Modeling of Greenhouse Gas Reduction Measures to Support the Implementation of the California Global Warming Solutions Act (AB32)

ENERGY 2020 Model Inputs and Assumptions

November 25, 2009
(revision date)

Prepared for:
California Air Resources Board

Prepared By:
ICF Consulting Canada, Inc.
277 Wellington St. W.
Suite 808
Toronto, ON M5V 3E4

Contact:
Glen J. Wood, M.B.A.
T: (416) 341-8952
F: (416) 341-0383

PLEASE NOTE:

This report outlines the assumptions and data inputs used in developing a Reference Case and Policy Analysis for the California Air Resources Board.

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.

Table of Contents:

Acronyms & Definitions

AEO	Annual Energy Outlook (published by EIA)
ARB	California Air Resources Board
BPA	Bonneville Power Administration
Btu	British Thermal Units
CAC	Criteria Air Contaminants (SOx, NOx, PM, etc.)
CEC	California Energy Commission
CFL	Compact Fluorescent Light bulb
CHP	Combined Heat and Power
CPUC	California Public Utilities Commission
CO_2e	Carbon Dioxide equivalent
GDP	Gross Domestic Product
GO	Gross Output
GWP	Global Warming Potential
DG	Distributed Generation
EDRAM	Environmental Dynamic Revenue Analysis Model
EIA	Energy Information Administration
EISA	Energy Independence and Security Act
EPACT	Energy Policy Act of 2005
ESCO	Energy Service Company
GHG	Greenhouse Gas
IECC	International Energy Conservation Code
IGCC	Integrated Gasification Combined Cycle
kW	Kilowatt
kWh	Kilowatt-hour
Mt	Mega ton
MW	Megawatt
MWe	Megawatt electric
MTCE	Megatons Carbon Equivalent (also as Mt CO_2e)
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
SOx	Sulphur Oxides (including sulphur dioxide)
USEPA	United States Environmental Protection Agency
W	Watt

1 Background and Project Scope

California has for many years led the nation in combating climate change. In 2006, the most ambitious element of the State's policy was enacted: *The California Global Warming Solutions Act of 2006*, known as AB32. AB32 requires the California Air Resources Board (ARB) to implement a program that reduces the State's GHG emissions to 1990 levels by 2020. The California Air Resources Board estimated that the State would need to reduce GHGs by approximately 174 million tons from baseline levels to achieve this target in 2020.[1]

ICF International (ICF) in partnership with Systematic Solutions Inc. (SSI) was engaged by the California Air Resources Board to provide a version of ENERGY 2020 to be used to assist the Board in modeling GHG reductions under AB32. Under this contract ICF and SSI agreed to develop and deliver a version of ENERGY 2020 tailored to the ARB's requirements and reflecting California-specific data wherever appropriate. The model has been used to develop a Reference Case of expected GHG emissions under a business-as-usual scenario over the period to 2020. ICF and SSI have also assisted the ARB in modeling proposed policies for comparison with this Reference Case in order to determine the extent to which such policies could reduce future emissions and the effects of such policies.

This report outlines the assumptions and data inputs used in developing the Reference Case and policies modeled. The report describes the initial data and assumptions used, the sources of this data, and the processes used in developing the Reference Case as well as assumptions used in modeling the policies considered.

2 Organization of the Report

The report is organized into five 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. Section 4 describes the model inputs and assumptions used in modeling the Reference Case while section 5 describes the policies modeled and the assumptions made in

[1] California Greenhouse Gas Emissions Inventory http://www.arb.ca.gov/cc/inventory/inventory.htm

representing these policies in the model. A more detailed explanation of the ENERGY 2020 model is included as Appendix A. Additional appendices describe some of the data or relationships used in the model.

3 Analytic Approach

This project uses ENERGY 2020 to model the likely business-as-usual outlook for California and neighboring jurisdictions in the WECC region, and the impact of potential GHG reduction policies.

ENERGY 2020 is an integrated multi-region multi-fuel energy and emissions model that provides complete and detailed, demand and supply sector simulations. These simulations can additionally include macroeconomic interactions to determine the benefits or costs to the local economy of new facilities or changing energy prices. The model can be used in regulated as well as deregulated and transitioning environments. Greenhouse Gas and Criteria Air Contaminant pollution emissions and costs, including allowances and trading, are endogenously determined, thereby allowing assessment of environmental risk and co-benefit impacts.

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. Collections of state and provincial models are currently validated from 1986 to the most recent historic year available.[2]

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 national economic policy. For US regional and state level analyses, the REMI macroeconomic model is regularly linked to ENERGY 2020.[3] The Informetrica macroeconomic model is linked to ENERGY 2020 for

[2] Energy supplier data comes from FERC and US DOE for the US and Statistics Canada. US and Canadian fuel and demand data come from the US Department of Energy and Natural Resources Canada, respectively. US and Canadian pollution data come from US EPA and Environment Canada, respectively.
[3] Regional Economic Models, Inc. www.remi.com

Canadian national and provincial efforts.[4] The REMI and Informetrica macroeconomic models include inter-state/provincial, US and world trade flows, price and investment dynamics, and simulate the real-time impact of energy and environmental concerns on the economy and vice versa.

The structure of the 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 1990's, 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.[5]

The default model simulates demand by three residential categories (single family, multi-family, and agriculture/rural), over 40 NAICS commercial and industrial categories, 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.[6] Currently the technology families correspond to six fuels groups (oil, gas, coal, electric, solar and biomass) and 30 detailed fuel products. The transportation sector contain 45 modes 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 built up from the individual end-uses to capture changing conditions under consumer choice and combined gas/electric programs.

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

---

[4] Informetrica Limited www.informetrica.ca
[5] 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.
[6] 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.

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. ENERGY 2020 utilizes the historical and forecast data developed for each technology family to parameterize and disaggregate 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.[7] The model dispatches plants according to the specified rules whether they are optimal or heuristic and simulates transmission constraints when determining dispatch.[8] 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. 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. If the full supply sector is not needed, then a simplified simulation determines delivered-product prices.

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 SO2, NO2, N2O, CO, CO2, CH4, PMT, PM2.5, PM5, PM10, VOC, CF4, C2F6, SF6, 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.

---

[7] 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 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.

[8] 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.

National and international allowance trading is also included. Plant dispatch can consider emission restrictions.

The model captures the feedback among energy consumers, energy suppliers, and the economy using Qualitative Choice Theory and co-integration.[9] For example, a change in price affects demand which then affects future supply and price. Increased economic activity increases demand which increases the investment in new capital stock. The new investment affects the economy and energy prices. The energy prices also affect the economy.

Finally, the system includes confidence and validity testing software that places uncertainty bounds on simulation results, quantifies confidence intervals, and ranks the contributions to uncertainty in future conditions. This feature can be used to limit data efforts to information most important to the analysis.

In order to assess the potential impacts of proposed policy options, a b*usiness-as-usual* scenario 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 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 greenhouse gas emissions in California.

[9] The model has used the work of Daniel McFadden and Clive Granger since its inception in the late 1970's.

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., can be provided separately in Excel spreadsheets as required.

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, etc.). In past analyses, ENERGY 2020 has relied heavily on these federal sources to populate and calibrate the model. In developing the model for California, a considerable amount of state-specific information was available and has been used wherever possible.

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 to this point. It is expected that this data will change as the model is reviewed and evolves to incorporate more detailed California-specific data.

Data[10] inputs for ENERGY 2020 will be 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, along with the sources that have been used to supply this data for other analyses. For each data element the default data used in the model is described. This data is generally used in modeling the jurisdictions around California. In most instances, state-specific data has been used in place of national sources for modeling energy use and emissions in California.

[10] "Data" here refers to both historical data and assumptions and projections of future inputs.

ENERGY2020 requires both historical data and projections to calibrate and generate forward-looking projections. Historical data will be required from a base year (1985) to the last historic year (2005). 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.

The ARB implementation of ENERGY 2020 includes the geographic areas of California, Oregon, Washington, Idaho, Arizona, New Mexico, Nevada, Colorado, Utah, Montana and Wyoming, Alberta, British Columbia and the northern state of Baja California. Interactions between these states and provinces are modeled, particularly with respect to electricity generation. To ensure consistency the assumptions used in California are applied to other states to the extent possible. In determining which data sources to use for California, consideration has been given to the potential impacts of using different sources of data for different states (or in-state vs. out-of-state).

4.1 *Population and Economic Data*

Demographic and economic data is required to generate demands for services. For California, economic data and forecasts including gross output, personal income and inflation, used in the model were compiled by the ARB from several California sources. The historic data for the US states is from the BEA, for the Canadian provinces data is from CANSIM.

The table below describes the sources that have been used in the California model.

Description of Data/Input	Sources Used/Available
Total population, historical and growth over time	California Department of Finance US Census Bureau Statistics Canada/Informetrica
Population by housing type (single-family, multi-family, etc.)	US Census Bureau Statistics Canada/Informetrica
Households by housing type (single-family, multi-family, etc.)	US Census Bureau Statistics Canada/Informetrica
Personal income	California State Sources US Bureau of Economic Analysis Statistics Canada/Informetrica
Employment by sector	US Bureau of Economic Analysis Statistics Canada/Informetrica

The model covers the surrounding states and provinces that are part of the WECC region. In the table above, the state-specific data sources used for California are shown first, followed by the sources of US information used for surrounding states and the sources of data for the Canadian provinces.

The population forecast used in the model assumes population growth of just over one percent per year.

CALIFORNIA	2005	2010	2015	2020	2025	2030
Population (thousands)	36,154	38,045	40,125	42,287	44,548	46,905
Average Annual Growth Rate	1.05%					

Personal income, in nominal terms, is projected to increase by 0.7% annually, on average, over the 2005 to 2030 modeled period.

Personal Income					
	2005	2010	2015	2020	Avg. % Chg. Per Year
Income per Capita (Nominal$/ Capita)	36,154	38,045	40,125	42,287	0.7%

4.2 *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. ENERGY2020 calculates future electric prices based in part on these fuel costs.

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 prices for all states are obtained from the State Energy Consumption, Price and Expenditure Estimates in the State Energy Data System (SEDS) for the U.S. and from Statistics Canada for Canada. Price data for

California was obtained from the California Energy Commission website and directly from the ARB.

The default energy price forecast for the US is based on the Energy Information Administration's Annual Energy Outlook Reference Case forecast for 2009 to 2030. For Canada, the National Energy Board's price forecast has been used. Where inconsistencies exist between these two forecasts, the US AEO projection was used with appropriate currency conversion.

Biomass prices in the model are based on research completed for a previous project, shown in the table below. Unlike other fuels, biomass prices are significantly influenced by local cost and supply issues. As a result, the ARB may wish to adjust these values to reflect regional variations.

Biomass Cost *(per mBtu in 2006$)*	
Residential	$11.53
Commercial	$10.09
Industrial	$10.06

Power prices are calculated endogenously by the model based on generation costs and dispatch. While the model calculates retail electricity prices, actual consumer prices may differ as a result of political, regulatory or market influences. The model can be calibrated to actual prices, within reasonable parameters for the historic period if desired. A forecast of electricity prices for comparison purposes was obtained from the California Energy Commission (CEC).

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 pure economic evaluation.

Historic energy use and consumption data used in the model is derived from the federal Energy Information Administration (EIA) State Energy Data (SEDS) database. For California, state-specific data was used to replace national data sources.

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 Consumption Energy Survey (MECS).

The table below describes sources that have been used in the California model.

Description of Data/Input	Sources Used/Available
Residential Data - Household income by housing type - No. of people per household - End-use consumption data, including fuels used for space and water heating, air conditioning, etc.	California Statewide Residential Appliance Saturation Study: Final Report (400-04-009), California Energy Commission, June 2004. 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
Commercial Data - Floor area by sub-sector - End-use consumption data, including fuels used for space and water heating and energy intensities	California Commercial End-Use Survey, (CEC-400-2006-005), California Energy Commission, March 2006. 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
Industrial/Manufacturing Data - Energy use by fuel for each sub-sector and end-use	Non-Residential Market Share Tracking Study, Final Report on Phases 1 & 2 CEC, April 2005. 2002 EIA Manufacturing Energy Consumption Survey (MECS), by Census Region (2006 MECS underway) http://www.eia.doe.gov/emeu/mecs/contents.html
State Energy Data: - Energy consumption and expenditures by sector and energy source	California Energy Commission http://www.energy.ca.gov California Public Utilities Commission http://www.cpuc.ca.gov/PUC/energy/ 2004 EIA State Energy Data System (SEDS) http://www.eia.doe.gov/emeu/states/_seds.html

Household data for California was gathered from the US Census Bureau supplemented by data from the EIA's State data on Prices and Expenditures.

Information regarding past electricity consumption for the state was provided by the ARB and obtained from the California Energy Commission website.

4.4 *Historic Emission Data*

4.4.1 Emissions and Air Regulations

Historic GHG emissions are based on the inventory of California GHG emissions and sinks[11] and the US GHG emissions inventory as published by the EPA[12]. ENERGY 2020 is calibrated using historic information on all of the major greenhouse gas emissions including:

- Carbon dioxide (CO_2),
- Nitrous oxide (N_2O),
- Methane (CH_4),
- Sulphur 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 greenhouse gas emissions into CO_2e terms are provided in Appendix F.

Input	Sources Used/Available
Emissions by sector, end-use, fuel and GHG	California Greenhouse Gas Emissions Inventory http://www.arb.ca.gov/cc/inventory/inventory.htm US EPA http://www.epa.gov/climatechange/emissions/usinventoryreport.html Environment Canada http://www.ec.gc.ca/pdb/ghg/inventory_e.cfm

11 California Greenhouse Gas Emissions Inventory http://www.arb.ca.gov/cc/inventory/inventory.htm
12 EPA website: http://www.epa.gov/climatechange/emissions/usinventoryreport.html

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 however, the emission factors for CH_4 and N_20 pollutants were adapted from the Canadian National Inventory Report[13]. 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 bio-fuels 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.

Past research has resulted in a range of estimates of full cycle emissions for biofuels; particularly for ethanol production. The range of estimates found for emission coefficients for corn and cellulosic ethanol as well as biodiesel are provided below. The emissions estimates vary depending on assumptions regarding the type of farming practices, technology and processes assumed. In general, the energy balance for the production of corn ethanol has improved over time and is expected to improve further in future.

The full-cycle emission factor used in the model for each biofuels type is shown in the right hand column in the table below.

Fuel	Emission Coefficients (lbs of CO_2 per mmBtu)		
	Low	High	Proposed Value
Corn Ethanol	136	276	154
Cellulosic Ethanol	10	36	20
Bio-diesel	68	102	90

[13] Environment Canada. National Inventory Report 1990-2005, Greenhouse Gas Sources and Sinks in Canada, April 2007. (Annex 12 Emission Factors)

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. Therefore, *for each gallon of unblended, neat corn ethanol, the model uses an emission coefficient set at 154 lbs of CO_2 per mmBtu, or roughly 21% below that for a gallon of unblended motor gasoline.*

4.5 *Electricity Sector Data*

4.5.1 Generation Data

The electricity sector differs from other sectors in the extent to which emissions associated with power use within the state may result from emissions outside the state as power is imported from other areas. In California, 14% of total state gross GHG emissions in 2004 were due to in-state generation and a further 14% of total state gross GHG emissions that year were attributable to imported electricity.[14]

ENERGY 2020 contains information on every generating unit in the state, as well as in neighboring jurisdictions which may supply power to the 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;
- State or Province;
- Physical location (latitude and longitude);
- Ownership information;
- Plant type (Hydraulic, Coal, Combined Cycle Turbine, etc.)

[14] California Greenhouse Gas Emissions Inventory http://www.arb.ca.gov/cc/inventory/inventory.htm

The data used on existing and committed generating units was obtained from the National Electric Energy Data System (NEEDS) 2006 database and reconciled with a list of plants from Bonneville Power Administration (BPA) and data from FERC.

4.5.2 Electricity Generation Capacity and Operation Data

ENERGY 2020 has been populated with data describing the type, operation and performance of every generating unit in the western US. In addition to plant-level data, the table below includes sources for other inputs necessary to describe the electric system, including transmission capability.

Input	Sources Used/Available
Plant type	FERC reports for US Statistics Canada for Canada
Plant capacity	FERC reports for US Statistics Canada for Canada
Plant historical generation	FERC reports for US Statistics Canada for Canada Total generation output by plant type for California from CEC
Plant fuel type	FERC reports for US Statistics Canada for Canada
Plant Heat Rate	FERC reports for US Statistics Canada for Canada
Plant fuel consumption	FERC reports for US Statistics Canada for Canada
Plant emissions by pollutant	EPA or Environment Canada
Plant costs (operation and maintenance, variable and fixed)	FERC reports for US Statistics Canada for Canada
Plant historical capacity factor	FERC reports for US Statistics Canada for Canada
Plant availability (outages)	FERC reports for US Statistics Canada for Canada
Plant owner and location	FERC reports for US Statistics Canada for Canada
Planned capacity additions and retirements	California Public Utility Commission GHG Modeling process (E3)
Transmission Capability	NERC

This data was compared to generation data provided by Energy and Environmental Economics, Inc. (E3) as part of its modeling for the California Public Utilities Commission[15] (CPUC) to ensure consistency between the models.

Modeling results were compared to statistics published by the California Energy Commission. Information was also obtained from the Bonneville Power Administration[16] and from the Federal Electricity Commission for Mexico[17].

The resulting list of generating units was matched to emission data from the EPA and Environment Canada in order to calculate emission rates. 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 was calibrated with historic generation data available from the CEC and the EIA.

4.5.3 Transmission Structure and Dispatch / Natural Gas Pipeline System

Power flows between neighboring US states are modeled within ENERGY 2020 based on existing transmission capabilities and interconnections as obtained from NERC reports. Appendix B describes the inter-regional transmission capabilities between model regions (or nodes) as well as the maximum capacity limit of each transmission path used in the model. Interconnection capacities used in the model were based on the IPM Model 2006[18] updated to reflect changes in the region based on past work for past clients such as the Bonneville Power Administration.

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

---

[15] www.ethree.com/cpuc_ghg_model.html

[16] BPA, 2007 Pacific Northwest Loads and Resource Study, Operating Years 2008 through 2017, March 2007.

[17] http://aplicaciones.cfe.gob.mx/aplicaciones/QCFE/EstVenta/Historico.aspx?Estado=M%C3%A9xico&Idioma=I&YearMin=2000&YearMax=2006&imp=1

[18] Table 3.5 of section 3 of the documentation for the EPA Base Case 2006 (v3.0) posted on the EPA website: http://epa.gov/airmarkets/progsregs/epa-ipm/index.html#docs

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. 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. In the interests of maintaining consistency with modeling completed for the CPUC, committed and planned generation was based on the results of the CPUC's GHG modeling process.

The mix of renewable resources to be used in meeting the State RPS in the Reference Case and complementary policies case has been based on the CPUC's "33% RPS Implementation Analysis".[19]

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 the model assumes 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 developed by Energy and Environmental Economics, Inc. as part of their modeling process for the California Public Utility Commission[20].

4.5.6 Industrial Generation and Co-generation

[19] http://www.cpuc.ca.gov/PUC/energy/Renewables/hot/33implementation.htm
[20] www.ethree.com/cpuc_ghg_model.html

ENERGY 2020 models both utility generation, which supplies the power grid, and industrial generation which supplies a particular end user. Industrial generation is defined as power generation that is within the industrial end user's facility and is not used to supply power to the grid. 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 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.

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.

4.6 *Transportation*

ENERGY 2020 models passenger, freight, and off road transportation separately, based on different underlying drivers. Passenger and freight transportation are modeled by mode and vehicle type. Changes in transportation demand, in terms of passenger miles traveled and ton-miles of freight are calibrated for the historic period.

The bulk of existing and forecast passenger transportation is used in personal vehicles. Off road transportation energy use is modeled in ENERGY 2020 based on drivers including Agriculture, Forestry and Construction activity.

4.7 *Built Environment*

The State of California has a long history of promoting energy efficiency and demand side management for electricity and natural gas energy use. As a result, average appliance and equipment efficiencies are expected to be higher than for the US as a whole. Information on current levels of equipment efficiency and the state of the market for efficiency technologies was used to adjust end-use data within the model to reflect current levels of efficiency of market saturations.

The Reference Case does not assume any increase in equipment or appliance efficiency other than the improvements due to the *Energy Independence and Security Act of 2007*, as noted in section 4.8 and existing California appliance standards[21].

4.8 *Programs/Policies Incorporated in Reference Case*

Specific laws and regulations may be incorporated in the model to reflect policies which have been approved but have not yet come into effect. The Federal Energy *Independence and Security Act of 2007,* which was passed into law in early January 2008, has been included in the model. A portion of the EISA are

[21] *2007 Appliance Efficiency Regulations, California Energy Commission, December 2007.*

included below, the rest are modeled as part of complementary policies. The following assumptions will be used to model the Act in the Reference Case:

- **Vehicle Efficiency**:
  - California – Pavley Vehicle Standard: The marginal vehicle efficiency for passenger cars and light trucks is incrementally increased by a fixed percentage each year starting in 2011 to reach the mandated new vehicle fleet efficiency of 35.5 mpg; consistent with Pavely I Vehicle Standards (per above).
  - Other States - Marginal vehicle efficiency reaches 35.5 mpg by 2020 as per the requirements of the EISA.

- **Biofuels for Transportation**:
  - California and Other States - EISA targets for increasing the percentage of biofuels have been implemented in all States other than California. The Act also requires an increasing portion of biofuels to be derived from cellulosic ethanol and advanced biofuels. These targets have been reflected in the model by adjusting the full-cycle emission factors associated with ethanol between 2010 and 2020. The effect of this adjustment is to reduce the full cycle emission factor for ethanol by about 40% from the initial level (the level for corn-based ethanol) by 2020.

- **Renewable Portfolio Standard**: The reference case includes Renewable Portfolio Standards (RPS) for each US state as well as renewable energy targets established by Canadian provinces. For California, the RPS implemented in the Reference Case requires that 20% of electricity sales be supplied by renewable sources by 2020.

5 Policy Case Inputs and Assumptions

5.1 *Programs/Policies Incorporated in Complementary Case*

The following policies were implemented as "complementary policies" in the model:

- **Vehicle Efficiency:** In the Reference Case average new vehicle efficiency is increased starting in 2010 to reach the standard of 35.5 mpg by 2016. Under the complementary policies scenario average new vehicle efficiency for cars and light trucks will be further increased to reach a target of 42.5 mpg by 2020.
- **California - Low Carbon Fuel Standard: This standard calls** for a 10% reduction in the carbon intensity of fuels by 2020 in California. This is modeled by increasing the ethanol share of passenger ground transportation fuels to approximately 18% for light vehicles and by increasing the biodiesel share of freight ground transportation to approximately 15%.
- **Renewable Energy Standard**: In the complementary policies case, the RES for California is increased to require that 33% of electricity sales be supplied by renewable sources. The type of renewable generation built to meet the RES requirement was based on the resource mix projections by the California Public Utilities commission.[22] As the level of electricity demand varied between cases, it was assumed that the renewable content of imports would match the required RES percentage (renewables as a percentage of sales) for that year. In-state renewable generation as projected by the CPUC was then adjusted to meet the total level of renewables required.
- **Energy Efficiency** – The modeling assumes that programs are introduced to achieve a State target of reducing electricity sales by 10% and natural gas sales by 4% reduction by 2020. This reduction is modeled through increases in process and device efficiencies

[22] http://www.cpuc.ca.gov/PUC/energy/Renewables/hot/33implementation.htm

distributed across the residential, commercial and industrial sectors. The costs of actual equipment upgrades associated with these efficiency gains are captured in the model, however, program and administration costs are not modeled. The following assumptions were made with respect to the energy efficiency policies.

- Efficiency Improvement - In order to translate this policy into modeling terms, ICF/SSI assume that the increase in efficiency would be implemented across all sectors (residential, commercial and industrial) and all end uses. Through an iterative process, operating this policy on a stand-alone basis, we will determined a level of efficiency gain for marginal devices for each year that would achieve the targeted reduction in electricity and natural gas use. The increase in efficiency will be introduced into the model through a multiplier applied evenly across processes and devices.

- Economies of Scale - An assumption was made that as more efficient devices are required, the cost of devices would benefit from economies of scale; shifting the cost curve for the efficiency improvement down.

  For modeling purposes the economies of scale achieved as these technologies gain market share will be limited to no more than 10% reduction in cost. In addition, the model was constrained such that this reduction did not bring the cost of more efficient devices to a level below the cost for standard devices with current levels of efficiency.
- Retrofits - No retrofits, or premature retirements of existing equipment, were assumed in the modeling. The efficiency improvements required to meet the policy target were assumed to take place at the margin. In ENERGY 2020 devices and processes are each continually replaced with assumed lifetimes of less than 20 years so at least 5% of the devices and processes are replaced each year.
- Process Efficiency Impacts on Device Investments – Changes in process efficiency generally reflect changes in the level of energy service required (e.g. the amount of lighting reduced due to day-lighting or improved design or

water heating needs reduced due to more efficient end-use devices). To the extent the process efficiency increases, this tends to lower the level of device investment required in these end-uses; as lower lighting requirements are reflected in fewer new fixtures being required. For modeling purposes, we have assumed that 30% of the efficiency gains attained under the complementary policy will come from process efficiency gains, while 70% come from device efficiency gains.

- **Combined Heat and Power**: The electricity output from CHP facilities in California was assumed to increase by 30,000 GWh by 2020. For modeling purposes it was assumed that the heat output of these facilities is used to serve existing or new heating loads. This means that the addition of these facilities results in some increase in overall fuel requirements based on the heat rate assumed for the co-generation unit but contributes additional electricity supply.
- **VMT Reduction**: Vehicle miles travelled per year in California were assumed to be reduced by 4% by 2020. No assumptions were made with regards to how this reduction would be achieved. For example, an increase in public transit use was not assumed in the modeling.
- **Heavy Duty Vehicle Efficiency**: This policy simulates an increase in freight end use efficiency to reflect Smart Way Truck Efficiency.
- **Ship Electrification at Ports**: This policy reflects the provision of on-shore electricity to ships in port to reduce the use of on-board engines and associated emissions.

5.2 *Cap and Trade Scenarios*

The following describes the cap-and-trade scenarios modeled.

a) Region — California only

b) GHG Pollutants — CO2, CH4, N2O, SF6, PFC, and HFC

c) 2020 Goal — State-wide target of 427 MMT in 2020

d) Covered Sectors

2012-2014:

- Narrow Scope: Electricity and Industrial facilities emitting >25,000 metric tonnes CO2e per year
- In order to approximate the 25kt CO2e cut off, it is assumed that only emission intensive industrial sectors are included in this initial phase
- Emission intensive industries defined as chemicals, paper, petroleum products, primary metals, mining, and oil & gas extraction. In the case of petroleum products sector only emissions associated with operations are included in this phase.

2015-2020:

- Broad Scope: Narrow Scope plus transportation fuels, commercial and residential fuels and small industrial

e) Banking

- Allowed without limitation
- Banking parameters vary depending on scenarios with and without offsets
- ARB may wish to re-evaluate these parameters after seeing model runs incorporating them:
    - Parameters *without* offsets:
        - The price below which sectors bank: $40
        - The maximum amount of banking as a percent of emissions: 10%
        - The price above which sectors withdraw from their bank: $85
        - The maximum percentage withdrawn from inventory: 30%
    - Parameters *with* offsets:
        - The price below which sectors bank: $25
        - The maximum amount of banking as a percent of emissions: 8%
        - The price above which sectors withdraw from their bank: $40
        - The maximum percentage withdrawn from inventory: 20%

f) Allowance Allocation

- 100% Auction

g) Offsets

Two offset scenarios will be modeled, both based on the 100% auction allocation scheme.

- No offsets
- With offsets at 49% of reduction from base at a fixed price of $20 per tonne.

h) Sensitivities

Summary of Modeling Scenarios:

In all cases:

- Offsets are assumed to be available at a cost of $20 per tonne
- Banking is permitted without limitation.

No.	Scenario Name		Allocation Percentage Auctioned	Offsets (as % of reduction)	Complementary Policies				
					VMT	Pavley II	CHP	EE	RPS
1	S0_CT01	No Auction with offsets	0%	49%	-4%	Y	Y	Y	33%
2	S0_CT02	No Auction/no offsets	0%	0%	-4%	Y	Y	Y	33%
3	S0_CT03	Auction with offsets	100%	49%	-4%	Y	Y	Y	33%
4	S0_CT04	Auction/no offsets	100%	0%	-4%	Y	Y	Y	33%
5	S1_CT01	Lower Transport CP	0%	49%	0%	50%	Y	Y	33%
6	S2_CT01	Less Efficiency	0%	49%	-4%	Y	50%	50%	20%
7	S3_CT01	Less Trans & Efficiency	0%	49%	0%	50%	50%	50%	20%

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.

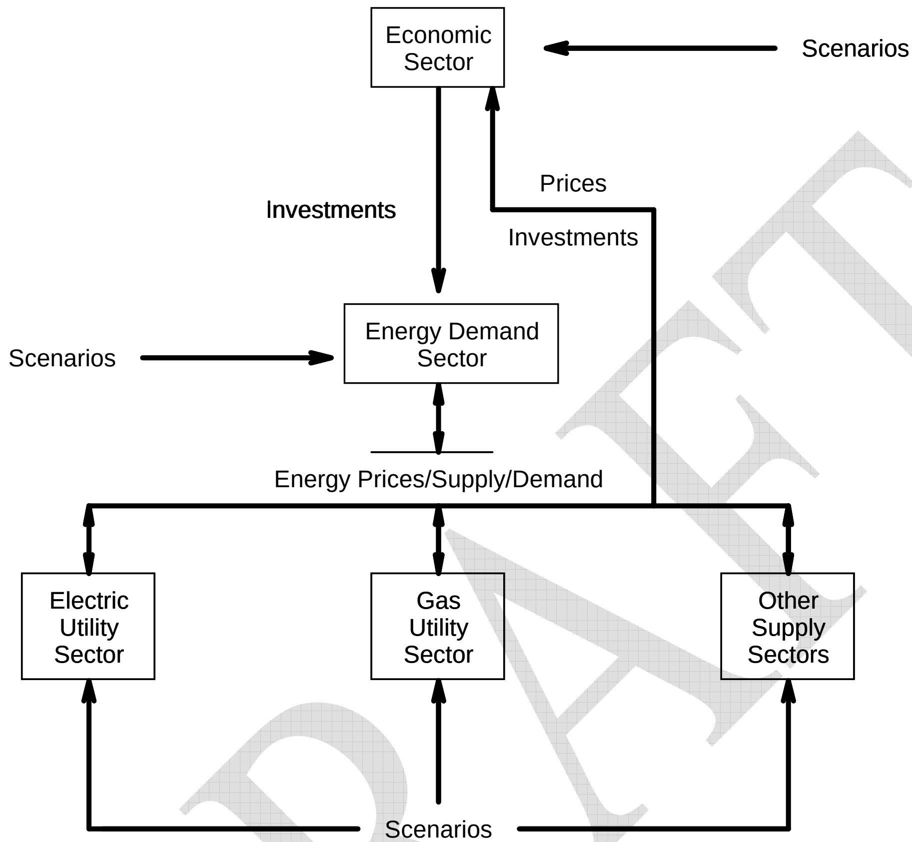
ENERGY 2020 is an outgrowth of the FOSSIL2/IDEAS model developed for the US Department of Energy (DOE) and used for all national energy policy since the Carter administration.[23] This early version of ENERGY 2020 was developed in 1978 at Dartmouth College for the DOE's Office of Policy Planning and 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.

[23] 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 subsectors based on energy services. As many or as few subsectors can be incorporated as required. 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:

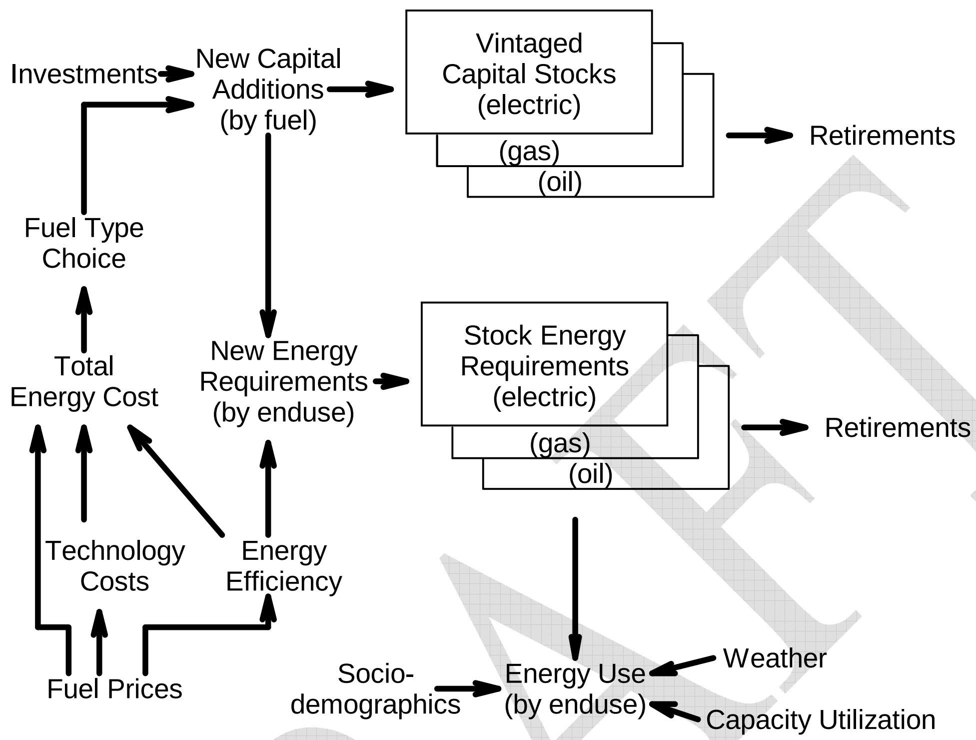
- Residential sector which includes three classes, single family, multifamily and rural/agricultural with 8 end-uses including space heating, water heating, lighting, cooling, refrigeration, other substitutable, and other non-substitutable.

- Commercial sector which is aggregated into one class and end-uses including space heating, water heating, cooling, lighting, other substitutable, other non-substitutable.
- Industrial sector which includes 10 (23 for US) 2-digit SIC categories and is further broken down into process heat, motors, lighting, miscellaneous as the end uses.
- Transportation sector which includes several modes of transportation including automobile, truck, bus, train, plane, marine and electric vehicles. Also, each of the residential, commercial and industrial sectors has separate transportation demands.

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 3-1 (Demand Overview) illustrates the demand sector interactions.

Figure 3.2: 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.

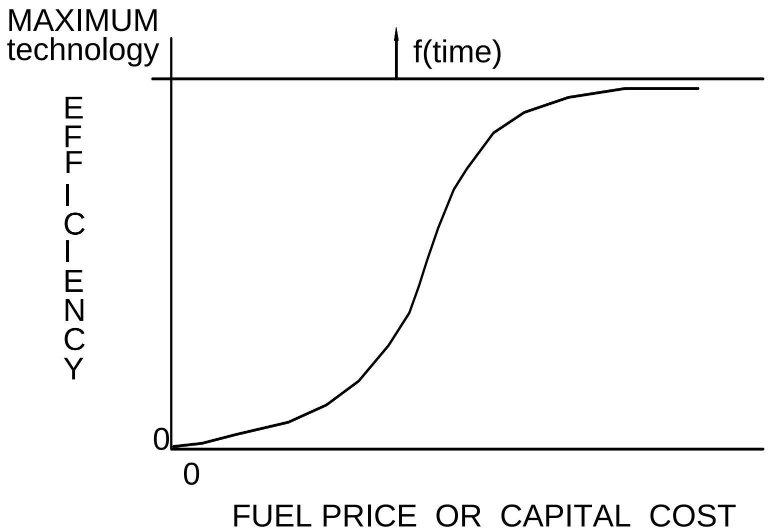
The size and efficiency of the capital stock, and hence energy demands, change over time as consumers make new investments and retire old equipment. Consumers determine which fuel and technology to use for new investments based on perceptions of cost and utility. Marginal trade-offs between changing 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 3.3 (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 3.3: Efficiency/Capital Cost Trade-Off



The standard 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.

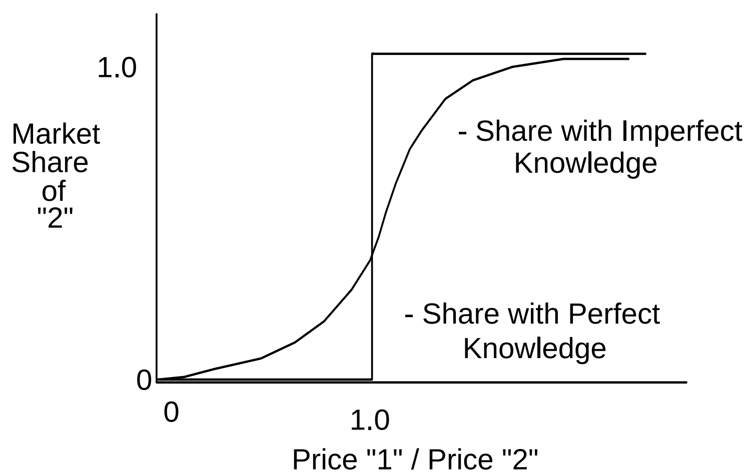
Cumulative investments determine the average "embodied" efficiency. The efficiency of new investments versus the average efficiency of existing equipment is one measure of the gap between realized and potential conservation savings.

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 3.4 (Market Share Dynamics).

Figure 3.4: 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.

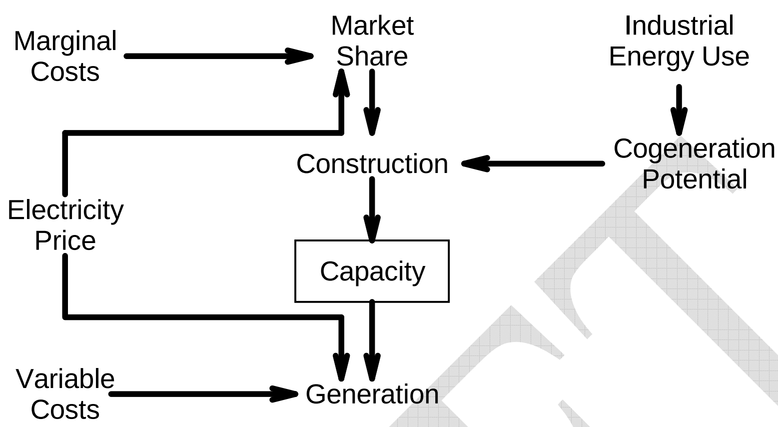
Accounting for Fungible Demand:

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 3.5 shows a simplified overview of the cogeneration structure.

Figure 3.5: 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 represented in the electric supply model.

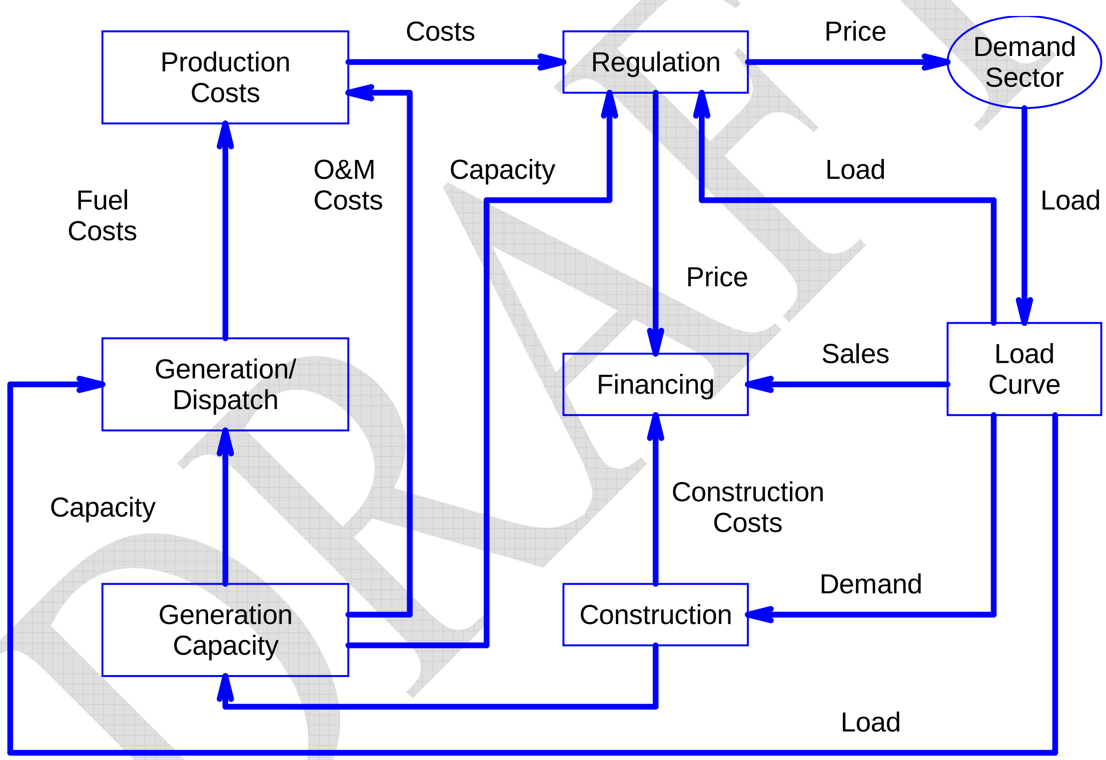
Energy Supply:

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 used in this analysis has only 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 endogenously simulates 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 3.6

Figure 3.6: 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. If future electricity requirements, including reserves, are forecast to exceed available capacity (using seasonal ratings), then construction of additional capacity is initiated.

If additional capacity is needed to meet forecast 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 forecast 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 (Accumulated Funds Used During Construction/Construction Work in Progress). 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 activated based on endogenous least-cost analysis or can be chosen by user-specified criteria. 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 subsector 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 subsector 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.

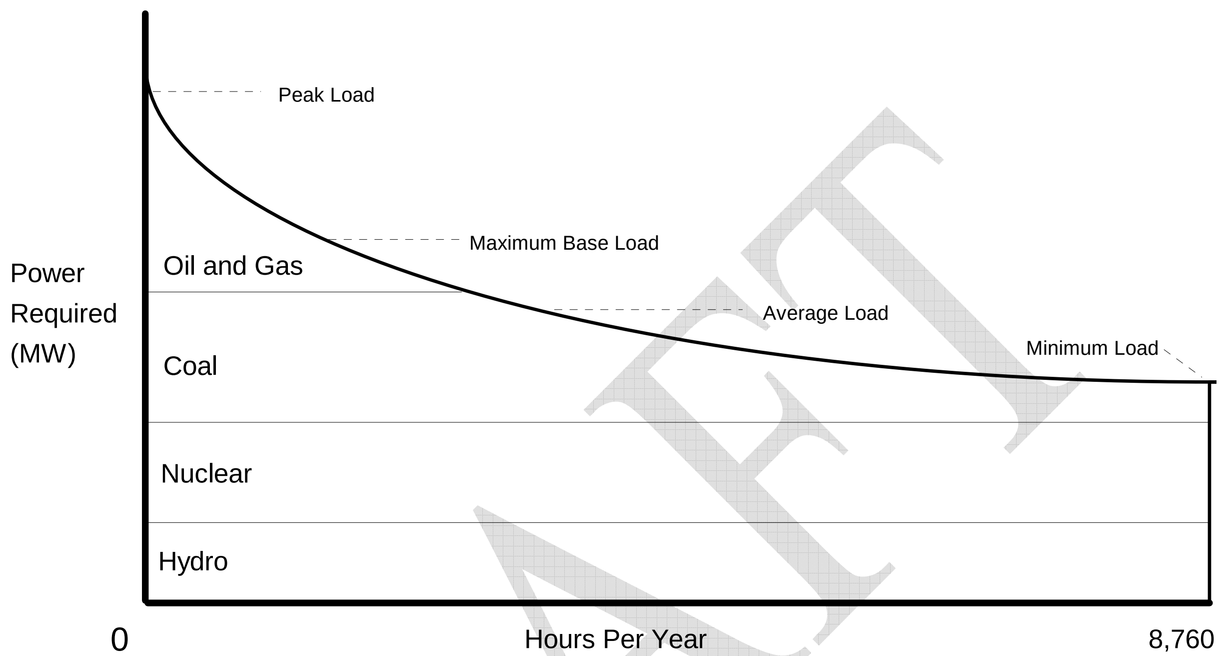
Environmental constraints, such as air pollution restrictions, can also be included in the model. If ENERGY 2020 is configured as a regional or state-wide system, municipal utilities, with their unique tax and rate structures, are incorporated. Similarly, regional or power pool interchange is also recognized by ENERGY 2020. As with the other sectors of ENERGY 2020, the regulatory subsector is flexible enough to accommodate any existing or hypothetical circumstance.

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 subsector 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 3.7 also shows a typical plant dispatch schedule.

Figure 3.7: 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. The US EPA uses ENERGY 2020 to perform the regional (energy, environmental and macroeconomic) impacts of proposed Kyoto initiatives at the 50-state level. 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.[24] 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 show, before the fact, many of the "games" played in the California market.

[24] 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.

Appendix B: Inter-Regional Transmission Capacity in Energy 2020

Transmission Capabilities between Model Regions

Region From	Region To	Capacity Limit (MW)
Alberta	British Columbia	1,000
British Columbia	Alberta	1,200
Allston, OR	Olympia, WA	4,200
Olympia, WA	Allston, OR	4,200
Allston, OR	Williamet, OR	4,120
Williamet, OR	Allston, OR	4,120
Arizona	LADWP, CA	1,229
LADWP, CA	Arizona	1,229
Arizona	New Mexico	2,500
New Mexico	Arizona	2,500
Arizona	Pace, UT	600
Pace, UT	Arizona	600
Arizona	San Diego & Imperial Valley, CA	1,133
San Diego & Imperial Valley, CA	Arizona	1,133
Arizona	Southern California	2,150
Southern California	Arizona	2,150
Arizona	WAPA L.C. (AZ,NM)	9,999
WAPA L.C. (AZ,NM)	Arizona	9,999
British Columbia	North Puget, WA	2,850
North Puget, WA	British Columbia	2,000
British Columbia	Spokane, WA	200
Spokane, WA	British Columbia	200
British Columbia	West Kootenay, BC	9,999
West Kootenay, BC	British Columbia	9,999
Bonanza, UT	Bridger, WY	300
Bridger, WY	Bonanza, UT	300
Bonanza, UT	Pace, UT	785
Pace, UT	Bonanza, UT	400
Bonanza, UT	WAPA R.M., CO	650
WAPA R.M., CO	Bonanza, UT	650
Bridger, WY	Eastern Idaho	2,200
Eastern Idaho	Bridger, WY	600
Bridger, WY	WAPA R.M., CO	1,450
WAPA R.M., CO	Bridger, WY	1,450
Bridger, WY	Wyoming R.M.	400
Wyoming R.M.	Bridger, WY	400
Bridger, WY	Yellowtail, MT	625
Yellowtail, MT	Bridger, WY	400
Brownlee, ID	Lower Columbia (WA,OR)	50
Lower Columbia (WA,OR)	Brownlee, ID	50

Region From	Region To	Capacity Limit (MW)
Brownlee, ID	McNary, WA	300
McNary, WA	Brownlee, ID	300
Brownlee, ID	Oxbow, OR	1,700
Oxbow, OR	Brownlee, ID	1,700
Brownlee, ID	Southern Idaho	1,850
Southern Idaho	Brownlee, ID	1,850
Coulee, WA	Grant County, WA	2,396
Grant County, WA	Coulee, WA	2,396
Coulee, WA	Mid Columbia (WA,OR)	1,844
Mid Columbia (WA,OR)	Coulee, WA	1,844
Coulee, WA	North Puget, WA	1,451
North Puget, WA	Coulee, WA	1,451
Coulee, WA	Olympia, WA	126
Olympia, WA	Coulee, WA	126
Coulee, WA	Seattle South, WA	5,275
Seattle South, WA	Coulee, WA	5,275
Coulee, WA	Spokane, WA	1,140
Spokane, WA	Coulee, WA	1,140
Eastern Idaho	Garrison, MT	224
Garrison, MT	Eastern Idaho	337
Eastern Idaho	Idaho	400
Idaho	Eastern Idaho	270
Eastern Idaho	Pace, UT	400
Pace, UT	Eastern Idaho	630
Eastern Idaho	Southern Idaho	2,557
Southern Idaho	Eastern Idaho	2,557
Garrison, MT	WAPA U.M., MT	200
WAPA U.M., MT	Garrison, MT	200
Garrison, MT	Western, MT	2,200
Western, MT	Garrison, MT	2,200
Garrison, MT	Yellowtail, MT	2,573
Yellowtail, MT	Garrison, MT	2,573
Idaho	Ogden, UT	9,999
Ogden, UT	Idaho	9,999
Idaho	Pace, UT	9,999
Pace, UT	Idaho	9,999
Idaho	Wyoming R.M.	9,999
Wyoming R.M.	Idaho	9,999
LADWP, CA	Lower Columbia (WA,OR)	3,100
Lower Columbia (WA,OR)	LADWP, CA	3,100

Region From	Region To	Capacity Limit (MW)
LADWP, CA	Pace, UT	1,400
Pace, UT	LADWP, CA	1,200
LADWP, CA	Sierra, NV	235
Sierra, NV	LADWP, CA	235
LADWP, CA	Southern Nevada	1,841
Southern Nevada	LADWP, CA	1,841
LADWP, CA	Southern California	9,999
Southern California	LADWP, CA	9,999
LADWP, CA	WAPA L.C. (AZ,NM)	1,231
WAPA L.C. (AZ,NM)	LADWP, CA	1,231
Lower Columbia (WA,OR)	Malin, OR	1,708
Malin, OR	Lower Columbia (WA,OR)	1,708
Lower Columbia (WA,OR)	McNary, WA	1,948
McNary, WA	Lower Columbia (WA,OR)	1,948
Lower Columbia (WA,OR)	Mid Columbia (WA,OR)	5,277
Mid Columbia (WA,OR)	Lower Columbia (WA,OR)	5,277
Lower Columbia (WA,OR)	Slatt, OR	3,031
Slatt, OR	Lower Columbia (WA,OR)	3,031
Lower Columbia (WA,OR)	Williamet, OR	3,334
Williamet, OR	Lower Columbia (WA,OR)	3,334
Lower Granite Dam, WA	Mid Columbia (WA,OR)	5,560
Mid Columbia (WA,OR)	Lower Granite Dam, WA	5,560
Lower Granite Dam, WA	Spokane, WA	1,155
Spokane, WA	Lower Granite Dam, WA	1,155
Malin, OR	PG and E, CA	4,800
PG and E, CA	Malin, OR	4,800
Malin, OR	Sierra, NV	300
Sierra, NV	Malin, OR	300
Malin, OR	Southern Idaho	1,500
Southern Idaho	Malin, OR	1,500
Malin, OR	Southern Oregon	4,782
Southern Oregon	Malin, OR	4,782
McNary, WA	Mid Columbia (WA,OR)	2,000
Mid Columbia (WA,OR)	McNary, WA	2,000
McNary, WA	Slatt, OR	2,854
Slatt, OR	McNary, WA	2,854
McNary, WA	Williamet, OR	227
Williamet, OR	McNary, WA	227
Baja, Mexico	San Diego & Imperial Valley, CA	800
San Diego & Imperial Valley, CA	Baja, Mexico	800

Region From	Region To	Capacity Limit (MW)
Mid Columbia (WA,OR)	Oxbow, OR	400
Oxbow, OR	Mid Columbia (WA,OR)	400
Mid Columbia (WA,OR)	Seattle South, WA	3,700
Seattle South, WA	Mid Columbia (WA,OR)	3,700
Mid Columbia (WA,OR)	Slatt, OR	4,100
Slatt, OR	Mid Columbia (WA,OR)	4,100
Mid Columbia (WA,OR)	Spokane, WA	273
Spokane, WA	Mid Columbia (WA,OR)	273
Mid Columbia (WA,OR)	Williamet, OR	2,600
Williamet, OR	Mid Columbia (WA,OR)	2,600
N. King, WA	Seattle South, WA	526
Seattle South, WA	N. King, WA	526
New Mexico	PS Colorado	558
PS Colorado	New Mexico	558
New Mexico	WAPA L.C. (AZ,NM)	817
WAPA L.C. (AZ,NM)	New Mexico	817
New Mexico	WAPA R.M., CO	690
WAPA R.M., CO	New Mexico	690
North Puget, WA	Seattle North, WA	3,000
Seattle North, WA	North Puget, WA	3,000
North Puget, WA	Seattle South, WA	3,000
Seattle South, WA	North Puget, WA	3,000
Ogden, UT	Pace, UT	9,999
Pace, UT	Ogden, UT	9,999
Olympia, WA	Seattle South, WA	4,500
Seattle South, WA	Olympia, WA	4,500
OVERTHRS, WY	Wyoming R.M.	9,999
Wyoming R.M.	OVERTHRS, WY	9,999
Oxbow, OR	Southern Idaho	90
Southern Idaho	Oxbow, OR	50
Oxbow, OR	Spokane, WA	450
Spokane, WA	Oxbow, OR	300
Pace, UT	Scenic SW, UT	300
Scenic SW, UT	Pace, UT	300
Pace, UT	Sierra, NV	205
Sierra, NV	Pace, UT	205
Pace, UT	Station Load, WY	9,999
Station Load, WY	Pace, UT	9,999
Pace, UT	WAPA L.C. (AZ,NM)	265
WAPA L.C. (AZ,NM)	Pace, UT	265

Region From	Region To	Capacity Limit (MW)
Pace, UT	Wyoming R.M.	9,999
Wyoming R.M.	Pace, UT	9,999
PG and E, CA	Sierra, NV	160
Sierra, NV	PG and E, CA	150
PG and E, CA	Southern Oregon	30
Southern Oregon	PG and E, CA	80
PG and E, CA	Southern California	3,400
Southern California	PG and E, CA	3,000
PS Colorado	WAPA R.M., CO	9,999
WAPA R.M., CO	PS Colorado	9,999
Southern California Edison	Southern California	200
Southern California	Southern California Edison	200
Scenic SW, UT	Southern Nevada	300
Southern Nevada	Scenic SW, UT	300
Scenic SW, UT	St. George, UT	9,999
St. George, UT	Scenic SW, UT	9,999
Scenic SW, UT	Station Load, WY	26
Station Load, WY	Scenic SW, UT	26
San Diego & Imperial Valley, CA	Southern California	5,000
Southern California	San Diego & Imperial Valley, CA	5,000
Seattle North, WA	Seattle South, WA	1,690
Seattle South, WA	Seattle North, WA	1,690
Sierra, NV	Southern Idaho	262
Southern Idaho	Sierra, NV	500
Sierra, NV	Southern California	17
Southern California	Sierra, NV	17
Southern Oregon	Williamet, OR	4,495
Williamet, OR	Southern Oregon	4,495
Southern Nevada	Southern California	2,754
Southern California	Southern Nevada	2,754
Southern Nevada	WAPA L.C. (AZ,NM)	4,554
WAPA L.C. (AZ,NM)	Southern Nevada	4,554
Southern California	WAPA L.C. (AZ,NM)	1,140
WAPA L.C. (AZ,NM)	Southern California	1,140
Spokane, WA	West Kootenay, BC	200
West Kootenay, BC	Spokane, WA	200
Spokane, WA	Western, MT	6,500
Western, MT	Spokane, WA	6,500
Station Load, WY	Wyoming R.M.	9,999
Wyoming R.M.	Station Load, WY	9,999

Region From	Region To	Capacity Limit (MW)
WAPA L.C. (AZ,NM)	WAPA R.M., CO	485
WAPA R.M., CO	WAPA L.C. (AZ,NM)	485
WAPA U.M., MT	Yellowtail, MT	390
Yellowtail, MT	WAPA U.M., MT	390

Appendix C: 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 1985.
- The end year of the analysis is 2030.
- The last historic year of data will be 2005.
- 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

Each area in the model will represent a state or a province (no sub-state break-outs). The model will provide separate results for the state of California, the surrounding Region, the rest of the U.S., and for Canada.

The States and Provinces included in the "Region" for modeling purposes include:

- California
- Oregon
- Washington
- Idaho
- Arizona
- New Mexico
- Nevada
- Colorado
- Utah
- Montana
- Wyoming
- Alberta
- British Columbia
- Manitoba
- Saskatchewan
- Baja, Mexico

Generating Units

The list of units is based on the NEEDS database for the US plus a similar database for the units in Canada. Within the Region and the rest of the US, some of the smaller plants may be aggregated by plant type in order to allow the expedite model operation. With the aggregation of smaller plants, the model will likely end up with approximately 2000 units/plants.

Electric Companies

California electric utilities will be simulated in a manner similar to the E3 representation of seven total including: PG&E, SCE, SDG&E, LADWP, SMUD, Other North and Other South. Outside California in the broader western region, we will assume that each state has a single aggregate electric company. The exception to this is BPA.

Sectors and Classes

The energy demand portion of the model will simulate residential, commercial, industrial, and transportation demands. There will be an electric sales class 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. It may be possible to develop a full energy demand simulation for one or more of these.

Offsets

Possible offset categories, if broken out as a set, could include:

- Sequestration
- Landfill Gas Capture
- Agricultural Methane
- Energy Efficiency (for each sector)

Pollutants

The model currently has the capability to cover 15 pollutants, although the final set will depend on the ARB's requirements and available data. The GHG pollutants include Carbon Dioxide, Methane, Nitrous Oxide, Sulfur-Hexafluoride, Perfluorocarbon, and Hydrofluorocarbon. The criteria air pollutants include Sulfur Dioxide, Nitrogen Oxides, Total Particulate Matter, Volatile Organic Compounds, Carbon Monoxide, Particulate Matter 2.5, Particulate Matter 10, Mercury, and Ozone.

Fuels

There are currently three sets of fuels in the model. The largest category contains 34 fuels (shown below). The second category includes the fuels that emit pollution and contains 15 fuels. The third category is the list of technologies which the energy demand sectors choose from. This smaller set contains only the basic types of fuels (Electricity, Natural Gas, Oil, LPG, Biomass, and Solar). The aggregate category oil is later broken out into the different types of oil (LFO, HFO, petroleum coke, etc.).

Entire List of Fuels

- Asphalt
- Aviation Fuel
- Biomass
- Coal
- Coke
- Coke Oven Gas
- Diesel
- Electric
- Ethanol
- Geothermal
- Heavy Fuel Oil
- Hydro
- Hydrogen
- Kerosene
- Landfill Gases
- Light Fuel Oil
- LPG
- Lubricants
- Motor Gasoline
- Naphtha Specialties
- Natural Gas
- Nuclear
- Oil, Unspecified
- Other Non-Energy Products
- Petrochemical Feedstocks
- Petroleum Coke
- Solar
- Steam
- Still Gas
- Wave
- Wind
- Unknown 1
- Unknown 2

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:

- Gas/Oil Peaking
- Gas/Oil Combined Cycle
- Gas/Oil Steam
- Coal
- Coal Advanced
- Coal with CCS
- Gas CC with CCS
- Nuclear
- Base Hydro
- Peak Hydro
- Other Generation
- Biomass
- Landfill Gas
- Wind
- Solar
- Fuel Cells
- Pumped Hydro
- Small Hydro
- Wave
- Geothermal
- Other Storage
- Biogas
- Trash

Residential Sectors

The residential sector is split into housing types:

- Single Family
- Multi-Family
- Other Residential

Commercial Sectors

- Transportation Services
- Pipelines
- Communication
- Electric Utilities
- Gas Utilities
- Water & Other Utilities
- Wholesale
- Retail
- FIRE
- Offices - Business Services
- Education
- Health & Social
- Food, Lodging, Recreation
- Government

Industrial Sectors

- Food & Tobacco
- Textiles
- Apparel
- Lumber
- Furniture
- Pulp & Paper Mills
- Converted Paper
- Printing
- Petrochemicals
- Industrial Gas
- Other Chemicals
- Fertilizers
- Petroleum Products
- Rubber
- Leather
- Cement
- Glass
- Lime & Gypsum
- Other Non-Metallic
- Iron & Steel
- Aluminum
- Other Nonferrous
- Fabricated Metals
- Machines
- Computers
- Electric Equipment
- Transport Equipment
- Other Manufacturing
- Iron Ore Mining
- Other Metal Mining
- Non-metal Mining
- Light Oil Mining
- Heavy Oil Mining
- Frontier Oil Mining
- Oil Sands In-Situ
- Oil Sands Mining
- Oil Sands Upgraders
- Gas Mining
- Coal Mining
- Construction
- Forestry
- Agriculture

Transportation Sectors

- Passenger
- Freight
- Off Road

Miscellaneous Sectors

- Misc. & Street Lighting
- Electric Resale
- Utility Electric Generation
- Industry Electric Generation
- Steam Generation
- Solid Waste
- Waste Water
- Incineration
- Land Use

Residential End-Uses

- Space Heating
- Water Heating
- Other Substitutable
- Refrigeration
- Lighting
- Air Conditioning
- Other Non-Substitutable

Commercial End-Uses

- Space Heating
- Water Heating
- Other Substitutable
- Refrigeration
- Lighting
- Air Conditioning
- Other Non-Substitutable

Industrial End-uses

- Process Heat
- Electric Motors
- Other Substitutable
- Miscellaneous

Transportation End-Uses

- Ground
- Air/Water

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

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.

- Plug-in Hybrids
- Light Gasoline
- Light Diesel
- Light Propane
- Light CNG
- Light Electric (Plug-in)
- Light Ethanol
- Light Hybrid Gasoline
- Light Hybrid Diesel
- Light Fuel Cell Gasoline
- Light Fuel Cell CNG
- Light Fuel Cell Hydrogen
- Medium Gasoline
- Medium Diesel
- Medium Propane
- Medium CNG
- Medium Ethanol
- Medium Hybrid Gasoline
- Medium Hybrid Diesel
- Medium Fuel Cell Gasoline
- Medium Fuel Cell CNG
- Medium Fuel Cell Hydrogen
- Heavy Gasoline
- Heavy Diesel
- Heavy Propane
- Heavy CNG
- Heavy Ethanol
- Heavy Hybrid Gasoline
- Heavy Hybrid Diesel
- Heavy Fuel Cell Gasoline
- Heavy Fuel Cell CNG
- Heavy Fuel Cell Hydrogen
- Motorcycle
- Bus Gasoline
- Bus Diesel
- Bus Propane
- Bus CNG
- Bus Fuel Cell Gasoline
- Bus Fuel Cell Hydrogen
- Bus Fuel Cell Ethanol
- Train
- Plane
- Marine
- Off Road

Prices

Delivered energy prices are presented for the following fuels:

- Residential Electricity
- Residential Natural Gas
- Residential Coal
- Residential Oil
- Residential Biomass
- Residential LPG
- Residential Steam
- Commercial Electricity
- Commercial Natural Gas
- Commercial Coal
- Commercial Oil
- Commercial Biomass
- Commercial LPG
- Commercial Steam
- Industrial Electricity
- Industrial Natural Gas
- Industrial Coal
- Industrial Oil
- Industrial Biomass
- Industrial LPG
- Industrial Steam
- Gasoline
- Diesel
- Aviation Fuel
- Transportation HFO
- Transportation Natural Gas
- Transportation LPG
- Electric Utility Residual Oil
- Electric Utility Distillate Oil
- Electric Utility Natural Gas
- Electric Utility Coal
- Electric Utility Nuclear
- Electric Utility Biomass
- Ethanol
- Hydrogen

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 D: Mapping of EDRAM and REMI Macro-Economic Categories to ENERGY 2020 Sectors/Sub-Sectors

Map Between EDRAM and ENERGY 2020		
EDRAM Sectors	**Description**	**Energy 2020 Sector/ Sub-Sector**
AGRIC	Agriculture	Agriculture
CATTLE	Cattle	Agriculture
DAIRY	Dairy	Agriculture
FOREST	Forestry	Forestry
OILGAS	Petroleum and Natural Gas Extraction	Gas Mining
OTHPRI	Mining	Other Metal Mining
DISTEL	Electrical Power Generation and Distribution	Electric Utilities
DSTGAS	Natural Gas Distribution	Gas Utilities
DSTOTH	Water Distribution and Sewage Treatment	Water & Other Utilities
CONRES	Residential Construction	Construction
CONNON	Nonresidential Construction	Construction
CONSTR	Street and Bridge Construction	Construction
CONUTL	Utility Infrastructure Construction	Construction
CONOTH	Other Construction-related Industry	Construction
FDMFG	Food Manufacturing	Food & Tobacco
FDPROC	Food Processing	Food & Tobacco
FDOTH	Other Food Related Industry	Food & Tobacco
BEVTOB	Beverage and Tobacco Products	Food & Tobacco
TEXLTH	Textile and Leather Manufacturing	Textiles
APPREL	Apparel Manufacturing	Apparel
WOOD	Wood Products Manufacturing	Lumber
PLPMLL	Pulp and Paper Mills	Pulp and Paper Mills
PAPER	Paper Products Manufacturing	Pulp and Paper Mills
PRINT	Printing	Printing
OILREF	Oil Refineries	Petroleum Products
INDGAS	Industrial Gas	Petrochemicals
CHMDRG	Chemical and Drugs Manufacture	Petrochemicals
CHMBAS	Basic Chemical Manufacture	Petrochemicals
CHMSPS	Soaps and Detergents Manufacture	Petrochemicals
CHMOTH	Other Chemical Products Manufacture	Petrochemicals
PLASTC	Plastics Manufacture	Petrochemicals
GLASS	Glass Products Manufacture	Glass
CEMENT	Cement	Cement
CONCRT	Concrete	Lime & Gypsum
SCAOTH	China and Clay Products	Lime & Gypsum

Map Between EDRAM and ENERGY 2020		
EDRAM Sectors	**Description**	**Energy 2020 Sector/ Sub-Sector**
PRIMTL	Primary Metals	Iron & Steel
ALUM	Aluminum	Aluminum
MTLFAB	Metal Fabrication	Fabricated Metals
MACHIN	Machinery Manufacture	Machines
RFARCN	Refrigeration and Air Conditioning	Machines
CMPMFG	Computer Manufacture	Computers
CMPCMM	Communications Equipment Manufacture	Electric Equipment
CMPRTS	Electronic Components Manufacture	Electric Equipment
CMPINS	Electronic Instruments Manufacture	Electric Equipment
CMPMED	Electronic Recording Media Manufacture	Electric Equipment
ELCTRC	Electrical Equipment Manufacture	Electric Equipment
AUTOMF	Automobile Manufacturing	Transport Equipment
VEHMFG	Other Vehicle Manufacture	Transport Equipment
VEHBDY	Motor Vehicle Body Manufacture	Transport Equipment
VEHPRT	Motor Vehicle Parts Manufacture	Transport Equipment
VEHSHP	Ship Building and Repair	Transport Equipment
VEHOTH	Other Vehicle Manufacture	Transport Equipment
VEHAER	Aerospace Manufacture	Transport Equipment
FURN	Furniture	Furniture
LABDNT	Laboratory and Dental Equipment	Other Manufacturing
MSCMFG	Miscellaneous Manufacturing	Other Manufacturing
VEHSRV	Vehicle Services	Transportation Services
WHLDUR	Wholesale Durable Goods	Wholesale
WHLNON	Wholesale Non Durable Goods	Wholesale
WHLGAS	Wholesale Gas	Wholesale
WHLAGN	Wholesale Trade	Wholesale
TRANSP	Transportation	Transportation Services
AIRTNS	Air Transportation	Transportation Services
RRTNS	Railroad Transportation	Transportation Services
WATTNS	Waterway Transportation	Transportation Services
TRKTNS	Truck Transportation	Transportation Services
PUBTNS	Public Transportation	Transportation Services
OTHTNS	Other Transportation	Transportation Services
VEHTNS	Vehicle Transportation	Transportation Services
RETVEH	Retail Vehicles and Parts	Retail
RETFRN	Retail Furniture	Retail
RETELC	Retail Electronics and Appliances	Retail
RETBLD	Retail Building Materials	Retail
RETFD	Retail Food and Beverage	Retail
RETDRG	Retail Health and Personal Care	Retail

Map Between EDRAM and ENERGY 2020

EDRAM Sectors	Description	Energy 2020 Sector/ Sub-Sector
RETGAS	Retail Gasoline Stations	Retail
RETAPP	Retail Clothing and Accessories	Retail
RETSPT	Retail Sporting Goods, Books, Music	Retail
RETGEN	Retail General Merchandise	Retail
RETMSC	Retail Miscellaneous	Retail
RETNON	Retail Nonstore	Retail
INFOPC	Motion Picture Industry	Communication
INFOTH	Other Broadcasting and Recording Industry	Communication
INFOTL	Telecommunications	Communication
INFCOM	Internet and Information Services	Communication
FINSEC	Financial Securities	FIRE
FINSUR	Insurance	FIRE
FIBNKS	Banking	FIRE
FIREAL	Real Estate	FIRE
FINOTH	Other Financial	FIRE
PROLEG	Legal Services	Offices - Business Services
PROACC	Accounting	Offices - Business Services
PROARC	Architecture	Offices - Business Services
PRODES	Design	Offices - Business Services
PROCOM	Computer Related Services	Offices - Business Services
PROCNS	Consulting	Offices - Business Services
PRORES	Research	Offices - Business Services
PROADV	Advertising	Offices - Business Services
PROOTH	Other Professional Services	Offices - Business Services
BUSSRV	Business Services	Offices - Business Services
ADMTMP	Temporary Administrative Services	Offices - Business Services
ADMSEC	Security Services	Offices - Business Services
ADMBLD	Building Maintenance	Offices - Business Services
ADMOTH	Other Administrative Services	Offices - Business Services
WSTSRV	Waste Management	Waste Water
LNDFIL	Landfills	Solid Waste
EDUC	Education	Education
MEDAMB	Medical Services	Health & Social
MEDHSP	Hospitals	Health & Social
MEDNRS	Nursing	Health & Social
MEDSA	Day Care	Health & Social
RECENT	Recreation and Entertainment	Food, Lodging, Recreation
RECAMS	Amusement Parks	Food, Lodging, Recreation
ACCHOT	Hotels	Food, Lodging, Recreation
ACCRST	Full Service Restaurants	Food, Lodging, Recreation

Map Between EDRAM and ENERGY 2020		
EDRAM Sectors	**Description**	**Energy 2020 Sector/ Sub-Sector**
ACCFST	Fast Food	Food, Lodging, Recreation
ACCSPC	Caters and Mobile Food Services	Food, Lodging, Recreation
ACCBRS	Drinking Establishments	Food, Lodging, Recreation
PERSRV	Personal Services	Offices - Business Services

Appendix E: New Generation Performance and Cost Assumptions

Table 1A. Input Values to Busbar Energy Costs - California Resources (2008 $)

Resource Technology	2020 Overnight Capital Cost ($/kW) ($/kW)		Fixed O&M Cost ($/kW-year)		Variable O&M Cost ($/MWh)		Capacity Factor	Nominal Heat Rate (Btu/kWh)
	Low (if range)	High (if range)	Low (if range)	High (if range)	Low (if range)	High (if range)		
Biogas	$3,065		$139		1.20		80%	13,648
Biomass	$4,484		$65		1.20		80%	8,911
Geothermal	$3,339	$8,131	$157	$226	1.20		90%	n/a
Hydro - Small	$2,539	$5,170	$14	$31	0.94	1.81	25% - 65%	n/a
Solar - Thermal	$3,235		$64		1.20		37% - 40%	n/a
Wind	$1,962		$37		1.20		27% - 40%	n/a
Coal ST	$2,479		$33		1.20		85%	8,844
Coal IGCC	$2,866		$47		1.20		85%	8,309
Coal IGCC with CCS	$4,101		$55		1.20		85%	9,713
Gas CCCT	$1,054		$14		1.20		90%	6,917
Gas CT	$807		$15		1.20		5%	10,807
Hydro - Large	$1,486	$2,193	$9	$13	0.63	0.89	12% - 57%	n/a
Nuclear	$3,999		$83		1.20		85%	10,400

Table 1B. Input Values to Busbar Energy Costs - Rest of WECC Resources (2008 $)

Resource Technology	2020 Overnight Capital Cost ($/kW) ($/kW)		Fixed O&M Cost ($/kW-year)		Variable O&M Cost ($/MWh)		Capacity Factor	Nominal Heat Rate (Btu/kWh)
	Low (if range)	High (if range)	Low (if range)	High (if range)	Low (if range)	High (if range)		
Biogas	$2,350	$2,835	$107	$128	0.92	1.11	80%	13,648
Biomass	$3,438	$4,148	$50	$60	0.92	1.11	80%	8,911
Geothermal	$1,582	$19,451	$157	$226	0.96	1.11	90%	n/a
Hydro - Small	$1,758	$4,782	$11	$28	0.71	1.69	22% - 65%	n/a
Solar - Thermal	$2,588	$2,939	$51	$58	0.96	1.09	36% - 39%	n/a
Wind	$1,504	$1,815	$28	$34	0.92	1.11	27% - 40%	n/a
Coal ST	$1,901	$2,293	$26	$31	0.92	1.11	85%	8,844
Coal IGCC	$2,197	$2,651	$36	$43	0.92	1.11	85%	8,309
Coal IGCC with CCS	$3,144	$3,794	$42	$51	0.92	1.11	85%	9,713
Gas CCCT	$808	$975	$11	$13	0.92	1.11	90%	6,917
Gas CT	$619	$747	$11	$14	0.92	1.11	5%	10,807
Hydro - Large	$1,122	$2,031	$5	$11	0.41	0.78	15% - 65%	n/a
Nuclear	$3,066	$3,699	$63	$76	0.92	1.11	85%	10,400

Source: Energy and Environmental Economics, Inc., CPUC GHG Modeling - Generation Costs, www.ethree.com/cpuc_ghg_model.html

Appendix F: 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 ENERGY2020 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
Sulphur Hexafluoride (SF_6)	23,900
Perfluorocarbons (PFC)	7,000
Hydrofluorocarbons (HFC)	1,300

These values are consistent with the Global Warming Potential values used in the 1996 Second Assessment Report based on 100-year warming potential for the individual gases. In the case of HFCs and PFCs the GWP values used in the model are based on an estimated average GWP for these gases.

Appendix G: Efficiency & Cost Data – Built Environment

Residential:

Residential Device Standards	
Equipment	**Effective Efficiency Standard**
Gas hot water from 1990 to the final year	59%
Oil hot water from 1990 to the final year	51%
Electric hot water from 1990 to the final year (inc.tank losses)	92%
LPG hot water from 1990 to the final year	59%
Electric air conditioning for 1990	260% COP = 2.6
Electric air conditioning for 1991	261% COP = 2.61
Electric air conditioning for 1992 to 2006	265% COP = 2.65
Electric air conditioning for 2007 to the final year	344% COP = 3.44
Electric Refrigeration for 1990 to 1992	34.5%
Electric Refrigeration for 1993	40.0%
Electric Refrigeration for 1994 to 2000.	42.0%
Electric Refrigeration from 2001 to the final year	54.7%
Biomass space Heating from 1993 to the final year (wood burning equipment)	63.0%
Gas space Heating from 1993 to the final year	80.0%
Oil space Heating from 1993 to the final year	80.0%
LPG space Heating from 1993 to the final year	80.0%

Residential (cont'd.)

Maximum Device Efficiency							
(Btu/Btu)	Electric	N.Gas	Coal	Oil	Biomass	LPG	Steam
Primary Heat	278%	97%	97%	97%	78%	97%	99%
Water Heating	250%	86%	97%	97%	78%	97%	99%
Other Substitutable Loads	130%	97%	97%	97%	65%	97%	99%
Refrigerators	98%	0%	0%	0%	0%	0%	0%
Lighting	95%	0%	0%	0%	0%	0%	0%
Air Conditioning	447%	113%	0%	0%	0%	113%	0%
Other Non-Substitutable Loads	98%	0%	0%	0%	0%	0%	0%

Note – Electric heating applications include heat pumps.
Non-substitutable loads are those loads which require electricity (refrigerators, electronics, etc.).
Substitutable loads are those loads which can use multiple fuels (i.e. Range, dryers, etc.).

Device Capital Cost								
1985$/mmBtu/Year	Electric	N.Gas	Coal	Oil	Biomass	Solar	LPG	Steam
Space Heating	17.7	23.1	19.0	36.0	17.2	132.0	23.1	36.0
Water Heating	8.5	18.5	19.0	23.5	17.2	82.0	18.5	23.5
Other Substitutable Loads	65.0	85.0	19.0	85.0	17.2	-	85.0	85.0
Refrigerators	96.5	-	-	-	-	-	-	-
Lighting	0.23	-	-	-	-	-	-	-
Air Conditioning	4.4	34.1	-	-	-	-	34.1	-
Other Non-Substitutable Loads	19.8	-	-	-	-	-	-	-

Device Operating Costs								
1985 $/mmBtu	Electric	N.Gas	Coal	Oil	Biomass	Solar	LPG	Steam
Space Heat	0.018	0.024	0.011	0.020	0.013	0.012	0.024	0.030
Water Heating	-	-	-	-	-	0.010	-	-
Other Substitutable Loads	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-
Lighting	-	-	-	-	-	-	-	-
Air Conditioning	0.015	0.017	-	-	-	-	0.017	-
Other Non-Substitutable Loads	-	-	-	-	-	-	-	-

Residential (cont'd.)

Physical Life of Equipment in Years (Residential)							
	Space Heat	Water Heating	Substitutable Loads	Refrigeration	Light	Air Conditioning	Non-Substitutable Loads
Electric	18	15	13	18	6	15	10
Natural Gas	18	15	13	0	0	15	0
Coal	18	15	13	0	0	0	0
Oil	18	15	13	0	0	0	0
Biomass	18	15	13	0	0	0	0
Solar	18	15	13	0	0	0	0
LPG	18	15	13	0	0	0	0
Steam	18	15	13	0	0	0	0

Commercial:

Device Efficiency Standards (Commercial)								
Btu/Btu	Electric	N.Gas	Coal	Oil	Biomass	Solar	LPG	Steam
Space Heating (primary)	450%	97%	97%	97%	65%	1000%	97%	99%
Water Heating	400%	97%	97%	97%	65%	1000%	97%	99%
Other Substitutable Loads	130%	97%	97%	97%	65%	1000%	97%	99%
Refrigerators	140%	0%	0%	0%	0%	0%	0%	0%
Lighting	95%	0%	0%	0%	0%	0%	0%	0%
Air Conditioning	400%	240%	0%	0%	0%	0%	200%	0%
Other Non-Substitutable Loads	98%	0%	0%	0%	0%	0%	0%	0%

Device Capital Cost (Commercial)								
$/mmBtu/Year	Electric	N.Gas	Coal	Oil	Biomass	Solar	LPG	Steam
Primary Heat	9.20	7.5	42.2	19.0	25.5	138.9	22.9	42.2
Water Heating	5.20	8.9	42.2	19.0	-	138.9	22.9	42.2
Other Substitutable Loads	19.80	11.3	11.3	19.0	-	-	11.3	11.3
Refrigeration	0.21	-	-	-	-	-	-	-
Lighting	0.02	-	-	-	-	-	-	-
Air Conditioning	9.20	34.1	-	-	-	-	34.1	-
Other Non Substitutable Loads	22.00	-	-	-	-	-	-	-

Device Operating Cost Fraction ($/Year/$)								
1985 $/mmBtu	**Electric**	**N.Gas**	**Coal**	**Oil**	**Biomass**	**Solar**	**LPG**	**Steam**
Space Heating (primary)	0.02	0.03	0.01	0.03	0.01	0.01	0.03	0.04
Water Heating	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Other Substitutable Loads	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Air Conditioning	0.01	0.02	0.00	0.00	0.00	0.00	0.03	0.00
Other Non-Substitutable Loads	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Physical Life of Equipment in Years							
	Space Heat	**Water Heating**	**Substitutable Loads**	**Refrigeration**	**Light**	**Air Conditioning**	**Non-Substitutable Loads**
Electric	18	8	10	15	7	18	7
Natural Gas	25	8	10	0	0	18	0
Coal	18	8	10	0	0	0	0
Oil	25	8	10	0	0	0	0
Biomass	18	8	10	0	0	0	0
Solar	18	8	10	0	0	0	0
LPG	18	8	10	0	0	18	0
Steam	18	8	10	0	0	0	0