AB 32 - California Global Warming Solutions Act
Scoping Plan Background Information

Modeling Scenarios

ARB is utilizing three models for the economic analysis of the AB32 Scoping Plan. One model, ENERGY 2020, shows shifts in **energy use** (and associated GHG emissions) in response to GHG reduction policies. The other two models are macroeconomic models that analyze changes in the **flow of money** in response to GHG reduction policies. Interaction between ENERGY 2020 and the macroeconomic models is two-way. These two macroeconomic models are known as (a) Environmental Revenue Dynamic Assessment Model (E-DRAM) and the (b) Berkeley Energy And Resources (BEAR) forecasting model. The two models (E-DRAM and BEAR) are similar. BEAR is meant to provide a check and balance to the E-DRAM model. This control helps ensure that data output from E-DRAM is verifiable and accurate; if the outputs for both are similar; then confidence in the output is increased. If there is significant difference in the results of E-DRAM and BEAR additional analysis would be needed to determine whether the differences can be explained in the way the models treat various inputs and assumptions, or if there are underlying problems in the models.

Energy 2020 and E-DRAM (or BEAR) can be used together in an iterative process. The main drivers of emission reductions in the Energy 2020 model are efficiency improvements and fuel switching. Both drivers of Energy 2020 are inputs into the E-DRAM model. These inputs inform the E-DRAM model's predictions of how adjustments in energy use and carbon intensity ripple though the California economy. E-DRAM then simulates how the individual sectors of the State economy grow and change in response to policy alternatives. As sector and economy-wide energy demand change in E-DRAM, energy and emissions predictions change in Energy 2020. Through an iterative process the models identify an equilibrium point between the measures, the associated emissions, and the economy-wide costs of meeting the mandate under AB 32. In this case, equilibrium is defined as a balance between supply forces and demand forces.

A simplified expression of this interaction is as follows:

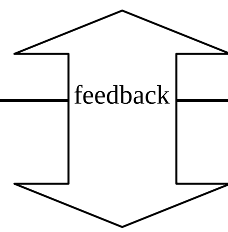
> **Example Policy:** Switching the use of coal to natural gas for cement manufacturers.
>
> **How ENERGY 2020 and E-DRAM/BEAR interact:** ENERGY 2020 would forecast energy reductions and emission reductions resulting from that policy. Then, that data would be fed into EDRAM and BEAR, which would analyze how this would affect the economy. The results from EDRAM and BEAR can be re-fed into ENERGY 2020, and back and forth, until equilibrium (balance between supply forces and demand forces) between

the two occur. Feeding the results back into ENERGY 2020 does not change the policy assumptions; it only changes the amount of energy thought to be needed to be used, the cost, or other similar factors. The final equilibrium point, in theory, signifies what is expected to happen in the economy as a result of that policy. Details on the E-DRAM model are provided in below; details of the BEAR model are still being developed, however a short description is provided below as well.

Economic Feedback between the models

ENERGY 2020

1. Energy Prices
2. Energy Demand Investments
3. Energy Supply Investments
4. Energy Taxes
5. Government Expenditures



Macro-economic Models

1. Gross Regional Product
2. Gross Output
3. Personal Income
4. Employment
5. Population
6. Interest Rates and Inflation

The economic analysis work that ARB is conducting to support the Scoping Plan would undergo an in-depth peer review. ARB has contracted with the University of California to conduct this review, with the results expected to be available prior to publication of the revised Scoping Plan in early October.

I. Energy 2020 model

Overview

ENERGY 2020 would help ARB chose between policy options. It is based upon historic data from 1985 – 2005 and also provides forecasts into 2030. Data inputs that feed into this model (and its sources) are described in detail below.

ENERGY 2020 provides multi-region and multi-sector analysis. It considers interactions between states, it simulates the supply, price and demand for all fuels, and it simulates the physical and economic flows of energy users and suppliers. The model also has the ability to pull out California from other states such that it can analyze the impact of various potential GHG reduction policies.

Model:

ENERGY 2020 grew out of a model developed for the US Department of Energy (DOE). The original model has been used to guide national energy policy since the Carter administration. It was developed in 1978 at Dartmouth College for the DOE.

Contractor:
ICF International

Website for Energy 2020
Website with detailed information on the model (work in progress):
http://www.arb.ca.gov/cc/scopingplan/economics-sp/models/models.htm

Energy 2020:

ENERGY 2020 incorporates the following basic time frame:

a. Based on actual past experience: includes past historic data from 1985 – 2005. Data sets include annual data for each year of history.
b. Forecasts: end year of the analysis may be set from 2008-2030. Data sets include each year of forecast through 2030.
c. Takes into account both price and non-price elements of decisions:
    a. Examples of non-price elements may be: consumer choices such as design, technology, values, - choices that go beyond cost
    b. Price elements – assumptions on costs
d. Reacts in a manner that reflects real-life scenarios (what is reasonable to expect would occur as one action affects another).

B. Major sources for key inputs

Note: all inputs identified below represent the most recent available data. Data is pulled from ICF presentations and/or the Draft Modeling of Greenhouse Gas Reduction Measures to Support the Implementation of the California Global Warming Solutions Act (AB32) ENERGY 2020 Model Inputs and Assumptions, presented by ICF to the California Air Resources Board, March 31st, 2008 . Inputs and sources may be adjusted or replaced. For more information, see:
http://www.arb.ca.gov/cc/scopingplan/economics-sp/models/models.htm

Data inputs for ENERGY 2020 are found in five general areas (refers to both historical data and assumptions and projections of future inputs). A summary outline is presented below.

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

Each category is broken down by component and sources used in the model's assumptions below.

A.1 Draft Population and Economic Data

Description of Data	Source of Data
a. Total population, historical and growth over time	US Census Bureau, California Department of Finance
b. Population by housing type (single, multi, etc)	US Census Bureau, California Department of Finance
c. Personal income	US Census Bureau, E-DRAM
d. Employment by sector	US Bureau of Economic Analysis
Population assumes growth of 1% per year. Personal income projected to increase 1.5% annually from 2005 – 2030	

A.2 Draft Fuel Prices data

Description of Data	Source of Data
Historic energy prices for all states (except CA)	State Energy Consumption, Price and Expenditure Estimates in the State Energy Data System, U.S. Energy Information Administration (EIA)
Historic price data for California	California Energy Commission and ARB
Forecasted energy prices	EIA Annual Energy Outlook Reference Case forecast for 2007-2030
Biomass prices	Based on prior ICF research
Power prices	Calculated within the model based on costs and dispatch

A.3 Draft Energy Use and Consumption Data (Historic)

Description of Data	Sources
Residential Data Single family, Multi-family, Rural / agricultural	
Household income by housing type	
No. of people per household	
End-use consumption: Space heating Water heating Lighting Cooling Refrigeration Other substitutable Other non-substitutable	2001 EIA Residential Energy Consumption survey by Census Region and Division California Statewide Residential Appliance Saturation Study: Final Report California Energy Commission, June 2004
Commercial Data	
Floor area by sub-sector	
End-use consumption Space heating Water heating Cooling Lighting Other substitutable Other non-substitutable	2003 EIA Commercial Buildings Energy Consumption Survey, by Census Regional and Division (2007 ongoing) California Commercial End-Use Survey, California Energy Commission, March 2006
Industrial/Manufacturing Includes 10 SIC categories	2002 EIA Manufacturing Energy Consumption Survey by Census Region (2006 ongoing) Non-Residential Market Share Tracking Study, Final Report on Phases 1 & 2 CEC, April 2005.

Energy use by fuel for each sub-sector and end-use: Process heat Motors Lighting Miscellaneous	
State Energy Data	California Energy Commission 2004 EIA State Energy Data System California Public Utilities Commission Inventory of California Greenhouse Gas Emissions and Sinks: 1990-2004 (Appendix B)
Energy consumption and expenditures by sector and energy source	
Where California data was available, it was used to replace national data sources. Household data came from the US Census Bureau and the EIA State data on Prices and Expenditure. Historic electricity consumption data came from the CEC. For each end-use category, up to six fuels are modeled for that particular end-use.	

A.4. Draft Emissions and Air Regulations (Historic)

<table>
<tr><th>Description of Data</th><th>Source of Data</th></tr>
<tr><td>GHG Emissions for CA</td><td>California 1990 Greenhouse Gas Emissions Level and 2020 Emissions limit Report, ARB; November 16, 2007</td></tr>
<tr><td>GHG emissions for US</td><td>EPA US Inventory Report</td></tr>
<tr><td colspan="2">All major GHG emissions are included: carbon dioxide, nitrous oxide, methane, sulphur hexafluoride, hydrofluorocarbons, perfluorocarbons. GHG emissions are presented in CO_2 equivalent terms.

Emission factors for most fuels are based on Consultant's derived value assigned to each fuel and used in national and state inventories. For the transportation sector, emission factors for methane and nitrous oxide were adapted from the Canadian National Inventory Report 1990-2005, Greenhouse Gas Sources and Sinks in Canada, April 2007 (Annex 12 Emission Factors).

ENERGY 2020 calculates GHG emissions at the point of combustion. Upstream emissions from extraction and processing are captured as part of those respective economic sectors. The model assumes no GHG emissions are created from biomass. Emissions from ethanol and other bio-fuels are an exception; for these the model applies a full cycle emission factor, recognizing upstream emissions.

Factors for corn ethanol, cellulosic ethanol, and biodiesel can be found in "Modeling of Greenhouse Gas Reduction Measures to Support the Implementation of the California Global Warming Solutions Act, ENERGY 2020 Model Inputs and Assumptions. March 31, 2008.</td></tr>
</table>

A.5 Draft Electricity Generation Capacity and Operation (supplied to the grid)

<table>
<tr><th>Description of Data</th><th>Data sources</th></tr>
<tr><td>Generating Unit data
Historic Peak capacity (MW)
Historic generation levels (GWh)
Type of fuel used
Heat rate
Historic annual fuel use (Petajoule)
Emissions (from each generating unit) by pollutant type
O&M costs
Capacity factors
Emission rates
Outage rates
State
Physical location
Ownership
Plant type (hydraulic, coal, combined cycle, etc)</td><td>National Electric Energy Data System 2006 database; Bonneville Power Administration</td></tr>
<tr><td colspan="2">ENERGY 2020 contains information on each generating unit in the state as well as in neighboring jurisdictions that supply power to the state. The model tracks and uses the above information for each generating unit. 12% of total state GHG emissions in 2004 were due to in-state generation and another 13% of total state GHG emissions in 2004 were attributable to imported electricity. The model assumes that 15% of installed wind capacity is available during peak hours. Costs and characteristics of new generation are based on information developed by Energy and Environmental Economics, Inc. (E3) as part of their modeling process for the California PUC www.ethree.com/cpuc_ghg_model.html

Industrial generation supplies a specific end-user. It does not supply power to the grid. These plants are treated similarly to 'must run' units – they would always operate when available. Heat produced from co-generation is used to meet industrial heat requirements; co-generated electricity is used to meet industrial power needs.

ENERGY 2020 will also contain data describing the type, operation, and performance of every generating unit in the western U.S. In additional to plant-level data, the table below shows other sources of inputs which are necessary to describe the electric system and transmission capability. This data was compared to generation data provided to the CPUC and CEC to ensure consistency between the models. This list of generating units was matched to emission data from the EPA and Environment Canada to calculate emission rates for targeted GHG emissions were then reviewed for reasonableness based on plant type and capacity factors. Historic generation by plant type was determined by historic generation data available from the CEC and the EIA.</td></tr>
<tr><td>Plant capacity
Plant historic generation
Plant fuel type
Plant heat rate
Plant fuel consumption
Plant emissions by pollutant
Plant costs
Plant historical capacity factor
Plant availability (outages)
Plant owner and location
Planned capacity additions and retirements
Inter-regional transmission capability</td><td>FERC Reports for US
California Public Utility Commission

North American Electric Reliability Council (NERC);

EPA Base Case 2006 9 (v.3.0); Table 3.5; Section 3.</td></tr>
</table>

B. Other Inputs:

B.1. Transportation

- Passenger (mode and vehicle type)
    - Automobile
    - Truck
    - Bus
    - Train
    - Plane
    - Marine
    - Electric vehicle
- Freight (mode and vehicle type)
- Off road transportation (bulldozers, cranes, etc)

B.2 Built Environment

Data on current levels of equipment efficiency of appliances and equipment for California was derived from the Energy Independence and Security Act of 2007, section 4.8 and existing California appliance standards; 2007 Appliance Efficiency Regulations, California Energy Commission, December 2007.

B.3 Laws and Regulations

Specific laws and regulations were incorporated in the business-as-usual case to reflect policies which have been approved but have not yet come into effect.

B.4 Process Efficiencies and Market Drivers (incorporated into model)

- Capital stock energy efficiency (efficiency of a house or building – behavioral and technological)
- Devices (new investments, retirements, retrofitting)
- Temporary response to budget constraints (reduced consumption due to limited-time budgetary changes)
- Short-term fuel switching (for appliances/devices that can use two different types of fuel)
- Co-generation (self-generation such as diesel generators or fuel cells)

C. Major Model Outputs for ENERGY 2020

- Fuel usage for all fuels
- Device and process efficiencies
- Fuel shares
- Electricity generation, capacity, and prices
- Oil and gas imports and exports
- Emissions – GHG and Criteria Air Contaminants (SOx, NOx, PM, etc.)
- Outputs for all end uses, sectors, and states
- When linked to macro-economic model provides economic changes resulting from policies (GDP, employment, personal disposable income, etc.)

II. E-DRAM Model

Overview

Environmental Dynamic Revenue Assessment Model (E-DRAM) will be used to predict how the broad California economy would grow and change as we begin to restrict greenhouse gas emissions. E-DRAM has been used extensively by ARB in previous proceedings.

E-DRAM simulates supply and demand for all sectors of the economy. E-DRAM models how changes in energy price and energy use (as predicted by Energy 2020) would affect how California's businesses and residents live their lives. It would capture all fundamental economic relationships among consumers, producers, and government. Specifically, this analysis would include estimates of how personal income may change and anticipates behavioral shifts with regard to how people choose to spend their money. Beyond impacts on individuals, E-DRAM models how different sectors of the economy interact, including how companies would buy from and sell to each other. Generally, the total amount that companies and individuals buy from and sell to each other determines how, and in which sectors, the State economy grows.

Model History:

E-DRAM was originally designed for the Department of Finance and the Air Resources Board by Professor Peter Berck at the University of California - Berkeley. It was first used following the passage of State Senate Bill 1837 in 1994 by the Department of Finance to analyze revenue impacts of tax and other State policies, and later by the California Energy Commission and ARB to assess impacts of reducing petroleum dependency (AB2076). It has also been used by ARB to assist in its analysis of the Vehicle Climate Change Standards, the State Implementation Plan and others. As a part of the application of the model to these analyses, it has been peer reviewed and adjusted to be representative of the California economy.

Contractor:
University of California-Berkeley; Professor Peter Berck et al.

Website for E-DRAM
Website with more information on the model is found at http://www.are.berkeley.edu/~wkam/. This site refers to a "Social Accounting Model (SAM) which is the data used to feed into the E-DRAM model.

How E-DRAM will be used:
When used together with ENERGY 2020, the two models are meant to provide a complete analysis of the economic impact to various policy options for achieving greenhouse gas reductions. To facilitate the comparison between options, a base case scenario was established. In this case, the models were run to predict how the economy would change and greenhouse gas emissions would be expected to grow if no action was taken to combat climate change. Results matched against CEC and other predictors to ensure the model is representative of California. Scenarios that analyze GHG reduction policy measures, cap and trade, and carbon fees would build upon the base case.

Major categories / sources for key inputs:
E-DRAM groups like-industries together. It uses average energy efficiency by sector, new investment by sector, and energy use by sector, all of which are key outputs of the Energy 2020 model (the energy/electricity model). The E-DRAM model would interpret these energy inputs as *costs* and determine how each of the sectors of the economy react to this change and interact with each other. Embedded in E-DRAM are linkages between sectors which predict how money flows through the economy. Key outputs of E-DRAM are gross state output, overall spending, employment, personal income, consumption, and investment.

E-DRAM divides the California economy into 188 distinct sectors; each sector is combined. For example, for the industrial sector, closely related industries are combined and grouped into one sector. An industrial sector is a list of the aggregate purchases and sales of these related industries. Similarly, a consumer sector shows the income and expenditures of a group of consumers. A government sector shows the income and expenditures of a type of government. The 188 sectors in the E-DRAM model include:

- 120 industrial sectors
- 2 factor of production sectors (labor and capital)
- 10 household sectors
- 9 composite goods sectors (consumption)
- 1 investment sector
- 45 government sectors
- 1 sector that represents the rest of the world (e.g. outside of CA)

The sector design is an important element of this model because it determines the flows that the model would be able to trace explicitly. If the sectoring is done well, the major flows in the economy, both positive and negative, would be evident. If the sectoring is done poorly, the impact of policy would be blurred, with negative and positive flows occurring within a single sector. The third model – known as the BEAR model – would provide another tool to check against the results of E-DRAM. If BEAR and E-DRAM results are similar, one can assume the models are representative. Inputs and more detailed information is available upon request.

Results (output) would show:

- Change in output
- Change in prices
- Change in employment
- Change in personal income
- Change in consumer spending

Sources

- U.S. Department of Commerce Bureau of Economic analysis Census of Business (2003)
- Employment data: CA Employment Development Department
- Demand data: Estimated from the Consumer Expenditure Survey for the Western
- Bureau of Economic Analysis (BEA)

III. Berkeley Energy and Resources (BEAR) Model

Overview

The BEAR Forecasting model, named after the Center for Energy, Resources, and Economic Sustainability at UC Berkeley, is an independent model that will be used to compare against the results of the E-DRAM model. BEAR is solely focused on the State of California, in contrast to ENERGY 2020, which looks at other states as well as California. The economic and emissions data will be the same data that is fed into the E-DRAM model. BEAR, like E-DRAM will analyze the way money flows in response to GHG reduction policies. BEAR will forecast these economic shifts to the years 2020, 2050, and 2080; it will model GHG emissions in proportion to energy use by energy source. This will permit detailed sectoral estimation of tradable emission rights schemes, such as cap and trade. All program characteristics within the scheme can be modeled on a sector by sector basis as well.

Model History:
The BEAR model was originally developed for the California Energy Commission.

Contractor:
Center for Energy, Resources, and Economic Sustainability, Department of Agricultural and Resource Economics, UC Berkeley. Professor David Roland-Holst.

Website for BEAR:
None at this time

Major sources for key inputs:

As with E-DRAM, ENERGY 2020 energy and emissions data will be fed into the BEAR model. From that point, economic data is layered into the emissions data that has been fed into the model. The following sectors are included in the BEAR model:

- 125 production activities
- Detailed fiscal accounts
- 10 Household groups by tax bracket
- 14 emission categories

Results (output) would show:

- Change in output
- Change in prices
- Change in employment
- Change in personal income
- Change in consumer spending