UHERO
THE ECONOMIC RESEARCH ORGANIZATION AT THE UNIVERSITY OF HAWAI'I

ENERGY & GREENHOUSE GAS SOLUTIONS RESEARCH PROGRAM

Statewide Economy and Electricity-Sector Models for Assessment of Hawai'i Energy Policies

JULY 2012

There are a variety of economic modeling approaches to assess the cost and greenhouse gas (GHG) implications of various energy and environmental policy alternatives. They can be categorized into "top-down" and "bottom-up" methods. The Hawai'i Computable Generable Equilibrium Model (H-CGE) is a "top-down," economy-wide model that captures the interaction between both producers and consumers, including full price effects between sectors. The Hawai'i Electricity Model (HELM) is a "bottom-up" representation of Hawai'i's electricity sector. The dynamic optimization model solves for the least-cost mix of generation subject to satisfying demand, regulatory requirements, and system constraints. The models are fully integrated in respect to the electricity sector, where overall economic conditions determine electricity demand and, subsequently, the type of electricity generation has economic impact.

OVERVIEW

Petroleum manufacturing accounts for 4.4% of economic activity in Hawaii (a $4.6b industry relative to a $105.9b economy) (DBEDT, 2011); therefore fluctuating oil prices can have a dramatic effect on real economic activity (Coffman, Konan and Surles (2007); Coffman (2010); and cites therein). Hawaii is particularly vulnerable to increases in world oil prices, because unlike most other U.S. states, Hawaii meets nearly 80% of its electricity needs through oil-burning. Hawaii, with leadership from the Governor's Office, the State Energy Office, the Public Utilities Commission, Hawaiian Electric Company, and the Legislature, currently plans a significant shift away from fossil fuels towards renewable energy sources. Decision-makers will need to understand the sector-level and economy-wide impacts of policy decisions. To this end, UHERO built and maintains two complementary models for this purpose: 1) a statewide economy model with a focus on energy consumption and supply, and 2) a detailed electricity sector model.

A CLOSER LOOK AT "TOP-DOWN" AND "BOTTOM-UP" MODELS

Top-down energy sector models are often general equilibrium representations of the entire economy, with specific focus on the energy sector. Top-down models are often utilized because they lend themselves to analysis of links of the energy sector to overall economic activity, welfare impacts, and policy. Top-down models do not, however, contain a detailed representation of the energy sector and thus lack the ability to realistically represent various engineering constraints and other discontinuities. H-CGE is a top-down model of Hawaii's overall economy.

Bottom-up energy sector models, on the other hand, are often dynamic optimization and thus allow for greater detail on capital costs, operating costs, technological constraints and environmental factors. Bottom-up models of the electric sector simulate competition among electricity types by choosing the most cost-effective technology, or mix of technologies, to meet electricity demand within given load and other physical constraints. HELM is a bottom-up model of Hawaii's electricity sector.

H-CGE

H-CGE is an economy-wide computable general equilibrium model calibrated to the most currently available State of Hawaii Input-Output (I-O) Table maintained by the State of Hawaii Department of Business, Economic Development and Tourism.

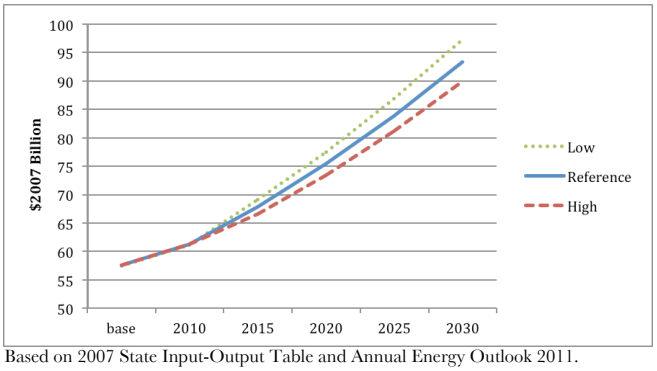
The I-O Table provides a Social Account Matrix (SAM) of economic activity for Hawaii, at the macroeconomic level, sector level, and for final demand amongst key agents such as households, visitors, state and federal government. The I-O Table details 68 sectors of Hawaii's economy, 11 agents of final demand, and value-added in the form of capital endowments, wage labor, and proprietor income.

The oil price projections provided in EIA's *Annual Energy Outlook* (reference, low, and high) are used to provide baseline scenarios. The model projects dynamically in five-year intervals to the year 2030, with endogenous capital accumulation that is propelled by a historic rate of 2.2% annual economic growth.

H-CGE is solved using GAMS (General Algebraic Modeling System) and MPSGE (Mathematical Programming for General Equilibrium Analysis).

Figure 1 shows Real Gross State Product for Hawaii's economy to the year 2030 (in constant 2007 dollars) under low, reference and high oil price scenarios. Real Gross State Product is an indicator of overall economic health, where gross state product accounts for the value of total output, net the value of imports, in constant 2007 dollars.

FIGURE 1. REAL GROSS STATE PRODUCT



Based on 2007 State Input-Output Table and Annual Energy Outlook 2011.

The cost of petroleum enters either directly or indirectly (through other goods and services) into the production (and cost function) of every sector of Hawaii's economy. Thus there are real aggregated impacts of oil price increases throughout the economy. As such, the economy clearly performs best under the low oil price scenario. It is important to note, however, that this scenario does not yet include renewable energy technologies and thus provides three baseline scenarios against which to assess Hawaii's clean energy alternatives. Although oil price increases have been linked to recessionary economic conditions in their aftermath, this is nonetheless a fairly "short-term" assessment of oil price increases. The long-term impacts include allowing for price signals relative to alternative energy types (which will occur through the link with HELM).

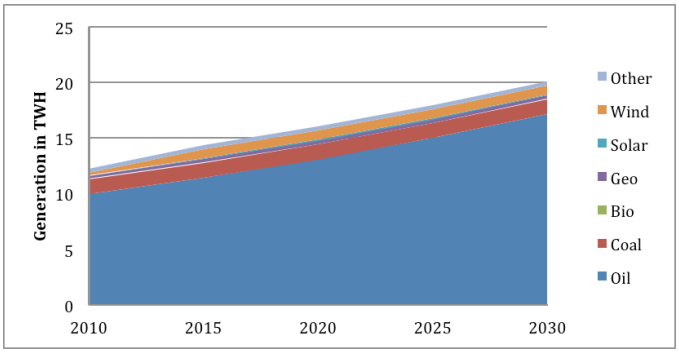
HELM

HELM is calibrated to existing electricity units prior to year 2010 for Hawaii's four counties: the City & County of Honolulu, Maui County, Kauai County, and Hawaii County. The database for HELM is constructed from several publicly available sources – ranging from planning documents including the utilities' Integrated Resources Plans (IRPs), "rate case" approvals to the PUC, and the U.S. Energy Information Administration's (EIA) state energy database.

HELM is formulated as a fully dynamic nonlinear program model (i.e. a partial equilibrium representation of the electricity sector for the State) that solves for the least cost mix of generation to satisfy demand while complying with system operating conditions and environmental policies. HELM similarly optimizes decisions through the year 2030.

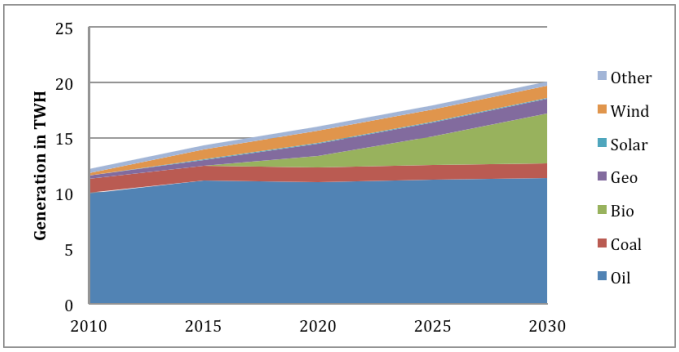
HELM is designed to solve for the least-cost mix of electricity generation under a variety of policy assumptions. As an example, the following two graphics illustrate possible least-cost generation outcomes assuming the Renewable Portfolio Standard (RPS) does and does not exist. The first graphic, "No RPS Policy" shows the least-cost mix of generation assuming there is no mandate to achieve 40% of electricity sales by renewable sources by the year 2030. The second graphic, "RPS Policy," shows that when this policy is put into place

NO RPS POLICY



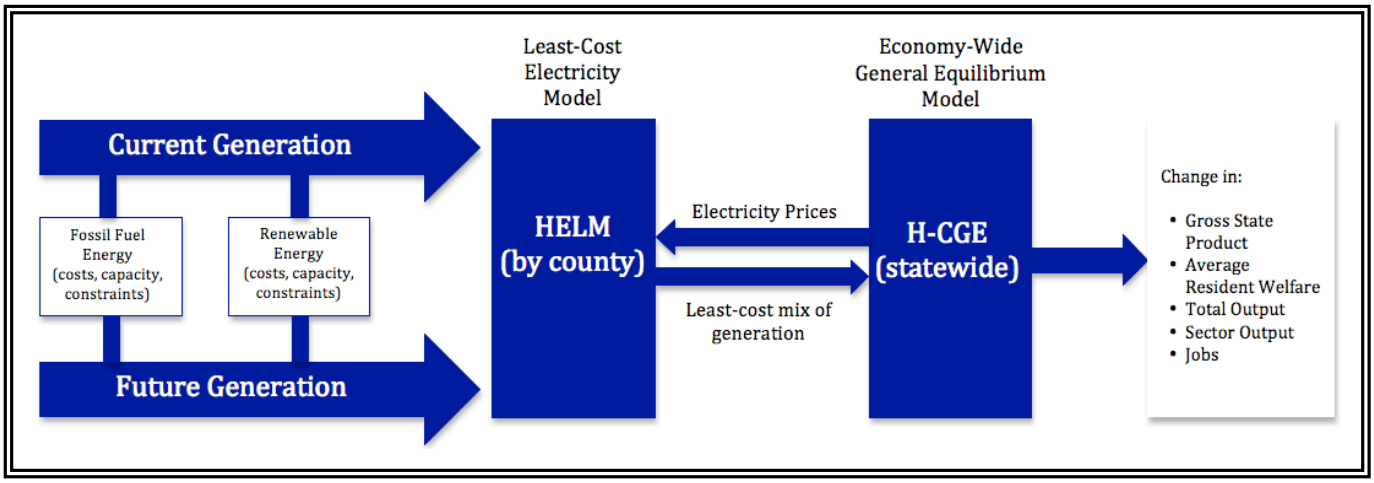
*No RPS Policy scenario assumes no RPS Policy exists. This also reflects a "no more coal" assumption, which means that no additional coal is introduced even though there is currently no law deterring the introduction of coal.

RPS POLICY



*This similarly reflects a "no more coal" assumption.

HELM & H-CGE INTERACTION



H-CGE and HELM are fully integrated through the electric sector. H-CGE is calibrated using the three fuel price projections provided by the EIA's Annual Energy Outlook and, with this, informs HELM of electricity prices (and implicitly electricity demand). HELM then solves for the least-cost mix of electricity generation, given system constraints and various policy scenarios, which then informs H-CGE of the cost of electricity generation over the time horizon projecting to 2030. This process iterates until equilibrium is reached. Economic indicators of interest include changes to gross state product, average resident welfare, total and sector output, and jobs. In addition, HELM solves for the overall level of electricity demand, the mix of fuels and technologies as well as electric sector greenhouse gas emissions.

Full model report, ***Statewide Economy and Electricity-Sector Models for Assessment of Hawaii Energy Policies****, can be found at www.uhero.hawaii.edu under Products, Research Papers.*