APPENDIX F

Supporting Documentation for the Economic Analysis

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Appendix F
Supporting Documentation for the Economic Analysis

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Appendix F1

Bill Impact Calculator

This section presents supporting detail on the methodology used for the Bill Impact Calculator.

A. Inputs

1. Revenue Requirement

The RES Calculator provides the 2020 revenue requirement projections for the 20 percent RPS, which serves as the baseline, and the proposed RES. The incremental cost for the proposed RES is the difference between the two revenue requirement projections.

2. Sales

Each IOU provided the 2009 sales by customer class, including the breakout of sales by residential tier and by CARE and non-CARE customers. The customer class sales were increased to 2020 forecasts by an escalation factor based on CEC sales projections, from the CEC's IEPR report.

3. Customer Class Allocators

The IOUs provided their 2009 cost allocation factors and the model assumes no changes in these allocation factors for 2020.

4. Customer monthly usage

Usage is defined by the average usage for the residential and small commercial customer classes. For the residential class, however, bill impacts vary significantly for higher usage customers. In order to clearly identify these varying bill impacts, the IOUs calculate bills for a hypothetical high usage customer at 1500 kWh per month, for a moderate usage customer at 1000 kWh per month, and for a low usage customer at 500 kWh per month.

B. Functional Cost Allocation Methodology

Revenue requirements from the RES Calculator are first allocated to each utility based on its percent of total state energy sales. Next, the incremental cost impacts that meeting the proposed RES will have on the transmission, distribution and generation functions are allocated separately to their respective customer classes. This is necessary because different classes of customers incur different shares of these costs. The BIC uses 2010 functional allocations to determine the rate class splits for the residential and small commercial rate classes.

The BIC calculates the incremental rate (RES adder) by dividing the customer class allocated revenue requirement by the 2020 electricity sales forecast, as determined in the CEC IEPR report. In the low demand scenario, the sales forecast is reduced by the load reductions provided by the output from the RES Calculator.

The non-CARE allocation scenario removes CARE sales from the forecast, so that costs are allocated using only non-CARE sales. Table F1-1 shows the income eligibility requirements for the CARE program. CARE rates were developed assuming a two-tiered structure, and assuming the estimated CARE deficiency would be borne by other rate classes. The incremental proposed RES costs for both cases were added to the estimated 2020 rates. In the allocation that exempts CARE customers from the proposed RES costs, the bill impact is zero percent, as the costs were redistributed to the remaining customers.

Table F1-1
CARE Income Eligibility Requirements[a]

Household Size	CARE Income Limit
1 to 2	$30,500
3	$35,800
4	$43,200
5	$50,600
6	$58,000
Each additional	$7,400

A final feature of the BIC relates to legislation passed in 2009 that will gradually change the structure of the residential rates of IOU customers.[b] Since the 2001 energy crisis, rates for basic residential usage had been frozen, but the 2009 legislation allows for a gradual relaxation of this rate freeze. In order to calculate the projected 2020 bill, the calculator adjusts the rate escalation to meet this legislative mandate. To model this simply and accurately, the model projects a two-tiered rate structure by 2020, with Tier 1 consisting of “baseline” usage, and

[a] California Public Utilities Commission, 2009. California Alternate Rates For Energy (CARE), http://www.cpuc.ca.gov/PUC/energy/Low+Income/care.htm
[b] California State Senate, 2009. Senate Bill No. 695 (Chapter 337), http://www.leginfo.ca.gov/pub/09-10/bill/sen/sb_0651-0700/sb_695_bill_20091011_chaptered.pdf

Tier 2 consisting of all remaining usage. More specifically, the estimated residential rates take into account the new allowance in the new law for a Cost of Living Adjustment (COLA) increase to Non-CARE Tiers 1 and 2 of between three percent and five percent. Finally, the average Tier 1 rate, including customer charges, shall not exceed 90 percent of the System Average Rate (SAR). The updated model reflects this restriction. The model also assumes that any existing customer charge remains frozen until 2020, and that the CARE Tier 1 rate will not increase.

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Appendix F2

Environmental-Dynamic Revenue Analysis Model Results

This section presents inputs and sector specific results from the EDRAM analysis of the proposed RES regulation.

A. Economic Impacts

This section presents results from EDRAM which was used to estimate the macroeconomic impacts of the proposed RES. The RES Calculator was used to estimate the revenue requirement for a mix of renewables sufficient to meet the 33 percent target in 2020 for a low load and a high load scenario. The revenue requirement and resource mix results from the RES Calculator were used as inputs to EDRAM.

1. High Load Scenario

a. Modeling Inputs

EDRAM's baseline scenario assumes no or little renewable electricity in 2020. Therefore in order to estimate the incremental impact of 33 percent RES over the 20 percent RPS, a 20 percent RPS scenario was developed and run in EDRAM and then the 33 percent RES scenario was run. The difference in economic indicators such as gross state product and statewide employment for these two scenarios provides an estimate of the statewide economic impacts of proposed 33 percent RES relative to the currently required 20 percent RPS.

In order for EDRAM to estimate the impacts of RES on the statewide economy the economic activity related to the build out of renewables must be assigned to the appropriate economic sectors. The economic sectors most affected by renewable electricity are identified in Table F2-1. The economic activity associated with building and operating renewable electricity generation is closely related to the following industrial sectors used in EDRAM: agricultural sector (agriculture), industrial building construction sector (construction), and fabricated structural metal manufacturing sector (manufacturing). For each type of renewable resource, it was estimated what percentage of the money spent on that resource would go to each affected sector. For example, for every $100 spent on generating electricity from solar PV, it was estimated that $35 is spent in the industrial construction sector, and $65 is spent in the metal manufacturing sector. The percentage assumptions for each type of resource were based on literature review.[1,2,3,4]

Table F2-1
Percent Allocation of Electricity-Generating Expenditure to Relevant EDRAM Sectors

Renewables	Agriculture	Construction	Manufacturing
Solar PV	0%	35%	65%
Solar Thermal	0%	25%	75%
Wind	0%	25%	75%
Geothermal	0%	35%	65%
Landfill/Digester Gas	26%	24%	50%
Solid-Fuel Biomass	27%	23%	50%
Small Hydro (< 30 MW Capacity)	0%	35%	65%
Transmission	0%	25%	75%

b. Scenario Details

Tables F2-2 and F2-3 show data from the RES Calculator for the 20 percent RPS in 2020 and 33 percent proposed RES 2020 scenario runs. This cost and resource mix information is translated into inputs for EDRAM based on resource type and expenditure in 2020. Table F2-2 contains the data used for the 20 percent RPS baseline scenario in EDRAM and Table F2-3 has the data used for the proposed 33 Percent RES scenario in EDRAM.

Table F2-2
EDRAM Inputs for 20 Percent RPS Baseline in 2020, High Load
(Billion 2008 $)

		Expenditure by Industry Sector			
Renewable Resources	**Total Expenditure**	**Agriculture**	**Construction**	**Manufacturing**	**Fuel Extraction**
Solar PV	0.199	0	0.070	0.129	0
Solar Thermal	0.594	0	0.148	0.445	0
Wind	1.197	0	0.299	0.898	0
Geothermal	1.800	0	0.630	1.170	0
Landfill/Digester Gas	0.112	0.029	0.027	0.056	0
Solid-Fuel Biomass	1.136	0.307	0.261	0.568	0
Small Hydro (< 30 MW Capacity)	0.504	0	0.177	0.328	0
New Transmission	0.157	0	0.039	0.117	0
Gas-Fuel	(1.794)	0	0	0	(1.794)
Gas-Capital, O & M[c]	(1.641)	0	(0.213)	(1.427)	0
Total	2.264	0.336	1.438	2.285	(1.794)

[c] O & M means operations and maintenance

Table F2-3
EDRAM Inputs for 33 Percent Proposed RES in 2020, High Load
(Billion 2008 $)

		Expenditure by Industry Sector			
Renewable Resources	**Total Expenditure**	**Agriculture**	**Construction**	**Manufacturing**	**Fuel Extraction**
Solar PV	0.622	0	0.218	0.405	0
Solar Thermal	2.652	0	0.663	1.989	0
Wind	2.006	0	0.501	1.504	0
Geothermal	2.966	0	1.038	1.928	0
Landfill/Digester Gas	0.112	0.029	0.027	0.056	0
Solid-Fuel Biomass	1.136	0.307	0.261	0.568	0
Small Hydro (< 30 MW Capacity)	0.504	0	0.177	0.328	0
New Transmission	0.889	0	0.222	0.667	0
Gas-Fuel	(2.743)	0	0	0	(2.743)
Gas-Capital, O & M	(2.757)	0	(0.358)	(2.399)	0
Total	5.387	0.336	2.749	5.046	(2.743)

EDRAM assumes since there is more money being spent in the industry sectors related to renewables there is less money being spent in the sector representing conventional electricity generation. This translates to less spending from the conventional electricity sector to its supply source: California's fossil fuel extraction sector, mainly natural gas[d]. Tables F2-4 and F2-5 show the economic transactions between industrial sectors. This is the amount of money that is no

[d] California imports much of its natural gas supply from out of state. It is likely that less demand for natural gas will result in decreased imports, rather than less in-state production, resulting in a small impact on California's fossil fuel extraction sector.

longer being spent in the conventional electricity sector and in which sectors it is now being spent for the baseline and 33 percent RES scenario.

Table F2-4
Aggregate Impacts in the 20 Percent RPS Baseline Scenario as Input to EDRAM, High Load

To-Sector	From-Sector	Aggregate Impacts (Billion $)
Agriculture	Conventional Electricity	0.336
Construction	Conventional Electricity	1.438
Manufacturing	Conventional Electricity	2.285
Fuel Extraction	Conventional Electricity	-1.794

Table F2-5
Aggregate Impacts in the 33 Percent RES Scenario as Input to EDRAM, High Load

To-Sector	From-Sector	Aggregate Impacts (Billion $)
Agriculture	Conventional Electricity	0.336
Construction	Conventional Electricity	2.749
Manufacturing	Conventional Electricity	5.046
Fuel Extraction	Conventional Electricity	-2.743

c. Sector Results

Once the flow of money through the different economic sectors is assigned, EDRAM can be run. The results derived from running EDRAM, for scenario year 2020 and in 2008 dollars, are summarized below.

Staff used EDRAM to estimate the impacts of the policy on individual economic sectors. Tables F2-6 through F2-10 present the potential impacts of the proposed RES on the economic sectors which are closely related to the implementation of the proposed RES. EDRAM estimates the impacts on all 120 sectors included in the model, however many sectors will have minor impacts (e.g., well under one percent increase or decrease). These results are illustrative and provide the impacts from a sample of sectors where the impact is at a least a few percent.

Table F2-6 shows the impact of the proposed 33 percent RES on the construction sector. Production goes up in this sector, as expected, because this sector will benefit as more renewable electricity resources are built.

Table F2-6
EDRAM Results for Industrial Building Construction Sector, High Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	22.6	23.4	0.8	3.6%
Employment (Thousand)	101.0	104.7	3.7	3.7%

Table F2-7 presents the impacts on the conventional electricity sector. The modeled scenarios assume renewable electricity displaces output from the conventional electricity sector; therefore its production goes down, as expected.

Table F2-7
EDRAM Results for Conventional Electricity Supply Sector, High Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	33.0	29.3	-3.7	-11.2%
Employment (Thousand)	19.9	17.6	-2.3	-11.5%

Table F2-8 shows, as expected, production in the metal manufacturing sector goes up. This is because this sector will benefit as more renewable electricity resources are built.

Table F2-8
EDRAM Results for Fabricated Structural Metal Manufacturing Sector, High Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	40.4	42.4	2.0	5.0%
Employment (Thousand)	181.8	191.2	9.4	5.2%

Table F2-9 shows the impacts of the proposed RES on the agricultural sector of the State. Despite the fact some of the investment in renewable resources will go to agriculture, we see a small negative impact on this sector. This is because the proposed RES increases the price of electricity, thus requiring the expenditure of more money on construction, agriculture, and manufacturing than it saves in avoided fossil fuel purchases. Because the price of electricity goes up, so does the price of many goods that use electricity as an input, for instance agriculture. Without a price increase, these goods would sell at a loss. With the price increase, these goods just break even. So the price increase in electricity is just offset by the price increase in the good and there is no incentive to supply more of the good. On the demand side the price increase decreases demand and therefore less is sold.

Table F2-9
EDRAM Results for Agriculture Sector, High Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	94.8	94.2	-0.6	-0.6%
Employment (Thousand)	377.1	375.0	-2.2	-0.6%

Table F2-10 shows the impacts of the proposed RES on California's domestic fossil fuel extraction sector. EDRAM assumes when California's demand for fossil fuels (mainly natural gas) goes down, the import of fossil fuels is cut accordingly and its production stays almost constant.[e] The table shows the fuel extraction sector will reduce its imports by almost four percent in the 33 percent RES high load growth scenario.

Table F2-10
EDRAM Results for the Fossil Fuel Extraction Sector, High Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	7.3	7.4	0.1	1.9%
Employment (Thousand)	2.3	2.4	0.05	2.1%
Import (Billion $)	94.7	92.8	-1.9	-2.0%
Export (Billion $)	39.3	39.3	-0.03	-0.1%

2. Low Load Scenario

a. Modeling Inputs

The EDRAM analysis was also conducted using the RES Calculator results for the low load scenario. This section shows the analysis for the low load scenarios. The same percentage allocation for the related sectors was used to derive the expenditures input for EDRAM.

b. Scenario Details

Tables F2-11 and F2-12 show data from the RES Calculator for the 20 percent RPS in 2020 and 33 percent proposed RES 2020 scenario runs. This cost and resource mix information is translated into inputs for EDRAM based on resource

[e] This is consistent with how the California market has historically reacted to marginal changes in demand for fossil fuels.

type and expenditure in 2020. Table F2-11 contains the data used for the 20 percent RPS baseline scenario in EDRAM and Table F2-12 has the data used for the proposed 33 Percent RES scenario in EDRAM.

Table F2-11
EDRAM Inputs for 20 Percent RPS Baseline in 2020, Low Load
(Billion 2008 $)

		Expenditure by Industry Sector			
Renewable Resources	**Total Expenditure**	**Agriculture**	**Construction**	**Manufacturing**	**Fuel Extraction**
Solar PV	0.187	0	0.065	0.121	0
Solar Thermal	0.468	0	0.117	0.351	0
Wind	0.762	0	0.190	0.571	0
Geothermal	1.796	0	0.628	1.167	0
Landfill/Digester Gas	0.112	0.029	0.027	0.056	0
Solid-Fuel Biomass	1.136	0.307	0.261	0.568	0
Small Hydro (< 30 MW Capacity)	0.504	0	0.177	0.328	0
New Transmission	0.053	0	0.013	0.040	0
Gas-Fuel	(1.544)	0	0	0	(1.544)
Gas-Capital, O & M	(1.475)	0	(0.192)	(1.283)	0
Total	1.999	0.336	1.288	1.920	(1.544)

Table F2-12
EDRAM Inputs for 33 Percent Proposed RES in 2020, Low Load
(Billion 2008 $)

		Expenditure by Industry Sector			
Renewable Resources	**Total Expenditure**	**Agriculture**	**Construction**	**Manufacturing**	**Fuel Extraction**
Solar PV	0.593	0	0.207	0.385	0
Solar Thermal	2.509	0	0.627	1.882	0
Wind	2.006	0	0.501	1.504	0
Geothermal	1.796	0	0.628	1.167	0
Landfill/Digester Gas	0.112	0.029	0.027	0.056	0
Solid-Fuel Biomass	1.136	0.307	0.261	0.568	0
Small Hydro (< 30 MW Capacity)	0.504	0	0.177	0.328	0
New Transmission	0.727	0	0.182	0.545	0
Gas-Fuel	(2.305)	0	0	0	(2.305)
Gas-Capital, O & M	(2.308)	0	(0.300)	(2.008)	0
Total	4.770	0.336	2.311	4.428	(2.305)

Tables F2-13 and F2-14 show the flow of money through the industry sectors most related to the renewable electricity sector as explained in the previous section.

Table F2-13
Aggregate Impacts in the 20 Percent RPS Baseline Scenario as Input to EDRAM, Low Load

To-Sector	From-Sector	Aggregate Impacts (Billion $)
Agriculture	Conventional Electricity	0.336
Construction	Conventional Electricity	1.288
Manufacturing	Conventional Electricity	1.920
Fuel Extraction	Conventional Electricity	-1.544

Table F2-14
Aggregate Impacts in the 33 Percent RES Scenario as Input to EDRAM, Low Load

To-Sector	From-Sector	Aggregate Impacts (Billion $)
Agriculture	Conventional Electricity	0.336
Construction	Conventional Electricity	2.311
Manufacturing	Conventional Electricity	4.428
Fuel Extraction	Conventional Electricity	-2.305

c. Sector Results

This section shows the results of the EDRAM analysis for the low load scenario. Tables F2-15 through F2-19 present the potential impacts of the proposed RES on the economic sectors which are closely related to the implementation of the proposed RES.

Table F2-15 shows the impact of the proposed 33 percent RES on the construction sector. Production goes up in this sector, as expected, because this sector will boom to assist in generating renewable electricity.

Table F2-15
EDRAM Results for Industrial Building Construction Sector, Low Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	22.5	23.1	0.65	2.9%
Employment (Thousand)	100.5	103.4	2.9	2.9%

Table F2-16 presents the impacts on the conventional electricity sector. The model assumes no renewable electricity comes from the conventional electricity sector; therefore its production goes down, as expected.

Table F2-16
EDRAM Results for Conventional Electricity Supply Sector, Low Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	33.4	30.0	-3.4	-10.1%
Employment (Thousand)	20.1	18.0	-2.1	-10.3%

Table F2-17 shows, as expected, production in the metal manufacturing sector goes up. This is because this sector will boom to assist in generating renewable electricity.

Table F2-17
EDRAM Results for Fabricated Structural Metal Manufacturing Sector, Low Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	40.0	41.9	1.9	4.8%
Employment (Thousand)	180.4	189.3	8.9	4.9%

Table F2-18 shows the impacts of the proposed RES on the agricultural sector of the state. Despite the fact some of the investment in renewable resources will go to agriculture we see a small negative impact on this sector. The reasons for the small negative impact are explained in the high load section and apply to the low load scenario as well.

Table F2-18
EDRAM Results for Agriculture Sector, Low Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real Output (Billion $)	94.8	94.3	-0.6	-0.6%
Employment (Thousand)	377.4	375.4	-2.0	-0.5%

Table F2-19 shows the impacts of the proposed RES on California's domestic fossil fuel extraction sector. EDRAM assumes when California's demand for fossil fuels (mainly natural gas) goes down, the import of fossil fuels is cut accordingly and its production stays almost constant.[f] The table shows the fuel extraction sector will reduce its imports by four percent in the high load growth

[f] This is consistent with how the California market has historically reacted to marginal changes in demand for fossil fuels.

scenario and the negative impact in the fossil fuel sector will be felt outside California.

Table F2-19
EDRAM Results for the Fossil Fuel Extraction Sector, Low Load

	20% RPS	33% RES	Incremental Impact	Percent Impact
Real output (Billion $)	7.4	7.5	0.1	1.9%
Employment (Thousand)	2.4	2.4	0.05	2.0%
Import (Billion $)	95.0	93.3	-1.7	-1.8%
Export (Billion $)	39.3	39.3	-0.03	-0.1%

3. Summary of Economic Impacts

The macroeconomic model EDRAM has been applied to estimate the impacts of the proposed RES under both low and high load growth scenarios. This provides insights into the potential range of the economic impacts that the proposed RES will have. In the low and high load scenarios, the analysis indicates that the proposed RES will have a small impact on California's macro indicators. Specifically, the analysis indicates that the economic impacts of the proposed RES are imperceptible given the size of the California economy.

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Appendix F3

Environmental-Dynamic Revenue Analysis Model

The Environmental-Dynamic Revenue Analysis Model (EDRAM) was used to estimate the macroeconomic impact of the proposed RES on the state. This portion of the appendix contains a full methodological description of the EDRAM.

A. Environmental-Dynamic Revenue Analysis Model

1. Overview of the EDRAM

Computable General Equilibrium (CGE)[g] models represent explicitly the utility and profit maximizing behavior of households and firms and estimate how policy impacts affect agents both directly and indirectly. The models are "computable" because numeric solutions are found using computers rather than solved for algebraically. They are "general" in the sense that all markets and all income flows in the economy are accounted for. They reflect "equilibrium" insofar as prices adjust to equilibrate the demand for and supply of goods, services, and factors of production (labor and capital) of the model.

The specific model described here is a modified version of the EDRAM. The EDRAM was built for the California Air Resources Board (ARB) by researchers at the University of California at Berkeley. The EDRAM evolved from the Dynamic Revenue Analysis Model (DRAM), which was developed jointly by the California Department of Finance (DOF) and Berkeley researchers to perform dynamic revenue analyses of proposed legislation as mandated by Senate Bill 1837 in 1994. Much of the description of EDRAM is closely adapted from Berck, Golan, and Smith (1996),[1] which, henceforth, will be referred to as the DRAM Report.[h] The model has been updated to a 2003 base year.

The remainder of this Appendix is a non-technical description of EDRAM.

2. Description of EDRAM

The EDRAM describes the relationship among California producers, California households, California governments, and the rest of the world. Rather than tracking each individual producer, household, or government agency in the economy, however, EDRAM combines similar agents into single sectors. Constructing a sectoring scheme, the first step of model construction, is discussed immediately below; this discussion is followed by a description of the key agents in the economy—producers and consumers.

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[g] For EDRAM's sources and methods discussed in this Appendix, an unpublished paper by Professor Peter Berck is liberally quoted.

[h] The DRAM Report is available at www.dof.ca.gov/HTML/FS_DATA/dyna-rev/dynrev.htm.

a. Aggregation and Data Sources

The EDRAM, like all other empirical economic models, treats aggregates rather than individual agents. Aggregation is done both to provide focus for the analysis and constrain the number of variables in the model. Constructing an aggregation (or sectoring) scheme is critical in the development of a CGE model because it determines the flows that the model will be able to trace explicitly. For the EDRAM model, the California economy has been divided into 186 distinct sectors: 120 industrial sectors, 2 factor sectors (labor and capital), 9 consumer good sectors, 8 household sectors, 1 investment sector, 45 government sectors, and 1 sector representing the rest of the world. The complete details of the sectoring are given in Chapter II of the DRAM Report.

For industrial sectoring purposes, all California firms making similar products are aggregated together. The agriculture sector, for example, contains all California firms producing agricultural products. The output value of that sector is the value of all output produced by California agricultural producers. A sector's labor demand is the sum of labor used by all firms in the sector. Along with agriculture, there are 119 other producer aggregates in the model. These aggregates generally represent the major industrial and commercial sectors of the California economy, though a few are tailored to capture sectors of particular regulatory interest. For instance, production of internal-combustion engines and consumer chemicals are each delineated as distinct sectors, as requested by ARB.[i]

Data for the industrial sectors originate from the U.S. Department of Commerce's Bureau of Economic Analysis and are based on the Census of Business—a detailed survey of U.S. companies conducted every five years. The survey contains information about intermediate purchases, factor (labor, capital, land, and entrepreneurship) payments, and taxes. Although quite extensive, the survey only allows inference about groups of firms at the national level. The disaggregation of national data to a California level is accomplished using a combination of state-level employment data and estimates from California Department of Finance.

Like firms, households are also aggregated. California households are divided into categories based upon their income. The model includes eight such categories, each one corresponding to a California Personal-income Tax marginal tax rate (0, 1, 2, 4, 6, 8, 9.3, and a high-income 9.3 percent). Thus, the income from all households in the 1 percent bracket is added together and becomes the income for the "1 percent" household sector. Similarly, all expenditure on agricultural goods by the 1 percent households is added and becomes the expenditure of the 1 percent household sector on agricultural goods. Total household expenditure on agricultural goods is the sum of expenditures by all eight household sectors. Household income data come from

[i] The alcohol, tobacco, and horse-racing sector, distinct in DRAM, has been folded into the foods sector in the latest version of EDRAM.

the California Franchise Tax Board Personal-income Tax “sanitized” sample. Data on consumption by income class are derived from national survey data.

The government sectors in EDRAM are organized so that both government revenue flows and expenditure flows are traced explicitly. The EDRAM includes 45 government sectors: 7 federal, 27 state, and 11 local. Government sector data are culled from published federal, state, and local government reports.

b. Producers and Households

Fundamental to the California economy and, hence, EDRAM, are the relationships between the two principal types of economic agents—producers and households.

Producers are aggregated into industrial sectors. For example, the output of all of California’s agricultural firms is modeled as coming from a single entity—the agriculture sector. Each sector takes the price that it receives for its output and the prices that it pays for its inputs (capital and labor, called “factors of production,” and other inputs, called “intermediate goods”) as given. The model assumes perfect competition which means that producer purchase decisions have no effect on input prices. Each producer is assumed to choose inputs and output to maximize profits. Inputs are labor, capital, and intermediate goods (outputs of other firms). Thus, the producer’s supply of output is a function of its product price and the prices of inputs. More information on producers is provided in Chapter IV of the DRAM Report.

Households make two types of decisions: they buy goods and services and they sell labor and capital. Households are assumed to make these decisions in the way that maximizes their well-being (called “utility” in the economics literature). Like firms, consumer purchases have no effect on product prices. In addition to their labor income, households receive dividends and interest from their stocks and bonds and other ownership interests in capital.

Households’ supply of labor, as a function of the wage rate, is called the “labor-supply function.” A more detailed description of the supply of labor is given in Chapter VII of the DRAM Report.

Households’ demand for goods or services, as a function of prices, is simply called the “demand function.” A more detailed description of the demand for goods and services is given in Chapter III of the DRAM Report as well as in Berck, Hess, and Smith, 1997. The latter report explains how the distribution of household spending across the 120 industrial sectors via the nine consumer goods sectors is based on analysis of U.S. Bureau of Labor Statistics’ Consumer Expenditure Survey data.

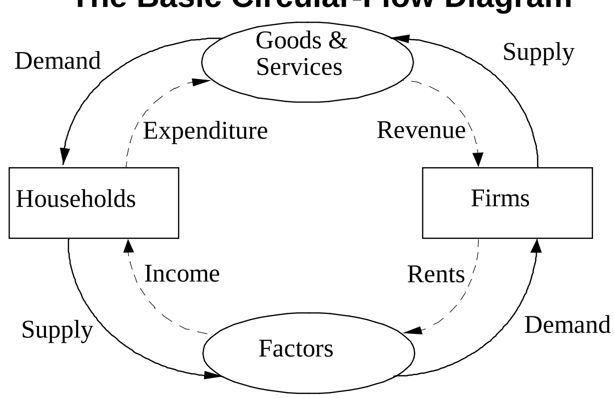
c. Equilibrium

So far, two types of agents have been described: firms and households. It remains to be explained how these agents relate. Agents relate through two types of markets: factor markets and goods-and-services markets. Firms sell goods and services to households in the goods-and-services markets. Households sell labor and capital services to firms in the factor markets. There is a price in each of these markets. There is a price for the output of each of the 120 industrial sectors. There is a price for labor, called the “wage,” and a price for capital, called the “rental rate.” Equilibrium in the market means that the quantity supplied is equal to the quantity demanded. Equilibrium in the factor markets for labor and capital and in the markets for goods and services defines a simple general equilibrium. That is, there are 122 prices (the wage, the rental rate, and one for each of the 120 goods made by the 120 sectors) and these 122 prices have the property that they equate quantities supplied and demanded in all 122 markets.

These relationships are shown in more detail in Figure F3-1, called a “circular-flow diagram.” The outer set of flows, shown as solid lines, are the flows of “real” items, goods, services, labor, and capital. The inner flows, shown as broken lines, are monetary flows. Thus, firms supply goods and services to the goods-and-services market in return for revenues that they receive from the goods-and-services markets. Firms demand capital and labor from the factor markets and in return pay wages and rents to the factor markets.

Households, the other type of agent in a simple model, buy goods and services from the goods-and-services markets. Households sell capital and labor on the factor markets and receive income in exchange.

Figure F3-1
The Basic Circular-Flow Diagram[2]

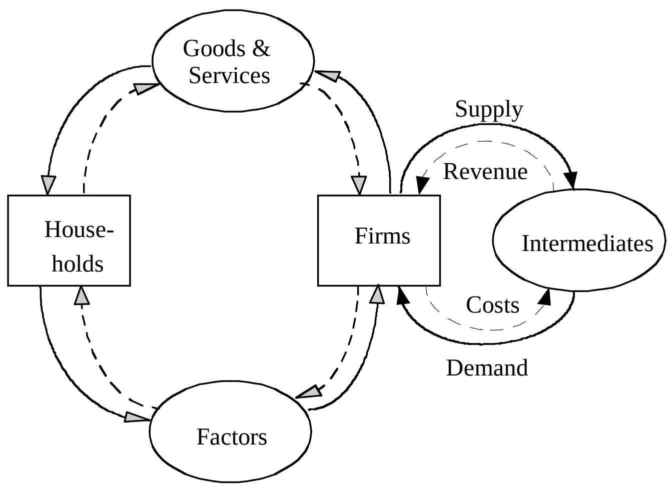


Source: Berck, Golan, and Smith, 1996.

d. Intermediate Goods

The economy of California is far more complex than that shown in Figure F3-1. There are not only final goods-and-services markets but also intermediate-goods markets in which firms sell to firms. A typical example of a market for intermediate goods would be fertilizer sold to agricultural firms. A final output of the chemical industry is fertilizer, which is an intermediate good in the agricultural industry. This type of market interaction is demonstrated in Figure F3-2. Here, part of the output of a chemical firm (chemical industry in the example) is not sold to households but rather to another firm. The expense of buying the input is a cost of production. Chapter IV of the DRAM Report contains the model specification for these types of transactions, which are based upon a national input-output table.

Figure F3-2
The Circular-Flow Diagram with Intermediate Goods[1]

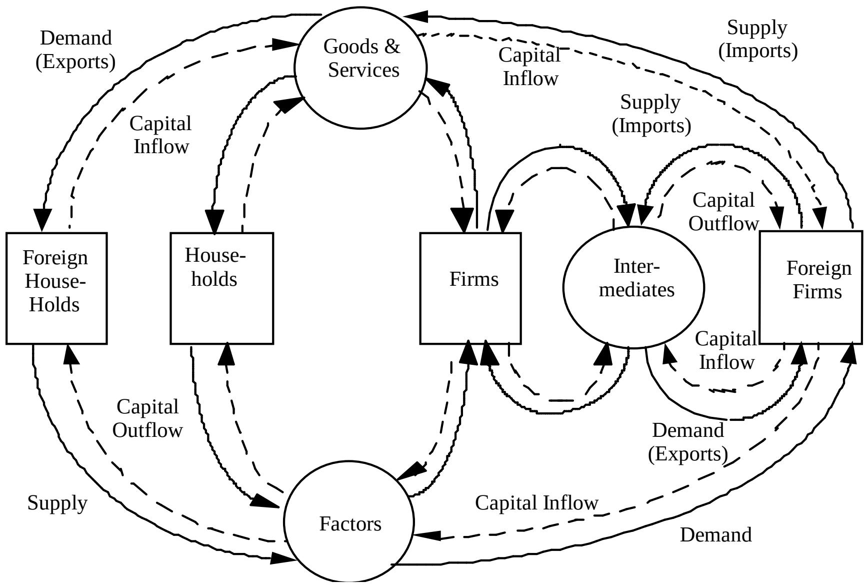


Source: Berck, Golan, and Smith, 1996.

e. Rest of the World

California is an open economy, which means that it trades goods, services, labor, and capital with neighboring states and countries. In this model, all agents outside California are modeled in one group called "Rest of World." No distinction is made between the rest of the United States and foreign countries. California interacts with two types of agents: foreign consumers and foreign producers. Taking the producers first, Figure F3-3 shows that the producers sell goods on the (final) goods-and-services markets and on the intermediate markets, i.e., they sell goods to both households and firms. The model takes these goods as being imperfect substitutes for the goods made in California. Agricultural products from outside of California (e.g., feed grains, bananas) are taken as being close to, but not identical to, California-grown products (e.g., avocados, fresh chicken). The degree to which foreign and domestic goods substitute for each other is very important, and the evidence is described in Chapter V of the DRAM Report. Foreign households buy California goods and services on the goods-and-services markets. They and foreign firms both can supply capital and labor to the California economy, and domestic migration patterns.

Figure F3-3
The Circular-Flow Diagram with Intermediate Goods and Trade[1]

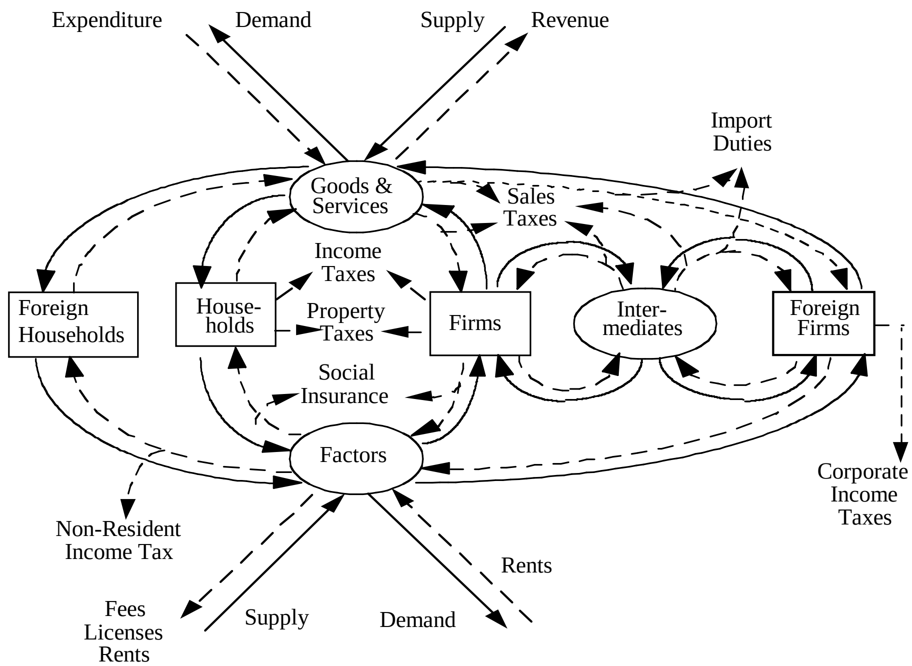


Source: Berck, Golan, and Smith, 1996.

f. Government

Finally, government is considered. Combining the taxing and spending effects of the three levels of government (federal, state, and local) gives the additional flows in Figure F3-4. Beginning at the top, the figure shows that government buys goods and services and gives up expenditure. It supplies goods and services for which it may or may not receive revenue. Government also supplies factors of production, such as roads and education. Government also makes transfers to households, which are not shown in the diagram. The middle section of the diagram shows the myriad of ways in which government raises revenue through taxation. Chapter II of the DRAM Report includes a detailed description of the government activities in the model.

Figure F3-4
The Complete Circular-Flow Diagram[1]



Source: Berck, Golan, and Smith, 1996.

3. Data Organization: The Social Accounting Matrix

The first step in constructing a CGE model is to organize the data. The traditional approach to data organization for a CGE model is to construct a Social Accounting Matrix (SAM). A SAM is a square matrix consisting of a row and column for each sector of the economy. Each entry in the matrix identifies an exchange of goods and services purchased by one sector from another sector (or itself). The entries along a row in the SAM show each payment received by that particular row sector from each column sector. Summing across the row gives total payments made to that row sector by all column sectors. The entries down a column in the SAM show the expenditures made by that particular column sector to all row sectors. Summing down a column gives total expenditures by that column sector to all row sectors. For accounting purposes, a SAM must "balance," i.e., each row sum and corresponding column sum must be equal. This balancing ensures that no money "leaks" out of the economy, i.e., that all money received by firms (row sum) is spent by them (column sum).

4. Other Considerations and Model Building

Computable General Equilibrium models are not forecasting models; they are calibrated to reproduce a base year. In the case of EDRAM, the model is constructed to exactly reproduce the economic conditions of calendar year 2003.

Of course, there are forecasting models. However, such models typically do not have the level of detail needed to examine dynamic policy effects. Given the paucity of California-specific data, it seems a better compromise to use a forecasting model, such as the one maintained by DOF, to set a base case and then use a policy model, such as DRAM, to analyze deviations from that case.

The EDRAM model incorporates two assumptions that require some comment. It assumes competitive behavior in all private sectors. This is a good first approximation, particularly at the level of a sector. The alternative, market power, may well be present, but the degree of non-competitive pricing is not likely to be significant in aggregated sectors. The second assumption is that involuntary unemployment is constant. This assumption is unlikely to be strictly true. The model has voluntary unemployment, which are agents deciding to work less when the wage is lower. This assumption is common to all equilibrium models. Technical issues of model closure are described in Chapter IX of the DRAM Report.

Once the major agents in the economy have been identified and the relationship between these agents has been specified, the model can be built. In EDRAM, the algebraic representation of the relationships between the agents in the California economy is achieved with the General Algebraic Modeling System (GAMS). The model currently has 1,100+ equations, exclusive of definitions and of the code to read in and organize the data. All of the model's equations and GAMS code are detailed in Chapter X of the DRAM Report.

5. Further Documentation

Fuller description of common features shared by EDRAM and DRAM is available in the report cited above. The primary contents of that report, the presentation of which mirrors the sequence of tasks involved in building DRAM, are as follows. In Chapter II of the DRAM Report, the major agents in the economy are identified and aggregated into sectors. These aggregates are constructed to focus the model on the major industries, taxpayers, and government agencies in the California economy. Data sources are also identified.

Chapters III through VIII of the DRAM Report review the literatures, functional forms, and elasticities relevant to the six primary behavioral equations that link all the various sectors of the model and drive its results. Chapter III of the DRAM Report reviews the literature on the economic behavior of households with respect to consumption and savings decisions. The literature on the production decisions of firms is examined in Chapter IV of the DRAM Report. Chapter V of the DRAM Report summarizes the literature on international and interregional trade. Investment theory is discussed in Chapter VI of the DRAM Report. Chapter VII of the DRAM Report covers the literature on regional labor-supply response to taxation and economic growth, while the literature on migration and economic growth is examined in Chapter VIII of the DRAM Report.

After establishing the sectoring scheme, data sources, and behavioral equations for the model, all that remains before the actual model can be built is a description of the model-closure rules. Closure rules concern the mathematics of insuring that a solution exists to the 1,100+ equations of the model. Model closure is developed in Chapter IX of the DRAM Report.

Chapter X of the DRAM Report describes the mathematical and corresponding GAMS notation for each equation in DRAM.[3, 4] It is a technical description of the complete California DRAM.[j] Chapter XI of the DRAM Report presents some sensitivity analyses.

Appendices follow Chapter XI of the DRAM Report. They include the original literature search by Dr. Berck and Mr. Dabalen in the summer of 1995, explanations of notational methods used, lists of parameter and variable names used in the mathematical and software input files, and printed copies of the input files themselves.

The updating to the 2003 base year is documented at http://are.berkeley.edu/~peter/Research/DRAM03B/OverviewIII_1018.doc.

The most recent updating is documented at http://are.berkeley.edu/~peter/Research/.

Particularly, see "Construction of SAM" for technical details and spread sheet models. See SAM120 for the basic models. See "Predicting Future Years" for an explanation of how the future SAMs were calibrated to data on employment, income, and the like.

6. Sector Base Data Modification

EDRAM's original industrial accounts are national accounts scaled to the state level using California employment data. These accounts do not give the same values as the Energy Information Administration does for California energy usage and production. We have used the Energy Information Administration data for these accounts in preference to the estimates derived from the industrial accounts.

7. Extrapolation from 2003 to 2020

The EDRAM is not a forecasting model but, rather, a model constructed to exactly reproduce the economic conditions of calendar year 2003. To answer questions concerning the impacts of emission reduction strategies far into the

[j] See Berck, Hess, and Smith (1997) for revisions to the consumer demand portion of the model. Modification of equations from DRAM to EDRAM are discussed in Berck and Hess (2000). Changes introduce parameters that facilitate running policy scenarios as some combination of price, intermediate good, and/or investment changes.

future, EDRAM must be augmented to reflect future conditions. To “rebase” EDRAM, i.e., move from a model of the 2003 economy to model of the economy in 2020, EDRAM’s input data must be modified to reflect economic conditions in those “out years.” The following process leaves the basic structure of economic relationships intact while scaling up 2003 monetary and employment data using state personal income (SPI), population, and industry-specific forecasts.

The transformation of the 2003 SAM into the 2020 SAM was based on the projected changes to personal income, population, and energy. The sources for these projections were as follows:

Personal-income growth.
The California Personal-income Growth data and California Consumer Price Index data are taken from the DOF. The annual percentage change of both is taken, and then the real growth percentage is determined by taking the differences of the percentage changes. This is done for years 2004-2020.

Working population growth (ages 18-64).
The California working population forecast through 2050 is from the DOF.

Refinery growth.
The factors assume a 0.5 percent growth rate in the refining and gas-producing sectors.

Oil and gas extraction growth.
The growth rates are based on the assumption that the gas and oil extraction sector of California will halve its production by 2020 (starting 2003). This is equivalent to a 4 percent fall in output each year and continues after 2020 at the same rate.

Natural gas per dollar efficiency.
The natural gas per unit of Gross State Product is calculated from the University of California, Davis, Advanced Energy Pathways baseline demand scenario reports.

Electricity per dollar efficiency.
The electricity per unit of Gross State Product is calculated from the University of California, Davis, Advanced Energy Pathways baseline demand scenario reports.

Fuel per dollar efficiency.
The California Energy Commission estimates of total fuel use (gas and diesel) for future years are used to calculate the per unit of Gross State Product usage of fuel.

The basic method of projection is first to increase the size of all values in the SAM by the projected increase in personal income and then to increase or reduce the rows and columns pertaining to the specific energy sectors by their intensities. The result of this exercise is that California in the future is predicted to have the same basic industrial structure as it does today, except that the named sectors generally grow more slowly than the economy as a whole. As a result, California is predicted to be more energy efficient over time.

8. Adjusting for Technological Change

As described in Berck and Hess (2000), the original EDRAM allows for changes in production technology. Each industrial sector in EDRAM is implicitly characterized by a production function that relates output to factor (capital and labor) and intermediate inputs. Technological change is modeled by altering the relationships of input mix per unit of output as follows. Industry J's demand for intermediates from industry I's per unit of output is governed by production parameters AD(I,J), which are input-output coefficients calculated from primary data contained in the SAM. These coefficients can be altered via technology multiplier parameters REG1(I,J). Changing REG1(I, industry J label) from its default setting of unity to 0.9, for example, simulates a technological change enabling one unit of industrial good J to be produced using only 90 percent of the intermediate inputs (from all 120 industries) previously required. Specifying AD(industry I label, industry J label) = 0.9, in contrast, simulates a technological change enabling one unit of good J to be produced using 90 percent of the intermediate inputs previously required from industry I (with inputs from the 119 other industries unchanged).

Similarly, there are expenditure pattern multipliers for government spending. For state spending, REG18(I,G) increases the expenditure from government G to sector I while decreasing the expenditure to all other sectors so as to keep the total expenditure constant.

9. Conclusion

This model overview summarizes the essence of the EDRAM for the California economy. As stated earlier, EDRAM describes the relationship among California producers, California households, California governments, and the rest of the world. The EDRAM, like all other empirical economic models, treats aggregates rather than individual agents. For this it combines similar agents into single sectors. In the EDRAM model, the California economy has been divided into 186 distinct sectors.

To answer questions concerning the impacts of emission reduction strategies far into the future, the model uses specific growth factors to model future years. To "rebase" EDRAM, i.e., move from a model of the 2003 economy to model of the economy in 2020, EDRAM's input data must be modified to reflect economic conditions in those "out years." This process leaves the basic structure of economic relationships intact while scaling up. Overall, the measures and changes in expenditure patterns are captured in the EDRAM model as changes in technology and changes in government and personal expenditure patterns.

Attachment 1. Sectors Used for the EDRAM Model

SECTOR DESCRIPTION
Agriculture, Forestry and Fishing
Agriculture
Cattle
Dairy
Forestry
Mining
Petroleum and Natural Gas Extraction
Mining
Utilities
Electrical Power Generation and Distribution
Natural Gas Distribution
Water Distribution and Sewage Treatment
Construction
Residential Construction
Nonresidential Construction
Street and Bridge Construction
Utility Infrastructure Construction
Other Construction-related Industry
Manufacturing
Food Manufacturing
Food Processing
Other Food Related Industry
Beverage and Tobacco Products
Textile and Leather Manufacturing
Apparel Manufacturing
Wood Products Manufacturing
Pulp and Paper Mills
Paper Products Manufacturing
Printing
Oil Refineries
Industrial Gas
Chemical and Drugs Manufacture
Basic Chemical Manufacture
Soaps and Detergents Manufacture
Other Chemical Products Manufacture
Plastics Manufacture
Glass Products Manufacture
Cement

SECTOR DESCRIPTION
Concrete
China and Clay Products
Primary Metals
Aluminum
Metal Fabrication
Machinery Manufacture
Refrigeration and Air Conditioning
Computer Manufacture
Communications Equipment Manufacture
Electronic Components Manufacture
Electronic Instruments Manufacture
Electronic Recording Media Manufacture
Electrical Equipment Manufacture
Automobile Manufacturing
Other Vehicle Manufacture
Motor Vehicle Body Manufacture
Motor Vehicle Parts Manufacture
Ship Building and Repair
Other Vehicle Manufacture
Aerospace Manufacture
Furniture
Laboratory and Dental Equipment
Miscellaneous Manufacturing
Wholesale Trade
Vehicle Services
Wholesale Durable Goods
Wholesale Non Durable Goods
Wholesale Gas
Wholesale Trade
Transportation and Warehousing
Transportation
Air Transportation
Railroad Transportation
Waterway Transportation
Truck Transportation
Public Transportation
Other Transportation
Vehicle Transportation
Retail Trade
Retail Vehicles and Parts

SECTOR DESCRIPTION
Retail Furniture
Retail Electronics and Appliances
Retail Building Materials
Retail Food and Beverage
Retail Health and Personal Care
Retail Gasoline Stations
Retail Clothing and Accessories
Retail Sporting Goods, Books, Music
Retail General Merchandise
Retail Miscellaneous
Retail Nonstore
Information
Motion Picture Industry
Other Broadcasting and Recording Industry
Telecommunications
Internet and Information Services
Finance, Insurance and Real Estate
Financial Securities
Insurance
Banking
Real Estate
Other Financial
Services
Legal Services
Accounting
Architecture
Design
Computer Related Services
Consulting
Research
Advertising
Other Professional Services
Business Services
Temporary Administrative Services
Security Services
Building Maintenance
Other Administrative Services
Waste Management
Landfills
Education

SECTOR DESCRIPTION
Medical Services
Hospitals
Nursing
Day Care
Recreation and Entertainment
Amusement Parks
Hotels
Full Service Restaurants
Fast Food
Caters and Mobile Food Services
Drinking Establishments
Personal Services
Labor and Capital Factors
FACTOR FACTOR LABOR
FACTOR FACTOR ALL OTHER FACTORS COMBINED AS CAPITAL
Commodity
COMMODITY FOOD AND BEVERAGE
COMMODITY SHELTER
COMMODITY FUEL AND UTILITIES
COMMODITY HOUSEHOLD FURNISHING AND OPERATION
COMMODITY APPAREL AND ITS UPKEEP
COMMODITY TRANSPORTATION
COMMODITY MEDICAL CARE
COMMODITY ENTERTAINMENT
COMMODITY OTHER GOODS AND SERVICES
California Marginal Personal Income Tax Brackets
HOUSEHOLD 0.0 PERCENT MARGINAL CA PIT
HOUSEHOLD 1.0 PERCENT MARGINAL CA PIT
HOUSEHOLD 2.0 PERCENT MARGINAL CA PIT
HOUSEHOLD 4.0 PERCENT MARGINAL CA PIT
HOUSEHOLD 6.0 PERCENT MARGINAL CA PIT
HOUSEHOLD 8.0 PERCENT

SECTOR DESCRIPTION
MARGINAL CA PIT
HOUSEHOLD 9.3 PERCENT MARGINAL CA PIT UNDER 200K
HOUSEHOLD 9.3 PERCENT MARGINAL CA PIT OVER 200K
INVESTMENT
INVESTMENT
GOVERNMENT
GOVERNMENT FEDERAL TAX SOCIAL SECURITY
GOVERNMENT FEDERAL TAX PERSONAL INCOME TAX
GOVERNMENT FEDERAL TAX PROFITS
GOVERNMENT FEDERAL TAX DUTY
GOVERNMENT FEDERAL TAX MISCELLANEOUS
GOVERNMENT CALIFORNIA TAX VARIOUS HOUSEHOLD TAXES
GOVERNMENT CALIFORNIA TAX ALCOHOL TAXES
GOVERNMENT CALIFORNIA TAX CIGARETTE TAXES
GOVERNMENT CALIFORNIA TAX HORSE RACING
GOVERNMENT CALIFORNIA TAX ESTATE TAXES
GOVERNMENT CALIFORNIA TAX TRAILER FEES
GOVERNMENT CALIFORNIA TAX MOTOR VEHICLE LICENSE FEES
GOVERNMENT CALIFORNIA TAX DIESEL FUEL TAXES
GOVERNMENT CALIFORNIA TAX MOTOR VEHICLE REGISTRATION FEES
GOVERNMENT CALIFORNIA TAX MISCELLANEOUS
GOVERNMENT CALIFORNIA TAX INSURANCE GROSS PREMIUM TAX
GOVERNMENT CALIFORNIA TAX GASOLINE FUEL TAXES

SECTOR DESCRIPTION
GOVERNMENT CALIFORNIA TAX SALES AND USE TAXES
GOVERNMENT CALIFORNIA TAX BANK AND CORPORATION TAX
GOVERNMENT CALIFORNIA TAX LABOR TAXES UI AND WORKERS COMP
GOVERNMENT CALIFORNIA TAX PERSONAL INCOME TAX
GOVERNMENT CALIFORNIA TAX REGULATORY LICENSES AND FEES
GOVERNMENT CALIFORNIA TAX SERVICES TO THE PUBLIC
GOVERNMENT CALIFORNIA TAX USE OF PROPERTY AND MONEY
GOVERNMENT CALIFORNIA GENERAL FUND
GOVERNMENT LOCAL TAX PROPERTY
GOVERNMENT LOCAL TAX SALES AND USE
GOVERNMENT LOCAL TAX MISCELLANEOUS ON FIRMS
GOVERNMENT LOCAL TAX MISCELLANEOUS ON HOUSEHOLDS
GOVERNMENT LOCAL TAX MISCELLANEOUS ON FIRMS AND HOUSEHOLDS
GOVERNMENT FEDERAL SPENDING DEFENSE
GOVERNMENT FEDERAL SPENDING NON DEFENSE
GOVERNMENT CALIFORNIA SPENDING TRANSPORTATION
GOVERNMENT CALIFORNIA SPENDING CORRECTIONS
GOVERNMENT CALIFORNIA SPENDING K TO 14 EDUCATION
GOVERNMENT CALIFORNIA SPENDING UNIVERSITIES
GOVERNMENT CALIFORNIA SPENDING WELFARE
GOVERNMENT CALIFORNIA SPENDING HEALTH

SECTOR DESCRIPTION
GOVERNMENT CALIFORNIA SPENDING OTHER
GOVERNMENT LOCAL SPENDING TRANSPORTATION
GOVERNMENT LOCAL SPENDING CORRECTIONS
GOVERNMENT LOCAL SPENDING K TO 14 EDUCATION
GOVERNMENT LOCAL SPENDING WELFARE
GOVERNMENT LOCAL SPENDING HEALTH
GOVERNMENT LOCAL SPENDING OTHER
REST OF WORLD /
REST OF WORLD /

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