Hawaii Greenhouse Gas Emission Reductions Modeling

ENERGY 2020 Model Inputs and Assumptions

31 August 2009

Prepared for:
Hawaii Department of Business, Economic Development & Tourism

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PLEASE NOTE:

This report outlines the assumptions and data inputs used in developing a Reference Case for the Hawaii Department of Business, Economic Development and Tourism, in support of the Greenhouse Gas Emission Reduction Task Force.

The development of the Reference Case is on-going and as such this should be viewed as a living document that will evolve as the model is reviewed and refined.

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Acronyms & Definitions

AEO	Annual Energy Outlook (published by EIA)
AFUDC	Accumulated Funds Used During Construction
Bunker Fuel	Fuel supplied to ships and aircraft, both domestic and foreign.
Btu	British Thermal Units
CAC	Criteria Air Contaminants (SO_x, NO_x, PM, etc.)
CECS	Commercial Energy Consumption Survey
CFL	Compact Fluorescent Light bulb
CHP	Combined Heat and Power
CO_2e	Carbon Dioxide equivalent
GDP	Gross Domestic Product
GO	Gross Output
GWP	Global Warming Potential
DBEDT	Department of Business, Economic Development and Tourism
DG	Distributed Generation
DOE	United States Department of Energy
DSM	Demand Side Management
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse Gas
IECC	International Energy Conservation Code
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resource Plan
kW	Kilowatt
kWh	Kilowatt-hour
MECS	Manufacturer's Energy Consumption Survey
Mt	Megatonne
MW	Megawatt
MWe	Megawatt electric
Mt CO_2e	Megatonne Carbon Dioxide Equivalent
MTCE	Megatonne Carbon Equivalent (as distinct from Carbon Dioxide Equivalent)
NAICS	North American Industry Classification System
NERC	North American Electric Reliability Corporation
NHTSA	National Highway Traffic Safety Administration
NOx	Nitrogen Oxides
OGCC	Oil/Gas Combined Cycle Turbine
OGCT	Oil/Gas Combustion Turbine
OGST	Oil/Gas Steam Turbine
PC	Pulverized Coal
REMI	Regional Economic Models, Inc.
RECS	Renewable Energy Certificates
Rest of US	Balance of systems in US
SEDS	State Energy Data System
SLH	Session Laws of Hawaii
SO_x	Sulfur Oxides (including sulfur dioxide)
SSI	Systematic Solutions, Inc.

USEPA	United States Environmental Protection Agency
W	Watt

1 Background and Project Scope

The State of Hawaii has committed to reducing its greenhouse gas (GHG) emissions to 1990 levels or below by 2020. The State's Greenhouse Gas Emissions Reduction law (Act 234, SLH 2007) established a Greenhouse Gas Emissions Reduction Task Force (the 'Task Force') to develop a plan to achieve this state goal.

ICF International ('ICF') was selected to assist the state and the Task Force in updating the State's inventory of GHG emissions and to develop and model alternative plans to achieve the State's GHG reduction target.[1] ICF selected ENERGY 2020, a multi-fuel, multi-sector energy and emissions model, owned by Systematic Solutions Inc. ('SSI') as the most appropriate tool to model different emission reduction plans. ENERGY 2020 realistically represents the impacts of potential policies, including the interactions of those policies as part of a broader action plan.

This report outlines the assumptions and data inputs used in developing the Reference Case that will be used as the basis for evaluating proposed policy changes. The report describes the data and assumptions used, the sources of this data, and the processes used in developing the Reference Case.

2 Organization of the Report

The report is organized into four main sections. Section 1 provides background information regarding the purpose and scope of the project. Section 2 describes how the report is organized. Section 3 describes the analytic approach used by ENERGY 2020 and the characteristics of the model. The final section (4) describes the model inputs. A more detailed explanation of the ENERGY 2020 model is included as Appendix A.

3 Analytic Approach

ICF developed an updated inventory of GHG emissions for Hawaii in December 2008. The inventory covered sources and sinks of GHG emissions by island for 1990 and 2007. Building on the information collected as part of this inventory, ENERGY 2020 was then used to model a business-as-usual outlook for Hawaii to 2020 – the Reference projection – at a county level. While this projection represents only one possible trajectory for future emissions, it provides a realistic structure on which to test the implications of various proposed GHG reduction policies. The model will be used to develop alternative combinations of policies (i.e., work plans) to meet the State's GHG emissions reduction target.

ENERGY 2020 is an integrated multi-region energy model that provides complete and detailed, all-fuel demand and supply sector simulations. These simulations can additionally include

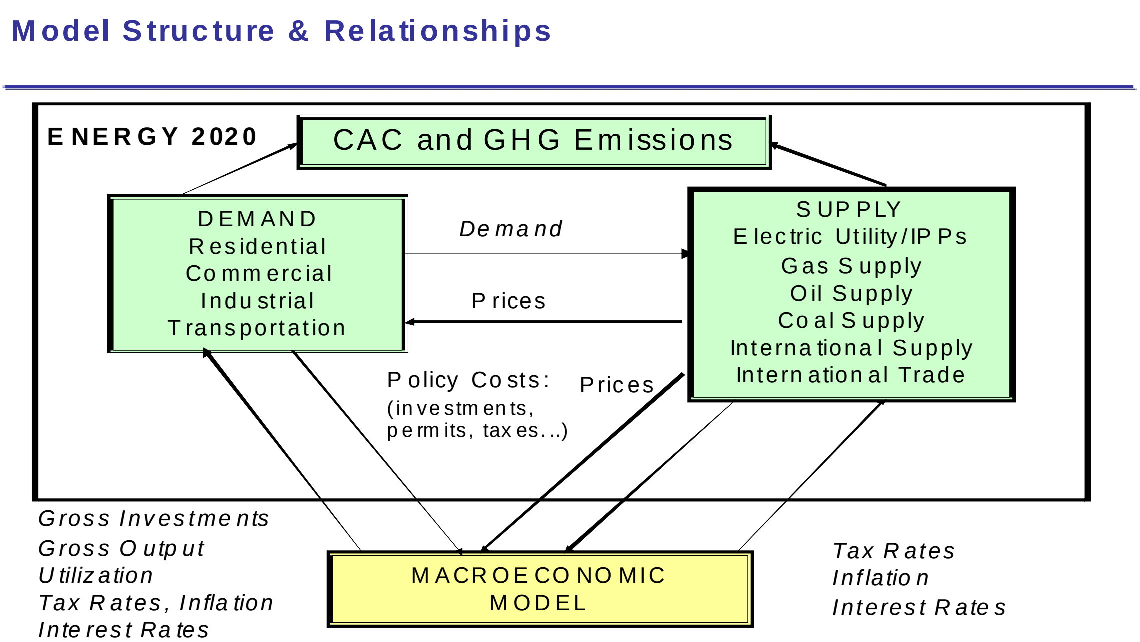
[1] The target levels do not include emissions resulting from aviation. Act 234 specifies that emissions from aviation cannot be regulated as part of the emissions reduction effort. International bunker fuels (fuel supplied to ships and aircraft for international transportation) are also excluded from totals per IPCC convention.

macroeconomic interactions to determine the benefits or costs to the local economy of new facilities or changing energy prices.

The basic implementation of ENERGY 2020 for North America now contains a user-defined level of aggregation down to the 10 provincial and 50 state (and sub-state) level. ENERGY 2020 contains historical information on all generating units in the US and Canada. Data for Mexico can be incorporated as needed. ENERGY 2020 is parameterized with local data for each region/state/province as well as all the associated energy suppliers it simulates. Thus, it captures the unique characteristics (physical, institutional and cultural) that affect how people make choices and use energy. The specific data sources used for Hawaii are described in Section 4.5 below.

ENERGY 2020 can be linked to a detailed macroeconomic model to determine the economic impacts of energy/environmental policy and the energy and environmental impacts of proposed policies. For US regional and state level analyses, the Regional Economic Models Incorporated[2] (REMI) macroeconomic model is regularly linked to ENERGY 2020. The REMI macroeconomic model includes inter-state/provincial, US and world trade flows, price and investment dynamics, and simulates the real-time impact of energy and environmental concerns on the economy and vice versa.

The macro-economic model, in this case REMI, is used to provide a forecast of the economy to ENERGY 2020. The projected level of economic activity is then used in the model to drive requirements for new investments, processes and equipment (as described in Appendix A).



ENERGY2020 simulates energy choices relating to these investments regarding the types of fuel and energy efficiency associated with those investments based on prices, policies and other

[2] Regional Economic Models, Inc. www.remi.com

factors. Once ENERGY 2020 has completed its simulation, outputs from ENERGY 2020, including the level of investments, energy prices, policy costs, etc., can be fed back to REMI. These outputs are then used to determine the extent of economic impacts resulting from changes in energy policy.

The structure of the ENERGY 2020 model is well tested and has been used to simulate not only US and Canadian energy and environmental dynamics, but also those of several countries in South America, Western, Central, and Eastern Europe. These efforts include strategic and tactical analyses for both planning and energy industry restructuring/deregulation. In the 1990s, the US EPA made ENERGY 2020 available to interested states to analyze emissions, energy, and economic impacts of state-level climate change initiatives. Further, the model has been used successfully for deregulation analyses in all the US states and Canadian provinces. Many US and Canadian energy suppliers use the model for the analysis of combined electricity and gas deregulation dynamics.[3]

The default version of ENERGY 2020 simulates demand by three residential categories (single family, multi-family, and agriculture/rural), over 40 North American Industry Classification System (NAICS) commercial and industrial categories[4], and three transportation services (passenger, freight, and off-road). There are approximately six end-uses per category and six technology/mode families per end-use.[5] Currently, the technology families correspond to six fuels groups (oil, gas, coal, electric, solar and biomass) and 30 detailed fuel products. The transportation sector contains 45 modes of transportation, including various type of automobile, truck, off-road, bus, train, plane, marine and alternative-fuel vehicles. More end-uses, technologies, and modes can be added as data allow. For all end-uses and fuels, the model is parameterized based on historical, locale-specific data. The load duration curves are dynamically constructed from the individual end-uses to capture changing conditions under consumer choice and combined gas/electric programs. ***The specific data sets used to model Hawaii are described in Appendix B.***

Each energy demand sector includes cogeneration, self-generation, and distributed generation simulation, including mobile-generation, micro-turbines, and fuel-cells. Fuel-switching responses are rigorously determined. The technology families (which can be split, as an option, to portray specific technology dynamics) are aggregates that, within the model, change building shell, economic-process and device efficiency and capital costs as price or other information that the decision makers see, change. Historical and forecast energy use developed for each technology family is disaggregated by economic sector, end-use and technology to parameterize the model.

The supply portion of the model includes endogenous detailed electric supply simulation of capacity expansion/construction, rates/prices, load shape variation due to weather, and changes in regulation.[6] The model dispatches plants according to the specified rules whether

[3] ENERGY 2020 is the only model known to have simulated and predicted the dynamics that occurred in the UK electric deregulation. These include gaming, market consolidation and re-regulation dynamics.
[4] NAICS is the North America Industrial Classification System which was developed jointly by the U.S., Canada, and Mexico to provide new comparability in statistics about business activity across North America.
[5] End-uses include Process Heat, Space Heating, Water Heating, Other Substitutable, Refrigeration, Lighting, Air Conditioning, Motors, and Other Non-Substitutable (Miscellaneous). Detailed modes include: small auto, large auto, light truck, medium-weight truck, heavy-weight truck, bus, freight train, commuter train, airplane, and marine. Each mode type can be characterized by gasoline, diesel, electric, ethanol, NG, propane, fuel-cell, or hybrid vehicles.
[6] ENERGY 2020 does include a complete, but aggregate representation of the electric transmission system. Electric transmission data is provided by FERC, the Department of Energy, and the National Electric Reliability Council. The dispatch technologies in the basic model include: Oil/Gas Combustion turbine, Oil/Gas Combined Cycle, Oil/Gas Combined Cycle with CCS, Oil/Gas Steam

they are optimal or heuristic and simulates transmission constraints when determining dispatch.[7] A sophisticated dispatch routine selects critical hours along seasonal load duration curves as a way to provide a quick but accurate determination of system generation. Peak and base hydro usage is explicitly modeled to capture hydro-plant impacts on the electric system.

ENERGY 2020 supply sectors include electricity, oil, natural gas, refined petroleum products, ethanol, land-fill gas, and coal supply. For Hawaii, coal and natural gas supply are not modeled. Energy used in primary production and emissions associated with primary production and its distribution is included in the model. The supply sectors included in a particular implementation of ENERGY 2020 will depend on the characteristics of the area being simulated and the problem being addressed.

The ENERGY 2020 model includes pollution accounting for both combustion (by fuel, end-use, and sector) and non-combustion, and non-energy (by economic activity) for SO_2, NO_2, N_2O, CO, CO_2, CH_4, PMT, $PM_{2.5}$, PM_5, PM_{10}, VOC, CF_4, C_2F_6, SF_6, and HFC at the state and provincial level by economic sector. Other (gaseous, liquid, and solid) pollutants can be added as desired. Pollution does not need to be determined directly by coefficients but can recognize the accumulation of capital investments that result in pollution emission with usage. National and international allowance trading is also included. Plant dispatch can consider emission restrictions. For Hawaii, only GHG emissions are simulated.

The model captures the feedback among energy consumers, energy suppliers, and the economy using Qualitative Choice Theory and co-integration.[8] For example, a change in price affects demand that then affects future supply and price. Increased economic activity increases demand; increased demand increases the investment in new supplies. The new investment affects the economy and energy prices. The energy prices also affect the economy.

In order to assess the potential impacts of proposed policy options, a *business-as-usual* scenario (the Reference Case) is developed as a point of reference. This *Reference Case* represents a scenario that is viewed as a reasonable expectation of how the economy, energy use and emissions might develop over time.

Part of the nature of developing a Reference Case is the need to address inherently uncertain issues that can have significant impacts on future energy use and emissions. No forecast is going to be *right* or *accurate* in that no one can tell today how some of the key underlying issues may develop. Given the level of uncertainty involved in any projection of a possible future, caution should be used in applying a high level of precision to the modeling results. Understanding the Reference Case, however, can be extremely useful in providing an underlying structure against which to model proposed policies, and in determining directionality and cause and effect.

Numerous assumptions are required to perform an analysis of this type across a range of topic areas, including economic developments, fuel and electric markets, and regulatory structures. Projected outcomes are only as good as the input assumptions upon which they are based, with

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Turbine, Coal Steam Turbine, Advanced Coal, Coal with CCS, Nuclear, Baseload Hydro, Peaking Hydro, Small Hydro, Wind, Solar, Wave, Geothermal, Fuel-cells, Flow-Battery Storage, Pumped Hydro, Biomass, Landfill Gas, Trash, and Biogas.

[7] A 110 node transmission system is used in the default model, but a full AC load-flow bus representation model has also been interfaced with ENERGY 2020.

[8] The model has used the work of Daniel McFadden and Clive Granger since its inception in the late 1970s. A description of theory, its development and application, can be found in McFadden's Nobel Prize Lecture from December 2000, available at: http://nobelprize.org/nobel_prizes/economics/laureates/2000/mcfadden-lecture.html.

more rigorous assumptions leading to a more rigorous analysis. The inputs and assumptions described in this document were developed to provide as accurate a representation as possible of the activities and structures underlying energy use and GHG emissions in Hawaii.

4 Reference Case Inputs

ENERGY 2020 derives energy demands, such as the demand for electricity based on economic activity and device efficiency. The following sections provide a brief overview of the data inputs and assumptions as well as the sources of data used in the Reference Case. Actual data inputs for specific elements such as generating units, emission factors, etc., will be provided to the client separately in Excel spreadsheets.

As a multi-sector analytical tool, ENERGY 2020 requires data and assumptions covering a broad range of economic sectors and their interactions. In most cases, the necessary data – both historical and projected – is available from the federal government (EIA, EPA, FERC, etc.), the private sector (REMI) and the state government (DBEDT, State of Hawaii Data Book, IRP). In developing the model, a considerable amount of state-specific information was available and has been used wherever possible as described in the sections which follow.

The following sections provide an overview of the data and assumptions that will be required to perform the multi-sector analysis, and list the data sources that have been used to populate ENERGY 2020.

Data[9] inputs for ENERGY 2020 are required in five areas:

1. Population and economic
2. Fuel prices
3. Energy use and consumption
4. Emissions and air regulations
5. Electricity generation capacity and operation

The sections below list the key data elements required in each of these areas and the specific data and assumptions used in modeling Hawaii's energy use and emissions.

ENERGY 2020 requires both historical data and projections to calibrate and generate forward-looking projections. Various historical data will be used up to and including 2007, which is the most recent year for which detailed data is available.[10] Projections for the period to be modeled (e.g., through 2020) will be gathered where possible to provide points of comparison and check the reasonableness of the projection.

4.1 *Population and Economic Data*

Population and economic data are required to generate demands for services. The following data sources were used to establish the Reference Case for the State of Hawaii. For each

[9] "Data" here refers to both historical data and assumptions and projections of future inputs.
[10] ICF International completed the 2007 GHG Inventory for the state in December 2008. Hawaii Greenhouse Gas Inventory: 1990 and 2007, Prepared by ICF International for the Hawaii Department of Business, Economic Development & Tourism, December 2008

area, the tables below show the source of default data for the US as well as state and county-specific sources used.

For both the population and economic data, the base information provided by REMI was adjusted to conform to the DBEDT 2035 projections of population[11] and economic activity.

Description of Data/Input	**Sources**	**Detailed Reference**
Total population, historical and projected	REMI	REMI projection modified to align with the DBEDT 2035 Series.
	DBEDT	DBEDT 2035 Series. Population and Economic Projections for the State of Hawaii to 2035. Research and Economic Analysis Division; Department of Business, Economic Development and Tourism. January 2008
Housing Units	U.S. Census Bureau	Population Estimates Program, Population Division
Households by housing type (single-family, multi-family, etc.)	US Census Bureau	Household splits (data available through 2001, then held constant): *Source: U.S. Census Bureau, Housing and Household Economic Statistics Division* Last Revised: *December 16, 2005* http://www.census.gov/hhes/www/housing/census/historic/units.html **Household size** US Census Bureau, Census 2000 - assumes household size is same for all housing types in state. **Number of households** Calculated based on population, household fraction, and household size.
Personal income	REMI	REMI projection.
	DBEDT	DBEDT 2035 Series
	Future	DBEDT 2035 Series
Gross Domestic Product	DBEDT/REMI	REMI projection DBEDT 2035 Series.
Employment	DBEDT/REMI	DBEDT 2035 Series
Tourism	DBEDT	DBEDT 2035 Series

[11] Resident population estimates (as opposed to de facto population estimates, which include visitors) were used in calibrating the baseline in REMI, per correspondence between Bansari Saha, ICF, and Fred Treyz, REMI, in May 2009.

4.2 *Energy Price Data*

Energy prices can play a significant role in end user decisions on equipment, capital and operating decisions. Fuel costs can be critical in determining the costs of electric dispatch, as well as input costs of some industrial processes and home heating. ENERGY 2020 calculates future electric prices based in part on these fuel cost, combined with the costs of dispatched generation.

Energy prices are largely determined by international markets, although domestic demand, such as electric sector demand for natural gas can influence prices. As a result, fuel prices are treated by the model as an exogenous input.

Historic energy price data are taken from US DOE State Energy Data and the DBEDT Data Book. For this project, DBEDT agreed to use a projection of energy prices based on the Energy Information Administration's 2009 Annual Energy Outlook Reference Case Price scenario for 2009 to 2030.[12]

Power prices are calculated endogenously by the model based on generation costs and dispatch. While the model estimates retail electricity prices, actual consumer prices may differ as a result of political, regulatory or market influences. The model has been calibrated to actual electricity prices by county, within reasonable parameters, for the historic period[13].

4.3 *Historic Energy Consumption Data*

ENERGY 2020 models energy use at the end-use level within each economic sector based on the existing physical stock and the efficiency of that stock. The database of device efficiencies reflects both the average efficiency of energy use for current stocks and the efficiency/energy alternatives available to consumers at the margin. Technology and efficiency choices are modeled based on past experience with consumer choice rather than on a purely economic evaluation.

Historic energy use and consumption data used in modeling US jurisdictions is generally derived from the federal Energy Information Administration (EIA) State Energy Data System (SEDS) database. For Hawaii, considerable volume of state-specific data was available, and this data was used to replace national data sources wherever possible.

Default sectoral and end-use data as well as energy intensities are based on the Residential Energy Consumption Survey (RECS), Commercial Energy Consumption Survey (CECS) and Manufacturers Energy Consumption Survey (MECS).

Description of Data/Input	Sources Used/Available
Residential Data - Household income by housing type - No. of people per household - End-use consumption data, including	2001 EIA Residential Energy Consumption Survey (RECS), by Census Region and Division (2005 RECS in process) http://www.eia.doe.gov/emeu/recs/contents.html

[12] Energy Information Administration, Annual Energy Outlook 2009, Report #DOE/EIA-0383(2009), March 2009, http://www.eia.doe.gov/oiaf/aeo/

[13] Based on data from DBEDT, Hawaii Data Books.

Description of Data/Input	Sources Used/Available
fuels used for space and water heating, air conditioning, etc.	Hawaii: HELCO IRP 3, Appendix O - Demand-Side Management Report Phase II study, Global Energy Partners, February 2006. Maui: MECO IRP 3, Appendix L - Assessment of Demand-Side Management Resource Options, Global Energy Partners, December 2006; Oahu: HECO IRP 4, Appendix N – Assessment of Energy Efficiency and Demand Response Potential, Volume II, Appendix D, Global Energy Partners, 2006. Kauai: KIUC IRP, Energy Efficiency Potential Study, April 26, 2005, prepared by KEMA Inc. Data on Military electricity use provided by DBEDT, April 2009
Commercial Data - Floor area by sub-sector - End-use consumption data, including fuels used for space and water heating and energy intensities	2003 EIA Commercial Buildings Energy Consumption Survey (CBECS), by Census Region and Division (2007 CBECS underway) http://www.eia.doe.gov/emeu/cbecs/contents.html Hawaii- sources as above for Residential.
Industrial/Manufacturing Data - Energy use by fuel for each sub-sector and end-use	2002 EIA Manufacturing Energy Consumption Survey (MECS), by Census Region (2006 MECS underway) http://www.eia.doe.gov/emeu/mecs/contents.html Hawaii – as above.
State Energy Data: - Energy consumption and expenditures by sector and energy source	2004 EIA State Energy Data System (SEDS) http://www.eia.doe.gov/emeu/states/_seds.html State of Hawaii Data Book (2000 to 2007) http://hawaii.gov/dbedt/info/economic/databook/

4.4 *Historic Emission Data*

4.4.1 Emissions and Air Regulations

Historic GHG emissions are based on the GHG emissions inventory as prepared by ICF.[14] ENERGY 2020 is calibrated using historic information on all of the major GHG emissions including:

[14] Hawaii Greenhouse Gas Inventory: 1990 and 2007, Prepared by ICF International for the Hawaii Department of Business, Economic Development & Tourism, December 2008

- Carbon dioxide (CO_2),
- Nitrous oxide (N_2O),
- Methane (CH_4),
- Sulfur hexafluoride (SF_6),
- Hydrofluorocarbons (HFCs) and
- Perfluorocarbons (PFCs).

GHG emissions are presented in CO_2 equivalent (CO_2e) terms. The global warming potentials used to convert the different GHG emissions into CO_2e terms are provided in Appendix D.

Input	Sources Used/Available
Emissions by sector, end-use, fuel & GHG	US EPA http://www.epa.gov/climatechange/emissions/usinventoryreport.html ICF International, Hawaii Greenhouse Gas Inventory, 1990 & 2007.

4.4.2 Emission Factors

Emission factors for most fuels are based on values used by ICF in developing national and state inventories. For the transportation sector, the emission factors for CH_4 and N_2O pollutants were adapted from the Canadian National Inventory Report.[15] ENERGY 2020 calculates GHG emissions at the point of combustion for most fuels. Upstream emissions from extraction and processing are captured as part of those respective economic sectors.

Emissions associated with the use of biomass as a fuel are deemed to be biogenic and therefore not contribute to global warming. As a result, the model assumes no GHG emissions are created from the use of biomass.

Emissions from ethanol and other biofuels represent an exception from a modeling perspective. In order to capture the emissions associated with their production and distribution, the model applies full cycle emission factors for these fuels. While the combustion of ethanol and biodiesel are not deemed to result in any anthropogenic emissions, the model uses an emission factor to recognize upstream emissions for biofuels produced within the state. Biofuels produced outside of the state but used within Hawaii will be treated as biogenic emissions.

The full-cycle emission factors used in the model for each biofuels type are shown in the table below:

Sugar Ethanol	26.6 g CO_2e / MJ[16]
Cellulosic Ethanol	14 gCO_2e / MJ[17]
Biodiesel	26.1 gCO_2e / MJ[18]

[15] Environment Canada. National Inventory Report 1990-2005, Greenhouse Gas Sources and Sinks in Canada, April 2007. (Annex 12- Emission Factors)
[16] PEW Centre on Global Climate Change, Ethanol Factsheet, http://www.pewclimate.org/technology/factsheet/Ethanol
[17] Alexander Farrell, UC Berkeley and Daniel Sperling, UC Davis, A Low-Carbon Fuel Standard for California Part 1: Technical Analysis May 29, 2007 Table 2-3 http://www.energy.ca.gov/low_carbon_fuel_standard/UC-1000-2007-002-PT1.PDF
[18] California Air Resources Board, Detailed California-Modified GREET Pathway for Biodiesel (Esterified Soyoil)from Midwest Soybeans, February 2009.

When these fuels are used in combination with other fuels, for example in a mix of gasoline and ethanol, the emissions associated with gasoline combustion are reported as part of total gasoline-related emissions.

4.5 *Electricity Sector Data*

4.5.1 Generation Data

ENERGY 2020 contains information on every generating unit in the county/state. The model tracks and uses the following information for each generating unit:

- Historic Peak Capacity (MW);
- Historic generation levels (GWh);
- Type of fuel used;
- Heat rate;
- Historic annual fuel use (PJ);
- Emissions by pollutant type;
  O&M costs;
- Capacity factors;
- Emission rates;
- Outage rates;
- Location (county);
- Ownership information;
- Plant type (Hydraulic, Coal, Combined Cycle Turbine, etc.)

The data on existing and committed generating units for Hawaii were derived from EIA data (Form 860) supplemented by utility-specific information from the Hawaii Public Utilities Commission (PUC) Integrated Resource Planning (IRP) process.

4.5.2 Electricity Generation Capacity and Operation Data

ENERGY 2020 is populated with data describing the type, operation and performance of every generating unit in the US and Canada. In order to improve model performance, some smaller units with common characteristics have been combined (i.e., wind units at the same site, or small hydraulic units). In addition to plant-level data, the table below includes other inputs necessary to describe the electric system, including transmission capability.

Input	Sources Used/Available
Plant type	Annual Electric Generator Report: EIA Form 860 (2007) IRP 3 documents
Plant capacity	Annual Electric Generator Report: EIA Form 860 (2007) IRP 3 documents
Plant historical generation	EIA Form 906/920 (2001-2007) IRP 3 documents
Plant fuel type	Annual Electric Generator Report: EIA Form 860 (2007)

Input	Sources Used/Available
	IRP 3 documents
Plant heat rate	EIA Form 906/920 (2001-2007)
Plant fuel consumption	EIA Form 906/920 (2001-2007)
Plant emissions by pollutant	EPA CAMD (2001-2007)
Plant costs (operation and maintenance, variable and fixed)	IRP 3 documents
Plant historical capacity factor	EIA Form 906/920 (2001-2007)
Plant availability (outages)	Calculated using generation data
Plant owner and location	Annual Electric Generator Report: EIA Form 860 (2007)
Planned capacity additions and retirements	Annual Electric Generator Report: EIA Form 860 IRP 3 documents
Sales by Rate Class (historic)	FERC Form 1 and Annual Reports to PUC. HELCO: Schedule C Statistical Information from p. 36 of Annual Report to PUC, Data through 2007 obtained from DBEDT; KIUC: Schedule C Statistical Information from p. 36 of Annual Report to PUC, MECO: Sales of Electricity by Rate Schedules from p. 304 of FERC Form No. 1 Annual Report HECO: Sales of Electricity by Rate Schedules from p. 304 of FERC Form No. 1 Annual Report State of Hawaii Data Book (2000 to 2007) http://hawaii.gov/dbedt/info/economic/databook/

The resulting list of generating units was matched to emission data from the EPA in order to calculate emission rates. The resulting emission rates for the targeted GHG emissions were then reviewed for reasonableness based on plant type and capacity factors, etc.

Historic generation by plant type will be calibrated with historic generation data available from the EIA.

4.5.3 Transmission Structure and Dispatch

Power flows are modeled within ENERGY 2020 based on existing transmission capabilities and interconnections as obtained from NERC and IRP reports. In Hawaii, each county has been treated as one node. In the Reference Case it is assumed that there are no interconnections between counties.

Generation is dispatched at the node level for a set of sample hours in each season. Each node is economically dispatched, selecting lowest cost generation first with the resulting clearing price determining the generation price for that node as described in Appendix A. As part of the calculation the model can utilize resources from a neighboring node within the constraints of the transfer capacity between nodes. The transfer of energy between nodes is subject to a 1% loss to represent additional transmission losses.

4.5.4 Planned Capacity Changes

As part of the modeling process, ENERGY 2020 builds new capacity endogenously as needed to meet capacity and reserve requirements or to minimize the total cost of generation (e.g., in response to allowance prices). At any given time, however, plans may already be in place to build, re-furbish, upgrade or retire generation facilities. These plans must be incorporated into the model in order to reflect decisions and commitments that have already been made.

For this project, we reviewed information on generation projects proposed in Hawaii PUC's IRP 3 process. While it is not possible to determine which specific projects will proceed, it was agreed that this modeling effort would assume that units proposed in the IRP 3 process would be completed.

ENERGY 2020 can determine the need for new generation based on a pre-determined reserve requirement. Normally, this determination is based on the highest level of demand for power and the available capacity at the time of that peak. Some types of generation, such as wind or some types of hydro-electric generation however, may not be available at the time of the peak. For modeling purposes, we have assumed that only 15% of installed wind capacity is available at the time of the peak.

4.5.5 New Generation Characteristics

The costs and characteristics of new generation are based on information provided in the IRP 3 reports for each of the utilities in Hawaii.

Carbon capture and storage (CCS) is not assumed to be available during the time frame modeled.

4.5.6 Industrial Generation and Co-generation

ENERGY 2020 models both utility generation, which supplies the power grid, and what the model defines as "industrial generation," which supplies a particular end user.

Industrial generation is defined as power generation that is within an end user's facility that is primarily designed to supply the end user's load. This type of generation may supply some power to the grid through net metering or other arrangements but is primarily run to supply a specific end user. The term is used because this type of generation is most commonly found in industrial operations but may also occur in the commercial, institutional or residential sectors.

In Hawaii, there are a several such generators which serve industrial, residential, resort and medical facilities. Industrial generation, as defined in ENERGY 2020, could also be referred to as “self-generation” or “load displacement generation”. Industrial generation may be supplied by any of the fuels listed below:

- Biomass
- Coal
- LPG
- Oil
- Solar
- Steam

Co-generation, or combined heat and power facilities, simultaneously generate electricity and supply a heat load. ENERGY 2020 recognizes that co-generation may occur either as industrial generation or as utility generation and may use any of a number of fuels.

- Within the power sector, these plants are normally treated as ‘must run’ units, meaning that they will always operate when available. Power from these units contributes to overall electricity supply. Heat from these units may be captured as part of a separate steam supply system; however, limited data is available regarding overall US steam demand.
- Within the industrial sector, co-generation capacity will run based on heating requirements. Heat produced from co-generation is used to meet industrial heat requirements based on a co-generation heat rate. Co-generated electricity is used to meet industrial power requirements, reducing net demand from the grid.

Where the heat contribution of co-generation is significant, the preferred modeling approach is to include these units in the industrial sector as has been done in this project.

The databases used to represent electricity generation often include all significant generators, including both utility and industrial boilers and generators. By contrast, reported electricity consumption information tends to be based on metered electricity sales, and as such are net of self generation. Total electricity consumption and generation will generally be slightly higher than reported electricity sales. It is therefore important in calibrating the model with historic electricity consumption that existing generation used as industrial or self-generation be appropriately identified.   This is particularly true in Hawaii where the level of industrial or self generation is relatively high.

Hawaii has historically had significant levels of industrial and self-generation, primarily associated with the petroleum and sugar refining industries but also serving a variety of commercial and even residential facilities.   Historic levels of industrial generation for Hawaii are based on information from EIA reports (Form EIA-860 Database and EIA-923 Survey), and supplemented by information from the IRP3 process, the Combined Heat and Power Installation Database (supported by US DOE), the Hawaii Data Books and DBEDT. Appendix F contains a list of industrial or self-generation facilities included in the model.   Note that the listing includes generators which have been retired.   These units have been included to allow the model to be run and calibrated with the historic period.

4.6 *Transportation*

ENERGY 2020 models passenger, freight and off road transportation separately, based on different underlying drivers. Transportation is assumed to be a derived demand based on levels of economic output (for freight) or population growth (for passenger). As the economic drivers (industrial gross output and population) grow, transportation demand increases. The amount of transportation required per unit of economic output changes over time based on historic trends. Off road transportation energy use in ENERGY 2020 is driven by activity in the Agriculture, Forestry and Construction sectors.

Transportation requirements are developed for each geographic area in the model based on historic demands for transportation, consumer preferences, business requirements, and the cost for each mode of transportation. Consumers of transportation select among available modes within the model based on preferences and relative costs. Mode choices include bus, train, and various types of personal and freight vehicles. Consumers choose among modes based on consumer preferences and cost. The model uses average vehicle lifetimes to vintage the vehicle stock.

Personal vehicle choices are made in a similar manner. Consumers consider capital cost, fuel cost and efficiency as well as non-price factors in their purchase decision and seek to maximize perceived utility. Historically, non-price factors such as vehicle size, performance and appearance have dominated the choice decision with efficiency playing a relatively minor role. Costs are presented in the model in terms of the capital cost per mile traveled for different vehicle classes. Larger vehicles therefore have a higher associated capital cost as well as lower energy efficiency for the level of delivered service (miles traveled).

The transportation categories represented in the model are shown below.

ENERGY 2020 Classifications				
Economic Categories	**Modes**	**Vehicle Classes** *(Personal Vehicles)*	**Fuel Types** *(Personal Vehicles)*	**Technology Types**
Residential	Ground	Light	Gasoline	Internal Combustion Engine
Local Tourism	• Highway	Medium	Diesel	Hybrids
Aviation	• Bus	Heavy	Propane	Fuel Cell
Marine	• Train		CNG	Plug-In Hybrid
Commercial/Institutional	Passenger Freight		Electric	
Agriculture	Air/Water		Ethanol	
	• Aviation • Marine		Biodiesel Hydrogen	

Vehicle and modal efficiencies used in the model are based on the *Transportation Energy Data Book* (Edition 28, 2009)[19] published by the US Department of Energy's Oak Ridge National Laboratory. Specific data references are provided in the table below. This information has

19 http://cta.ornl.gov/data/download28.shtml

been supplemented by information on vehicle registration and fuel use from the State of Hawaii Data Books and information supplied by DBEDT.

Information regarding state-specific travel patterns has been obtained from the Research and Innovative Technology Administration Bureau of Transportation Statistics.[20] The model also reflects the changes to new passenger vehicle CAFE standards recently announced by the Obama administration (please see section 4.8). Within the model, we have separated the transportation category into the visitor and resident populations, due to the unique level of tourism in Hawaii.

Input	Sources Used/Available
*All tables below are from **Transportation Energy Data Book** (Edition 28, 2009)[21] published by the US Department of Energy's Oak Ridge National Laboratory.*	
Average fuel economy	Tables 4.1, 4.2 and 4.3
New Vehicle Efficiency	Tables 4.7 and 4.9
Scrap/Survival Rates	Tables 3.7, 3.8 and 3.9
Freight Truck Fuel Economy	Tables 5.1 and 5.2
Bus Efficiency	Table 2.13
Rail Efficiency – Passenger	Table 9.10 and 9.11
Rail Efficiency - Freight	Table 9.8
Marine – Freight	Table 9.5
Air Travel	Table 9.2

The Reference Case assumes that the High Capacity Transit system will be completed to serve the Honolulu area. Estimates from the draft Environmental Assessment[22] projections indicate that the transit system will result in about a 3.6% reduction in vehicle miles traveled (VMT) and fuel use for passenger transportation in Honolulu by 2030. For modeling purposes, we have assumed that Oahu VMT will be reduced by 2.8% by 2020, with the reduction starting in 2012. Power consumption for the system has been based on information from the HECO IRP[23].

4.7 *Built Environment*

ENERGY 2020 models multiple residential, commercial and industrial sectors and multiple end uses within each sector as described in Appendices A and B. When a new model is built for a particular project, actual historic energy use is input to the model (generally from the EIA SEDS database) and allocated by sector based on census region data from the most recent energy surveys available from the EIA (e.g., Residential Energy Consumption Survey, Commercial Building Energy Consumption Survey) or jurisdiction-specific sources. The model does not represent the spatial distribution of buildings or how compact the urban form is, however, the pattern and level of transportation and building energy demands is represented based on historic levels of energy use. For this project, the distribution of electricity use has been based

[20] RITA, Bureau of Transportation Statistics, State Transportation Statistics 2007. http://www.bts.gov/publications/state_transportation_statistics/state_transportation_statistics_2007
[21] http://cta.ornl.gov/data/download26.shtml
[22] Honolulu High-Capacity Transit Corridor Project, Draft Environmental Impact Statement, U.S. Department of Transportation, Federal Transit Administration, November 2008.
[23] Hawaiian Electric Company Inc., Integrated Resource Plan 2009-2028, Docket No. 2007-0084, September 30, 2008. Appendix L, Exhibit 7, August 2007 and March 2008 sales and Peak Forecast.

on county-specific analyses prepared as part of the IRP process. Average and maximum device efficiencies are adjusted within the model over time in calibrating to this actual energy use data. Over the past two years, ICF and SSI have subjected this data to an internal review and updated the values based on expert opinion and data from a variety of sources.

Each end use within the model has a minimum and maximum level of efficiency associated with it. The minimum efficiency level is established by standards, such as building codes, lighting, appliance and equipment standards. The maximum is set by technical limitations. As regulations are introduced to raise efficiency standards for a particular end use, new equipment decisions for that end use are restricted from choosing a level of efficiency below the new standard. This same logic applies in transportation choices.

4.8 *Waste, Agriculture, Forestry and Other Land Uses (AFOLU)*

Non-energy emission sources and sinks such as those from waste and AFOLU sectors are modeled within ENERGY 2020. However, the model does not include the same level of detail with regards to the underlying drivers of these emissions as that included for energy-related emissions. For Hawaii, historic emission levels and other assumptions required as inputs to the model are based upon the Hawaii Greenhouse Gas Inventory.[24]

The waste sector cover emissions from municipal solid waste landfills, incineration facilities and wastewater, while AFOLU includes emissions and sinks resulting from enteric fermentation, manure management, agricultural soil management, field burning of agricultural residues, urea application, landfilled yard trimmings and food scraps, urban trees, and forests, and forest fires.

A description of the methodologies used to project future emissions from these sources and sinks is provided in Appendix G. For modeling purposes, it is assumed that waste emissions will increase at a rate projected in Appendix G. Given the uncertainties surrounding some elements of AFOLU emissions they have been held constant at 2007 levels over the period.

4.9 *Programs/Policies Incorporated in Reference Case*

The following policies are assumed to be implemented in the Reference Case.

- The US Energy Independence and Security Act (EISA or Energy Act 2007) – includes changes to CAFE standard, biofuels mandate and lighting, equipment and appliance standards. The CAFÉ standard is modeled by incrementally increasing the efficiency of new vehicles to meet the required fleet average by 2020. Lighting and equipment standards are introduced as changes to the specified end use to meet the standards set out in the Act. The renewable fuel standard is discussed further below.
- US Emergency Economic Stabilization Act of 2008 changes to Energy Tax Incentives.

[24] Hawaii Greenhouse Gas Inventory: 1990 and 2007, Prepared by ICF International for the Hawaii Department of Business, Economic Development & Tourism, December 2008. See pages 39 to 55.

- o Hawaii Renewable Portfolio Standards (RPS) law provided in Chapter 269, Part V, Hawaii Revised Statutes (HRS).[i] The assumptions used in modeling this policy are discussed below.
- o Hawaii Net Energy Metering (NEM) provided in Chapter 269, Part VI, HRS. This policy is modeled by including the opportunity to sell power to the grid at grid prices in the economic evaluation of potential distributed renewable projects.
- o Hawaii Public Benefits Fund (PBF) provided in Chapter 269, Part VII, HRS. This policy was not specifically modeled.
- o Hawaii ethanol content requirement provided in §486J-10, HRS (modeling of renewable fuel requirements is discussed below).
- o Hawaii Lead by Example Initiatives for State Facilities provided in Chapter 196, Part III, HRS. (not specifically modeled in reference projection).
- o Hawaii Solar water heater system requirements provided in Chapter 196, HRS.. Modeling of this policy assumes that 90% of new homes will install solar water heating.

The Hawaii State legislature passed several relevant pieces of legislation in the 2009 session. This legislation could affect RPS requirements, net metering, tax credits for ethanol, establish an Energy Efficiency Portfolio Standard and incent or encourage more efficient transportation. The Governor signed into law Act 155 (HB 1464)[25] and Act 156 (SB 1202)[26] on June 25, 2009. The changes that will be associated with this new legislation have not been included in the reference case, however, per discussion and agreement by Task Force members at the June 16, 2009, meeting.

The U.S. *Energy Independence and Security Act of 2007* was passed into law in early January 2008. The following assumptions have been used to model the Act in the Reference Case:

- Renewable Fuels: The Act specifies a minimum volume of biofuels to be produced each year. The EIA in its Energy Outlook 2009 projects that the level of biofuels produced and consumed by 2020 will fall somewhat below the levels proposed in the Act. For modeling purposes, we have assumed a level of biofuel production that is consistent with the AEO projection. Renewable Fuel Standards are included in the model by modifying the percentage of vehicles which use renewable fuels in order to meet the Standard.
- Residential Boilers and Furnace Fans: Savings estimates developed by the American Council for an Energy-Efficient Economy (ACEEE) for the state has been used to model this portion of the Act, using only the benefits realized by upgrades to the residential energy boilers, leaving out any energy benefits associated with reduced electricity consumption by furnace fans.
- Walk-In Coolers and Walk-In Freezers: Savings estimates developed by the ACEEE for the state has been used to model this portion of the Act.
- Electric Motor Efficiency Standards: The model will utilize the ACEEE savings projections, pro-rated to the state's relative industrial electricity sales.
- External Power Supply Efficiency Standard: savings estimates developed by the ACEEE for each state have been used to model this portion of the Act.

[25] The final text of House Bill 1464 is available online at:
http://www.capitol.hawaii.gov/session2009/Bills/HB1464_CD1_.HTM
[26] The final text of Senate Bill 1202 is available online at:
http://www.capitol.hawaii.gov/session2009/Bills/SB1202_CD1_.HTM

- Energy Efficient Light Bulbs: The base assumptions are that general service lighting accounts for about 90% of residential lighting, 10% of commercial lighting and 5% of industrial lighting.
- Metal Halide Lamp Fixtures: The model assumes that 15% of commercial lighting and 60% of industrial lighting now use metal halide fixtures. For new installations, the model assumes that 80% of this market would use pulse start ballasts.

On May 19, 2009, the Obama administration announced its intention to establish standards for vehicle GHG emissions and CAFE standards which would align with the GHG emission standards previously proposed by California. If this proposal proceeds, it would establish a national standard which would require the fuel efficiency of new passenger cars and light trucks to reach an average fleet efficiency of 35.5 mpg by 2016. Based on discussions with the Task Force, it was determined that this proposal would not be included in the Reference Case but may be modeled as part of later policy scenarios.

The reference case includes a Renewable Portfolio Standard (RPS) for the state as described in Appendix E. As stated above, the amendments to the RPS requirements signed into law on June 25, 2009,have not been included in the Reference Case. The RPS is introduced into the model as a constraint which must be met as the model selects among available generation technologies.

Appendix A: The ENERGY 2020 Model

The Model – ENERGY 2020

ENERGY 2020 is an integrated multi-region, multi-sector energy analysis system that simulates the supply, price and demand for all fuels. It is a causal and descriptive model, which dynamically describes the behavior of both energy suppliers and consumers for all fuels and for all end-uses. It simulates the physical and economic flows of energy users and suppliers. It simulates how they make decisions and how those decisions causally translate to energy-use and emissions.

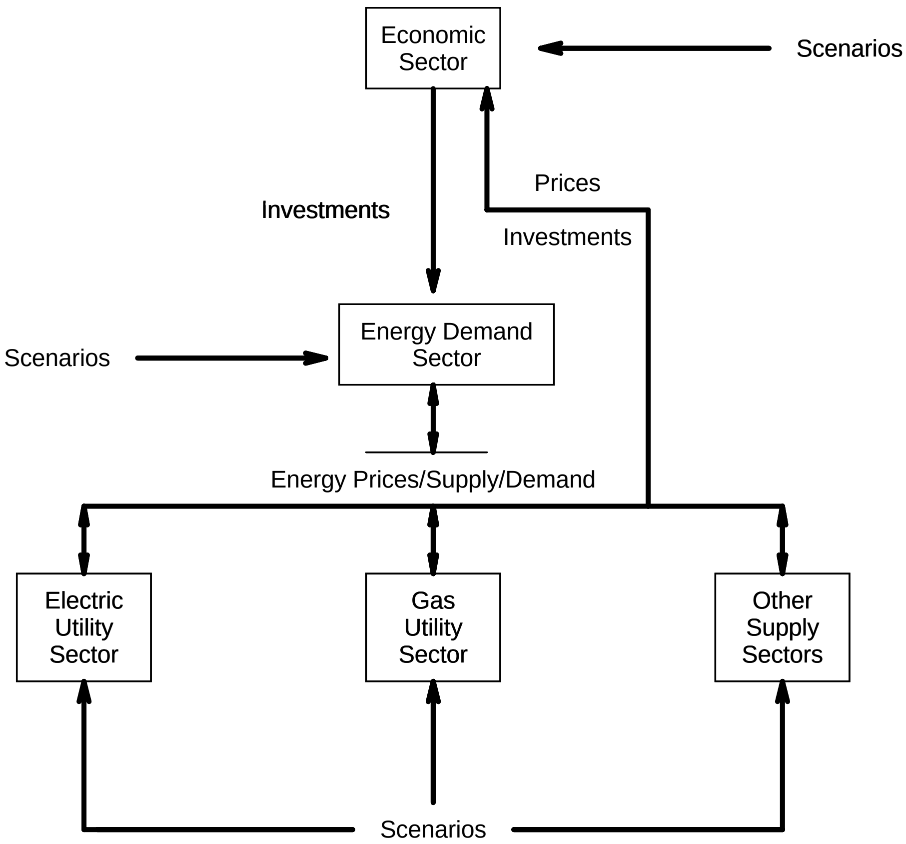
ENERGY 2020 is an outgrowth of the FOSSIL2/IDEAS model developed for the US Department of Energy (DOE) and used for all national energy policy since the Carter administration.[27] This early version of ENERGY 2020 was developed in 1978 at Dartmouth College for the DOE's Office of Policy Planning and Analysis.

Model Overview:

The basic structure of ENERGY 2020 is provided in Figure 1.1. Energy Demand sector interacts with the Energy Supply sector to determine equilibrium levels of demand and energy prices. Energy Demand is driven by the Economy sector, which in turn provides inputs to the Economy sector in terms of investments in energy using equipment and processes and energy prices. The model has a simplified Economy sector to capture the linkages between the energy system and the macro-economy. However, the model is best run with full integration with a macroeconomic model such as REMI. Given the modular nature of ENERGY 2020, additional sectors or modules from other, non-ENERGY 2020 related, models (macroeconomic, supply such as oil, gas, renewables etc.) can be incorporated directly into the ENERGY 2020 framework.

[27] *FOSSIL2 was the original version but was renamed to IDEAS a few years ago to reflect its evolutionary development since its original construction.*

Figure 1.1: ENERGY 2020 Overview



Energy Demand:

The demand sector of the model represents the geographic area by disaggregating the four economic sectors into sub-sectors based on energy services. As many sub-sectors as required can be incorporated into the model. Multiple technologies, multiple end-uses and multiple fuels are detailed. The level of detail that can be incorporated is of course subject to the data availability. The four economic sectors are:

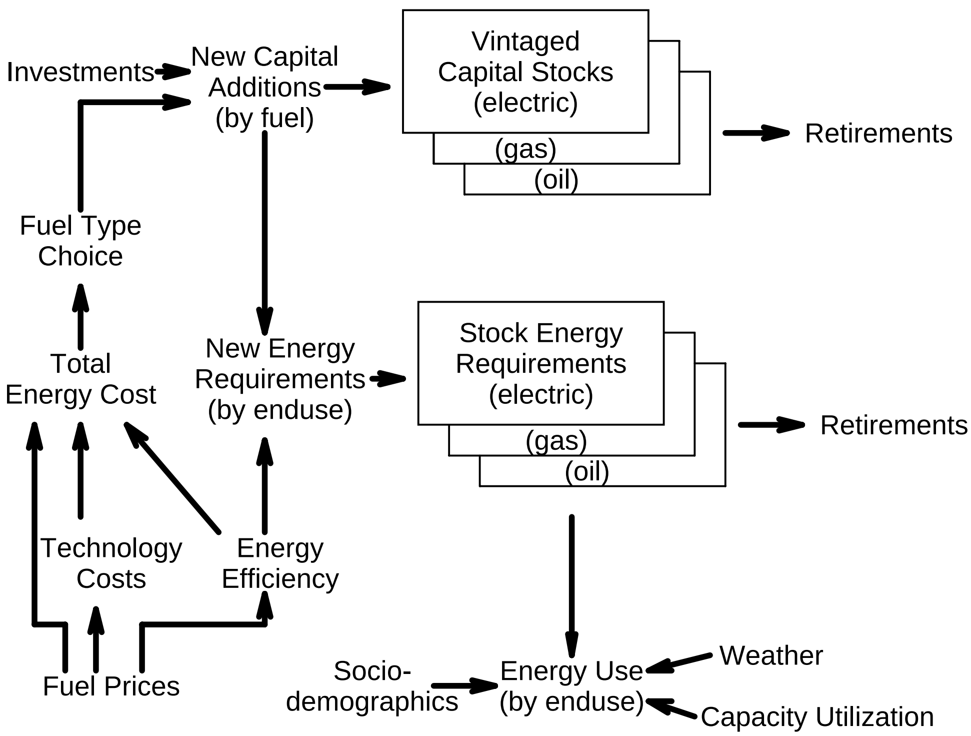
- Residential sector which includes three classes, single family, multi family and other, with 7 end-uses including refrigeration, lighting, water heating, cooking, drying, air conditioning and miscellaneous.
- Commercial sector which is divided into 11 classes: hotel, small office, large office, retail, grocery, warehouse, school, college, health, restaurant and miscellaneous. End-uses include refrigeration, lighting, water heating, cooking, drying, ventilation, air conditioning and miscellaneous.
- Industrial sector which includes 6 categories including sugar, other food/agriculture, oil refineries, steel plants, other industrial and water pumping & sewage. This sector is further broken down into motors, process heat, lighting, cooling and miscellaneous.
- Transportation sector which includes eight categories: residential passengers, tourist passenger, aviation, international aviation, marine, international marine, freight, and

agriculture. These categories are broken down into residential, local tourism, aviation, marine, commercial/institutional and agriculture.

For each of the end-uses, up to six fuels are modeled, for example, the residential space heating has the choice of a gas, oil, coal, electric, solar and biomass space heating technologies. Added end-uses, technologies and modes can be added as data allow. For all end-uses and fuels, the model is parameterized based on historical locale-specific data. The load duration curves are dynamically built up from the individual end-uses to capture changing condition under consumer choice and combined gas/electric programs.

A few basic concepts are crucial to an understanding of how the model simulates the energy system. These concepts including, the capital stock driver, the modeling of energy efficiency through trade-off curves, the fuel market share calculation, utilization multipliers and the cogeneration module are discussed below in abbreviated form. Figure 1.2 (Demand Overview) illustrates the demand sector interactions.

Figure 1.2: Demand Overview



Energy Demand as a Function of Capital Stock:

The model assumes that energy demand is a consequence of using capital stock in the production of output. For example, the industrial sector produces goods in factories, which require energy for production; the commercial sector requires buildings to provide services; and the residential sector needs housing to provide sustained labor services. The occupants of these buildings require energy for heating, cooling, and electromechanical (appliance) uses.

The amount of energy used in any end-use is based on the concept of energy efficiencies. For example, the energy efficiency of a house along with the conversion efficiency of the furnace determines how much energy the house uses to provide the desired warmth. The energy efficiency of the house is called the capital stock energy or process efficiency. This efficiency is primarily technological (e.g. insulation levels) but can also be associated with control or life-style changes (e.g. less household energy use because both spouses work outside the home.) The furnace efficiency is called the device or thermal efficiency. Thermal efficiency is associated with air conditioning, electromotive devices, furnaces and appliances.

The model simulates investment in energy using capital (buildings and equipment) from installation to retirement through three age classes or vintages. This capital represents embodied energy requirements that will result in a specified energy demand as the capital is utilized, until it is retired or modified.

The size and efficiency of the capital stock, and hence energy demands, change over time as consumers make new investments and retire old equipment. Consumers determine which fuel and technology to use for new investments based on perceptions of cost and utility. Marginal trade-offs between changing fuel costs and efficiency determine the capital cost of the chosen technology. These trade-offs are dependent on perceived energy prices, capital costs, operating costs, risk, access to capital, regulations and other imperfect information.

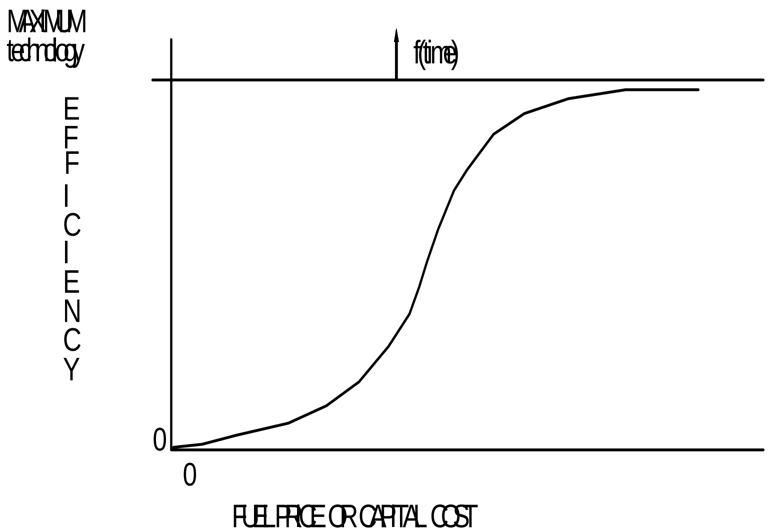
The model formulates the energy demand equation causally. Rather than using price elasticities to determine how demand reacts to changes in price, the model explicitly identifies the multiple ways price changes influence the relative economics of alternative technologies and behaviors, which in turn determine consumers' demand. In this sense, price elasticities are outputs, not inputs, of the model. The model accurately recognizes that price responses vary over time, and depend upon factors such as the rate of investment, age and efficiency of the capital stock, and the relative prices of alternative technologies.

Device and Process Energy Efficiency:

The energy requirement embodied in the capital stock can be changed only by new investments, retirements, or by retrofitting. The efficiency with which the capital uses energy has a limit determined by technological or physical constraints. The trade-off between efficiency and other factors (such as capital costs) is depicted in Figure 1.3 (Efficiency/Capital Cost Trade-Off). The efficiency of the new capital purchased depends on the consumer's perception of this trade-off. For example, as fuel prices increase, the efficiency consumers choose for a new furnace is increased despite higher capital costs. The amount of the increase in efficiency depends on the perceived price increase and its relevance to the consumer's cash flow.

Figure 1.3: Efficiency/Capital Cost Trade-Off

The



standard the model efficiency trade-off curves are called consumer-preference curves because they are estimated using cross-sectional (historical) data showing the decisions consumers made based on their perception of a choice's value. Many planners are now interested in measure-by-measure or least-cost curves which use engineering calculations and discount rates to show how consumers should respond to changing energy prices. Another analysis focuses on the technical/price differences in alternative technologies and the incentives needed to increase the market-share or market penetration of a specific technology. This perspective on the choice process uses market share curves. The model allows the user to select any of these three types of curves to represent the way consumers make their choices. Shared savings, rebate, subsidy programs, etc. can be tested using any of the curves.

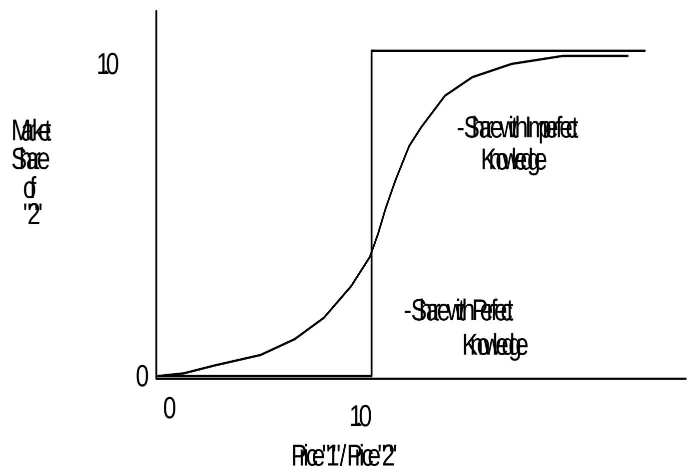
Cumulative investments determine the average embodied efficiency. The efficiency of new investments versus the average efficiency of existing equipment is one measure of the gap between realized and potential conservation savings.

The model uses saturation rates for devices to represent the amount of energy services necessary to produce a given level of output. Saturation rates may change over time to reflect changes in standard of living or technological improvements. For example, air conditioning has historically increased with rising disposable incomes. These rates can be specified exogenously or can be defined in relation to other variables within the model (such as disposable income).

The Market Share Calculation:

Not all investment funds are allocated to the least expensive energy option. Uncertainty, regional variations, and limited knowledge make the perceived price a distribution. The investments allocated to any technology are then proportional to the fraction of times one technology is perceived as less expensive (has a higher perceived value) than all others. This process is shown graphically in Figure 1.4 (Market Share Dynamics).

Figure 1.4: Market Share Dynamics



Short Term Budget Responses:

A short-term, temporary response to budget constraints is included in the model. Customers reduce usage of energy if they notice a significant increase in their energy bills. The customers' budgets are limited and energy use must be reduced to keep expenditures within those limits. These cutbacks are temporary behavioral reactions to changes in price, and will phase out as budgets adjust and efficiency improvements (true conservation) are implemented. This causes the initial response to changing prices to be more exaggerated than the long-term response, a phenomenon called "take-back" in studies of consumer behavior.

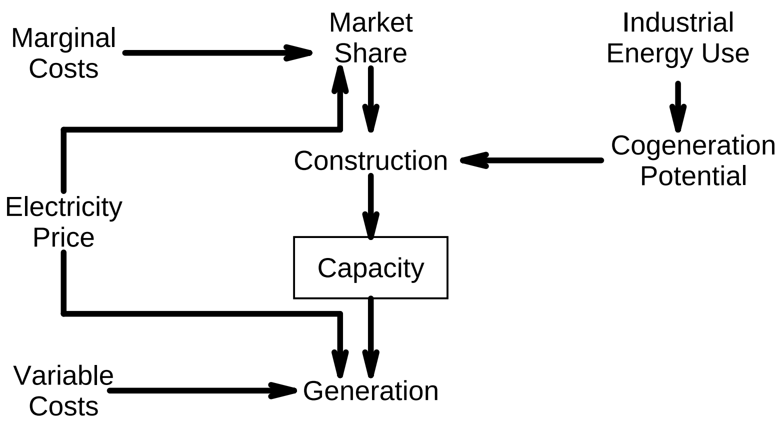
Accounting for Fungible Demand:

Some furnaces and processes can use multiple fuels. That is, they can switch almost instantaneously between, for example, gas and oil or coal and biomass as prices or the market dictates. Energy demand that is affected by this short-term fuel switching phenomena is called fungible demand. The model explicitly simulates this market share behavior.

Modeling Cogeneration:

Most energy users meet their electricity requirements through purchases from a utility. Some users (industrial and commercial) can, however, convert some of their own waste heat into usable electricity when economics warrant such action. Other users (residential and commercial) can purchase self-generation energy sources such as gas turbines, diesel-generators or fuel cells. Figure 1.5 shows a simplified overview of the cogeneration structure.

Figure 1.5: Cogeneration Concepts



In the model all energy used for heating is a candidate for cogeneration. The cost of cogeneration is the fixed capital cost of the investment plus the variable fuel costs (net of efficiency gains). This cogeneration cost is estimated for all technologies and compared to the price of electricity. The marginal market share for each cogeneration technology is based on this comparison.

Cogeneration is restricted to consumers who directly produce part of their own electricity requirement. Companies which generate power primarily for resale to the electric utility are considered independent power producers and are included in the electric supply model.

Energy Supply:

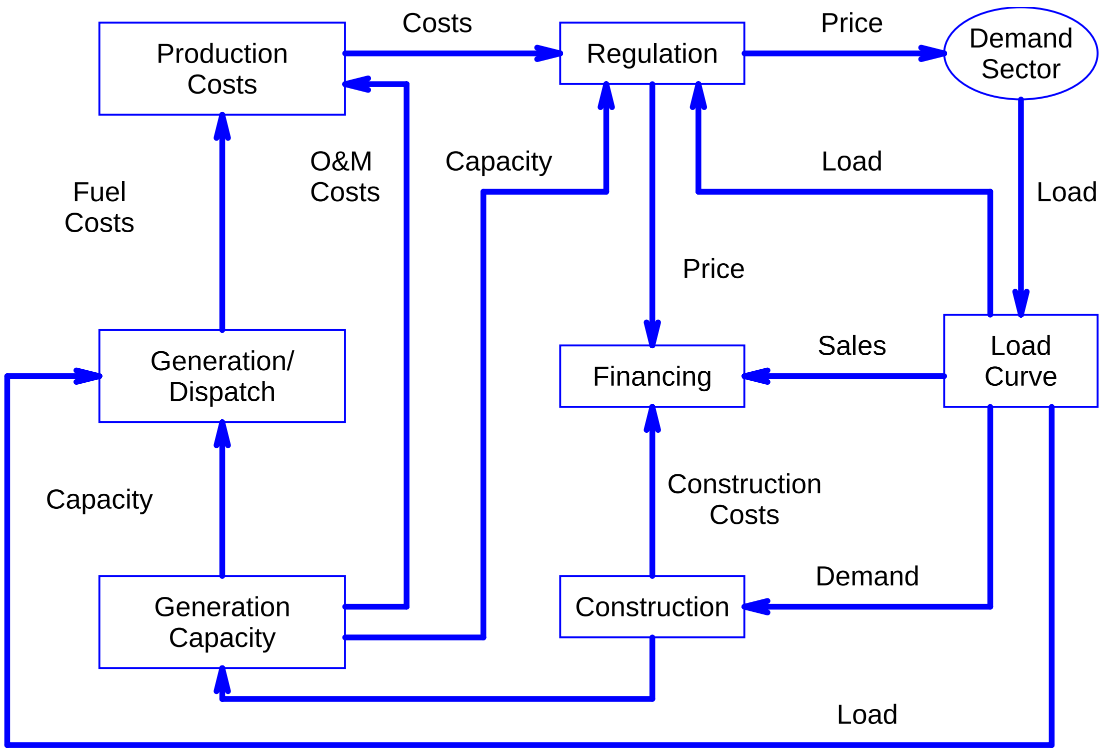
For electric and gas utilities (separate or combined), ENERGY 2020 internally and self-consistently simulates sales, load (by end-use, time-of-use, and class), production (across thirty-six dispatch types), demand-side management (by technology), forecasting, capacity expansion (new generation, independent power producers, purchases, and DSM), all important financial variables, and rates (by class, end-use, and time-of-use.)

The version currently used in this analysis only has the electricity utility sector.

With the inclusion of the electric utility sector, the generic supply model turns over the calculation of electricity prices to that sector. The model is capable of endogenously simulating the forecasting of capacity needs, as well as the planning, construction, operation and retirement of generating plants and transmission facilities. Each step is financed in the model by revenues, debt, and the sale of stock. The simulated utility, like its real world counterpart, pays taxes and generates a complete set of accounting books. In ENERGY 2020, the regulatory function is modeled as a part of the utility sector. The regulator sets the allowed rate of return, divides revenue responsibility among customer classes, approves rate base, revenues and expenses, and sets fuel adjustment charges.

The interactions in the electric utility sector are summarized in Figure 1.6

Figure 1.6: Electric Utility Structure Overview



Expansion Planning:

The utility sector endogenously forecasts future demand for electricity. From the forecast it projects the future capacity required meeting future demand by taking into account retirements and plants already under construction. Construction of additional capacity is initiated if future electricity requirements, including reserves, are forecast to exceed available capacity (using seasonal ratings).

If additional capacity is needed to meet forecasted needs, the basic capacity expansion module in ENERGY 2020 determines whether base or peaking capacity is required. The model determines the maximum number of hours that new peaking capacity can be economically operated, before it would be less expensive to construct and operate base load capacity instead. If the forecasted peaking capacity would operate more than that economic maximum, base loads units are initiated, otherwise peaking units are initiated. Any plant type including geothermal, wind, biomass and storage can be considered.

New plants, of a pre-specified minimum size, are initiated when the reserve margin would be violated if the plants were not built or if base load capacity is inadequate to serve base load energy needs at the end of the forecast period. The model does allow the minimum reserve margin to be temporarily violated at the peak if new base load capacity is scheduled to be available within the year. Peaking units are allowed to serve more than the maximum economical number of hours until base load capacity comes on-line.

Minimum plant size is exogenous. The mix of new base load plants (i.e. alternative coal technologies, hydro, or nuclear) is user-specified in the standard ENERGY 2020 configuration. The model also evaluates the financial implications of new construction, including total construction costs, cost schedules, and AFUDC/CWIP. The gross rate on AFUDC equals the weighted average cost of capital. The actual construction progress and financial impacts are simulated on a year by year basis.

ENERGY 2020 can also be configured to consider intermediate load units, firm purchases contracts, external sales, independent power producers, and demand-side options. These options can be optionally selected based on endogenous least-cost analysis or can be chosen by user-specified criteria to meet. A detailed automatic Integrated Resource Planning module that would endogenously choose (with user control) from DSM measures utility and non-utility generation and purchase alternatives using linear programming techniques is now being offered as an enhancement.

Financing:

The ENERGY 2020 utility finance sub-sector simulates the activities of a utility's finance department. It forecasts funding requirements and follows corporate policies for obtaining new funds. The model simulates borrowing and issuing of stock, and can repurchase stock or make investments if it has excess cash. Cash flows are explicitly modeled, as are any decision that affects them. Coverage ratios, intermediate- and long-term debt limits, capitalization, rates of return, new stock issues, bond financing, and short-term investments are endogenously calculated. The model keeps track of gross, net, and tax assets. It also calculates the depreciation values used for the income statement and tax obligations.

Regulation:

The utility sector sets electricity prices according to regulatory requirements. The regulatory procedures use allowed rate-of-return and test year cost and demands to determine allowed revenues. Electricity prices are calculated from peak-demand fractions by allocation of costs. Any other allocation scheme can also be considered. The regulatory sub-sector of ENERGY 2020 automatically factors in a wide variety of regulatory policies and options. More importantly, the model can be readily modified to consider a wide spectrum of scenarios.

The regulatory process revolves around a test year, usually one year forward, when proposed rates will go into effect. The utility sector forecasts test year sales and peak demands by season and customer class, just as it does to determine capacity needs. These test year demand estimates are used to allocate responsibility for system peak, and therefore, generation capacity costs.

Fuel costs for the test year are estimated by dispatching the plants that will be available in the test year, using the dispatching routine explained below. Fuel costs and operating and maintenance costs are adjusted for expected inflation, and these costs are factored into the electricity rates using forecasted sales.

ENERGY 2020 calculates the utility rate-base according to a detailed conventional rate making formula. The model allows the user to adjust allowable costs, and has been used extensively to evaluate alternative rate-base scenarios for individual plants, including allowing return of, but no return on investment, and partial disallowment of construction and interest costs.

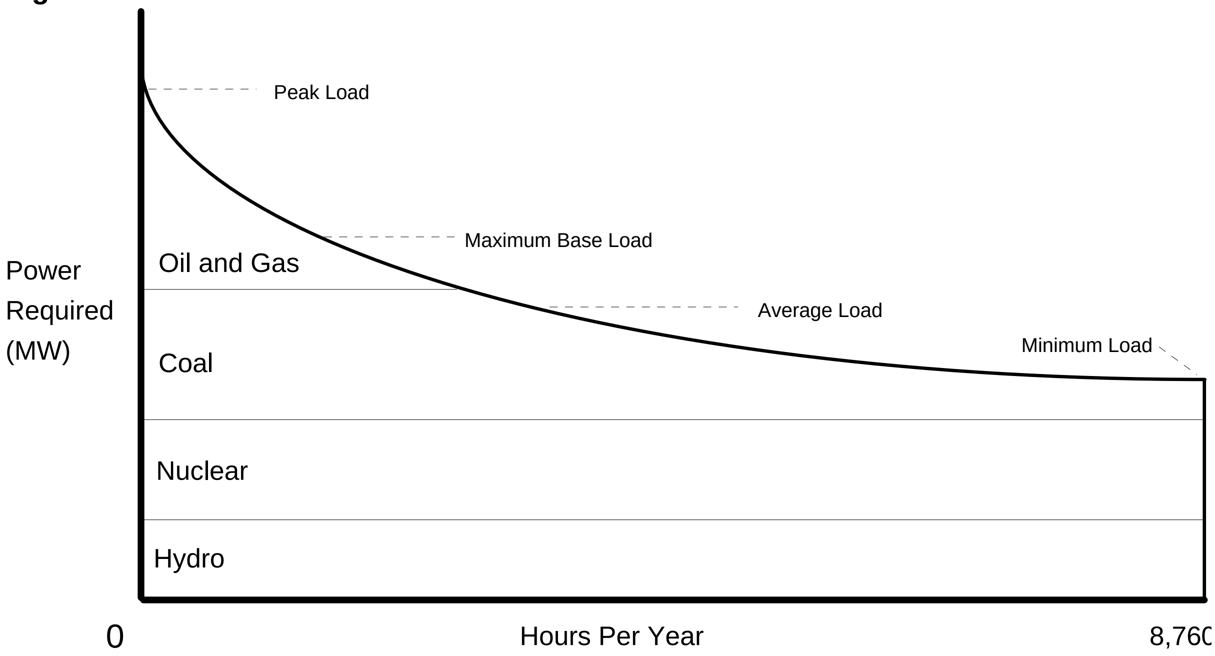
The ENERGY 2020 system also includes estimation of avoided costs, which determines when the utility may be required to purchase third party power. Environmental constraints, such as air pollution restrictions, can also be included in the model. If ENERGY 2020 is configured as a regional or state-wide system, municipal utilities, with their unique tax and rate structures, are incorporated. Similarly, regional or power pool interchange is also recognized by ENERGY 2020. As with the other sectors of ENERGY 2020, the regulatory sub-sector is flexible enough to accommodate any existing or hypothetical circumstance. Hawaii is modeled as a fully regulated market and modeled as four separate utilities with boundaries corresponding to the four counties.

Operations:

Each end-use in ENERGY 2020 has a related set of load shape factors. Typically, these factors define the relationship between peak, minimum and average load for each season. These factors when combined with the weather-adjusted energy demand by end-use and corrected for cogeneration, resale, and load management programs, form the basis of the approximated system load duration curve. Alternatively, unit hourly loads for each end-use for three days per month (average weekday, weekend and peak weekday) are used.

The standard ENERGY 2020 production sub-sector uses an advanced de-rating or chronological method to estimate the seasonal or hourly dispatch of plants. It purchases power externally when economic or necessary. Plant availability and generation for coal, nuclear, hydroelectric, oil and gas are currently considered, as well as pumped storage, firm purchases, interruptible load, and fuel switching and qualified facilities. Figure 1.7 also shows a typical plant dispatch schedule.

Figure 1.7: Generation from the Load Curve



The ENERGY 2020 system estimates conventional fuel costs based on the unit dispatch, heat rates, and fuel prices (from the supply sector.) Nuclear fuel costs are capitalized and depreciated throughout the re-fuelling cycle. Nuclear fuel expenses also include fuel disposal costs.

ENERGY 2020 explicitly models the costs of maintaining the transmission and distribution (T&D) system. New facility investments are scheduled and incurred endogenously. In addition, the user can specify the decision rules that dictate T&D expenditures. ENERGY 2020 also explicitly models both fixed and variable operation and maintenance costs, power pool interchanges, nuclear decommissioning costs, plant capital additions, plant cancellations, and general administration costs.

Model Applications:

The structure of the model is well tested and has been used to simulate not only US and the Canada energy and environmental dynamics but also those of several countries in Western, Central and Eastern Europe. Current efforts include strategic and tactical analyses for South America deregulation. Further, the model has been used successfully for deregulation analyses in over 50 energy suppliers and in all the US states and Canadian provinces. Several US and Canadian energy suppliers currently use the model for the analysis of combined electricity and gas deregulation dynamics.[28] The model contains confidence and validity packages that allow it to determine how to take maximal advantage of RTO rules. The ISO NE used the model to find gaps in its rules and to develop more efficient market conditions. The model was used for the CAPX/ISO to model to show, before the fact, many of the "games" played in the California market.

[28] ENERGY 2020 is the only model known to have simulated and predicted the dynamics that occurred in the UK electric deregulation. These include gaming, market consolidation and re-regulation dynamics.

Policy Modeling:

Building and Equipment Standards

The processes by which energy demand is derived are described in the earlier sections on "*Energy Demand*", "*Energy Demand as a Function of Capital Stock*" and "*Device and Process Energy Efficiency*".

Choices can be made between different levels of energy efficiency when making device and process investments for each sector, end use and fuel combination (i.e. residential electric water heating). The level of efficiency available is bounded on the upper end by the maximum technical level of efficiency (close to 100% in the case of electric water heating). The lower boundary is set by the minimum allowable level of efficiency allowed by regulation (ie. an appliance standard or building code). As regulations are changed through new policies, these standards are adjusted in the model; limiting the range of efficiency choices available for new investments. Using new passenger vehicles as an example, if a policy is introduced to raise the average efficiency of new vehicles (ie. a CAFÉ standard), then car buyers will only be able to select vehicles with efficiency levels above the new standard. They may select a more efficient vehicle up to the maximum technical efficiency based on their perceptions of utility and costs.

Performance Standards

Some policies, such as an EEPS, RPS or Alternative Fuel Standard, require utilities or other actors to attain a certain target; for example, that 25% of electricity sales must come from renewable sources by 2020. These policies are applied in the model by establishing a target or constraint that the defined sector must meet. Using the RPS as an example, the model will build new capacity using a defined class of 'renewable' resources in order to meet the established target, adjusting the level of generation output required as electricity sales vary. The model will solve for a solution which meets the established target to meet the imposed constraint using the processes described in the sections relating to "Energy Supply" above.

Appendix B: Data Sets Used in ENERGY 2020

This Appendix describes the initial set definitions for ENERGY 2020 used for this project. The sets are the dimensions of the variables (sometimes called indexes) which delineate the scope and detail of the model. For example, the time frame set could be defined as a base year 1990 and every 5 years.

Time Frame

The initial historical year for calibration is 2000. The last historic year of data is 2007.

Current end year of the analysis is 2020, but analysis can be extended to 2030 or beyond.

All data sets include annual data for each year of history and the forecast.

For some data sets, the period covered by actual data will depend on available data (e.g., emissions).

Geographical Areas

The model provides separate results for each county, identified for convenience as Oahu (City and County of Honolulu), Maui, Kauai, and Hawaii, as well as a total for the state.

Generating Units

The list of units is based on the FERC database for the US supplemented by Hawaii-specific information. Some of the smaller plants may be aggregated by plant type in order to expedite model operation.

Electric Companies

Although ENERGY 2020 can model individual utilities or groups of utilities, for this project the model assumes that each county has a single aggregate utility.

Sectors and Classes

The energy demand portion of the model simulates residential, commercial, industrial, and transportation demands. Electric sales are simulated for each sector.

Emission Only Sectors

Several sectors generate emissions, but do not have full energy demand simulations in the model. These include solid waste, waste water, incineration, and land use.

Pollutants

The model currently has the capability to cover 15 pollutants, although the final set used in each project depends on client requirements and available data. The GHG pollutants modeled in this project include Carbon Dioxide, Methane, Nitrous Oxide, Sulfur-Hexafluoride, Perfluorocarbon, and Hydrofluorocarbon.

Fuels

- Biodiesel
- Biomass
- Coal
- Electric
- Ethanol
- Gasoline
- Geothermal
- High Sulphur Diesel
- High Sulphur Fuel Oil
- Hydro
- Hydrogen
- Kerosene
- Liquefied Petroleum Gas (LPG)
- Low Sulphur Diesel
- Low Sulphur Fuel Oil
- Naphtha
- Oil
- Utility Gas
- Solar
- Still Gas
- Waste
- Wave
- Wind
- Other
- Unknown

Electric Generation Plants Types

The electric generation plant types are used to hold the data for future generic plants which the model will construct endogenously. The list currently includes:

- Internal Combustion Diesel
- Combustion Turbine 6
- Combustion Turbine 2
- Combustion Turbine Naphtha
- Combustion Turbine Refinery Gas
- Combustion Turbine Other
- Combined Cycle 6
- Combined Cycle 2
- Hydro
- Pumped Hydro
- Coal
- Biomass
- Refuse
- Wind
- Geothermal
- Solar Thermal
- Battery
- Sugar
- Firm Wind
- Solar PV
- Fuel Cells
- Wave

Residential Sectors

The residential sector is split into housing types:

- Single Family
- Multi-Family
- Other

Commercial Sectors

- Hotel
- Small Office
- Large Office
- Retail
- Grocery
- Warehouse
- School
- College
- Health
- Restaurant
- Miscellaneous Buildings

Industrial Sectors

- Sugar
- Other Food
- Oil Refineries
- Steel
- Other Industrial
- Water

Transportation Sectors

- Residential Passengers
- Tourist Passengers
- Aviation
- International Aviation
- Marine
- International Marine
- Freight
- Agriculture

Miscellaneous Sectors

- Forestry
- Street Lighting
- Military
- Utility Electric Generation
- Industrial Generation
- Solid Waste
- Waste Water
- Incineration

- Land Use

Residential End-Uses

- Refrigeration
- Lighting
- Water Heating
- Cooking
- Drying
- Air Conditioning
- Miscellaneous

Commercial End-Uses

- Refrigeration
- Lighting
- Water Heating
- Cooking
- Drying
- Ventilation
- Air Conditioning
- Miscellaneous

Industrial End-uses

- Motors
- Process Heat
- Lighting
- Cooling
- Miscellaneous

Residential, Commercial, and Industrial Technology Types

Each technology type has its own trade-off curve which determines the efficiency and the capital cost of the technology type. These curves allow the model to contain many different technologies within these broad types.

- Electric
- Utility Gas
- Coal
- Oil
- Bottled Gas
- Solar
- #2 Fuel
- #6 Fuel
- Biomass

Transportation Technology Types

Several technology types are provided for transportation, and each of these contains a trade-off curve which allows the model to simulate even more individual technologies.

- Light Gasoline
- Light Diesel
- Light Propane
- Light Hybrid Gasoline
- Light Hybrid Diesel
- Light Plug-In Hybrids
- Medium Gasoline
- Medium Diesel
- Medium Propane
- Medium Hybrid Gasoline
- Medium Hybrid Diesel
- Medium Plug-In Hybrids
- Heavy Gasoline
- Heavy Diesel
- Heavy Propane
- Heavy Hybrid Gasoline
- Heavy Hybrid Diesel
- Heavy Plug-In Hybrids
- Bus Diesel
- Bus Propane

- Bus Electric
- Train Diesel
- Train Electric
- Plane
- Marine Diesel
- Marine HFO

Prices

Delivered energy prices are presented for the following fuels:

- Residential Electricity
- Residential Utility Gas
- Residential Bottled Gas
- Commercial & Institutional Electricity
- Commercial & Institutional Utility Gas
- Commercial & Institutional Bottled Gas
- Commercial Oil
- Low Sulphur Fuel Oil
- High Sulphur Diesel
- Industrial Coal
- Industrial Biomass
- Industrial Electric
- Gasoline
- Low Sulphur Diesel
- Ethanol
- Biodiesel
- Blended Gasoline
- Blended Diesel
- Blended Ethanol
- Blended Biodiesel
- Jet Fuel
- High Sulphur Fuel Oil
- Naptha
- GU LPG
- Electric Utility SNG
- Electric Utility Ethanol
- Electric Utility Biodiesel
- Electric Utility Coal
- Electric Utility Biomass

Electric Load Segments

The model dispatches for 6 different hour types (high peak, low peak, high intermediate, low intermediate, high base load, low base load) for each of the four seasons.

Appendix C: Planned or Committed Plants Post-2007

County	Planned/option	Plant Name	Plant Type	Generating Capacity - Net (MW)	Fuel	Planned in-service date
Kauai	Planned	1x1 Titan 130	Combined Cycle CT	17.37	Diesel	2012
Kauai	Planned	Direct Fired Biomass	Biomass	20.00	Biomass	2013
Kauai	Planned	Kekaha	Landfill Gas	1.60	Refuse	2011
Kauai	Planned	Mass Burn	Waste-to-Energy	7.30	Refuse	2016
Kauai	Planned	Wainiha	Hydro-electric	4.00	Hydro	2015
Kauai	Planned	Upper Waiahi	Hydro-electric	0.30	Hydro	2015
Kauai	Planned	Wailua	Hydro-electric	6.6	Hydro	2015
Kauai	Planned	Wind Project	Wind	10.5	Wind	2013
Oahu	Planned	CT1 - GE PG7121 (EA)	Simple Cycle combustion turbine	110	Biofuel (ethanol or biodiesel)	2009
Oahu	Planned	Atmospheric FBC (180 MW)	Thermal Plant Resources	180	Coal	2022
Oahu	Planned	Biomass Combustion (25 MW)	Thermal Plant Resources	25	Banagrass (Biomass)	2009
Maui	Planned	Waena 1	Simple Cycle Resources	21.18	No. 2 FO	2011
Maui	Planned	Waena 2	Simple Cycle Resources	21.2	No. 2 FO	2013
Maui	Planned	Waena 3	Simple Cycle Resources	18.2	No. 2 FO	2024

County	Planned/option	Plant Name	Plant Type	Generating Capacity - Net (MW)	Fuel	Planned in-service date
Maui	Planned	Palaau 10	Simple Cycle Resources	2.2	No. 2 FO	2010
Maui	Planned	CHP system	CHP system			2005
Maui	Planned	WTE	Thermal Plant Resources	25	Banagrass	2018
Maui	Planned		Refuse	7.1	Waste	2023
Maui	Planned		Wind Energy Resources	3.6	Wind	2011
Hawaii	Planned	2-on-1 GE LM2500	Combined Cycle Resources	60.3	No. 2 FO	2009
Hawaii	Planned	Wind: 7 x 1.5MW	Wind Energy Resources	10	Wind	2020
Hawaii	Firm	Residential Application: 2kW Fixed Tilt	Photovoltaic Resources	0.002	Solar	2010
Hawaii	Firm	Residential Application: 2kW Hybrid Fixed Tilt and Battery System with Back-up Battery Charging System	Photovoltaic Resources	0.002	Solar, Propane,	2015
Hawaii	Planned	25MW Geothermal	Geothermal Resources	25.5	Geothermal	2022
Oahu	Planned	Wind Project	Wind	50	Wind	2009

County	Planned/option	Plant Name	Plant Type	Generating Capacity - Net (MW)	Fuel	Planned in-service date
Oahu	Planned	Diesel Project	Diesel	76	IC Diesel	2009
Oahu	Planned	Solar PV Distributed	Solar PV	0.30	Solar	2015
Oahu	Planned	Solar PV Distributed	Solar PV	0.30	Solar	2020
Oahu	Planned	Solar PV Distributed	Solar PV	0.30	Solar	2025
Maui	Planned	Diesel Projects	IC Diesel	4	LS Fuel Oil	2012
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2008
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2009
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2010
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2015
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2017
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2019
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2021
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2023

County	Planned/option	Plant Name	Plant Type	Generating Capacity - Net (MW)	Fuel	Planned in-service date
Maui	Planned	Solar PV Distributed	Solar PV	0.1	Solar	2025

Appendix D: Global Warming Potential

ENERGY 2020 models emissions of each of the six greenhouse gases reported under the Kyoto protocol. These emissions are then translated into equivalent quantities of CO_2 emissions (CO_2e) based on the global warming potential of each of the gases.

The Global Warming Potential (GWP) values used in ENERGY 2020 are shown in the table below.

Greenhouse Gas	Global Warming Potential
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
Sulfur Hexafluoride (SF_6)	23,900
Perfluorocarbons (PFC)	7,000
Hydrofluorocarbons (HFC)	1,300

The values currently used in the model (as shown in the Assumptions Book) are consistent with the Global Warming Potential values used in the 1996 Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report based on 100-year warming potential for the individual gases. In the case of HFC's and PFC's, the GWP values used in the model are based on an estimated average GWP for these gases.

The GWP associated with some of these gases has been re-stated based on subsequent scientific assessments. The 1996 values continue to be used internationally to maintain consistency and comparability in reporting. They have, therefore, been used for this modeling exercise.

Comparison of 100-Year GWP Estimates from the IPCC's Second (1996), Third (2001) and Fourth (2007) Assessment Reports			
Gas	*1996 IPCC GWP*[a]	*2001 IPCC GWP*[b]	*2007 IPCC GWP*[c]
Carbon Dioxide	*1*	*1*	*1*
Methane	*21*	*23*	*25*
Nitrous Oxide	*310*	*296*	*298*
HFC-23	*11,700*	*12,000*	*14,800*
HFC-125	*2,800*	*3,400*	*3,500*
HFC-134a	*1,300*	*1,300*	*1,430*
HFC-143a	*3,800*	*4,300*	*4,470*
HFC-152a	*140*	*120*	*124*
HFC-227ea	*2,900*	*3,500*	*3,220*

Comparison of 100-Year GWP Estimates from the IPCC's Second (1996), Third (2001) and Fourth (2007) Assessment Reports			
Gas	*1996 IPCC GWP[a]*	*2001 IPCC GWP[b]*	*2007 IPCC GWP[c]*
HFC-236fa	*6,300*	*9,400*	*9,810*
Perfluoromethane (CF_4)	*6,500*	*5,700*	*7,390*
Perfluoroethane (C_2F_6)	*9,200*	*11,900*	*12,200*
Sulfur Hexafluoride (SF_6)	*23,900*	*22,200*	*22,800*

a Intergovernmental Panel on Climate Change, Climate Change 1995: The Science of Climate Change (Cambridge, UK: Cambridge University Press, 1996).
b Intergovernmental Panel on Climate Change, Climate Change 2001: The Scientific Basis (Cambridge, UK: Cambridge University Press, 2001).
c Intergovernmental Panel on Climate Change Fourth Assessment Report, 2007, chapter 2 of IPCC Working Group 1 portion (table 2.14): http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf

Source: Comparison of Global Warming Potentials from the Second and Third Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC) http://www.eia.doe.gov/oiaf/1605/gwp.html, modified to add values from the Fourth Assessment Report, 2007.

Appendix E: Existing Policies Included in Reference Case

1. Renewable Portfolio Standards (RPS)

Source: Hawaii Revised Statutes, Chapter 269 Part V
http://www.capitol.hawaii.gov/hrscurrent/Vol05_Ch0261-0319/HRS0269/HRS_0269-0091.htm

"Renewable portfolio standard" means the percentage of electrical energy sales that is represented by renewable electrical energy.

Each electric utility company shall establish a RPS of
- 10% by 31 Dec 2010
- 15% by 31 Dec 2015
- 20% by 31 Dec 2020

An electric utility company and its electric utility affiliates may aggregate their renewable portfolios in order to achieve the renewable portfolio standard.

Renewable electrical energy	**Including**	**Excluding**	**% of RPS**
Renewable energy as the source	(1) Wind (2) Sun (3) Falling water (4) Biogas, including landfill and sewage-based digester gas (5) Geothermal (6) Ocean water, currents and waves (7) Biomass, including biomass crops, agricultural and animal residues and wastes, and municipal solid waste; (8) Biofuels (9) Hydrogen produced from renewable energy sources	(*)	at least 50%
Offsets or Displacement	(1) Solar water heating (2) Sea-water air-conditioning (3) District cooling systems (4) Solar air-conditioning (5) Customer-sited grid-connected renewable energy systems	(**)	

Renewable electrical energy	Including	Excluding	% of RPS
Energy efficiency	(1) Heat pump water heating (2) Ice storage (3) Ratepayer- funded energy efficiency programs (4) Use of rejected heat from co-generation (5) Combined heat and power systems (exclusions noted to right).	(1) Fossil-fuelled qualifying facilities that sell electricity to electric utility companies (2) Central station power projects	

(*) Where fossil and renewable fuels are co-fired in the same generating unit, the unit shall be considered to generate renewable electrical energy (electricity) in direct proportion to the percentage of the total heat value represented by the heat value of the renewable fuels.

(**) Where electrical energy is generated or displaced by a combination of renewable and non-renewable means the proportion attributable to the renewable means shall be credited as renewable energy.

July 2009 Update:

The Governor signed into law Act 155 (HB 1464)[29] and Act 156 (SB 1202)[30] on June 25, 2009. These Acts amend the RPS to raise the level of renewable electricity required. The proposed revisions would require that the following targets be met. These targets are expressed in terms of the percentage of net utility sales that must be met from defined renewable sources.

- 2010 – 10%
- 2015 – 15%
- 2020 - 25%
- 2030 – 40%

The proposed amendments also revise the definition of 'renewables' that can contribute to meeting the targets after 2015. These amendments would restrict the definition of 'renewable' sources under the Act to eliminate contributions from displacement sources or energy efficiency as of January 1, 2015. The revised Act would also prevent electricity-generating public utilities from owning or operating any new generating sources of over 2 MW fired by fossil-fuels. Co-operative associations are exempted from this provision.

The changes associated with this new legislation have not been included in the reference case, however, per discussion and agreement by Task Force members at the June 16, 2009, meeting.

[29] The final text of House Bill 1464 is available online at: http://www.capitol.hawaii.gov/session2009/Bills/HB1464_CD1_.HTM
[30] The final text of Senate Bill 1202 is available online at: http://www.capitol.hawaii.gov/session2009/Bills/SB1202_CD1_.HTM

2. Solar Water Heater System

Source: Hawaii Revised Statutes, Chapter 196 [196-6.5]
http://www.capitol.hawaii.gov/hrscurrent/Vol03_Ch0121-0200D/HRS0196/HRS_0196-0006_0005.htm

On or after January 1, 2010, no building permit shall be issued for a single-family dwelling that does not include a solar water heater system that meets the Standards that will be established in July 2009 by the Public Utilities Commission (PUC) (including but not limited to, specifications for the performance, materials, components, durability, longevity, proper sizing, installation, and quality).

A variance shall only be approved if an architect or engineer licensed attests that:

- Installation is impracticable due to poor solar resource
- Installation is cost-prohibitive based upon a life cycle cost-benefit analysis that incorporates the average residential utility bill and the cost of the new solar water heater system with a life cycle that does not exceed fifteen years;
- A substitute renewable energy technology system is used as the primary energy source for heating water
- A demand water heater device approved by Underwriters Laboratories, Inc., is installed; provided that at least one other gas appliance is installed in the dwelling. For the purposes of this paragraph, "demand water heater" means a gas-tankless instantaneous water heater that provides hot water only as it is needed.

Nothing in this section shall preclude participation in any utility demand-side management program or public benefits fund under part VII of chapter 269. (See the description in point 4)

3. Net Energy Metering (NEM)

Source: Hawaii Revised Statutes, Chapter 269, Part VI
http://www.capitol.hawaii.gov/hrscurrent/Vol05_Ch0261-0319/HRS0269/HRS_0269-0101.htm

Regulation legislated in 2001 amended in 2005

"Eligible customer-generator" means a metered residential or commercial customer, including a government entity, of an electric utility who owns and operates a solar, wind turbine, biomass, or hydroelectric energy generating facility, or a hybrid system consisting of two or more of these facilities, that is

(1) Located on the customer's premises
(2) Operated in parallel with the utility's transmission and distribution facilities
(3) In conformance with the utility's interconnection requirements
(4) Intended primarily to offset part or all of the customer's own electrical requirements.

"Net energy metering" means measuring the difference between the electricity supplied through the electric grid and the electricity generated by an eligible customer-generator and fed back to the electric grid over a monthly billing period.

Eligible customer generator
residential
commercial
government entity
Eligible renewable energy
solar
wind
biomass
hydroelectric
hybrid system consisting of 2 or more of the above
Maximum capacity of eligible customer-generator (except by order)
50 kW
Minimum capacity from eligible customer-generator each electric utility has to accept
combined customer-generators peak capacity = 0.5 % of peak demand (*)

(*) "Every electric utility shall develop a standard contract or tariff providing for net energy metering and shall make this contract available to eligible customer-generators, upon request, on a first-come-first-served basis until the time that the total rated generating capacity produced by eligible customer-generators equals 0.5 per cent of the electric utility's system peak demand;

- provided that the public utilities commission may modify, by rule or order, the total rated generating capacity produced by eligible customer-generators
- provided further that the public utilities commission shall ensure that a percentage of the total rated generating capacity produced by eligible customer-generators shall be reserved for electricity produced by eligible residential or small commercial customer-generators
- The public utilities commission may define, by rule or order, the maximum capacity for eligible residential or small commercial customer-generators.
- Notwithstanding the generating capacity requirements of this subsection, the public utilities commission may evaluate, on an island-by-island basis, the applicability of the generating capacity requirements of this subsection and, in its discretion, may exempt an island or a utility grid system from the generating capacity requirements."

Tariff:

Each net energy metering contract is identical with respect to rate structure to the contract to which the same customer would be assigned if the customer was not an eligible customer-generator.

The charges for all retail rate components for eligible customer-generators are based exclusively on the eligible customer-generator's net kilowatt-hour consumption over a monthly billing period.

The excess electricity generated by a customer-generator in each monthly billing period shall be carried over to the next month as credit, which may be accumulated used to offset the compensation owed the electric utility for the eligible customer-generator's net kilowatt-hour consumption for succeeding months within each twelve-month period; The eligible customer-generator shall not be owed any compensation for excess kilowatt-hours unless the electric utility enters into a purchase agreement with the eligible customer-generator for those excess kilowatt-hours.

Standards
A solar, wind turbine, biomass, or hydroelectric energy generating system, or a hybrid system consisting of two or more of these facilities, used by an eligible customer-generator shall meet all applicable safety and performance standards established by the *National Electrical Code*, the *Institute of Electrical and Electronics Engineers*, and accredited testing laboratories such as the *Underwriters Laboratories* and, where applicable, rules of the public utilities commission regarding safety and reliability.

4. Public Benefits Fee (PBF)

Source: Hawaii Revised Statutes, Chapter 269, Part VII
http://www.capitol.hawaii.gov/hrscurrent/Vol05_Ch0261-0319/HRS0269/HRS_0269-0121.htm

Regulation legislated in 2006 amended in 2008

The PUC, by order or rule, may require that all or a portion of the moneys collected by Hawaii's electric utilities from its ratepayers through a demand-side management surcharge be transferred to a third-party administrator contracted by the public utilities commission. The moneys transferred shall be known as the public benefits fee (PBF).

The PBF shall be used to support energy-efficiency and demand-side management programs and services, subject to the review and approval of the public utilities commission. This money shall not be available to meet any current or past general obligations of the State; provided that the State may participate in any energy-efficiency or demand-side management programs and services on the same basis as any other electric consumer.

The PBF can be used to identify, develop, administer, and implement demand-side management and energy-efficiency programs. Especially, the PBF administrator shall encourage programs, measures, and delivery mechanisms that reasonably reflect current and projected utility integrated resource planning (IRP), market conditions, technological options, and environmental benefits.

5. Ethanol Content Requirement

Source: Hawaii Revised Statutes, Chapter 486 J -10
http://www.capitol.hawaii.gov/hrscurrent/Vol11_Ch0476-0490/HRS0486J/HRS_0486J-0010.htm

Regulation legislated in 1997 amended in 2002 and in 2006

It is required that gasoline sold in the State for use in motor vehicle contains 10% ethanol by volume.

- Gasoline blended with an ethanol-based product, such as ethyl tertiary butyl ether, shall be considered to be in conformance with this section if the quantity of ethanol used in the manufacture of the ethanol-based product represents ten per cent, by volume, of the finished motor fuel.
- Ethanol used in the manufacture of ethanol-based gasoline additives, such as ethyl tertiary butyl ether, may be considered to contribute to the distributor's conformance with this section; provided that the total quantity of ethanol used by the distributor is an amount equal to or greater than the amount of ethanol required under this section

The sale of gasoline that does not meet the Ethanol percentage required may be authorized by the Director of Business, Economic Development, and Tourism only to the extent that sufficient quantities of competitively-priced ethanol are not available to meet the minimum requirements of this section or In the event of any other circumstances for which the director determines compliance with this section would cause undue hardship.

6. Lead by Example Initiatives for State Facilities or Energy efficiency & Environmental Standards for state facilities, motor vehicles, and transportation fuel

Source: Hawaii Revised Statutes, Chapter 196-9
http://www.capitol.hawaii.gov/hrscurrent/Vol03_Ch0121-0200D/HRS0196/HRS_0196-0009.htm

"Agency" means any executive department, independent commission, board, bureau, office, or other establishment of the State, or any quasi-public institution that is supported in whole or in part by state funds.

Each agency is directed to implement, to the extent possible, the following goals during planning and budget preparation and program implementation.

For buildings and facilities

"Facility" means a building or buildings or similar structure owned or leased by, or otherwise under the jurisdiction of, an agency.

- Design and construct buildings meeting the Leadership in Energy and Environmental Design silver or two green globes rating system or another comparable state approved, nationally recognized, and consensus based guideline, standard, or system, except when the guideline, standard, or system interferes or conflicts with the use of the building or facility as an emergency shelter.

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria.

http://www.usgbc.org/ShowFile.aspx?DocumentID=5546

LEED includes a minimum energy performance level as a component but does not necessarily require buildings to optimize energy performance.
http://www.epa.gov/solar/energy-programs/state-and-local/states/hi.html

- Incorporate energy efficiency measures to prevent heat gain in residential facilities up to three stories in height to provide R-19 or equivalent on roofs, R-11 or equivalent in walls, and high-performance windows to minimize heat gain and, if air conditioned, minimize cool air loss.

  R-value is the constant time rate resistance to heat flow through a unit area of a body induced by a unit temperature difference between the surfaces. R-values measure the thermal resistance of building envelope components such as roof and walls. The higher the R-value, the greater the resistance to heat flow. Where possible, buildings shall be oriented to maximize natural ventilation and day-lighting without heat gain and to optimize solar for water heating.

  This provision shall apply to new residential facilities built using any portion of state funds or located on state lands;

- Install solar water heating systems where it is cost-effective, based on a comparative analysis to determine the cost-benefit of using a conventional water heating system or a solar water heating system.
  The analysis shall be based on the projected life cycle costs to purchase and operate the water heating system. If the life cycle analysis is positive, the facility shall incorporate solar water heating.
  If water heating entirely by solar is not cost-effective, the analysis shall evaluate the life cycle, cost-benefit of solar water heating for preheating water.
  If a multi-story building is centrally air conditioned, heat recovery shall be employed as the primary water heating system.

  Single family residential clients of the department of Hawaiian home lands and any agency or program that can take advantage of utility rebates shall be exempted from the requirements of this paragraph so they may continue to qualify for utility rebates for solar water heating;

- Use life cycle cost-benefit analysis to purchase energy efficient equipment such as ENERGY STAR products and use utility rebates where available to reduce purchase and installation costs;

Motor vehicles and transportation fuel:

- Comply with Title 10, Code of Federal Regulations, Part 490, Subpart C, "Mandatory State Fleet Program", if applicable;

Mandatory State Fleet Program

Except as otherwise provided in this part, of the new light duty motor vehicles acquired annually for State government fleets, including agencies thereof but excluding municipal fleets, the following percentages shall be alternative fuelled vehicles for the following model years;

(1) 10 percent for model year 1997;
(2) 15 percent for model year 1998;
(3) 25 percent for model year 1999;
(4) 50 percent for model year 2000; and
(5) 75 percent for model year 2001 and thereafter.

http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=7e6135ee120c509494ff0dbe8d8675a5;rgn=div6;view=text;node=10%3A3.0.1.4.30.3;idno=10;cc=ecfr

- Once federal and state vehicle purchase mandates have been satisfied, purchase the most fuel-efficient vehicles that meet the needs of their programs; provided that life cycle cost-benefit analysis of vehicle purchases shall include projected fuel costs

Appendix F: Self Generation (non-utility) Generation Included in Reference Case

County	Owner	Facility Name	Capacity (MW)	Fuel Type	Source
Hawaii	Mauna Loa Macadamia Nut Corporation	Mauna Loa Macadamia Nut Corporation	1	Biomass	EEA
Honolulu	United Airlines	Honolulu International Airport	0.12	Propane	EEA
Honolulu	Dobbs House Cogeneration Project	Dobbs House Cogeneration Project	0.06	Propane	EEA
Honolulu	Pri Energy Systems, Inc.	Pauahi Block - A Non-Profit Housing Corp	0.06	Propane	EEA
Honolulu	Alpac Corporation	Pepsi Cola/Seven Up Bottling Company	0.18	Propane	EEA
Honolulu	U.S. Army	Fort Shafter	0.2	Propane	EEA
Honolulu	Pohai Nani Retirement Community	Pohai Nani Retirement Community	0.12	Propane	EEA
Honolulu	Hale Pauahi Condominiums	Multi-Family Building	0.09	Propane	EEA
Honolulu	City and County of Honolulu	Honolulu Hale	0.22	Propane	EEA
Maui	Grand Wailea Resort, Hotel, & Spa	Grand Wailea Resort, Hotel, & Spa	0.15	Propane	EEA
Kauai	Kauai Marriott	Kauai Marriott	0.81	Propane	EEA
Hawaii	Kona Community Hospital	Kona Community Hospital	0.455	#2 Fuel Oil	EEA
Hawaii	Hilo Medical Center	Hilo Medical Center	0.73	#2 Fuel Oil	EEA
Kauai	Kauai Veterans Memorial Hospital	Kauai Veterans Memorial Hospital	0.275	#2 Fuel Oil	EEA
Hawaii	Gulf Gas Cogen, Inc	Hawaii Preparatory Academy	0.12	#2 Fuel Oil	EEA
Honolulu	Earle M. Jorgensen Co.	Campbell Industrial Park	0.075	#2 Fuel Oil	EEA
Hawaii	Alaska Power Systems, Inc	Cyanotech Utility Master System	0.705	#2 Fuel Oil	EEA
Hawaii	Amerada Hess Company	Kailua-Kona Facility	0.105	Propane	EEA
Maui	Kaanapali Ocean Resort Villas	Kaanapali Ocean Resort Villas	0.9	Propane	EEA
Kauai	Lihue Plantation Co Ltd	Lihue Plantation Ltd	21.7	Biomass	EIA
Kauai	Lihue Plantation Co Ltd	Lihue Plantation Ltd	0.5	Hydro	EIA
Kauai	Lihue Plantation Co Ltd	Lihue Plantation Ltd	0.8	Hydro	EIA
Oahu	Tesoro Hawaii Corp	Tesoro Hawaii	20	JetFuel	EIA
Oahu	Chevron Refinery-Hawaii	Hawaii Cogen	3	Other Gas	EIA
Oahu	Chevron Refinery-Hawaii	Hawaii Cogen	3	Other Gas	EIA
Oahu	Chevron Refinery-Hawaii	Hawaii Cogen	3	Other Gas	EIA
Maui	Hawaiian Com & Sugar Co Ltd	Hawaiian Comm & Sugar Puunene Mill	4	Biomass	EIA
Maui	Hawaiian Com & Sugar Co Ltd	Hawaiian Comm & Sugar Puunene Mill	12	Biomass	EIA
Maui	Hawaiian Com & Sugar Co Ltd	Hawaiian Comm & Sugar Puunene Mill	10	Biomass	EIA
Maui	Hawaiian Com & Sugar Co Ltd	Hawaiian Comm & Sugar Puunene Mill	20	Biomass	EIA
Maui	Hawaiian Com & Sugar Co Ltd	Hawaiian Comm & Sugar Puunene Mill	16.1	Biomass	EIA
Kauai	Gay & Robinson Inc	Gay Robinson	0.4	#2 Fuel Oil	EIA
Kauai	Gay & Robinson Inc	Gay Robinson	0.4	#2 Fuel Oil	EIA
Kauai	Gay & Robinson Inc	Gay Robinson	1.2	Hydro	EIA
Kauai	Gay & Robinson Inc	Gay Robinson	4	Biomass	EIA

Sources:
EEA = Energy & Environmental Analysis (now part of ICF International), Combined Heat and Power Installation Database; supported by the U.S. Department of Energy and Oak Ridge National Laboratory. Last updated 1/21/2009. http://www.eea-inc.com/chpdata/States/HI.html

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Appendix G: Methodology for Projecting Non-Energy Emissions

Projections of GHG emissions in 2020 for all non-energy sectors and sources included in the updated inventory for 1990 and 2007 were developed using a wide range of growth rates for variables that would affect emissions for each source, such as population, economic indicators (e.g., agricultural jobs), and source-specific information (e.g., planned expansion of MSW combustion capacity). Methodological decisions were based on knowledge of the source categories and review of similar projections such as the California Air Resources Board's (CARB) Draft 2020 Forecast (http://www.arb.ca.gov/cc/inventory/data/forecast.htm).

Waste

Sources and Gases Covered:

- CH_4 from Municipal Solid Waste Landfills
- CO_2 and N_2O from Municipal Solid Waste Combustion
- CH_4 and N_2O from Municipal Wastewater

Municipal Solid Waste Landfills

Emissions from landfills were based on projections of waste disposal and de facto population[31] by island. Waste disposal projections were obtained from county-level reports provided by the Solid and Hazardous Waste Branch (SHWB) at the Department of Health (DOH) (Otsu 2008). These waste disposal projections varied in terms of years of projected data, with some counties projecting in 5-year increments out to 2020 and others only to 2013. Missing year information was estimated using de facto population projections calculated using the following methodology.

Projections of island-specific *resident* population in 5-year increments are available (DBEDT 2008). Projections of island-specific *de facto* population were calculated by applying the percent difference between each island's calculated 2007 resident and de facto population statistics to the projected resident population. It was, thus, assumed that the de facto population will grow at the same rate as the resident population for each island. These population estimates were used to calculate the amount of waste landfilled on each island and, in turn, estimate total emissions from landfills in 2020.

The emissions projections have taken into account the additional waste that will be diverted to the new H-POWER facility slated to open in 2013. Thus, the projected waste disposal values for the island of Oahu are lowered by the amount of waste that will be diverted to the new H-POWER facility starting in 2013. It was assumed that in the business-as-usual projection case, the same percentage of landfill gas recovery that occurred in 2007 will occur in 2020.

[31] The de facto population is defined as the number of persons physically present in an area, regardless of military status or usual place of residence. It includes visitors present but excludes residents temporarily absent, both calculated as an average daily census.

Municipal Solid Waste (MSW) Combustion

It was assumed that the average emissions for 2005-2007 from the existing H-POWER facility (as it is at or near capacity) were representative of the emissions for H-POWER in 2020 (Hahn 2008). Projections of emissions for the new H-POWER plant slated to come online in 2013 were developed based on activity data from Covanta Energy.

Specifications for the new H-POWER facility, as well as data on MSW and RDF combustion for its existing H-POWER facility, provided from Covanta energy, were used to estimate emissions for the planned H-POWER plant. This new facility will combust an additional 300,000 tons of MSW per year and thus emissions from the waste combustion sector is projected to significantly increase by 2020. Accordingly, the amount of waste projected to be landfilled in Oahu was decreased by the amount of waste expected to be handled by the new plant (as described in Municipal Solid Waste Landfills).

Municipal Wastewater

Emissions from wastewater were projected based on island-specific de facto population projections described in the Municipal Solid Waste Landfills section above. Per capita BOD 1990 value was used to project emissions to 2020. Projected emissions from the wastewater source increase to the extent that de facto population is projected to increase.

Agriculture, Forestry, and Other Land Uses (AFOLU)

Sources and Gases Covered:

- Enteric fermentation (CH_4)
  - *Dairy and beef cattle, sheep, goats, swine, horses*
- Manure management (CH_4, N_2O)
  - *Dairy and beef cattle, sheep, goats, swine, horses, chickens*
- Agricultural soil management (N_2O)
  - *Synthetic fertilizer, organic fertilizer, manure N, and crop residue inputs*
- Field burning of agricultural residues (CH_4, N_2O)
  - *Sugarcane*
- Urea application (CO_2)
- Agricultural soil management (CO_2)
- Landfilled yard trimmings and food scraps (CO_2)
- Carbon flux in urban trees (CO_2)
- Carbon flux in forests (CO_2)
- Forest fires (CO_2, CH_4, N_2O)

Enteric Fermentation (CH_4)

Specific projections were not available. The projected increase in the number of jobs in the agricultural sector by county from 2007 to 2020 from DBEDT's Population and Economic Projections for the State of Hawaii to 2035 (DBEDT 2008) were reviewed as one possible indicator of future emissions. Agricultural jobs for each county were projected to increase, with an average increase of 8.8 percent from 2007 and 2020. To the extent that changes in crop production areas and livestock populations do not track with agricultural job changes, GHG emissions projections would change at a different rate. Given the uncertainty and lack of specific projections, emissions were held constant at 2007 levels.

Manure Management (CH_4, N_2O)

Projections were based on projected job increases in the agricultural sector. For further details, see the Enteric Fermentation section above.

Agricultural Soil Management (N_2O)

Projections were based on projected job increases in the agricultural sector. For further details, see the Enteric Fermentation section above.

Field Burning of Agricultural Residues (CH_4, N_2O)

Projections were based on projected job increases in the agricultural sector. For further details, see the Enteric Fermentation section above.

Urea Application (CO_2)

Reported urea sales in Hawaii have not changed since 2000. Accordingly, this amount was extended to 2020.

Agricultural Soil Management (CO_2)

The National Resources Inventory has not reported changes in land-use data since 1997 (Ogle 2008), and the estimates in C flux for 2007 were developed based on the land-use changes through 1997. It was, thus, assumed that the best approach would be to hold 2007 values constant out to 2020.

Landfilled Yard Trimmings and Food Scraps (CO_2)

Combustion and landfilling trends between 2007 and 2020 were projected with an exponential growth model using a Microsoft Excel™ regression based on 1990 to 2007 data. For yard trimmings, the volume of generation has been slowing in growth, while the amount of composting has been steadily increasing. Accordingly, we used linear models based on 1997 to 2007 data instead of exponential models for yard trimmings projections. Food scraps were modeled using exponential functions based on the most recent data (1998 to 2007).

Population for future years was obtained from U.S. Census projections for the US and Hawaii (U.S. Census Bureau 2006). Island population projections, for apportioning estimates by island, were based on the 2007 Hawaii Databook.

Urban Trees (CO_2)

We obtained data from DBEDT's "Report on Urban Lands in the State of Hawaii" (DBEDT 2006) to estimate future sequestration by urban trees. This report provided an estimate of 2007 urban areas on Oahu and projections of urban land needs in 2010 and 2020. This estimate was developed by DBEDT accounting for factors such as changing lot sizes, the land needs for new schools, growth in industry, etc. This data was used to calculate the percentage growth from 2007 to 2010 and to 2020. We then applied the 2020 percentage growth to the 2007 sequestration estimate.

Forest Carbon (CO_2)

Forest land area has not substantially changed from 1990 to 2007. However, forests have been categorized in different ways over the different years of data compilation in the *Hawaii Databook*. These reporting changes made it difficult to compare data by island and by category, or to establish trends in the data spanning multiple years. Therefore, a linear regression was developed for each island based on the average forest acreage in the years 2005 and 2007. This regression was then used to develop estimates for forest acreage in 2020. The island estimates were summed in order to calculate the state total.

Forest Fires (CO_2, CH_4, N_2O)

For data on acres burned, the average for a 12-year increment (1994 to 2007) was used to develop 2020 projections. Trends are not a reliable predictor of future fires, due to the randomness with which they occur from year to year. It was assumed that the area of land under wildland protection will remain the same out to 2020, since the two available data points do not provide a robust trend estimate.

References

DBEDT (2008) *Population and Economic Projections for the State of Hawaii to 2035,* Appendix Tables. Research and Economic Analysis Division, Hawaii Department of Business, Economic Development and Tourism, January 2008. Available online at: http://hawaii.gov/dbedt/info/economic/data_reports/2035LongRangeSeries.

DBEDT (1990 to 2007) Dept. of Business, Economic, Development, and Tourism, State of Hawaii. *Hawaii Databook*. Available online at http://hawaii.gov/dbedt/info/economic/databook/db2001/history. Published annually from 1991 to 2007.

DBEDT (2006). Report on Urban Lands in the State of Hawaii. Table 1-9. Available online at: http://hawaii.gov/dbedt/op/projects/urban_lands_study/. May 2006.

Ogle, Stephen (2008). Email correspondence between Nikhil Nadkarni, ICF International, and Stephen Ogle, Colorado State University. September 24, 2008.

U.S. Census Bureau (2006). “Interim State Population Projections, 2006.” Table A1. April 21, 2006.