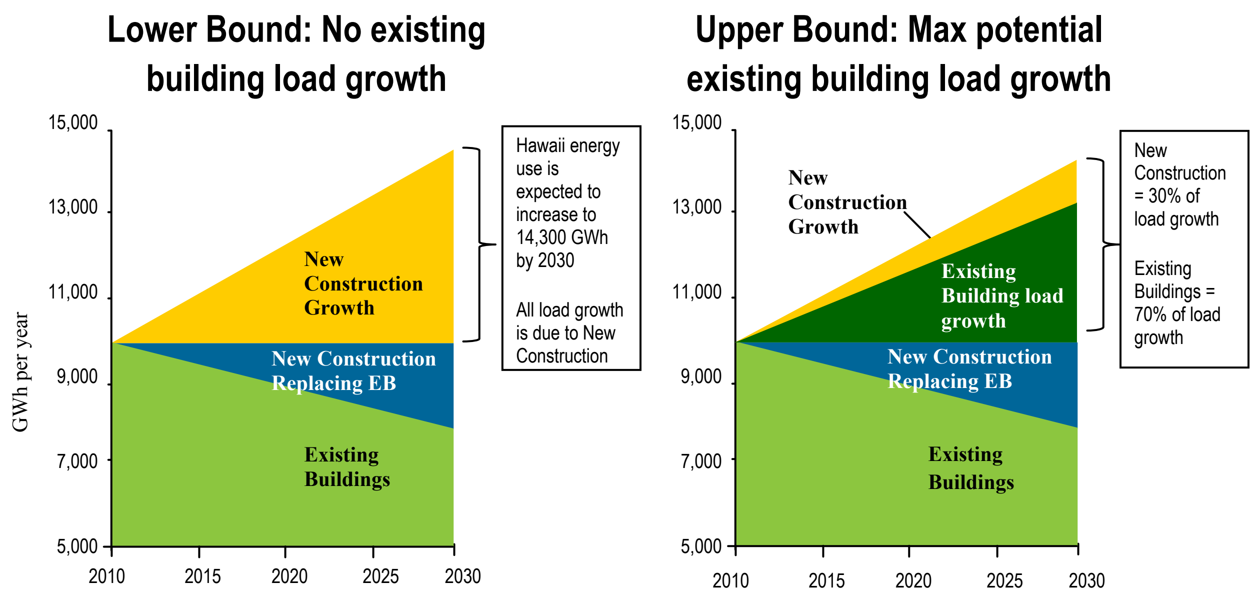


Figure 3. Hawaii 2030 load growth scenarios

Results

Based on 2007 Electricity Usage Levels

Figure 4 represents all of the electricity usage drawn from the Hawaii grid in 2007 (post-line loss). The residential sector comprises roughly 32% of this electricity use and includes single family housing, multifamily housing (less than 20 units) and high-rises (20 or more units). The remaining 68% is consumed by twelve commercial sector uses. The aggregate mapping results show that Hawaii electricity use in 2007 was approximately 9,900 GWh/yr and is forecast to grow up to roughly 14,300 GWh/yr by 2030 (BAH 2009b; HECO 2008, MECO 2007, HELCO 2007, KIUC 2008).[8]

[8] This 14,300 GWh figure reflects demand forecasts in the HECO IRP-4 and the HELCO, MECO, and KIUC IRP-3s to set a baseline for the 2010–2030 time frame. It does not make allowances for the potential increasing adoption of plug-in hybrid vehicles moving forward. Increased use of plug-in vehicles may elevate demand for both home and business electricity usage, as the vast majority of vehicle charging will take place at these locations. This did not impact our forecasts in this analysis, as the goal of 4,300 GWh was set independent of forecasts for PHEV demand, and no assumed efficiency gains were forecast to come from electric vehicle efficiency improvements over the 2010–2030 time frame.

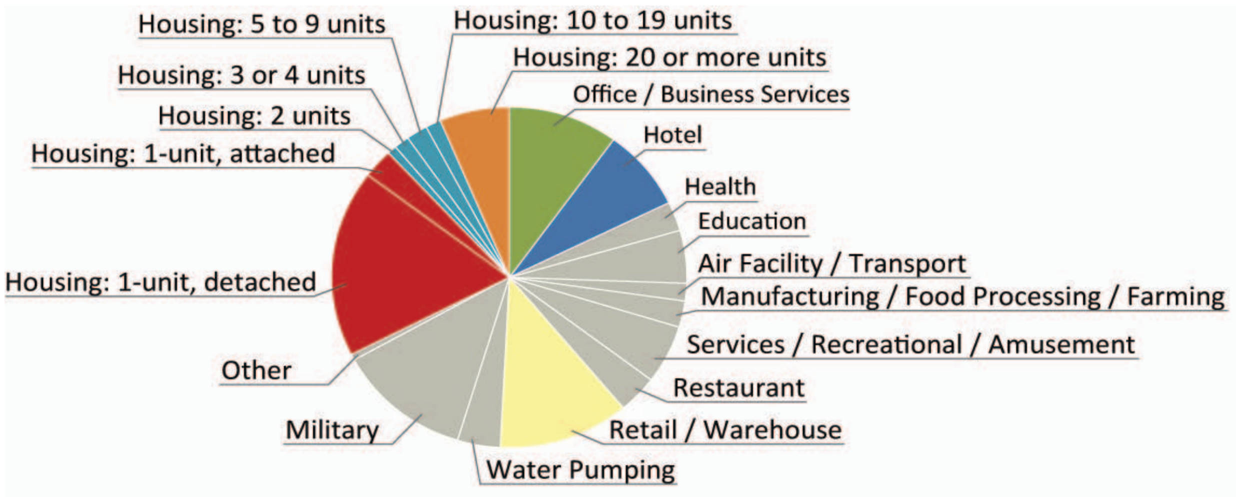


Figure 4. 2007 Electricity use in the state of Hawaii (MWh)

Based on the various magnitudes of energy usage indicated by the mapping effort, BAH selected the six highlighted building types that, combined, use 62% of Hawaii's electricity profile (**Figure 4**).[9] For this analysis, the military sector, although large, was excluded from our detailed review, as it is not under state jurisdiction. All sectors were not evaluated due to time and budgetary constraints, but given the significant footprint of the selected sectors in combination with that of the military, Booz Allen, in consultation with the stakeholders, determined that they represented a reasonable proxy for the entire Hawaii building stock and should be considered first.

Similar to screening for large building types, we limited our analysis to large energy usage drivers within each building type. Cooling, lighting, water heating, fans and motors, building controls, building envelope and computers were modeled for commercial buildings. Cooling, lighting, water heating, building envelope, refrigeration and other major appliances were modeled for residential buildings.

[9] By sector: single family homes (attached + detached): 2.0 million MWh, or 20.5%; multifamily homes (less than 20 units): 5.5 million MWh, or 5.6%; high-rise: 6 million MWh, or 6.1%; retail: 1.2 million MWh, or 12.1%; office: 1 million MWh, or 10.1%; hospitality: 7.6 million, or 7.7%

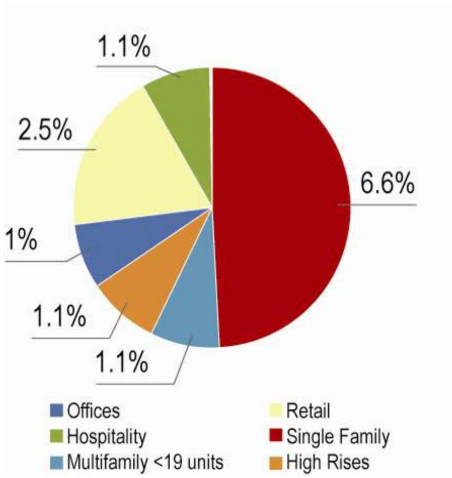


Figure 5. Electricity savings as a percent of 2007 Hawaii electricity usage = 13.5%

Should the advised retrofits be adopted across 80% of Hawaii single family, multifamily, office, retail and hospitality existing buildings, the aggregate savings potential is approximately 1,300 GWh, or 13.5% of the total 2007 Hawaii electricity use. By building type (See **Figure 5**), single family homes represent the largest amount of savings potential at 6.6% of 2007 electricity use. The remaining potential savings is represented by retail (2.5% of 2007 electricity use), high-rises (1.2%), the hospitality sector (1.1%), multifamily homes (1.1%), and offices (1%).

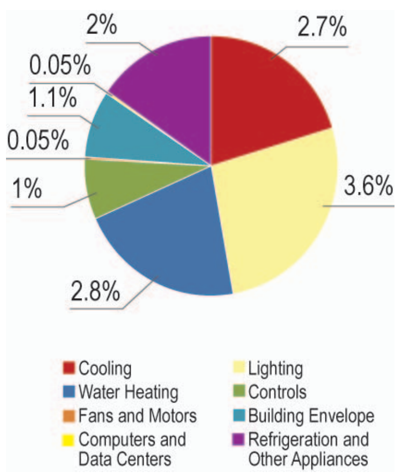


Figure 6. Electricity savings by end use as a percent of 2007 Hawaii electricity usage

By end use (**Figure 6**), lighting is the technology with the greatest energy savings potential, at 3.6% of 2007 electricity use. The remaining potential savings is represented by water heating (2.8% of 2007 electricity use); cooling (2.7%); appliances, including refrigeration (2.1%); building envelope improvements (1.1%); lighting and building temperature controls (1%); fans and motors (0.05%); and computers and data centers (0.05%).

By island (**Figure 7**), Oahu has the greatest potential for savings over 2007 electricity use at 9%, followed by Hawaii (1.9%), Maui (1.8%) , and Kauai (0.8%).

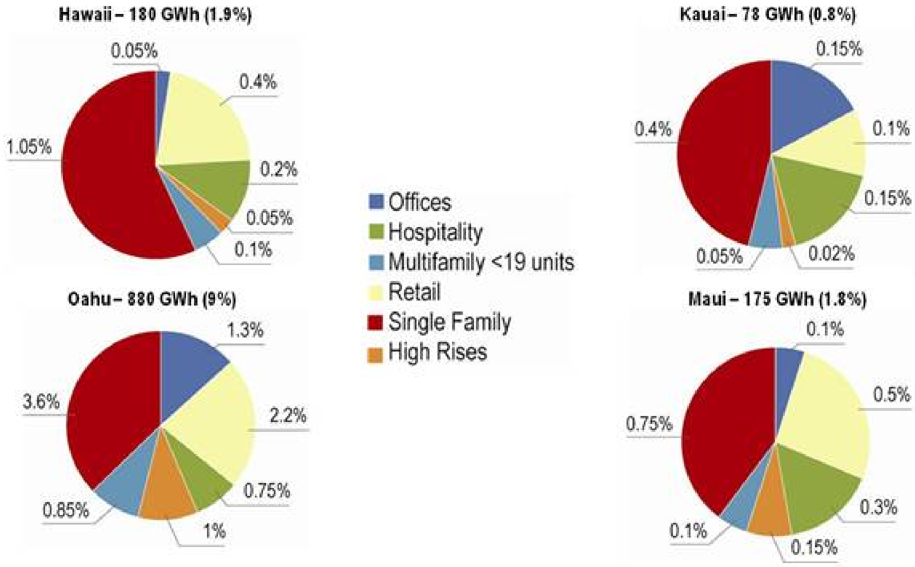


Figure 7. Electricity savings by island as a percent of 2007 Hawaii electricity use

Results are also tabulated on a per-building basis for each model building type (Figure 8–Figure 14). For the residential sector, the average high-rise can save 23% of total energy use, the average single family home can save 38%, and the average multifamily home can save 24%. In the commercial sector, large offices can save 12%, small offices can save 20%, retail buildings can save 26%, and hospitality buildings can save 18%.

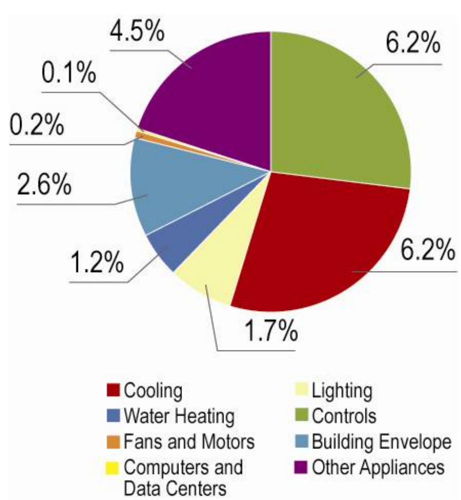


Figure 8. High-rise profile savings

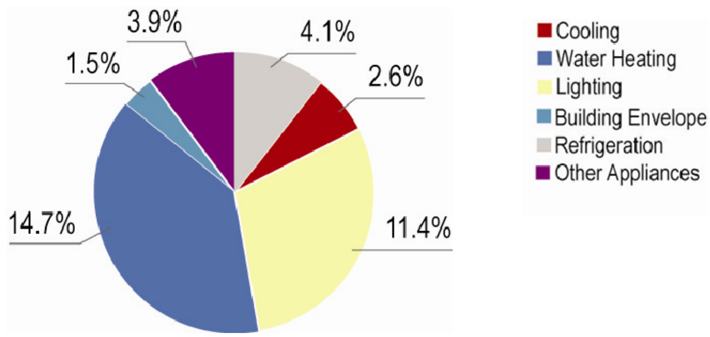


Figure 9. Single family profile savings

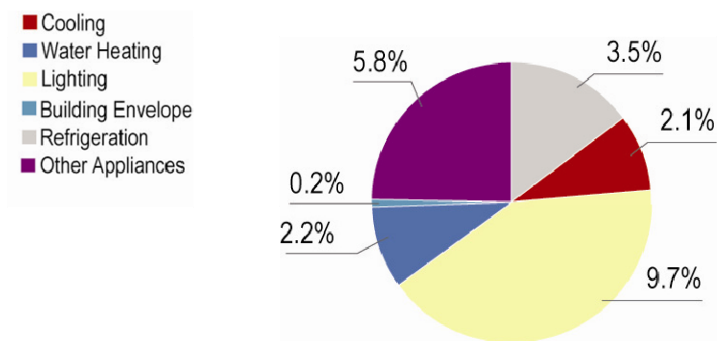


Figure 10. Multifamily profile savings

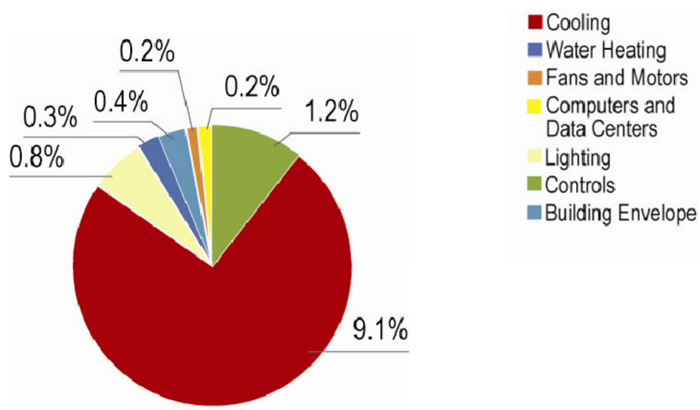


Figure 11. Large office profile savings

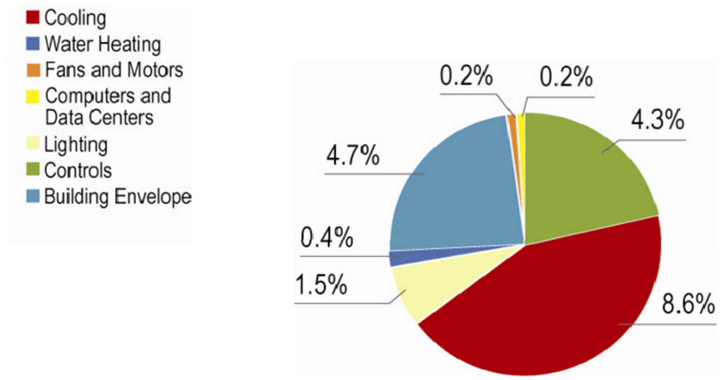


Figure 12.Small office profile savings

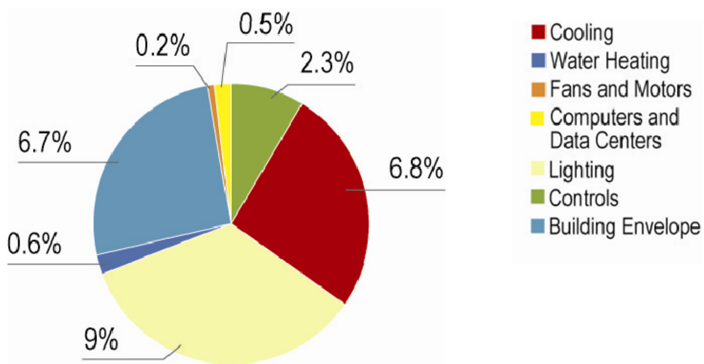


Figure 13. Retail profile savings

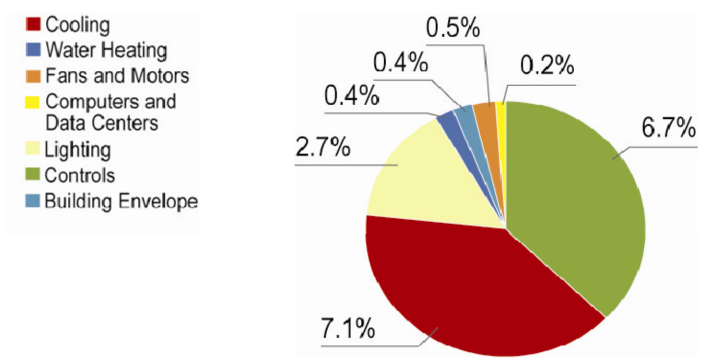


Figure 14. Hospitality profile savings

Combining building types and end-use technologies (See **Table 1**), single family water heating presents the greatest opportunity for efficiency improvements, with a potential savings of 250 GWh.

Table 1. Top 5 Individual Efficiency Measure Savings

Building Type and End Use	GWh Savings Potential	% of 2007 Electricity Use[10]
Single Family Water Heating	250 GWh	2.5%
Single Family Lighting	194 GWh	2%
Retail Lighting	85 GWh	1%
Office Cooling	72 GWh	1%
Single Family Refrigeration	69 GWh	1%

Other primary electricity efficiency drivers are single family lighting (194 GWh), retail lighting (85 GWh), office cooling (72 GWh), and single family refrigeration (69 GWh). A full list of aggregate efficiency savings by building type and end use is available in Appendix I.

Finally, once the potential electricity savings from these six building type is calculated, we adjusted to incorporate those buildings in the additional 38% of the building stock not accounted for in these six categories. Taking the average savings across all six building types (22% electricity savings per building) and applying it to the energy usage for the remaining building types results in an additional potential savings of 800 GWh, bringing the potential savings for the entire existing building stock up to 2,100 GWh overall, or roughly 22% of Hawaii 2007 electricity use.

Results Adjusted for Load Growth (2008–2030)

It is important to note that the EEPS is 30% of Hawaii electricity use in 2030, so to make a true longer-term projection, we must compare potential savings to the projected energy use in our end scenario, the year 2030, as opposed to the static 2007 electricity use context provided in the preceding section. The projected *annual* increase in electricity usage above 2007 levels in the year 2030 is 4,500 GWh,[11] including increased usage from both new construction and existing buildings (the energy intensity of an average building is forecast to increase over time with the adoption of more extensive air-conditioning units and more energy-intensive appliances).

[10] Due to the uncertain nature of how load growth and efficiency by category type will fluctuate, projections of what each efficiency measure savings will be as a fraction of 2030 energy usage is outlined here.

[11] Projected growth is calculated by subtracting 14,333 GWh (HECO 2005) minus 9,859 GWh (BAH 2009b; HECO 2005).

Since a detailed breakdown of these components of expected growth is not available, we have determined instead a likely range for potential electricity savings relative to projected 2030 electricity use, based on "minimum growth in existing buildings electricity demand" (Lower Bound) and "maximum potential growth in existing buildings electricity demand" (Upper Bound) scenarios (Also illustrated in **Figure 3**):

- Lower Bound: If there is no growth in existing building load, potential savings will not grow over time, capping the existing buildings portion of the final savings figure at 2,100 GWh (15% of 2030 electricity use), or approximately 50% of the 4,300 GWh EEPS goal.
- Upper Bound: If new construction grows to match historical population growth fully (0.7% per year [DBEDT 2008b]), equivalent to 30% of all new energy usage coming from new construction (based on utility 2007–2008 IRPs and BAH-estimated per-building energy usage [Appendix I]), but the entire remaining electricity growth forecast comes from existing buildings, potential existing building savings will equal 3,100 GWh, or 22% of 2030 Hawaii electricity use, maintaining existing buildings' approximate 70% share of the state EEPS goal.

This 50%–70% range for the existing buildings' contribution to the efficiency goal indicates that the targeted 70% contribution, estimated when the EEPS was enacted (Hawaii 2009), is a possibility (albeit a lower probability contingent on the balance of load growth between new construction and existing buildings moving forward).

Despite the variability in expected savings from existing building load growth, these added savings are not expected to change the modeling results of the primary building types on which policy should be focused. Cooling savings will likely increase with increased cooling equipment saturation, but cooling is already at the top of the list for efficiency savings potential. Any assumption about appliance growth, particularly the increase in home entertainment equipment saturation, is difficult to accurately include in the model. This added growth is not likely to be significant enough to become a primary efficiency driver, as the average entertainment equipment electricity consumption reflects a small percentage of Hawaii electricity use. For example, a plasma television is the most energy-intensive home entertainment appliance, using 441 kilowatt-hours (kWh) per year on average. This end use is only roughly 5% of the electricity use of an average single family building.

Conclusions

Once we established the level of savings needed, a general cost analysis was conducted, and conclusions were drawn on a number of key points essential to the attainment of the state goals. To be implemented effectively, the following recommendations rely heavily on collaboration between the public sector (state agencies, the PBF administrator) and the private sector (utility companies, private businesses, building owners) across a wide range of issues, including the identification and testing of technologies, the raising and investment of capital, the education of the public, and the refinement of existing programs.

- *Additional investment, on the order of $50 million to $100 million per year, is necessary to meet the Hawaii EEPS targets.*

  Private investment in energy efficiency is critical to Hawaii's meeting its efficiency target, and it is apparent that much will be necessary above and beyond what is already provided by the public sector via utility programs and contributions to the state's PBF. Based on a levelized cost of energy efficiency of $83 per megawatt-hour (MWh) (Rogers, Messenger, and Bender 2005) and linear projections from 2010 to 2030, the total cost to meet the EEPS target (regardless of source) would be $4.1 billion, or $196 million per year. Assuming existing building efficiency savings will contribute 50-70% to the EEPS target (See "Results Adjusted for Load Growth" section for the calculation of this range), then the funding needed for existing buildings would be $98 million to $137million per year ($196 × 50%70%). Currently, KIUC annual program funding is $1 million (KIUC 2010), and the Hawaii PBF funding for efficiency savings is roughly $20 million per year (HCEI 2009).[12] Additionally, according to our analysis, the military accounts for 12% of Hawaii electricity use. Assuming the military matches the 30% efficiency goal with its own pool of funding separate from that of the state as a whole, we assume that the costs for those improvements can be subtracted from the total costs to achieve the EEPS (12% × $196 million = $24 million). Thus, total additional investment (either private or public) needed to meet the existing building portion of the state's efficiency goal would be in the $53 million to $92 million range per year ($98 million to $137 million minus $45 million.) Given the ratio of existing building energy use between the residential and commercial sectors,[13] the residential sector will need an additional $24 million to $41 million per year ($53 million to $92 million × 45%), and the commercial sector will need an additional $29 million to $51 million per year ($53 million to $92 million × 55%), with much of this being contributed by the private sector. Thus, finding ways for public money to leverage high levels of private capital becomes essential to the attainment of the EEPS goal.

---

[12] $19.6 million per year is equivalent to roughly 0.6% of the total expected revenues for HECO, HELCO, and MECO. As revenue is expected to increase over time, PBF funds generated will increase to a predicted $60 million per year by 2014 (HCEI 2009).

[13] As the cost for energy efficiency retrofits is estimated based on "percentage improvement reached" (see footnote 2 in Executive Summary for overview), the $83/MWh cost assumed in this study reflects an average of commercial and residential retrofit projects. Therefore, we do not make a differentiation in cost between the two sectors here.

- *Given our assumption of cumulative 20% building turnover from 2010 to 2030, successfully identifying and retiring these buildings to maximize cost effectiveness would allow Hawaii to optimize efficiency gains.*

  The model assumes a 1% rate of building turnover per year and a total building turnover rate of 20% of the existing building stock by 2030. To maximize the amount of electricity savings from retrofits, the least viable candidates for retrofit must be identified and targeted for replacement with more efficient new buildings, while retrofit efforts are targeted at the buildings that are capable of being cost-effectively retrofitted. This is due to the fact that most buildings in the lower 20% of the energy efficiency curve are too costly to retrofit, so if they are not replaced, they will continue to act as a drag on the state's energy reduction efforts. Therefore, those buildings that can be retrofitted cost effectively should be upgraded, while those that will never be cost effective to retrofit should be replaced entirely. This will generate the maximum efficiency savings from both existing buildings (more retrofits will happen), as well as from new construction (highly efficient new construction replaces the worst of the energy users).

- *Full participation in retrofit and efficiency programs is essential to meeting the EEPS target.*

  Given the 20% overall building retirement assumption, an estimated 80% of Hawaii's buildings must participate in efficiency efforts for the state to meet the EEPS target. It was assumed that 20% of building owners enroll voluntarily in retrofit programs, which is a large portion of the overall population to enroll in any single public program. This leaves 60% of the building stock currently unaccounted for. Given policy initiatives that correctly target building and technology areas, additional outreach and education must be designed to achieve the retrofitting of as much of this 60% of the building stock as possible. It is also quite likely that our hypothetical 20% assumption is too optimistic, which would make the importance of outreach and education programming even greater.

- *Advanced technologies, not yet deployable, must play a role in creating efficiency savings to offset shortfalls in savings from non-cost-effective current technology.*

  An important caveat to our calculation of available savings is that some of the energy efficiency measures that are considered will not prove cost effective for all buildings types.[14] For example, building envelope retrofits to insulation are an expensive energy efficiency measure, and unlikely to be adopted in many cases, even when applicable. Where possible, Hawaii should seek to increase per building efficiency savings through the use of next-generation technologies. One possibility is LED lighting. If all

[14] The purpose of this study is to identify technologies that will be required to meet the 30% EEPS goal. To chart these technologies, we make the initial assumption that not all of them will be cost effective. Deployment of technologies that are not yet commercially viable can help offset these costs.

incandescent and CFL lighting is replaced with LED lighting, the modeled existing buildings could obtain an additional 134 GWh of savings (DOE 2010), or about 1.4% of 2007 state electricity use. SWAC is another example of a technology option under development. HECO estimates that a proposed Waikiki SWAC site could offset 140,000 MWh of cooling energy, equal to another 1.4% of 2007 electricity use (HECO 2010). As such, the development of pilot programs for new technologies to identify promising ones and to verify their performance becomes of key importance to the long-term attainment of any lofty efficiency goal such as the one in the EEPS.

- *In order to increase the effectiveness of efficiency policy, retro/recommissioning and O&M training should be incorporated into technology policy.*

  Efficiency savings estimates are based on manufacturer data and may not represent real-time results because of improper installation, calibration, and maintenance. Proper building commissioning and O&M are essential to achieving the full savings potential of retrofits, as building operators may be unfamiliar with new technologies. The proper operation of building controls, particularly, should be a focus of this type of policy because this equipment can have a large impact on building energy use for minimal cost as long as it is installed and operated correctly. A recent Lawrence Berkeley National Laboratory metadata study estimates average electricity savings of approximately 9% from the commissioning/retrocommissioning of a wide range of building types (Mills and Mathew 2009). Thus, the building commissioning will be a significant source of ongoing savings that is essential to the real-time reduction of electricity usage statewide.

References

[ACEEE] American Council for an Energy-Efficient Economy. (2010). "Consumer Guide to Home Energy Savings: Condensed Online Version; Water Heating." Accessed April 2010. http://www.aceee.org/consumerguide/waterheating.htm.

[BAH] Booz Allen Hamilton. (2009a). "Commercial Efficiency Survey." Booz Allen Hamilton, HECO companies and KIUC. October 2009.

BAH. (2009b). "Hawaii Building Stock Mapping and the Way Forward." *Booz Allen Hamilton*. April 22, 2009.

[Census 2000a] U.S. Census Bureau. Census 2000 Summary File 3, Matrix H34. Accessed April 2010. http://factfinder.census.gov/servlet/DTSubjectShowTablesServlet?_lang=en&_ts=290530765812.

[Census 2000b] U.S. Census Bureau. Census 2000 Summary File 3, Matrices P3, P4, H3, H4. Accessed April 2010. http://factfinder.census.gov/servlet/DTSubjectShowTablesServlet?_lang=en&_ts=290530765812.

[DBEDT] State of Hawaii Department of Business, Economic Development & Tourism. (2008a). "Annual Visitor Research Report - 2008." Accessed February 2010. http://hawaii.gov/dbedt/info/visitor-stats/visitor-research/.

DBEDT. (2008b). State of Hawaii Databook. Accessed May, 2010. http://hawaii.gov/dbedt/info/economic/databook/db2008/.

[DOE] U.S. Department of Energy. (2010). "DOE to Award Nearly $37 Million to 17 Solid-State Lighting Projects." U.S. Department of Energy Energy Efficiency & Renewable Energy. *EERE Network News*. January 20, 2010.

[ESH] *EnergySmart Hospitals Training Manual*. (2008). "Energy Management Training Session Two: Energy Efficient Opportunities for Hospitals." U.S. Department of Energy Energy Efficiency and Renewable Energy. March 4, 2008.

[FEMP] Federal Energy Management Program. (2010). "Purchasing Specifications for Energy-Efficient Products." U.S. Department of Energy, Energy Efficiency & Renewable Energy, Federal Energy Management Program. Accessed February 2010. http://www1.eere.energy.gov/femp/technologies/eep_purchasingspecs.html.

[EPA] U.S. Environmental Protection Agency. 2004. "Reducing Urban Heat Islands: Compendium of Strategies; Cool Roofs." Accessed February 2010. http://www.epa.gov/hiri/mitigation/coolroofs.htm.

Hawaii. (2009). "House Bill 1464 of the 2009 Legislative Session." Hawaii House of Representatives. Accessed November 2009. http://www.capitol.hawaii.gov/session2009/Bills/HB1464_SD2_.HTM.

[HCEI] Hawaii Clean Energy Initiative. (2009). "Hawaii Clean Energy Initiative Working Group Policy Recommendations for the 2010 Hawaii State Legislative Session." Accessed March 2010. http://www.hawaiicleanenergyinitiative.org/pdfs/policy_report_ly2010_part2.pdf, p.19.

[HECO] Hawaiian Electric Company. (1994). "1994 Commercial Energy-Use Survey." Prepared for HECO by Regional Economic Research, Inc. August 1995.

HECO. (2004). "Integrated Resource Plan – 3, Appendix L: Demand-Side Management Report, Assessment of Energy Efficiency and Demand Response Potential." Prepared for HECO by Global Energy Partners, LLC. Product ID # 1125-01. February 2004. Accessed May 2010 http//www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=d1ee5e658e0fc010VgnVCM1000008119fea9RCRD&vgnextfmt=default&cpsextcurrchannel=1.

HECO. (2008). "Integrated Resource Plan – 4."Accessed February 2010. http://heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=d1ee5e658e0fc010VgnVCM1000008119fea9RCRD&vgnextfmt=default&cpsextcurrchannel=1.

HECO. (2009a). "2008 Appliance Age Distributions." Personal Communication – George Willoughby. November, 24 2009.

HECO. (2009b). "UEC and Saturations Summary." Personal Communication – George Willoughby. Based on 2006 CDA, 2004 RASS data and 2008 RASS. October 29, 2009.

HECO. (2010). "Seawater Air Conditioning." Accessed February 2010. http://www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=a7eb202fe559b110VgnVCM1000005c011bacRCRD&vgnextchannel=deeaf2b154da9010VgnVCM10000053011bacRCRD&vgnextfmt=default%26amp%3Bamp%3Bamp%3Bamp%3Bamp%3Bamp%3Bamp%3Bamp%3Bquot%3B&vgnextrefresh=1&level=0&ct=article.

[HELCO] Hawaii Electric Light Company. (2007). "Integrated Resource Plan – 3." Accessed February 2010. http://www.heco.com/portal/site/helco/menuitem.b136fe8120a5c28884276c10c510b1ca/?vgnextoid=b41d9a796a4e2110VgnVCM1000005c011bacRCRD&vgnextfmt=default&cpsextcurrchannel=1

[KEMA] KEMA, Inc. (2005). "Energy Efficiency Potential Study." Prepared for Kauai Island Utility Cooperative. April 26, 2005.

KEMA. (2008). "Energy and Peak Demand Impact Evaluation Report of the 2005-2007 Demand Side Management Programs." Prepared for Hawaiian Electric Company, Maui Electric Company, and Hawaii Electric Light Company. December 2008.

[KIUC] Kauai Island Utility Cooperative. (2010). "Personal Communication to Patrick Finch at Booz Allen Hamilton." February 2010.

KIUC. (2008)."Integrated Resource Plan – 3." Accessed February 2010. http://www.kiuc.coop/IRP/Tariff/IRP2008_2008%20KIUC%20IRP.PDF.

[MECO] Maui Electric Company. (2007). "Integrated Resource Plan – 3." Accessed February 2010. http://heco.com/portal/site/meco/menuitem.ed4aed221358a44973b5c410c510b1ca/?vgnextoid=eb282e1f9d380110VgnVCM1000005c011bacRCRD&vgnextfmt=default&cpsextcurrchannel=1.

Mills, E.; Mathew, P. (2009). "Monitoring-Based Commissioning: Benchmarking Analysis of 24 UC/CSU/IOU Projects." Lawrence Berkeley National Laboratory. June 2009. Accessed April 2010. http://cx.lbl.gov/MBCx.html.

[RMI] Rocky Mountain Institute. (2008). "Systems Thinking for Radically Efficient and Profitable Data Centers." Newman, S., Palmintier, B. http://www.rmi.org/rmi/Library/E08-06_SystemsThinkingDataCenters.

Rogers, C., Messenger, M., Bender, S. (2005). "Funding and Savings for Energy Efficiency Programs for Program Years 2000 Through 2004." California Energy Commission. July 2005. Accessed February 2010. http://www.fypower.org/pdf/CEC%20_Trends2000-04.pdf.

Wigg, Howard. DBEDT Institutional Energy Analyst. (2009). E-mail Correspondence with Patrick Finch. December 30, 2009.

Appendix I: Study Assumptions and Calculations

The full list of aggregated potential energy savings by sector and end use is included in **Table 2** (below).

Table 2. Total Aggregate Savings by Building Type and Technology (State-wide)

	Potential Electricity Savings (GWh/year)
Offices	
Refrigeration	Did Not Estimate
Cooling	72
Lighting	6
Water Heating	3
Controls	10
Fans and Motors	1
Building Envelope	4
Appliances	Did Not Estimate
Computers and Data Centers	1
Retail	
Refrigeration	Did Not Estimate
Cooling	64
Lighting	85
Water Heating	5
Controls	22
Fans and Motors	2
Building Envelope	63
Appliances	Did Not Estimate
Computers and Data Centers	4
Hospitality	
Refrigeration	Did Not Estimate
Cooling	43
Lighting	17
Water Heating	3
Controls	41
Fans and Motors	3
Building Envelope	3
Appliances	Did Not Estimate
Computers and Data Centers	1
High-Rises	
Refrigeration	22
Cooling	31
Lighting	8
Water Heating	6
Controls	31
Fans and Motors	1
Building Envelope	13

Appliances	33
Computers and Data Centers	1
Single Family	
Refrigeration	70
Cooling	46
Lighting	194
Water Heating	250
Controls	Did Not Estimate
Fans and Motors	Did Not Estimate
Building Envelope	18
Appliances	66
Computers and Data Centers	Did Not Estimate
Multifamily	
Refrigeration	15
Cooling	9
Lighting	43
Water Heating	10
Controls	Did Not Estimate
Fans and Motors	Did Not Estimate
Building Envelope	0
Appliances	25
Computers and Data Centers	Did not estimate

These figures represent the difference in energy usage from the efficient case to the baseline case for each building type, aggregated across the full number of buildings in each category for the state.

While the total number of housing units in the state is known, due to a lack of detailed information on the number of commercial buildings, the total number of commercial buildings assumed for each category is back-calculated from their total electricity usage. Thus, our model profiles may represent in certain commercial building cases an average building that is the equivalent of multiple smaller buildings, all with the same baseline characteristics and efficiency options. While this represents an accurate picture of statewide potential savings, as we account for the full electricity usage in each sector, it may mean that for certain building types we are assuming a smaller number of buildings than exist in the current building stock. This correspondingly reduces the number of retrofits needed but is compensated for by an increase in the size of each individual retrofit in absolute terms (although not in percentages). An example: three small buildings retrofitted at a 20% savings level, if added together, form the equivalent one larger building retrofitted at a 20% savings level, provided the same combination of energy conservation measures is applied to each. Therefore, the accuracy of the total energy savings is not compromised, but it would not be correct to assume energy savings per building applies to any one given building in the state of Hawaii on the commercial side.

Commercial Sector Modeling

In many of our data sources, high-rise (multifamily, 20 units or greater) building profiles are grouped into the commercial sector. Therefore, a majority of the high-rise data points used in this study are estimated using the methodology for the commercial sector (i.e., averaging data collected in the 2009 building survey [BAH 2009a] with the 1994 HECO study [HECO 1994]). However, as high-rise buildings share more key components with residential buildings than with their commercial counterparts in terms of appliance saturation and mix, we have classified them as residential overall, and aggregated them using residential data in the post-profile modeling stage of this analysis.

On the office building side of things, one of our major data points, the 2004 HECO DSM study, contains data for large and small offices. With this to build upon, we have developed subbuilding profiles for large and small offices within the "Office" category, but to maintain continuity with our building stock map (Figure 4. 2007 electricity use in the state of Hawaii [MWh]), we re-aggregate these values in the final projections analysis. We do this because the building map results do not distinguish between large and small offices, therefore making it impossible to derive the number of large and small offices while maintaining consistency in the methodology for scaling up across building types.

Commercial Cooling

Baseline Building

We estimate baseline cooling load for commercial buildings, by building type, from three variables: average efficiency (kW/ton), average size (tons) and average cooling operating hours (**Table 3**).

- Average cooling operating hours, by building type, are equal to the average values from the 1994 study (HECO 1994) and the 2009 survey (BAH 2009a). For hospitality, average cooling hours are reduced to 70.4% of their total to reflect the average occupancy rate in 2008 (DBEDT 2008), thus adjusting for reduced usage in unoccupied rooms.
- Average efficiencies, by building type, are equal to the average of values from the HECO 2004 study baseline building profiles (HECO 2004) and the 2009 survey (BAH 2009a). Where values are reported as energy efficiency ratio (EER), they are converted to kW/ton by dividing them by 12.
- Average system size is calculated by dividing average building size by average square footage per ton of cooling.
- Average building sizes are equal to the 2004 study's (HECO 2004) assumptions for average building size.
- Average square footage per ton of cooling is derived from averaging 1994 (HECO 1994) values with 2009 survey results (BAH 2009a). 1994 values are back-calculated from total building type square footage, total building type cooling electricity sales, and average operating hours per year.

Since the 2004 study (HECO 2004) does not include model results for high-rises, we make a number of assumptions for high-rises where the calculations require 2004 values.

- Building size: Assuming the maximum number of floors is 47 and the minimum number is 2, the average floors per building is 24.5. Average area per floor is derived from the 2009 survey results and is equal to 18,727 square feet (SF) per floor (BAH 2009a). This value is scaled up to equate to 458,823 SF per building.
- Average operating hours per year: This value is assumed to be equivalent to the hospitality building type.
- Average efficiency: This value is assumed to equal the average of the 2004 value for multifamily units (HECO 2004) and the 2009 survey result for hospitality (BAH 2009a).

Table 3. Baseline Commercial Cooling Assumptions

	Large Office	Small Office	Retail	Hospitality	High-Rises
Average Building Area (SF)	330,00	10,000	50,000	404,700	458,823
Average Cooling Operating Hours Per Year	3,159	3,159	4,088	6,150	8,736
Average Efficiency (kW/Ton)	0.75	1.34	1.3	1.33	1.33
Average Cooling Size (Tons)	921.8	19.7	76.5	300.6	189.2
Average Cooling Consumption (kWh/year)	2,169,352	83,723	406,532	2,464,331	2,202,990

Efficient Building

The efficient building case predicts average cooling load when average cooling efficiency is improved, given assumptions from the baseline building profiles for average operating hours, average cooling system size, and average building area. By building type, efficiency values for kW/ton are derived from an average of FEMP values (FEMP 2010). The baseline building efficiency values represent average efficiencies from several different system types; thus the efficient building cooling efficiency values are represented by an average of different system types: commercial unitary air-conditioners, air-cooled chillers, packaged units and room AC units. For the large office building type, we assume the efficient system is a water-cooled chiller, which is an upgrade over the mix of centrifugal and less efficient water-cooled chillers prevalent in the base case (**Table 4**).

Table 4. Efficient Commercial Cooling Assumptions

	Large Office	Small Office	Retail	Hospitality	High-Rises
Average Efficiency (kW/Ton)	0.52	1.08	1.08	1.08	1.08

Commercial Lighting

Baseline Building

Average lighting load per building, by building type, is equal to the average of existing and new building lighting load profiles from the 2004 HECO building modeling results (HECO 2004).

Number of lamps per building, by lamp type, is derived by averaging 1994 lamp numbers (HECO 1994) and 2009 survey results (BAH 2009a). The 1994 lamp numbers are not reported on a per-building basis. Thus, we calculate 1994 lamps per building by dividing by the total number of lamps estimated in the study by the estimated number of buildings in 1994. Number of buildings in 1994 is back-calculated from the 1994 values for total building area (by building type) and the 2004 study values for average building size (by building type) (HECO 2004). This calculation results in 1994 lamps per building by lamp type and by building type. Next, by building type, 1994 lamp numbers per building by lamp type must be averaged with 2009 lamp numbers per building by lamp type. Since the 1994 and 2009 lamp types are reported in different subcategories, we roll these subcategories into larger categories to take the average (**Table 5**).

Table 5. Baseline Commercial Lighting Assumptions

	Large Office	Small Office	Retail	Hospitality	High-Rises
Average Lighting Consumption (kWh/Year)	1,664,365	55,285	415,617	1,343,157	1,522,787
Lamps Per Building (Average Wattage)					
T12 Fluorescent (82 W)	645	15	479	869	455
T8 Fluorescent (57 W)	511	12	37	99	97
Incandescent (60 W)	33	12	235	2,959	1,859
CFL (17 W)	50	18	6	3,189	751

Efficient Building

To estimate the efficient building lighting scenario, we calculate the expected energy savings from retrofitting all T12 lamps with T8 lamps and all incandescent lamps with CFLs. Energy use per lamp type is calculated for each lamp type, based on average light power (watts) and building type operating hours per year (FEMP 2010). Then, for each building type, the differences in energy use for each replacement (T8s, CFLs, and LED exit signs) are multiplied by the number of retrofits (number of T12s, incandescent lamps, and incandescent exit signs).

Commercial Water Heating

Baseline Building

The methodology for water heating is similar to the methodology for lighting. Baseline water heating electricity use is the average of 2004 water heating electricity values for new and existing buildings in the 2004 HECO energy model (HECO 2004). Number of water heaters by building type and by water heater type are derived from an average of 2009 survey responses (BAH 2009a) and 1994 water heater numbers (HECO 1994). Similar to lighting, some models of water heaters are not classified in the same way across studies, so they must be combined. For small offices, there are no 1994 or 2009 values for number of water heaters. These values are derived from the number of water heaters in large offices, adjusted by the ratio of average large office size to average small office size (**Table 6**).

Once the average number of water heaters is calculated (per building, by building type) we derive a weighted average energy factor, by building type, as a measure of baseline water heating efficiency. The weighted average is based on figures from the American Council for an Energy-Efficient Economy's (ACEEE's) "Consumer Guide to Home Energy Savings: Condensed Online Version; Water Heating," (ACEEE 2010), in combination with DOE's *EnergySmart Hospitals Training Manual* (ESH 2008), minimum efficiency water heating energy factors, and the number of water heaters per building, by building type. For the purpose of comparing with the efficient water heating case, we multiply the water heating energy loads by the energy factors to obtain measures of the heat energy in the water, net of efficiency losses (**Table 7**).

Table 6. Baseline Commercial Water Heating Assumptions

	Large Office	Small Office	Retail	Hospitality	High-Rises
Average Water Heating Electricity Consumption (kWh/Year)	84,435	2,559	17,119	714,480	714,480
Water Heaters Per Building					
Solar Water Heater	0	0	0	0	0
High-Efficiency Electric or Tankless	10.9	0.3	0.2	0.4	0
Electric Individual Tank Heaters	6.0	0.2	3.4	2.8	60.2
Gas Boilers	0	0	0.83	2.9	1.2
Heat Pumps	0.1	0.002	0.2	1.34	3.1
Fuel Oil Heaters	0	0	0	0.3	0
Average Electric Water Heater Energy Factor	0.87	0.87	0.82	0.96	0.86
Average Water Heating Electricity Consumption Adjusted for Losses (kWh/Year)	73,091	2,215	14,116	684,160	611,834

Table 7. Commercial Water Heater Efficiency Values

Water Heater Type	Average Energy Factor
Tankless/Electric High-Efficiency	0.9
Electric Tank	0.79
Gas Storage	0.6
Heat Pump	2.2
Fuel Oil	0.55
Solar Thermal	1.2

Efficient Building

To calculate the efficient water heater energy use per building scenario by building type, we derive energy factors if all existing water heaters are replaced with tankless or high-efficiency water heaters for hospitality and high-rises and with solar water heaters for offices and retail. We assume that solar hot water heaters are not feasible for hospitality and high-rise buildings because the ratio of roof space to building area is too small to support this technology. The energy factor for the efficient building is retabulated with these water heater replacements using the same methodology as for the baseline case. Last, we divide the average water heating electricity load adjusted for losses by the efficient building energy factor to estimate the average efficient building water heating electricity load (**Table 8**).

Table 8. Efficient Commercial Building Water Heating Electricity Load

	Large Office	Small Office	Retail	Hospitality	High-Rises
Average Water Heating Electricity Consumption (kWh/Year)	60,727	1,840	11,440	685,921	639,062

Commercial Controls

Baseline Building

Data for the percentage of buildings in Hawaii with EMS and programmable thermostats by building type are available from both the 1994 survey (HECO 1994) and the 2009 survey (BAH 2009a). We average these values to approximate the average percentage of buildings with these systems in the baseline scenario. Data were not available separately for small offices, so we assume that the saturation of controls in this building type is approximately the same as that of the large office building type (**Table 9**).

Table 9. Saturation of Building Controls, Baseline Case

	Large Office	Small Office	Retail	Hospitality	High-Rises
Buildings with EMS	49.7%	49.7%	16.4%	52.2%	57.9%
Programmable Thermostats	57.5%	57.5%	32.5%	24.3%	17.6%
Adjusted Savings as a Percent of Total Building Electricity Use	3.9%	4.3%	2.3%	6.7%	6.2%

Efficient Building

For the efficient building scenarios, we assume that all buildings will have an EMS and programmable thermostats. Gross electricity savings from installing this equipment are derived from savings per square foot values (**Table 10**) given in the 2004 study building modeling results (HECO 2004). For each building type, the savings values are multiplied by 1 minus the baseline equipment saturations and average square footage per building. Since we are not installing the EMS and programmable thermostats in isolation of other measures, we must reduce the amount of savings from this equipment to avoid double counting savings from lighting and cooling. To avoid double counting savings for each building type, control savings as a percentage of total building energy use (HECO 2004) are reduced by the sum of cooling savings as a percentage of cooling electricity use and lighting savings as a percentage of lighting electricity use (see adjusted values in **Table 10**).

Table 10. Control Savings

	Gross Electricity Savings Per SF (kWh/SF)[15]
EMS	1.44
Programmable Thermostat	0.68

Commercial Fans and Motors

Baseline Building

In this section, we calculate the number of standard and efficient fans and motors in each baseline building. These numbers are averages of values from the 1994 HECO survey (HECO 1994) and the 2009 survey (BAH 2009a). While results for number of fans and motors per building, by fan and motor type, are available from the 2009 survey, the 1994 survey reports the number of standard-efficiency fans and motors per building and the percentage of buildings with variable-speed fans and efficient motors. To calculate the number of efficient fans and motors per building in 1994, the number of 1994 fans and motors is multiplied by the percentage of buildings with variable-speed fans and efficient motors. Due to missing 1994 fan and motor values for offices, the number of fans and motors in offices is based entirely on 2009 survey

[15] A range of control savings values is available from the 2004 HECO study depending on building type and on whether the building is new construction or existing. We choose conservative values to avoid overestimating savings.

results. Small office fans and motors are scaled down based on the ratio of small office to large office per building areas (**Table 11**).

Table 11. Baseline Fan and Motor Assumptions (Number of Fans and Motors Per building)

	Large Office	Small Office	Retail	Hospitality	High-Rises
Standard Fans	15	0.5	2.3	41.7	13.5
Variable-Speed Drive Fans	29	0.9	0	6	0
Standard-Efficiency Motor	15	0.5	5.1	6.7	1.2
Premium-Efficiency Motor	53.5	1.6	1	9.8	10.5

Efficient Building

We assume that efficient buildings will replace all standard-efficiency fans and motors with variable-speed fans and premium-efficiency motors. Electricity savings from this retrofit are calculated based on a value of electricity savings per fan from the 2004 HECO study (HECO 2004) and on a value of electricity savings per premium-efficiency motor from a 2008 KEMA study (KEMA 2008) (**Table 12**).

Table 12. Efficient Fan and Motor Assumption

	Electricity Savings Per Unit (kWh/Unit)
Variable-Speed Fan	769.8
Premium-Efficiency Motor	54.8

Commercial Building Envelope

Baseline Building

There are four components to the building envelope efficiency measures in the model: percentage of buildings with roof insulation (R-19), percentage of buildings with wall insulation (R-13), percentage of buildings with high-reflectivity roofs, and percentage of buildings with efficient windows.[16] The percentages of buildings with roof insulation, by building type, are averages of 1994 survey results (HECO 1994) and 100% (we assume that all buildings on the upper end of the building efficiency curve will have roof insulation). Since we do not have data on wall insulation saturation, we assume that the percentage of buildings with roof insulation is approximately the same as the percentage of buildings with wall insulation.

For high-reflectivity roofs and high-efficiency window saturations, we assume that no buildings on the low end of the efficiency curve will have high-reflectivity roofs or high-efficiency

[16] Hawaii building codes specify at least R-19 building insulation, and we assume virtually no buildings have R-25 insulation (Wigg 2009).

windows and that the upper end of the efficiency curve is represented by responses to the 2009 survey (BAH 2009a) (**Table 13**).

Table 13. Saturation of Insulation Types for Building Envelope, Baseline Case

	Large Office	Small Office	Retail	Hospitality	High-Rises
Percentage of Buildings with Roof Insulation	62.1%	62.1%	61%	60.6%	66.5%
Percentage of Buildings with Wall Insulation	62.1%	62.1%	61%	60.6%	66.5%
Percentage of Buildings with High-Reflectivity Roofs	30%	30%	40%	0%	50%
Percentage of Buildings with High-Efficiency Windows	0%	0%	0%	0%	50%

Efficient Building

Building envelope electricity savings are based on retrofitting the buildings with no ceiling insulation to R-19 ceiling insulation (we assume no buildings will upgrade to higher than R-19 insulation, as R-19 is the current Hawaii building code level), R-13 to R-19 wall insulation, high-reflectivity roofs, and high-efficiency windows (**Table 14**). We assume buildings with R-13 wall insulation will upgrade to R-19 wall insulation, and buildings without wall insulation will not install wall insulation (we assume that most of the buildings without wall insulation are not cooled, so no electricity savings would result from increasing insulation).

- *Ceiling insulation savings*—These values are based on kWh savings per SF of roof area for small offices retrofitting from no insulation to R-19 (HECO 2004). These savings are multiplied by the percentage of buildings without insulation by building type (HECO 2004) and by average floor space per story (assuming this is equivalent to roof area).
- *Wall insulation savings*—The electricity savings due to upgrading from R-13 to R-19 insulation are based on kWh savings per SF of exterior wall area for small offices (HECO 2004).[17] This value is multiplied by estimated exterior wall area for each building type and by the percentage of buildings with R-13 wall insulation.

[17] We assume the average wall is 9' in height for the calculation of exterior wall area per building.

- *High-reflectivity savings*—High-reflectivity roofs save 18.6% of a building's cooling energy on average (EPA 2004). We apply this percentage to the baseline percentage of buildings without high-reflectivity roofs. To adjust for the effect of a building's ratio of roof to building area, we multiply savings by the ratio of roof to total building area. Percentage savings from roof upgrades will be less for taller buildings, with the roof as less of a percentage of the building envelope.
- *High-efficiency windows savings*—By building type, we multiply savings per square foot of window (from upgrading to double-pane windows (HECO 2004)[18]) by the average window square footage per building. We use a window-to-wall ratio from the 2004 study to derive window square footage based on our previous calculation of exterior wall area. We also assume that the average high-rise window-to-wall ratio is similar to that of an average hospitality building, since the window-to-wall ratio is not available in the 2004 study.
- All of the building envelope electricity savings are summed, and then we subtract cooling savings as a percentage of total building energy use to prevent double counting as we upgrade both building systems in the efficient building profile.

Table 14. Efficient Commercial Building Envelope Assumptions

	Electricity Savings Assumption
Installing Ceiling Insulation (No Insulation to R-19)	2.24 kWh Per SF of Roof
Installing Wall Insulation (R-13 to R-19)	0.038 kWh Per SF of Wall
Installing a High-Reflectivity Roof	18.6% Cooling Energy Savings
Installing High-Efficiency Windows	4 kWh Per SF of Window

Commercial Computers and Data Centers

Baseline Building

For computers and data centers, we estimate the number of standard efficiency computers, ENERGY STAR computers, standard data centers, and efficient data centers. We average values from the 1994 HECO study (HECO 1994) and a 2009 commercial sector survey (BAH 2009a) for all of these estimates. We assume that the number of ENERGY STAR computers at the low end of the efficiency curve is zero. All data centers reported in the studies are also assumed to be standard efficiency 1-U servers (**Table 15**).[19]

[18] We understand that additional U-value improvements could be made through the adoption of window film as opposed to double-paned glass in this case. However, given our data at hand, and the fact that main improvement in this area would be in reduced cost, rather than reduced savings and that cost is to be examined more closely at a programmatic level, we have opted to use double-paned glass as a proxy for window improvement for the purposes of this study.

[19] The 1994 study reports number of "mainframes" and we assume this is roughly equivalent to today's data center for the purposes of this study.

Table 15. Baseline Commercial Computer and Data Center Assumptions

	Large Office	Small Office	Retail	Hospitality	High-Rises
Standard Computers Per Building	37	1.1	15.2	54	15.2
ENERGY STAR Computers Per Building	1.5	0.1	0.2	100	3
Data Centers Per Building	1.1	0.1	0.3	0.5	0.5

Efficient Building

Savings for upgrading to ENERGY STAR computers and monitors are based on savings estimates in the 2004 HECO modeling results (HECO 2004). Savings from data centers are based on an estimate by Rocky Mountain Institute (RMI 2008) (**Table 16**).

Table 16. Efficient Commercial Computer and Data Center Assumptions

	Electricity Savings Per Unit (kWh/Unit)
ENERGY STAR Computer	84
ENERGY STAR Monitor	197
Efficient Data Center	534

Residential Sector Modeling

For most single family and multifamily building technology types in the model, baseline energy use and saturations are based on the 2008 HECO Residential Appliance Survey (HECO 2009b). Appliance saturations are listed by utility (HECO, MECO, or HELCO), so we combine these values by weighting them according to the percentage of the utility's contribution to total state electricity use. Energy use per appliance/system type is multiplied by its saturation to derive average energy use by end use and building type. Multifamily cooling and water heating appliance energy uses are reduced, relative to the values for single family buildings, by the percentage difference between the 2004 study's modeling results for each respective end use (HECO 2004). Below, we describe these assumptions in more detail and note adjustments and exceptions.

Since multifamily energy use is calculated on a per-housing-unit level, we multiply this value by the average housing units per building to derive the average energy use per building. To estimate average housing units per building, we calculate the weighted average units per building from the distribution of energy use per housing type (BAH 2009b). In the distribution, energy use is broken down by housing type, and these housing types are categorized by number of units per building (2, 3, or 4; 5 to 9; and 10 to 19).

Residential Refrigeration

Baseline Building

The baseline building refrigeration assumptions are estimated by multiplying appliance saturations with unit energy use, as described above. **Table 17**, below, outlines the base assumptions used in calculating the baseline residential refrigeration use.

Table 17. Baseline Residential Refrigeration Assumptions

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
First Refrigerator Saturation	100%	100%
First Refrigerator Average Energy Use (kWh/Year)	661	661
Second Refrigerator Saturation	50%	13%
Second Refrigerator Average Energy Use (kWh/Year)	1,979	1,979
Freezer Saturation	31%	14%
Freezer Average Energy Use (kWh)	563	563

Efficient Building

For both single family and multifamily efficient building profiles, energy savings per refrigerator and freezer are subtracted from the standard energy use values. These energy savings per efficient refrigerator values are estimated using modeling results from the 2004 HECO study for upgrading from a minimum NAECA efficiency refrigerator to an ENERGY STAR refrigerator (HECO 2004). Energy savings per efficient freezer is derived from FEMP efficient freezer values (FEMP 2010) (**Table 18**).

Table 18. Efficient Residential Building Refrigeration Assumptions

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
First Refrigerator Saturation	100%	100%
First Refrigerator Average Energy Use (kWh/Year)	558	558
Second Refrigerator Saturation	50%	13%
Second Refrigerator Average Energy Use (kWh/Year)	1,666	1,666
Freezer Saturation	31%	14%
Freezer Average Energy Use (kWh/Year)	350	350

Residential Cooling

Baseline Building

Appliance saturations and energy use values are estimated as described above. The data only list energy use values for central air-conditioning (AC), so we assume that packaged central AC and split central AC systems use a similar amount of electricity per year **(Table 19).** The efficiency values for each system type are not used in calculating energy use, as energy use per efficient unit is given. The efficiency value for room AC is an estimate used in the 2004 HECO study (HECO 2004). For central AC units, we derive efficiency from a FEMP example central AC unit (FEMP 2010). We scale the efficiency of our model central AC unit according to the energy use and efficiency of this example central AC unit.

Table 19. Baseline Residential Building Cooling Assumptions

	Single Family	**Multifamily (<20 Units per Building, Per Unit Assumptions)**
Room AC Saturation	29%	35%
Room AC Average Efficiency (EER)	8.6	8.6
Room AC Average Energy Use (kWh/Year)	1,397	652
Packaged Central AC Saturation	11%	9%
Packaged Central AC Average Efficiency (Seasonal Energy Efficiency Rating [SEER])	13	13
Packaged Central AC Average Energy Use (kWh/Year)	3,750	2,394
Split AC Saturation	19%	6%
Split AC Average Efficiency (SEER)	13	13
Split AC Average Energy Use (kWh/Year)	3,750	2,394

Efficient Building

Energy efficiency estimates for the efficient building profile cooling systems are based on minimum FEMP purchasing requirements (FEMP 2010). We adjust these efficiencies to correspond to energy saving values from the 2004 HECO modeling results (HECO 2004). For example, the minimum FEMP purchasing requirement for residential room AC units is 10.7 EER, but we only have energy savings values for improving efficiency from 8.6 to 10.2. Therefore, we set the efficient building profile cooling efficiency at 10.2 (**Table 20**).

Table 20. Efficient Residential Building Cooling Assumptions

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
Room AC Saturation	29%	35%
Room AC Average Efficiency (EER)	10.2	10.2
Room AC Average Energy Use (kWh/Year)	1,001	443
Packaged Central AC Saturation	11%	9%
Packaged Central AC Average Efficiency (SEER)	18	18
Packaged Central AC Average Energy Use (kWh/Year)	3,361	2,247
Split AC Saturation	19%	6%
Split AC Average Efficiency (SEER)	18	18
Split AC Average Energy Use (kWh/Year)	3,361	2,247

Residential Lighting

Baseline Building

Baseline residential lighting energy use is calculated using a sample distribution of the number of lights per building by lamp type (HECO 2009a). Average lamp number estimates are weighted averages from the distribution. Lighting electricity use per building is calculated by multiplying average lamp numbers by their average power and an estimate of average residential lighting operating hours (1,200 per year) (FEMP 2010) (**Table 21**).

Table 21. Baseline Residential Lighting Assumptions

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
Average Number of Lamps Per Building (Average Wattage)		
Incandescent (40 W)	16.4	10.8
CFL (17 W)	9.0	5.2
T12 Tube Fluorescent (47 W)	5.9	2.9
Spot Light (100 W)	2.3	1.0
Outdoor Light (100 W)	3.4	1.3
Average Operating Hours	1,200	1,200

Efficient Building

For the efficient building profiles, all incandescent lights are replaced with CFLs, all T12 tube fluorescent lights are replaced with T8 fluorescent lights, and both spot and outdoor lights are replaced with CFLs of the appropriate wattage. Average total lighting energy use is estimated using the same methodology as for the baseline profile (**Table 22**).

Table 22. Efficient Residential Lighting Assumptions (Average Number of Lamps Per Building)

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
Incandescent (40 W)	0	0
CFL (17 W)	25.4	15.9
T8 Tube Fluorescent (45.5 W)	5.9	2.9
Efficient Spot Light (27 W)	2.3	1.0
Efficient Outdoor Light (27 W)	3.4	1.3

Residential Water Heating

Baseline Building

To estimate average per-building water heating energy use, we use the 2008 survey's electric water heater saturation and energy use (HECO 2009b). The 2008 survey does not specify the type of electric water heater corresponding to the saturation or the efficient water heaters in the baseline. We assume that the electric water heater in the 2008 study is a standard efficiency electric storage water heater (**Table 23**).

Table 23. Baseline Residential Water Heating Assumptions

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
Standard Electric Storage WH Saturation	57%	61%
Standard[20] Electric Storage WH Average Energy Use (kWh/Year)	2,719	1,941
Solar WH Saturation	28%	0%
Solar WH Average Energy Use (kWh/Year)	644	460
High-Efficiency[18]Electric Resistance WH Saturation	0%	10%
High-Efficiency Electric Resistance WH Energy Use (kWh/Year)	2,462	1,758

Efficient Building

For the efficient case water heaters, we assume efficient water heater types based on those offered by the HECO Residential Water Heating Program and Residential New Construction Program (KEMA 2008). In the model, single family buildings with water heating upgrade to

[20] Our calculations do not use water heater efficiency values to calculate energy savings, only energy use. We compare the annual energy use of an average Hawaii water heater to the energy use of solar water heaters in the efficient case to reduce the need to forecast future water usage patterns per person.

solar water heaters, and multifamily buildings with water heating upgrade to high-efficiency electric water heaters (**Table 24**).[21] We assume no multifamily buildings will use solar water heaters due to feasibility issues for buildings with multiple stories, multiple units, and limited roof space. Energy use for the efficient technologies is calculated based on the average per unit impact of the technologies (KEMA 2008).

Table 24. Efficient Residential Water Heating Assumptions

	Single Family	Multi Family (<20 Units Per Building, Per Unit Assumptions)
Standard Electric Storage WH Saturation	0%	0%
Solar WH Saturation	84%	0%
High-Efficiency Electric Resistance WH Saturation	0%	71%

Residential Building Envelope

Baseline Building

The percentage of single family and multifamily buildings with wall insulation and ceiling insulation are derived from data collected by HECO (HECO 2009b). We assume that the baseline wall insulation is R-13 and the baseline and ceiling insulation is R-19 (**Table 25**). These levels of insulation are the current Hawaii building code (Wigg 2009).

Table 25. Baseline Residential Building Envelope Assumptions

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
Percentage of Buildings with R-13 Wall Insulation	20.4%	14.1%
Percentage of Buildings with R-19 Ceiling Insulation	21.1%	13.1%

Efficient Building

In the model, we calculate electricity savings from buildings with the baseline level of wall insulation that will upgrade to R-19 insulation and from buildings without the baseline R-19 ceiling insulation that will upgrade to this baseline level. We do not calculate savings from upgrading wall insulation to multifamily homes because this efficiency measure is likely too costly for existing multifamily buildings (**Table 26**).

- For ceiling insulation upgrades, we calculate electricity savings from only those buildings without insulation and with cooling. There will be no electricity savings for buildings

[21] The study does not derive the efficiency of "high-efficiency electric water heaters." Average per-unit impact, as defined in the KEMA 2008 DSM report, is used to derive the average energy use of this technology in the efficient case.

without cooling that install insulation. To calculate this percentage, we subtract the percentage of buildings with ceiling insulation from the total percentage of buildings with cooling.[22] This percentage is multiplied by an estimate of roof area and an estimate for electricity savings per square foot of R-19 insulation installed.

- To estimate the electricity savings from the percentage of buildings that will upgrade from R-13 to R-19 wall insulation, we multiply the percentage of buildings with insulation by average exterior wall area per building and by electricity savings per square foot of exterior wall area.
- All of the building envelope electricity savings are summed and then we subtract cooling savings as a percentage of total building energy use to prevent double counting as we upgrade both building systems in the efficient building profile.

Table 26. Efficient Residential Building Envelope Assumptions

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
Average Exterior Wall Area Per Building (SF)	1,704	6,814
Average Roof Area Per Building (SF)	995	1,184
Electricity Savings Per Square Foot of Installed R-19 Wall Insulation (kWh/Year)	0.012	0
Electricity Savings Per Square Foot of Installed R-19 Ceiling Insulation (kWh/Year)	0.44	1.1

Residential Appliances

Baseline Building

To calculate baseline energy use and saturation of dishwashers, clothes washers, clothes dryers and ranges/ovens, we use values from the 2008 saturation study (HECO 2009b) with some adjustments. First, the 2008 saturation study value for dishwasher energy use is higher than the 2004 HECO study value. We assume that the higher dishwasher values include the energy needed to heat water. Since we are counting this electricity in the water heater section, we use the lower 2004 HECO study value as the amount of electricity used by the dishwasher. Second, the energy use value for clothes washers is omitted from the 2008 data. Again, we use a 2004 HECO study value for the energy used by the average clothes washer motor (**Table 27**).

---

[22] Total % buildings with insulation (TI) = % buildings with cooling, with insulation (CI) + % buildings without cooling with insulation (NCI); Total % buildings with cooling (TC) = % buildings with cooling without insulation (CNI) + % buildings with cooling with insulation (CI).

To derive CNI: assume NCI = 0; CI = TI; CNI = TC – TI (substituting TI for CI). This methodology is slightly different from that used for commercial buildings, as we account for commercial buildings without cooling using average tons of cooling per SF, not saturation of buildings with cooling.

Table 27. Baseline Residential Appliance Assumptions

	Single Family	Multifamily (<20 Units Per Building, Per Unit Assumptions)
Dishwasher Saturation	40%	39%
Dishwasher Average Energy Use (kWh/Year)	179	179
Electric Cooking Saturation	87%	92%
Electric Cooking Energy Use (kWh/Year)	663	663
Clothes Washer Saturation	97%	71%
Clothes Washer Energy Use (kWh/Year)	103	103
Clothes Dryer Saturation	74%	59%
Clothes Dryer Energy Use kWh/Year)	354	354

Efficient Building

Energy savings values for each appliance are derived from either the HECO 2004 (HECO 2004) study's modeling results or FEMP minimum appliance efficiency requirements (FEMP 2010). Dishwasher savings are equal to the savings from going from a standard dishwasher to an NAECA minimum required efficiency dishwasher. Standard efficiency ovens are replaced by ENERGY STAR ovens. For clothes washers, we estimate that the electricity used by the motor is 10% of total energy use (the value for total energy use, including energy to heat water, is listed in FEMP's purchasing guidelines). The FEMP required minimum efficiency clothes washer model uses 750 kWh per year, so we assume that its motor will use 75 kWh per year. Dryer savings are values from the 2004 HECO modeling results (**Table 28**).

Table 28. Efficient Residential Appliance Assumptions

	Single Family	**Multifamily (<20 Units Per Building, Per Unit Assumptions)**
Dishwasher Average Energy Use (kWh/Year)	20	20
Electric Cooking Energy Use (kWh/Year)	546	546
Clothes Washer Energy Use (kWh/Year)	75	75
Clothes Dryer Energy Use (kWh/Year)	188	188

Appendix II: "Hawaii Building Stock Mapping and the Way Forward" (Booz Allen Hamilton, April 22, 2009)

In April of 2009, Booz Allen Hamilton (BAH) began the process of evaluating the energy efficiency potential of the Hawaii existing building stock by creating a roadmap of the energy demand in the state. This process involved several different data sources for both the residential and commercial sectors, which will be outlined in this appendix. Primary data sources on the residential side include the 2000 U.S. Census and the U.S. DOE's Energy Information Administration (EIA), while on the commercial side sources included data provided by the Hawaii state utilities: Hawaiian Electric Company (HECO), Hawaii Electric Light Company (HELCO), Maui Electric Company (MECO), and Kauai Island Utility Cooperative (KIUC). This analysis was presented to the Hawaii Clean Energy Initiative (HCEI) Energy Efficiency working group at its April, 2009 meetings.

Residential

On the residential side of the analysis, BAH began by gathering all the information available on the number and types of housing units in the state (Census, 2000b). This data was combined with the unit energy consumption (UEC data from HECO 2009b; where data was missing, it was supplemented with values from HECO 2004) for each housing type, by island, to create the table of demand for the year 2000, when the census data was collected (**Table 29**).

Table 29. Residential Electricity Demand, by Island (2000)

Residential Elect Demand (2000), MWh	Oahu	Hawaii	Maui	Kauai	Total
Housing: 1-Unit, Detached	902,314	306,749	200,931	106,956	1,516,951
Housing: 1-Unit, Attached	198,043	13,140	22,241	9,378	242,802
Housing: 2 Units	45,583	9,661	6,589	5,460	67,293
Housing: 3 or 4 Units	91,190	9,196	10,218	4,866	115,470
Housing: 5 to 9 Units	127,976	12,216	23,532	6,765	170,488
Housing: 10 to 19 Units	94,022	11,040	16,163	4,907	126,132
Housing: 20 or More Units	432,862	25,348	61,040	9,071	528,321

Once the relative energy demand was known, a table of factors was derived outlining the ratio of electricity usage for the subsectors within residential (**Table 30**). These factors were then applied to the EIA 2007 Hawaii residential electricity demand to generate the end usage numbers for the residential sector, by subsector, adjusted to 2007 demand levels (**Table 31**).

Table 30. EIA Electricity Demand, by Sector (2007)

Sector	EIA Demand (2007), MWh
Commercial & Industrial	6,677,905
Residential	3,182,000
Total	9,859,905

Table 31. Residential Energy Demand Allocation (Base Year) and 2007 Demand Levels

	% of Total Residential Demand, Base Year (2000)	2007 Subsector Demand (MWh)
Housing: 1-Unit, Detached	55%	1,744,178
Housing: 1-Unit, Attached	9%	279,172
Housing: 2 Units	2%	77,373
Housing: 3 or 4 Units	4%	132,767
Housing: 5 to 9 Units	6%	196,026
Housing: 10 to 19 Units	5%	145,025
Housing: 20 or More Units	19%	607,459
Total	100%	3,182,000

Commercial

On the commercial side, BAH began by collecting the last full year of recorded commercial electricity demand data (by sector) from the four major utility companies in Hawaii: HECO (2007), HELCO (2005), MECO (2005) and KIUC (2008). HECO and KIUC provided their billed MWh figures directly to BAH, while HELCO's and MECO's numbers were drawn from their most recent Integrated Resource Plans (IRPs) (HELCO 2007, MECO 2007). As this data tended to span a range of years from 2005 through 2008 (due to the cyclical nature of the IRP process), BAH harmonized it by converting it to a common year's value. This was done by utilizing the relative allocations of electricity demand provided by the utilities, by island, and applying them to the total electricity demand for the year 2007 as recorded by the EIA (**Table 30**, above) This allowed BAH to maintain a common year across all utilities, while at the same time reflecting island-specific variances in electricity demand. The demand factors identified by the utilities are provided in **Table 32**, while the EIA total and the relative distributions for the year 2007 calculated from these factors are provided in (**Table 33**).

Table 32. Commercial Electricity Demand Allocation by Sector and Island (% of Total Commercial Demand, Base Year)

Commercial	Oahu (2007)	Hawaii (2004)	Maui (2003)	Kauai (2008)
Office/Business Services	16%	6%	8%	25%
Hotel	8%	17%	24%	26%
Health	5%	3%	3%	4%
Education	8%	10%	4%	0%
Air Facility/Transport	2%	2%	2%	4%
Manufacturing/Food Processing/ Farming	4%	5%	1%	2%
Services/Recreational/Amusement	8%	12%	9%	9%
Restaurant	5%	5%	6%	5%
Retail/Warehouse	16%	21%	24%	18%
Water Pumping	4%	17%	11%	0%
Military	23%	1%	1%	5%
Other	0%	1%	7%	2%

Table 33. Commercial Electricity Demand by Sector and Island (2007)

Commercial (MWh)	Oahu	Hawaii	Maui	Kauai	Total
Office/Business Services	820,000	39,095	60,979	73,231	993,305
Hotel	400,000	113,934	174,806	74,894	763,634
Health	231,000	22,340	22,133	10,214	285,687
Education	402,000	63,669	29,247	791	495,708
Air Facility/Transport	122,000	10,053	12,760	11,139	155,953
Manufacturing/Food Processing/Farming	193,000	35,744	4,630	5,075	238,449
Services/Recreational/ Amusement	382,000	80,424	67,641	24,529	554,594
Restaurant	257,000	34,627	46,863	14,546	353,036
Retail/Warehouse	814,000	139,625	172,434	51,705	1,177,764
Water Pumping	210,000	111,700	81,192	-	402,892
Military	1,167,000	4,468	5,646	15,374	1,192,488
Other	-	5,585	52,735	6,076	64,397
Total	4,998,000	661,264	731,066	287,574	6,677,905

Combined

Once the data for the commercial and residential sectors was harmonized to 2007 levels, it was aggregated to form **Figure 15**, below (same as **Figure 4** in the main body of the report). This data was used to prioritize the key sectors of existing demand for Hawaii to focus on in its attempt to reduce its electricity usage by 4,300 GWh in the year 2030 (noncumulative). This also forms the basis for the six existing building profiles developed in this report, as the top six sectors by demand are where BAH focused its modeling efforts to begin.

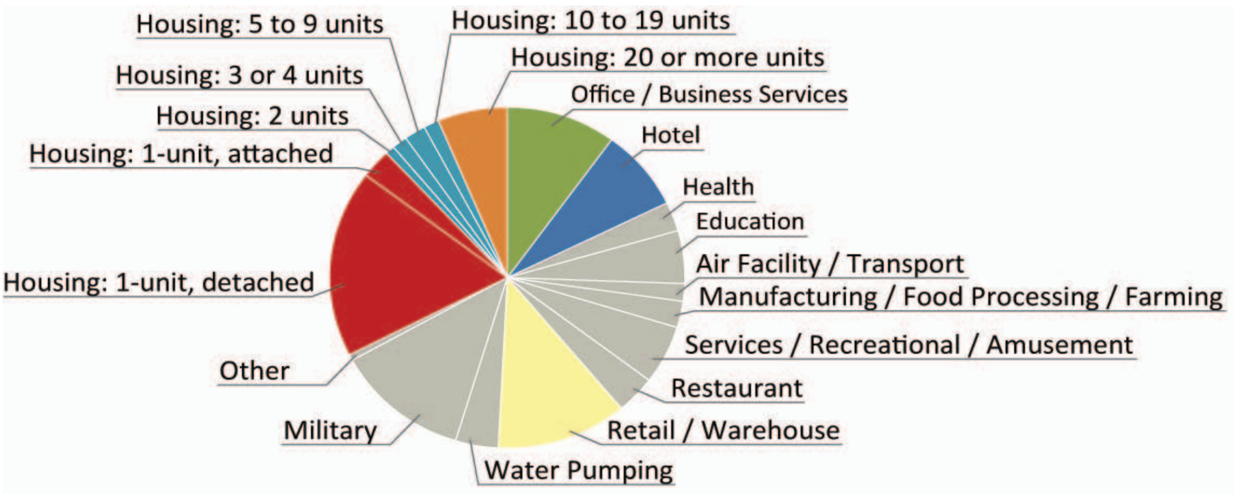


Figure 15. 2007 Electricity use in the state of Hawaii (MWh)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
June 2010

2. REPORT TYPE
Subcontractor Report

3. DATES COVERED *(From - To)*
11/17/09-6/30/10

4. TITLE AND SUBTITLE
Hawaii Clean Energy Initiative Existing Building Energy Efficiency Analysis: November 17, 2009 – June 30, 2010

5a. CONTRACT NUMBER
DE-AC36-08GO28308

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
P. Finch and A. Potes

5d. PROJECT NUMBER
NREL/SR-7A2-48318

5e. TASK NUMBER
IDHW9120

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Booz Allen Hamilton
8283 Greensboro Drive
McLean, VA 22102

8. PERFORMING ORGANIZATION REPORT NUMBER
Task Order# KLDJ-6-66282-07

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER
NREL/SR-7A2-48318

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES
NREL Technical Monitor: Sarah Busche/James Galvin

14. ABSTRACT *(Maximum 200 Words)*
In June 2009, the State of Hawaii enacted an Energy Efficiency Portfolio Standard (EEPS) with a target of 4,300 gigawatt hours (GWh) by 2030 (Hawaii 2009). Upon setting this goal, the Hawaii Clean Energy Initiative, Booz Allen Hamilton (BAH), and the National Renewable Energy Laboratory (NREL), working with select local stakeholders, partnered to execute the first key step toward attaining the EEPS goal: the creation of a high-resolution roadmap outlining key areas of potential electricity savings. This roadmap was divided into two core elements: savings from new construction and savings from existing buildings. BAH focused primarily on the existing building analysis, while NREL focused on new construction forecasting. This report presents the results of the Booz Allen Hamilton study on the existing building stock of Hawaii, along with conclusions on the key drivers of potential energy efficiency savings and on the steps necessary to attain them.

15. SUBJECT TERMS
Hawaii; Hawaii Clean Energy Initiative; HCEI; Energy Efficiency Portfolio Standard; EEPS; energy efficiency; energy savings; new construction; existing buildings; Building Efficiency

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	UL		19b. TELEPHONE NUMBER *(Include area code)*

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

F1146-E(10/2008)

Appendix I: Completed HCEI Supporting Analyses

Completed HCEI Supporting Analyses

- Hawaii Clean Energy Initiative Working Group Policy Recommendations for the 2010 Hawaii State Legislative Session, November 2009, http://www.hawaiicleanenergyinitiative.org/reports.html, last accessed October 1, 2010.
- HCEI Framework Agreement: "Energy Agreement Among the State of Hawaii, Division of Consumer Advocacy of the Department of Commerce and Consumer Affairs and the Hawaiian Electric Companies", October 28, 2010. http://www.heco.com/vcmcontent/StaticFiles/pdf/HCEI.pdf, last accessed October 1, 2010.
- OWITS Grid Modeling Study (Wind Integration)
- Overviews of the Big Island Energy Roadmap Study and Maui Smart Grid Demonstration Project, Jay Griffin, Hawaii Natural Energy Institute, University of Hawaii at Manoa, April 23, 2009
- Hawaii Energy Efficiency and Building Code Analysis, Kiatreungwattana, National Renewable Energy Laboratory, http://hawaii.gov/dbedt/info/energy/efficiency/EUEWG/Kosol%20HCEI%20-%20NC%20Analysis-Final2.pdf, last accessed October 1, 2010
- Hawaii DBEDT, Task 1 Assessment of Existing Biomass Feedstocks, February 2008. Black & Veatch
- Hawaii Bioenergy Master Plan, prepared for DBEDT by the Hawaii Natural Energy Institute, School of Ocean Earth Sciences and Technology, September 2009