Report on Scenario Development and Analysis

Prepared for

U.S. Department of Energy
Office of Electricity Delivery and Energy Reliability

Under Award No. DE-FC-06NT42847
Task 1. Deliverable #3

By

GE Global Research
Niskayuna, New York

And

University of Hawaii
Hawaii Natural Energy Institute
School of Ocean and Earth Science and Technology

November 2007

Acknowledgement: This material is based upon work supported by the United States Department of Energy under Award Number DE-FC-06NT42847.

GE Global Research

Hawaii Roadmap Phase 2

Strategic Energy Roadmap for the Big Island of Hawaii

Deliverable # 4

Scenario Identification, Development and Analysis Methodology

Delivered to:
Richard Rocheleau, Director
Hawai`i Natural Energy Institute
1680 East-West Rd, Post 109
Honolulu, HI 96822
Phone: 808-956-8346
e-mail: rochelea@hawaii.edu

Technical Contact at GE Global Research:
Devon Manz
Electric Power and Propulsion Systems Lab
One Research Circle, Niskayuna, NY, 12309
Phone: 518-387-7684
FAX: 518-387-7592
e-mail: manz@ge.com

Revision Date: November 21, 2007
GE Research 5125.022

Table of Contents

Background

Hawaii must make decisions about its energy future. Ideally, energy should be abundant, reliable, affordable, environmentally friendly, emissions-free and petroleum-independent. However, these characteristics really represent trade-offs; for example, a highly reliable system costs more, and a balance must be struck between the costs of increasing the reliability of energy supply versus the costs (economic, social, and public health and safety) of not having energy when it is needed. Deciding on this balance is critical for the State. Such a debate depends upon having accurate assessments of the effects of energy technology, policy, and design choices. New technologies in renewable energy, energy use, energy conversion, transmission, management and storage offer opportunities to provide clean, reliable, and secure energy for Hawaii at less cost. ***The purpose of the Hawaii Energy Roadmapping Study is to provide Hawaii with the capability of objectively evaluating its energy options and their true costs and environmental consequences***.

The Hawaii Energy Roadmapping Study is an evaluation of the Big Island's future electricity and transportation energy options with respect to local goals and future world conditions from a technology-neutral perspective. The US Department of Energy (DOE), the Hawaii Natural Energy Institute (HNEI), The General Electric Company (GE), and the Hawaiian Electric company (HECO) and its subsidiary the Hawaii Electric Light Company (HELCO) have collectively provided ~$1.5M over a two-year period to fund the first two phases of the study.

Introduction

In Phase 1 of the Hawaii program, baseline transportation and electricity models were developed, calibrated and validated against actual conditions in 2006. In Phase 2 of the program, stakeholders were engaged early in the process to identify key metrics, energy goals, technologies and policies of interest. The stakeholder input was translated into themes, which guided the scenario downselection process. Based on the results of these stakeholder interviews, four scenarios were outlined by the project team. On September 27, 2007 the Stakeholders assembled in Hawaii to hear the results of the Phase 1 analysis and the results of the stakeholder interviews. Both of these topics were described in earlier reports. At the summit, four scenarios were outlined and stakeholder input was solicited once again. There was general agreement among the stakeholders with the overall objectives and technologies specified in each scenario. In the weeks following the summit, the scenarios were defined in further detail.

On October 24th the GE/Sentech/HNEI team assembled at GE Global Research in Niskayuna, NY to further define the scenarios outlined at the Stakeholder Summit. The objective of this meeting was to outline two of the four scenarios and develop a timeline for completing the program.

Scenario Development

As a first step in developing the scenarios, incremental changes (relative to the baseline model) in wind power, solar power, geothermal power, system load, generating reserves, and energy storage were simulated. The results of the simulation provided a first-order sensitivity of these incremental changes on variable cost of production ($), fossil fuel consumption, emissions, power system stability, etc. The information provided by these incremental changes, and the input from the stakeholders during the stakeholder summit, were used to further define the scenarios during the October 24th workout.

The scenarios considered in this study are not meant to replace utility planning or the IRP exercise; instead the scenario analysis can provide those familiar with the HELCO system with directionally correct sensitivities, such as a change in the variable cost of production or emissions associated with a particular technology deployment decision. Insofar as it is possible to be technology neutral, the project team will examine technology deployments that achieve common themes or goals cited by the stakeholders during the interviews with them. As was mentioned, the scenario outlines were chosen using stakeholder input and guidance based on six general themes discussed during the interviews. These six themes were described in an earlier GE/HNEI document:

1. State policy goals,
2. Ancillary power generation,
3. Utility partnerships,
4. Energy security, economic security, and climate change,
5. Key energy metrics, and
6. Energy technologies.

A 2018 study year was chosen as the baseline (business-as-usual). This allows the project team to study the impacts on key metrics of various technology deployments in an assumed policy landscape around the 2018 baseline. The four scenarios are outlined below:

Scenario 1: Higher wind penetration

Given the trends in Hawaii for increased wind farm development, a renewable energy strategy consisting primarily of increased wind utilization will be considered. The key metric is the % increase in wind power.

Scenario 2: Enhanced Energy Management

Using new and/or innovative approaches, such as demand-side management, customer-sited energy storage, energy efficient technologies and plug-in hybrid electric vehicles to improve power system utilization and operability. The key metric is the cost of energy.

Scenario 3: Increasing Energy Security

Reducing dependence on imported oil, based on a specific technology deployment that is focused on using indigenous resources, especially renewable resources (wind, solar, geothermal, biofuel). The key metric is the % reduction in petroleum use.

Scenario 4: Reducing Cost of Electricity

Based on a change in customer energy use habits and/or a specific technology deployment that is focused on achieving the lowest energy cost, given assumptions about the future policy landscape and price of fuel. The key metric is the cost of electricity.

The four scenarios were mapped back to the themes outlined by the stakeholders. This ensured that the themes were captured in the development of the scenarios (see Figure 1).

SCENARIO	FOCUS	KEY METRIC	THEMES					
			1	2	3	4	5	6
Increasing Energy Security	Goal-oriented	% imported	X			X	X	X
Reducing Cost of Electricity	Goal-oriented	$/kWh	X			X	X	X
Higher Wind Penetration	Technology	% renewable		X		X	X	X
Enhanced Energy Management	Technology	$/kWh			X	X	X	X

THEMES

1. State policy goals
2. Ancillary power generation
3. Utility partnerships
4. Energy security, economic security, and climate change
5. Key energy metrics
6. Energy technologies

Figure 1. Mapping the scenarios to stakeholder themes

Methodology of Scenario Analysis

A four-stage approach will be used to analyze each of the scenarios. The methodology includes: (1) identifying specific technology deployments that satisfy each scenario's objective(s), (2) building the technology deployments for each scenario in MAPS, (3) simulating the scenario in PSLF to illustrate the scenario's validity, and (4) performing sensitivity analyses.

The sensitivity analyses can be organized into three groups. The first type of sensitivity is related to *technology deployment and consumer behavior*:

1. Supply-side: Generation & other technologies
    a. 1MW increment of geothermal power,
    b. 1MW increment in wind power,
    c. 1MW increment in solar power,
    d. 1MW increment in spinning reserve,
    e. 1MW increment of hard-wired storage (charging schedule), and
    f. 1MW increment of market-rational storage (based on present/forecasted cost of generation).

2. Demand-side: Load & other technologies
    a. 1MW increment in load,
    b. 1 MWhr / day increment in nighttime trough filling,
    c. 1 MWh / day increment in peak load shaving, and
    d. 1 MW increment in scaled load signature (i.e., scaled by the peak daily load).

The second type of sensitivity considers ***external factors***, such as world oil price and carbon policy. The following sensitivities can be performed as a parametric study:

- Carbon price,
- Fuel price, and
- Power Purchase Agreement amendments.

The third type of sensitivity considers ***changes in state***:

- Novel operating practices,
- Changes to the existing operating practices, and
- Retirement of some existing fossil fuel generation.

Some of the sensitivity cases outlined above will be considered for each of the scenarios, but each sensitivity case will not be exhaustively analyzed.

Based on the results of the baseline model, "higher wind penetration" scenario, "enhanced energy management" scenario, and "increased energy security" scenario analysis, the "lower cost of electricity" scenario may be revised or removed from the scope of Phase 2, by the project team, if additional perturbations to the first three scenarios and/or the baseline model are deemed more important than considering the "lower cost of electricity" scenario.

Definitions of Scenarios

In this section the baseline "business-as-usual" case and the first two scenarios ("higher wind penetration" and "enhanced energy management") are constructed. The remaining two scenarios ("increased energy security" and "lower cost of electricity") will be constructed based on the results of the baseline and first two scenario analyses.

Baseline: Business-as-usual

The baseline model, termed "business-as-usual," consists of a minimalist approach to meeting the island's electricity needs in 2018. A 16MW steam turbine (ST7) will be deployed at Keahole before 2018. This deployment enables dual train combined cycle operation in conjunction with two existing combustion turbines (CT4 and CT5). According to IRP, the deployment of ST-7 will allow HELCO to meet its capacity needs for the next several years[1].

Even though HELCO does not develop separate forecasts for the East and West regions of the Big Island[2], load is expected to grow more rapidly in the western region of the island. Peak load and electricity consumption in 2018 will be calculated based on IRP3 growth projections, 2006 historical peak load and 2006 historical load factor. HELCO IRP-based NYMEX fuel price projections will be used to estimate the fuel prices of MSFO, LSFO and diesel in 2018.

Currently, three transmission lines are not in compliance with HELCO's transmission planning criteria, for line loading[3]. The 7300 (Waimea-Ouli), 7200 (Waimea-Keamuku), and 6800 (Keamuku-Keahole) transmission lines have been identified to be at risk of exceeding their emergency ratings. In order to resolve the line overload conditions, HELCO is planning to reconductor/rebuild the three lines starting in 2007. The cost of the reconductoring is provided in the IRP[4]. These reconductored lines will be included in the baseline model.

Current HELCO operating practices (and must-run conditions) will be assumed the same for 2018 and will therefore be included in the baseline model.

[1] Ibid, p.1-29
[2] Ibid, p.1-27
[3] Ibid, p. 7-6
[4] Ibid, p. 12-7 to 12-10 and Table 7.6-2, p. 7-31

Scenario 1: Higher Wind Penetration

The higher wind penetration scenario is motivated by a trend on the big island for wind farm developments and an increasing penetration of renewables. As the island reaches higher penetrations of wind, HELCO indicates that system stability is at risk.

According to the HELCO IRP, high-resolution wind maps reveal that the offshore wind speeds are too low in regions having shallow depths necessary for today's offshore wind technologies[5]. Therefore, in this scenario, **50MW of additional on-island wind power will be added to the Big Island of Hawaii**. Wind power capacity will be increased at three existing locations:

- The current 20.5MW Pakini Nui / Apollo wind farm at South Point will be doubled from 14 to 28 GE 1.5MW turbines,
- 10.5MW of wind power will be added to the 10.5MW Hawi Renewable Development wind farm in Hawi, and
- 20.5MW of wind power (14 GE 1.5MW turbines with integrated controls) will be added at the Lalamilo site, near Waimea.

These technology deployments are shown in Figure 2.

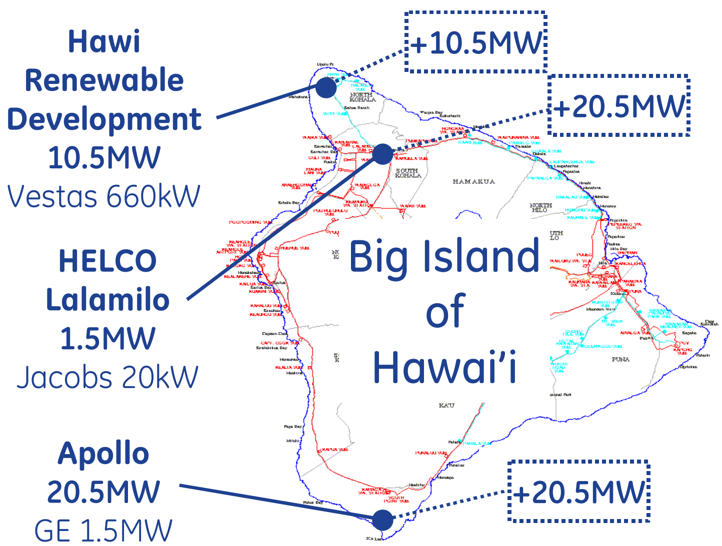

Figure 2. Higher wind penetration scenario for the big island of Hawaii.

As part of the HELCO Sustainability Plan, 40MW of wind with storage and 30MW pumped storage hydro were considered as potential IPPs[6]. One of the storage technologies used to

[5] Ibid, p. 6-7
[6] Ibid, p. 11-9

mitigate wind intermittency is pumped storage hydroelectric (PSH). Two PSH stations were outlined in IRP3[7]:

1. Puu Anahulu – 30MW, 5hr of storage (150MWh), operating with reversible Francis pump-turbines at a 21% capacity factor. 850 feet of gross head and 510 cfs rated flow. Upper and lower reservoirs are 17 and 16 acres, respectively, and
2. Puu Enuhe – 30MW, 5hr of storage (150MWh), operating with reversible Francis pump-turbines at an 11% capacity factor. 1230 feet of gross head and 350 cfs rated flow. Upper and lower reservoirs are 9 and 16 acres, respectively

One of the final plans outlined in the IRP indicates that a 40MW wind farm could be connected to a pumped hydro storage facility and not to the grid. IRP specifically notes that pumped hydro may not be able to mitigate the second-to-second fluctuations of wind power.[8]

Based on the addition of wind capacity in this scenario, additional transmission and distribution upgrades (beyond the scheduled reconductoring) will be considered. Other potential storage technologies may also be considered, including a battery energy storage system. Advanced grid integration control features may be evaluated as well. As an intermediate step in this scenario, changes in operating practices may be considered for some units, such as some aging fossil fuel generators.

[7] Ibid, p. 6-18
[8] Ibid, p. 8-9

Scenario 2: Enhanced Energy Management

Multiple demand-side and supply-side approaches will be considered in this scenario, including plug-in hybrid electric vehicles (PHEV), energy efficiency programs, distributed generation, combined heat and power, distributed photovoltaics, and residential and commercial load control and electrical and thermal energy storage programs.

The Energy Efficiency Docket No. 05-0069 proposed that the implementation of demand-side management (DSM) programs would be transitioned from HELCO to a third-party administrator in 2009; however load management DSM programs will continue to be administered by the utility[9]. The existing programs include[10]:

- Residential Efficient Water Heating Program (REWH),
- Commercial and Industrial Energy Efficiency Program (CIEE),
- Commercial and Industrial New Construction Program (CINC),
- Commercial and Industrial Customized Rebate Program (CICR),

The new DSM energy efficiency programs include:

- Residential New Construction Program (RNC),
- Energy Solution for the Home Program (ESH),
- Residential Qualifying Income Program (RQI),

New Load control programs include:

- Residential Direct Load Control (RDLC),
- Commercial and Industrial Load Management (CILM),

Additionally, in HELCO's test year 2006 rate case, Docket No. 05-0315 proposed four new time-of-use rate options (RTOU).

In this scenario, plug-in hybrid electric vehicles (PHEV) will constitute a significant percentage of the transportation fleet (10% of the light-duty car and truck fleet on the Big Island in 2018). This translates into approximately 170MWh / night if vehicles are charged daily. The presence of "smart-charging" technology results in **25MW peak PHEV load, occurring in the middle of the night.** The energy is distributed throughout the hours of the day in which load is less than the average hourly load (see Figure 3). By charging PHEVS at night, the 24hr load curve is flattened. Therefore, a greater percentage of generation can be provided by baseload generation, resulting in less cycling of fossil fuel units and potentially less curtailment of as-available renewables.

The State Renewable Portfolio Standard states that 20% of electricity production in 2020 must be met by renewable energy; half of which can be reduced by energy efficiency. In 2018, 9% of electricity consumption (half of the 2018 renewable electricity production

---

[9] Ibid, p. 1-20

[10] Ibid, p. 5-6

requirement) is reduced by energy efficiency programs. In this scenario, two energy efficiency programs will be considered to reduce the demand: (1) approximately half of the energy reduction is provided by a **uniform 7MW load reduction** (see Figure 3), and (2) the remaining reduction is provided by **a 10MW load reduction at peak, reduced by the load factor (ratio of the current load to the peak hourly load) in the other hours of the day** (see Figure 3).

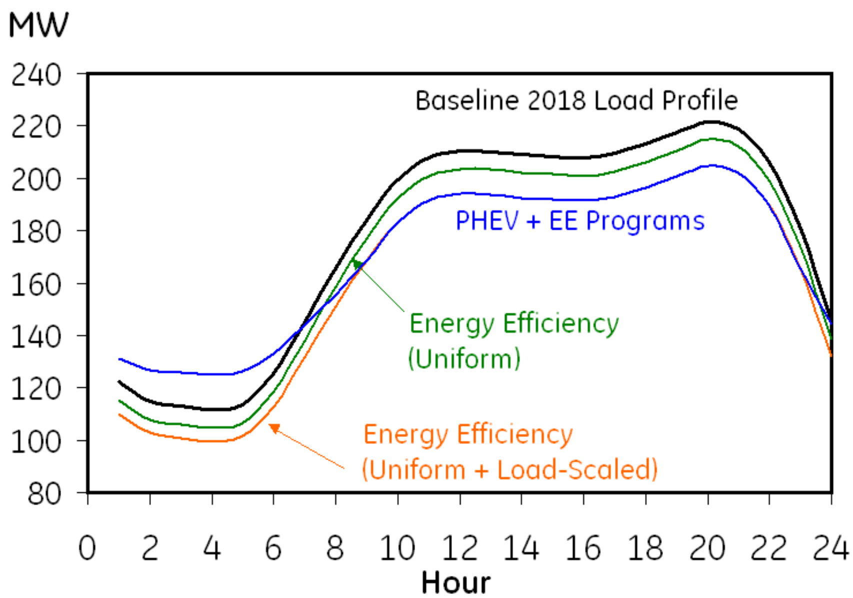

Figure 3. The impact of energy efficiency (uniform and load scaling reduction) and PHEVs on the average daily load profile for the Big Island in 2018.

Installation of **thermal storage** at some of the resorts located on the west side of the island shifts energy from the peak hours (hours greater than average load) to the off-peak hours (hours less than average daily load). This results in a **7W load reduction at peak**. During the hours less than peak, 25% additional energy (in excess of the amount displaced during the peak) is required (see Figure 4).

Direct load control programs will be assumed implemented at some of the resorts on the west side of the island. In this scenario, direct load control allows HELCO to **reduce the up-spinning reserve requirement by 2MW**. In addition, **residential demand side management allows for 5MW peak load reduction to be shifted from daytime to nighttime**. The energy is shifted from the hours greater than average load to the hours less than the average load (i.e., daytime to nighttime). Due to the load shift, only 80% of the energy that would have been consumed during peak is consumed at low load (see Figure 4).

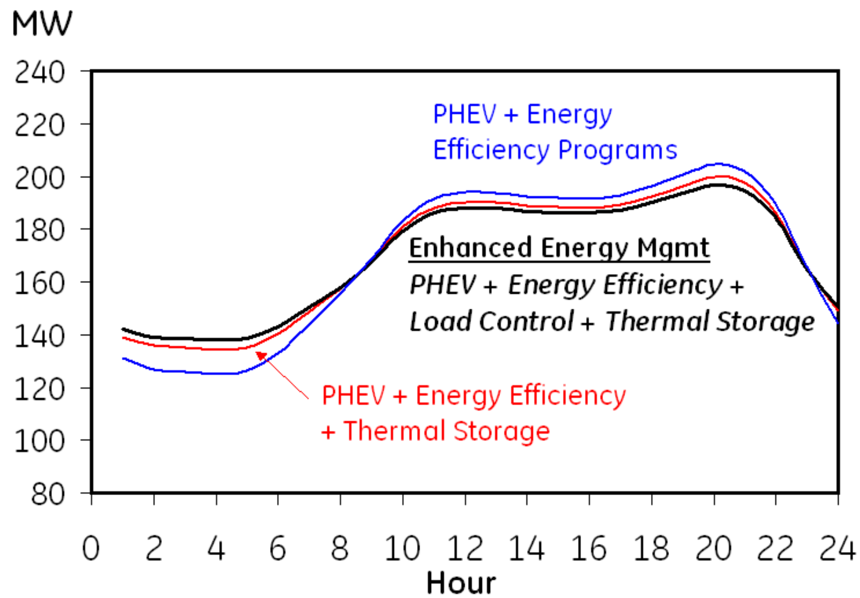

Figure 4. The impact of thermal storage and load control programs on the energy efficiency and PHEV load profile described in Figure 3.

From the supply-side perspective, **15MW of solar power** is distributed around the island at both resorts and residences. Based on IRP3, 856GWh from distributed, customer-sited PV is expected over the 20-year planning period of IRP[11].

Among a list of its attributes, Combined Heat and Power (CHP) technologies increase the efficiency of distributed generation by using the exhaust heat to displace electricity consumption in applications such as absorption chilling or water heating. The State Legislature has included the use of waste heat from CHP in the definition of renewable energy technologies that count towards the State Renewable Portfolio Standard.[12] In this scenario, **10MW of CHP installations are distributed around the island**. HELCO's updated CHP forecast[13] in the IRP indicates that there will be 5.5MW of installed CHP capacity by 2018. CHP will reduce grid electricity consumption in two ways: (1) CHP produces electricity from on-site generation, and (2) avoids grid consumption from other equipment on-site, such as using absorption chillers instead of conventional chillers.

[11] Ibid, Page 11-8
[12] Ibid, p. 6-30
[13] Ibid, Table 10.1-3

Conclusions

The models developed in Phase 1 of the Hawaii Energy Roadmap will be enhanced to accommodate the scenarios outlined in this document. A new baseline “business-as-usual” model will be built in MAPS (production cost model) and PSLF (dynamic simulation model). From there, the two scenarios (“higher wind penetration” and “enhanced energy management”) outlined in this document will be analyzed. Based on the results of the analyses the remaining two scenarios (“increased energy security” and “lower cost of electricity”) will be further defined. The results of the scenario analysis will provide insight into a sensible first project on the Big Island of Hawaii.