APPENDIX N.
ECONOMIC ANALYSIS

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Table of Contents

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Appendix N
Economic Analysis

A. Summary of Economic Impacts

The cap-and-trade program will lead to increased investment in efficient buildings and technologies and in advanced fuels. At expected allowance prices, these investments reduce fuel use by 2 to 4 percent in 2020, while economic growth between 2007 and 2020 continues at a rate virtually on par with current projections. Impacts on long-term projected growth rates in personal income and employment are similarly small. Implementation of the program will, however, shift investment and growth within the overall economy toward those sectors driven by the production of cleaner and more-efficient technologies.

Implementing the cap-and-trade program can also help mitigate the economic consequences of continued reliance on fossil fuels. Experience in recent decades, such as the spike in world oil prices in the summer of 2008, has illustrated the economic costs of volatile energy prices on California's economy. While this report does not attempt to quantify the benefits of reduced dependence on fossil fuels in the face of continued volatility of world energy prices, it does show that California can significantly reduce its dependence on these fuels and, therefore, its vulnerability to future price spikes.

The cap-and-trade program is designed to help drive investment into activities that result in lower GHG emissions. As businesses and consumers make investments in energy efficiency and clean fuels, some sectors will see significant new activity, including those that design or manufacture renewable technologies, and those that provide energy retrofits or efficiency improvements. Because the models used in this analysis are based on the structure of the economy in the base year, the analysis does not fully reflect the potential for increased growth in output and employment in sectors that could benefit from this new investment. This analysis should be viewed as a conservative estimate of the potential statewide impacts from the program.

This economic analysis focuses exclusively on the economic effects in California of implementing the cap-and-trade program, and does not consider the avoided costs of inaction. The potential effects of climate change on California could cause severe economic damage. While California has developed a Climate Adaptation Strategy to help alleviate these potential costs, the risk of potentially high economic costs from climate change in California remains real.[1]

While California acting alone cannot reduce emissions sufficiently to change the course of climate change worldwide, California's leadership has played and

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[1] *2009 California Climate Adaptation Strategy.* California Natural Resources Agency. http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF (accessed 10/23/10).

continues to play a critical role in moving federal and international climate policy forward. Successful implementation of AB 32, including the cap-and-trade program, has the potential to help move climate policy in a positive direction at the state, regional, and federal levels in the coming years. The magnitude of the impacts that California could face from climate change provide a useful context for understanding the significance of the relatively modest economic costs associated with taking action to reduce California's GHG emissions. Overall, staff finds no significant adverse impacts on California business or consumers as a whole as a result of the proposed regulation.

This appendix describes the economic impacts from the implementation of the proposed cap-and-trade regulation. Two models were used for this analysis. The ENERGY 2020 model, customized for ARB by Systematic Solutions Incorporated, was used to estimate the potential emissions reductions and the changes in investment and fuel use. The Environmental Dynamic Revenue Analysis Model (E-DRAM), provided under contract to ARB by Dr. Peter Berck of the University of California, Berkeley, was used to estimate the macroeconomic impacts of the proposed cap-and-trade regulation on the statewide economy, including impacts on domestic product, personal income, and employment. These analyses are presented in 2007 dollars and focus on the impacts of the proposed regulation in 2020.

B. Cap-and-Trade Program Design

The main design elements of the cap-and-trade program are described in

Table N-1. The economic analysis is performed with the assumption that no regional or federal climate program is in place prior to 2020. Furthermore, the analysis does not speculate about polices that may be adopted to reach targets beyond the 2020 goal established by AB 32.

The modeling utilizes exponentially rising allowance prices (i.e., prices rising at a fixed percentage each year). Banking is allowed without limitation. In the early years, relatively low-cost abatement opportunities are available. Thus banking motivates emitters to over-comply in early years if those low-cost reductions can be credited against compliance obligations in later years.

Banked allowances are the result of net over-compliance by covered sources, which comes with its own opportunity cost. Allowance holders will expect a rate of return on a banked allowance similar to any other investment. The effect of banking is to induce an exponential growth in the allowance price, whereby the growth rate reflects both the time value of money and the risk associated with financial offsets. In the early years, the allowance price with banking is higher than the no-banking price, as allowances are accumulated for future use. In later years, as banked allowances are used, the price with banking is lower than the no-banking price.

Table N-1: Cap-and-Trade Program Elements

1.	Region	California
2.	GHG Pollutants	CO_2, CH_4, N_2O, SF_6, PFC, NF_3, and HFC
3.	Covered Sectors	
	2012–2014	Electricity and large industrial
	2015–2020	Electricity, large industrial, transportation fuels, commercial and residential fuels, and small industrial
4.	Cap Trajectory	Linear phase-in
5.	Allocation	100 percent auction for the electricity sector
6.	Offsets	8 percent of emissions
7.	Banking	Allowed without limitation
8.	Allowance Reserve	Additional allowances made available, with prices in 2012 at $40,$45, and $50/metric ton of carbon dioxide equivalent ($MTCO_2e$), increasing to $60, $67, and $75/$MTCO_2e$ in 2020

The number of offsets available each year is calculated using the following offset supply curve:

$$Q \text{ (millions)} = (P - 8) / 0.75$$

where *P* > 8 and *P* is that year's allowance price.

With a price trajectory as low as $15/$MTCO_2e$, the allowance price exceeds $8/$MTCO_2e$ in 2012, so the condition of $P > 8$ is non-binding for all price trajectories considered in this analysis. Staff calculated the offset limit as 8 percent of emissions, where emissions were assumed to be 108.7 percent (= 1 / 0.92) of allowances available at that price trajectory. The number of allowances available is determined by the cap less the number of allowances remaining in the reserve. At each trigger price, emitters are assumed to purchase half the allowances in the reserve associated with that trigger price. Thus, for example, at $67/$MTCO_2e$, 2 percent of all allowances would remain in the reserve. For allowances remaining in the reserve, a proportional number of allowances were taken from each year's allowance budget for purposes of determining each year's offset limit. This equal proportion and the lack of banking in the offset calculation bias the number of offsets downward, which in turn bias the economic impacts upward.

C. Costs and Benefits

The cap-and-trade program does not specify how or where emissions reductions will be made. Reductions will be made by covered sources if the cost of making reductions is less than the cost of acquiring allowances. Reductions will also be made by all other sectors of the economy as a result of the increased price of energy which will induce investment in energy efficiency and energy conservation by the non-covered sectors.[2]

Some possible compliance options that are available to California producers and consumers are discussed in Appendix F: Compliance Pathway Analysis. In this economic analysis, energy and economic models are used to generate estimates of the potential compliance costs and the associated economic impacts.

The financial effects of the cap-and-trade program can be divided into four main categories:

- Transaction costs (for covered sectors only)
- Changes in device and/or process expenditures[3]
- Changes in fuel expenditures
- Changes in device operation and maintenance expenditures

Reductions in fuel use brought on by cap-and-trade will also provide for some reduction in criteria pollutants. This economic analysis does not attempt to measure the benefits from reductions in criteria pollutants.

1. Transactions Costs

Transaction costs apply only to facilities with a compliance obligation. These costs can be grouped into three categories: (1) early implementation costs; (2) monitoring, reporting, and verification costs; and (3) trading costs.

Early implementation costs are fixed costs that are incurred only once before the launch of the program; for example, the familiarization with program rules and guidelines, calculating baseline emissions, and the purchase of any necessary capital equipment. Annualized across the life span of the program, these costs would be significantly lower than the other transaction cost components for most of the program's participants.

The *monitoring, reporting, and verification costs* are considered to be a part of the ARB Mandatory Reporting Rule and are not considered as additional in this

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[2] A non-covered sector includes all other producing sectors along with the residential sector.
[3] *Devices* are mechanical end-uses of energy, such as lighting, space heating, or air conditioning, while *process* reflects building shell improvements, such as insulation or industrial process improvements.

analysis. However, it will be noted that over time, monitoring, reporting, and verification costs should decline as a result of learning-by-doing and increased competition among verifiers. A survey of Irish firms in the EU ETS found that for one-quarter of the respondents, monitoring, reporting, and verification costs had decreased over the first three years of the EU ETS.[4] Based on analysis of existing programs, *trading costs* are not expected to be significant. Therefore, trading costs will not be considered further in this analysis.

2. Expenditure Changes

The cap-and-trade program will affect the cost of using fossil energy, which in turn will affect the price of most goods and services throughout the California economy. Some covered entities will make efficiency improvements reduce their fuel expenditures and their emissions. The increased price of energy will cause secondary emissions reductions by non-covered entities though increased energy efficiency, decreased of purchases of energy-intensive goods and services, and conservation (e.g., driving less).

Since the cap-and-trade program does not specify how or where emissions reductions will occur, it is impossible to know ahead of time what covered or non-covered entities will do to comply or in response to the cap-and-trade program. Possible compliance responses must therefore be estimated using models. The ENERGY 2020 model was used to estimate the change in emissions and energy prices, and in capital, process, operation and maintenance, and fuel expenditures associated with a price on carbon dioxide (CO_2).

ENERGY 2020 is a detailed energy supply and demand and emissions accounting system of the Western United States. The model simulates the demand for all fuels for three residential categories, over 40 commercial and industrial categories, and three transportation categories. Additional detail on the ENERGY 2020 model is presented below and the ENERGY 2020 Assumptions Book.[5]

Methods available for Emissions Reductions in the ENERGY 2020 model:

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[4] J. Jaraite, F. Convery, and C. Di Maria. 2009. *Transaction Costs of Firms in the EU ETS.* University College Dublin, School of Geography, Planning and Environmental Policy, Richview, Clonskeagh, Dublin. Available at http://irserver.ucd.ie/dspace/bitstream/10197/2077/1/dimariac_confpap_014.pdf (accessed 10/23/10).

[5] *Modeling of Greenhouse Gas Reduction Measures to Support the Implementation of the California Global Warming Solutions Act (AB32) ENERGY 2020 Model Inputs and Assumptions.* February 01, 2010. Available at http://www.arb.ca.gov/cc/scopingplan/economics-sp/models/book1002.pdf.

- Fuel switching[6]

- Earlier replacement of devices

- Purchase of devices with greater efficiency

- Building shell improvements

- Reductions in High-Global Warming Potential (GWP) gases

Methods not available for Emissions Reductions in the ENERGY 2020 model:

- Carbon capture and sequestration

- New nuclear power plants

3. Economic Impacts

The overall impacts on the State economy are estimated using the Environmental Dynamic Revenue Assessment Model (E-DRAM). E-DRAM is a computable general equilibrium (CGE) model of the California economy. Computable general equilibrium models are standard tools of empirical analysis designed to assess the regional costs of GHG emission limits that take into account all secondary effects that these policies could have on prices, commodity and factor substitutions, and incomes. More detail on the E-DRAM model is presented Section H below.

D. Economic Analysis

The focus of this analysis is on presenting estimated impacts for a range of possible allowance prices. A large number of factors influence the allowance price.[7] The technological and behavioral factors include the ease of substitution by firms to low-GHG methods of production, the extent to which consumers shift to low-GHG products in response to changes in prices, and the pace of technological progress. A number of policy factors also apply. These include the stringency of the overall cap and the reductions from other AB 32 policies. Other important policy factors include the extent of output-based updated free allocation, linkages with other markets, the availability and price of offsets, provisions for allowance banking and borrowing, and leakage.

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[6] Renewable electricity above the 33 percent Renewable Electricity Standard or transportation biofuel penetration above the Low Carbon Fuel Standard is not assumed to occur in the ENERGY 2020 modeling.

[7] See, for example, the Economic and Allocation Advisory Committee report, *Allocating Emissions Allowances Under a California Cap-and-Trade Program.* http://climatechange.ca.gov/eaac/documents/eaac_reports/2010-03-22_EAAC_Allocation_Report_Final.pdf (accessed 10/23/10).

Given the uncertainties about the nature of these factors, it is impossible to predict with precision the allowance price. The best that can be done is to estimate the price based on reasonable estimates of technological opportunities and behavioral responses under various scenarios.

In 2010, ARB conducted a joint analysis of the AB 32 *Climate Change Scoping Plan* with Charles River Associates and Professor David Roland-Holst of the University of California Berkeley. The estimated price of CO_2 in these three analyses ranged from about \$20/MTCO_2e to \$100/MTCO_2e in 2020.[8] The range of prices in those analyses depended on assumptions about the success of other AB 32 policies and whether offsets were allowed for compliance.

Appendix E: Setting the Program Emissions Cap, presents detail on the number of allowances that will be made available and the reduction path for the proposed regulation. Cumulative projected emissions over the period 2012–2020 total 2,948 MMTCO_2e. The number of allowances that would be made available from 2012–2020 is 2,674 million. The difference between projected emissions and allowances is 273 million, which represents the required program reductions. However, approximately 123 million allowances will be placed in the reserve and only be made available at the prescribed reserve prices. For allowance prices to remain below the reserve prices—that is, for the reserve not to be fully depleted—approximately 397 million metric tons must be reduced by 2020.

Table N-2 presents the potential 2012–2020 cumulative reductions estimated by ENERGY 2020 that could occur at the various price levels, along with an estimate of the number of offsets that could be available for compliance at those prices.

AB 32 complementary policies in capped sectors that are either adopted or are likely to be adopted, such as the 33 Percent Renewable Energy Standard, Low Carbon Fuel Standard, and the California Advanced Clean Cars Program, could account for more than 150 million cumulative metric tons of reductions. Further, staff anticipates reductions from other complementary policies in capped sectors, such as aggressive energy efficiency and changes in land-use planning that result in reduced transportation sector emissions. Finally, there would be additional reductions that come from price-induced conservation (e.g., driving less) that are not captured in the ENERGY 2020 model.

Based on the assumptions about internal reductions available to capped sectors, the availability of offsets and the reductions from AB 32 complementary policies, staff believes that the 397 million cumulative metric ton reduction requirement is likely to be met at an allowance price that falls within the range of \$15/MTCO_2e to \$30/MTCO_2e in 2020. For example, at an allowance price of \$30/MTCO_2e, estimated internal reductions total 114 million, while an estimate of offsets

[8] See presentation links available at: http://www.arb.ca.gov/cc/scopingplan/economics-sp/meetings/042110/outline.pdf (accessed 10/23/10).

available at a $30/MTCO$_2$e price total 177 million. Therefore, to achieve the 397 metric ton reduction, the complementary policies would have to achieve slightly over 100 million metric tons in reductions. To the extent that they do more, that would mean that a lower allowance price could be maintained.

The 2020 prices used in this analysis include those that could be considered likely given the previous analyses and more recent estimates about emissions: a range of $10 to $20/MTCO$_2$e in 2012, which equates to $15 to $30/MTCO$_2$e in the year 2020; and the reserve trigger prices where additional allowances would be made available as part of the proposed cost containment mechanism: $40, $45, and $50/MTCO$_2$e in 2012, escalating at 5 percent per year to $60, $67, and $75/MTCO$_2$e in 2020 (rounded to the nearest dollar).

Table N-2: Estimated ENERGY 2020 Cumulative Emissions Reductions (2012–2020)

	2020 Prices per Ton of CO_2e				
	Expected Price Range		Reserve Prices		
	$15	$30	$60	$67	$75
Internal Reductions (ENERGY 2020)	99	114	148	156	166
Offsets	42	177	225	228	231
Total Available Reductions	141	291	373	384	397

The range of prices used in this analysis is illustrative of several uncertainties. The following uncertainties could lead to more reliance on the cap-and-trade program for reductions than previously estimated. For example:

- Less success of other AB 32 policies
- Faster-than-expected economic growth

The following uncertainties would require the same amount of reductions to be made, but at higher allowance prices. For example:

- More expensive internal reductions
- Less availability of offsets

E. ENERGY 2020 Estimated Price and Expenditures Changes

The estimated energy price increases in 2020 from the proposed cap-and-trade program are detailed in Table N-3. These price increases are based on full pass-through of allowance value to consumers. The manner in which allowances are distributed could affect how much the energy price increases. The potential effects of different allocation methods are discussed in Appendix J: Allowance Allocation and Appendix K: Leakage Analysis.

The change in energy prices induces consumers of energy to increase their energy efficiency. For example, consumers adjust the timing of their purchases and choose devices with a greater level of efficiency. Greater efficiency generally comes at a higher cost, but not necessarily. For example, a higher price on transportation fuel may induce some consumers to switch to smaller vehicles that are both more fuel-efficient but less expensive than the larger vehicles chosen without cap-and-trade. ARB does not assume that economies of scale or learning effects cause the price of energy efficiency to decrease from those in the initial case.

Table N-3: ENERGY 2020 Estimated Cap-and-Trade Energy Price Changes in 2020

	Expected Price Range		Reserve Prices		
	\$15 /MTCO$_2$e	**\$30 /MTCO$_2$e**	**\$60 /MTCO2e**	**\$67 /MTCO$_2$e**	**\$75 /MTCO$_2$e**
Residential					
Electric	1%	3%	6%	7%	9%
Gas	7%	14%	28%	31%	35%
Oil	5%	10%	21%	23%	26%
LPG	2%	4%	9%	10%	11%
Commercial					
Electric	1%	3%	7%	8%	9%
Gas	8%	16%	32%	36%	40%
Oil	6%	12%	24%	26%	29%
LPG	3%	5%	11%	12%	13%
Industrial					
Electric	1%	3%	8%	9%	11%
Gas	6%	13%	26%	29%	32%
Coal	54%	107%	215%	240%	269%
Oil	4%	8%	17%	18%	21%
Transportation					
Gasoline	4%	8%	15%	17%	19%
Diesel	2%	4%	9%	10%	11%

LPG = liquefied petroleum gas
Price changes reflect only the contribution of cap-and-trade and do not reflect changes from other AB 32 policies.

Table N-4 details the total change in 2020 energy use and Tables N-5 and N-6 detail the estimated 2020 changes in investment and fuel expenditures that are induced by the cap-and-trade program. At expected allowance prices, total energy demand in California would decrease by 2 to 4 percent. The investments in devices are annualized using a 5 percent real capital recovery factor over the life of the equipment. The fuel expenditures do not reflect the allowance value. At the prices modeled, the annual allowance value could be an additional \$5 billion to \$25 billion in 2020. The allowance value represents a transfer of income from consumers of energy to some other sectors of the economy. The allowance value is accounted for separately from the expenditures in the economy-wide analysis by increasing prices in the E-DRAM model.

Table N-4: ENERGY 2020 Estimated Cap-and-Trade Energy Total Energy Changes in 2020

	Expected Price Range (per $MTCO_2e$)		Reserve Prices (per $MTCO_2e$)		
Total Energy Demands	**$15**	**$30**	**$60**	**$67**	**$75**
Absolute Change (trillion Btu/Yr)	-183	-270	-458	-472	-495
Percent Change	-2.8%	-4.1%	-7.0%	-7.2%	-7.5%

The total cost estimates include both the change in fuel expenditures and the change in investment costs. These cost estimates become the inputs for the E-DRAM model to estimate the economy-wide impacts of the cap-and-trade program. As seen in Table N-5 and Table N-6, rising energy prices drive purchases of devices of greater efficiency which are generally more expensive. However the increase in fuel savings offsets much of this expenditure. As a result, the net change in expenditures remains fairly constant over the range of prices.

Table N-5: Detailed ENERGY 2020 Estimated 2020 Changes in Annualized Expenditures from Cap-and-Trade

	Absolute Change ($[2007]Millions)					Percent Change				
	Expected Price Range		Reserve Prices			Expected Price Range		Reserve Prices		
	$15	**$30**	**$60**	**$67**	**$75**	**$15**	**$30**	**$60**	**$67**	**$75**
A. Device Investment										
Residential	$909	$1,004	$1,196	$1,242	$1,298	4%	5%	6%	6%	6%
Commercial	$2,022	$2,137	$2,371	$2,426	$2,494	20%	21%	24%	24%	25%
Energy Intensive Industry[1]	$320	$308	$289	$287	$284	12%	11%	11%	11%	11%
Other Industry	$42	$39	$33	$32	$32	4%	4%	3%	3%	3%
Transportation	$66	-$16	-$180	-$218	-$261	0%	0%	0%	0%	0%
B. Process Investment										
Residential	$38	$64	$113	$124	$136	0.0%	0.0%	0.1%	0.1%	0.1%
Commercial	$1	$2	$3	$4	$4	0.0%	0.0%	0.0%	0.0%	0.0%
Energy Intensive Industry	$11	$22	$42	$47	$52	0.6%	1.1%	2.2%	2.4%	2.7%
Other Industry	$2	$5	$12	$13	$15	0.0%	0.1%	0.1%	0.2%	0.2%
Transportation	$0	$0	$0	$0	$0	0.0%	0.0%	0.0%	0.0%	0.0%
C. Operating and Maintenance										
Residential	$536	$575	$651	$668	$688	24.4%	26.2%	29.7%	30.4%	31.3%
Commercial	$204	$225	$269	$279	$290	40.3%	44.6%	53.2%	55.1%	57.4%
Energy Intensive Industry	$205	$209	$217	$219	$221	23.7%	24.2%	25.1%	25.4%	25.6%
Other Industry	$40	$42	$46	$47	$48	11.0%	11.6%	12.8%	13.0%	13.4%
Transportation	$23	$22	$20	$19	$18	0.5%	0.5%	0.4%	0.4%	0.4%
D. Fuel Expenditures[2]										
Residential	-$337	-$411	-$547	-$577	-$612	-1.4%	-1.7%	-2.3%	-2.4%	-2.6%
Commercial	-$678	-$694	-$728	-$737	-$748	-3.5%	-3.6%	-3.8%	-3.8%	-3.9%
Energy Intensive Industry	-$456	-$509	-$609	-$632	-$659	-2.7%	-3.0%	-3.6%	-3.8%	-3.9%
Other Industry	-$175	-$223	-$313	-$334	-$359	-1.6%	-2.0%	-2.9%	-3.1%	-3.3%
Transportation	-$1,227	-$1,407	-$1,747	-$1,822	-$1,907	-1.5%	-1.7%	-2.2%	-2.2%	-2.4%
Net Total (A+B+C+D)										
Residential	$1,146	$1,232	$1,413	$1,457	$1,510	0.5%	0.6%	0.7%	0.7%	0.7%
Commercial	$1,549	$1,670	$1,915	$1,972	$2,040	1.0%	1.1%	1.3%	1.3%	1.4%
Energy Intensive Industry	$79	$30	-$61	-$80	-$102	0.4%	0.1%	-0.3%	-0.4%	-0.5%
Other Industry	-$91	-$137	-$222	-$241	-$265	-0.4%	-0.7%	-1.1%	-1.2%	-1.3%
Transportation	-$1,138	-$1,402	-$1,907	-$2,021	-$2,150	-0.5%	-0.6%	-0.8%	-0.8%	-0.9%
Total	$1,544	$1,393	$1,138	$1,086	$1,034	0.2%	0.2%	0.2%	0.2%	0.2%

[1]Energy Intensive Industry includes Paper, Chemicals, Petroleum, Nonmetallic Minerals, Primary Metals, Mining except Oil and Gas, Oil and Gas Extraction.
[2]Fuel expenditures do not include the allowance value.

Table N-6: Detailed ENERGY 2020 Estimated Cumulative (2012–2020) Changes in Annualized Expenditures from Cap-and-Trade

	Absolute Change ($[2007]Millions)					Percent Change				
	Expected Price Range		Reserve Prices			Expected Price Range		Reserve Prices		
	$15	**$30**	**$60**	**$67**	**$75**	**$15**	**$30**	**$60**	**$67**	**$75**
A. Device Investment										
Residential	$2,968	$3,252	$3,816	$3,953	$4,114	2.6%	2.8%	3.3%	3.4%	3.6%
Commercial	$6,383	$6,769	$7,534	$7,717	$7,931	11.8%	12.5%	13.9%	14.2%	14.6%
Energy Intensive Industry	$1,235	$1,205	$1,152	$1,147	$1,145	8.0%	7.8%	7.4%	7.4%	7.4%
Other Industry	$154	$140	$115	$110	$105					
Transportation	$213	-$26	-$501	-$611	-$737	0.0%	0.0%	-0.1%	-0.1%	-0.1%
B. Process Investment										
Residential	$109	$182	$319	$349	$383	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	$2	$4	$7	$8	$9	0.0%	0.0%	0.0%	0.0%	0.0%
Energy Intensive Industry	$46	$93	$178	$197	$218	0.4%	0.8%	1.4%	1.6%	1.8%
Other Industry	$8	$23	$52	$58	$65	0.0%	0.0%	0.1%	0.1%	0.1%
Transportation	$0	$0	$0	$0	$0	0.0%	0.0%	0.0%	0.0%	0.0%
C. Operating and Maintenance										
Residential	$2,345	$2,522	$2,862	$2,940	$3,029	13.2%	14.2%	16.1%	16.6%	17.1%
Commercial	$903	$991	$1,162	$1,202	$1,248	20.4%	22.3%	26.2%	27.1%	28.1%
Energy Intensive Industry	$1,243	$1,312	$1,433	$1,459	$1,488	16.9%	17.8%	19.5%	19.8%	20.2%
Other Industry	$200	$218	$252	$260	$270	6.4%	7.0%	8.0%	8.3%	8.6%
Transportation	$95	$93	$90	$89	$88	0.2%	0.2%	0.2%	0.2%	0.2%
D. Fuel Expenditures										
Residential	-$1,196	-$1,447	-$1,902	-$2,004	-$2,121	-0.6%	-0.7%	-1.0%	-1.0%	-1.1%
Commercial	-$2,709	-$2,816	-$3,027	-$3,079	-$3,140	-1.6%	-1.7%	-1.8%	-1.9%	-1.9%
Energy Intensive Industry	-$1,918	-$2,188	-$2,688	-$2,802	-$2,932	-1.3%	-1.5%	-1.9%	-2.0%	-2.0%
Other Industry	-$744	-$976	-$1,404	-$1,501	-$1,613	-0.8%	-1.0%	-1.5%	-1.6%	-1.7%
Transportation	-$4,268	-$4,820	-$5,868	-$6,102	-$6,365	-0.6%	-0.7%	-0.9%	-0.9%	-0.9%
Net Total (A+B+C+D)										
Residential	$4,226	$4,509	$5,096	$5,239	$5,406	0.3%	0.3%	0.4%	0.4%	0.4%
Commercial	$4,580	$4,948	$5,676	$5,847	$6,047	0.5%	0.5%	0.6%	0.6%	0.6%
Energy Intensive Industry	$605	$421	$76	$1	-$82	0.3%	0.2%	0.0%	0.0%	0.0%
Other Industry	-$382	-$595	-$985	-$1,073	-$1,173	-0.2%	-0.4%	-0.6%	-0.7%	-0.7%
Transportation	-$3,960	-$4,753	-$6,279	-$6,624	-$7,013	-0.2%	-0.3%	-0.4%	-0.4%	-0.4%
Total	$5,069	$4,530	$3,584	$3,390	$3,185	0.1%	0.1%	0.1%	0.1%	0.1%

[1]Energy Intensive Industry includes Paper, Chemicals, Petroleum, Nonmetallic Minerals, Primary Metals, Mining except Oil and Gas, Oil and Gas Extraction.
[2]Fuel expenditures do not include the allowance value.

F. Economy-Wide Impacts from the Cap-and-Trade Program

To assess the economy-wide effects of the cap-and-trade program, the estimated allowance price and the expenditure changes and offset expenditures are used as inputs to the E-DRAM model. A model such as E-DRAM is not meant to predict which sectors may experience increased growth because of new opportunities brought on by imposing a carbon price, such as those that design or manufacture renewable technologies, or to predict the creation of green jobs. In E-DRAM, the economy and the way the economy uses inputs to production such as energy or labor look very similar in the future as it does today, only larger.

The 2020 expenditure changes presented in Table N-5 are used, and the assumption is made that all allowance value is recycled as income to California consumers. Allowance value may be redirected to a number of different uses. In E-DRAM, the manner in which allowance value is redistributed has a greater effect on the impact to specific groups and less of an effect at the state level, as long as the value remains in California. The 2020 state-level impacts are presented in Table N-7.

Table N-7: E-DRAM Estimated 2020 Economic Impacts of the Cap-and-Trade Program

		2020 No Cap-and-Trade	Expected Price Range		Reserve Prices		
($2007)	**2007**		**$15**	**$30**	**$60**	**$67**	**$75**
Gross State Product ($ Billions)	$1,845	$2,498	$2,495	$2,491	$2,484	$2,482	$2,481
Personal Income ($ Billions)	$1,492	$2,024	$2,021	$2,019	$2,015	$2,014	$2,013
Income Per Capita ($ Thousands)	$39.3	$46.0	$46.0	$46.0	$45.9	$45.9	$45.9
Labor Demand (Millions)	16.35	18.40	18.34	18.30	18.22	18.20	18.18
			Percent Change from No Policy Case				
Gross State Product	-	-	-0.1%	-0.3%	-0.6%	-0.6%	-0.7%
Personal Income	-	-	-0.1%	-0.2%	-0.5%	-0.5%	-0.6%
Income Per Capita	-	-	0.0%	-0.1%	-0.2%	-0.2%	-0.2%
Labor Demand	-	-	-0.3%	-0.6%	-1.0%	-1.1%	-1.2%
			Annual Average Growth 2007–2020				
Gross State Product	-	2.4%	2.3%	2.3%	2.3%	2.3%	2.3%
Personal Income	-	2.4%	2.4%	2.4%	2.3%	2.3%	2.3%
Income Per Capita	-	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%
Labor Demand	-	0.9%	0.9%	0.9%	0.8%	0.8%	0.8%

These results provide insight into the potential range of impacts that the proposed cap-and-trade program could have on the California economy. The estimated impacts show relatively small changes in economic growth when compared to growth otherwise expected over 2007 to 2020. The reference case forecast used in the E-DRAM model assumes that California gross state product will grow by about 35 percent between 2007 and 2020. With imposition of the cap-and-trade program, the annual average growth in gross state product is reduced by about one-half of 1 percent, even under the higher-than-expected allowance price assumption. These results indicate that at the state level, the cap-and-trade program does not have a significant adverse impact on California business or consumers as a whole.

Additionally, the decrease in labor demand from the reference case does not mean that people will lose their jobs in 2020 as a result of the proposed regulation. Rather, the estimates indicate that at expected allowance prices, more than 1.9 million jobs are created by 2020, which is nearly the same as business-as-usual.

Table N-8: E-DRAM Sensitivity Analysis: Estimated 2020 Economic Impacts of the Cap-and-Trade Program With Device, Process, and Operating and Maintenance Expenditures Doubled

		2020 No Cap-and-Trade	**Expected Price Range**		**Reserve Prices**		
($2007)	**2007**		**$15**	**$30**	**$60**	**$67**	**$75**
Gross State Product ($ Billions)	$1,845	$2,498	$2,488	$2,484	$2,476	$2,474	$2,472
Personal Income ($ Billions)	$1,492	$2,024	$2,016	$2,013	$2,008	$2,007	$2,005
Income Per Capita ($Thousands)	$39.3	$46.0	$45.9	$45.9	$45.8	$45.8	$45.8
Labor Demand (Millions)	16.35	18.40	18.31	18.27	18.18	18.16	18.13
			Percent Change from No Policy Case				
Gross State Product	-	-	-0.4%	-0.6%	-0.9%	-1.0%	-1.0%
Personal Income	-	-	-0.4%	-0.5%	-0.8%	-0.9%	-0.9%
Income Per Capita	-	-	-0.2%	-0.3%	-0.4%	-0.4%	-0.4%
Labor Demand	-	-	-0.5%	-0.7%	-1.2%	-1.3%	-1.5%
			Annual Average Growth 2007–2020				
Gross State Product	-	2.4%	2.3%	2.3%	2.3%	2.3%	2.3%
Personal Income	-	2.4%	2.3%	2.3%	2.3%	2.3%	2.3%
Income Per Capita	-	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%
Labor Demand	-	0.9%	0.9%	0.9%	0.8%	0.8%	0.8%

It is not possible to verify all of the expenditure data used in ENERGY 2020, so staff considered the potential for some estimated expenditures to be greater than what is estimated by the model as a sensitivity analysis. In this example, the change in device investment, process investment, and operating and maintenance expenditures used in the previous example were doubled. Since the change in the transportation sector's device investment and the operating and maintenance expenditures were negative reflecting the purchase of smaller less expensive vehicles, these values were set to zero.

The 2020 state-level impacts for the cost sensitivity are presented in Table N-8. The effect of doubling all expenditures except for fuel expenditures results in somewhat greater economic impacts, primarily at the lower allowance prices. At higher allowance prices, the estimated impacts are driven more by the allowance value and less by the expenditures.

G. Potential Impacts on Small Business

Very few small businesses have enough emissions to be regulated directly under the cap-and-trade program. Most small business impacts will be indirect and result from changes in energy expenditures. Therefore, this analysis focuses on how implementation of the cap-and-trade program could affect expenditures that small businesses make on electricity and natural gas and how such shifts could affect their profitability. ARB will continue to seek ways to measure the impacts of the program on small business and report to the Board as the program is implemented.

Dun and Bradstreet (D&B) provided ARB with data from a statistical data model that estimates the portion of revenue that businesses spend on energy. The model is based on D&B marketing files from approximately 17 million businesses nationwide, including over 2.1 million in California. The annual spending on electricity and natural gas was calculated for affected businesses as follows:

- D&B collected data on monthly electric and natural gas bills for approximately 628,000 businesses nationally from 18 electrical utility providers nationwide, including two California utilities, from April 2007 to March 2008.

- Annual spending on electricity and natural gas were calculated for these businesses by summing up monthly bills.

- Of the 628,000 businesses nationwide, D&B has revenue data for 210,000 of these businesses.

- Revenue data were available for a greater number of large businesses in the sample. Thus, the sample distribution was adjusted to represent the true universal distribution of the D&B database of 17 million businesses.

Table N-9 provides a list of the California industries with the greatest expenditures on retail electricity and natural gas as a percentage of their revenue, along with an estimate of the small business share in that industry. These industries are primarily service-related and serve local markets.

Spending Change = (Change in 2020 prices) x (% of revenue spent on electricity and natural gas)

This estimate assumes that these industries make no changes in their energy use in response to the price changes. Table N-10 reports the results. Under the likely range of prices, most sectors experience less than a 2 percent change in the share of revenue spent on energy. Even at the highest reserve price most sectors experience less than a 4 percent change. The majority of the listed business categories are those that serve local markets such as trailer parks and camps, hotels, barbershops, and bakeries). Out-of-state businesses cannot serve these local markets. As a result, most California small businesses are not likely to face competitiveness issues relative to out-of-state businesses.

The potential impact estimated here may be high because small businesses, like any other businesses, are likely to respond to the increase in energy prices by investing in energy-efficient technologies to achieve energy savings. In light of many public incentive programs available, most small businesses should not have difficulties in obtaining the required capital for investment in energy-efficient technologies. The savings from electricity efficiency improvements are likely to partially offset or mitigate the impact of any increase in electricity prices and could mean decreased energy bills even in the face of increased prices.

Table N-9: Industries with Greatest Share of Revenue Spent on Electricity and Natural Gas

SIC	Industry Description	Small Business Share of Industry [9] (%)	Electricity Expenditures/ Revenue (%)	Natural Gas Expenditures/ Revenue (%)
259	Poultry and Egg Houses	87	5.9	N/A
4941	Water Supply	24	6.0	2.7
5441	Candy, Nut, and Confectionery Stores	66	6.0	1.8
5461	Retail Bakeries	66	6.9	3.2
5813	Drinking Places	86	6.4	3.6
6719	Holding Companies	78	6.6	5.2
7011	Hotels and Motels	40	6.4	4.9
7021	Rooming and Boarding Houses	40	7.4	6.9
7032	Sporting and Recreational Camps	54	8.2	2.8
7033	Trailer Parks and Campsites	N/A	8.2	5.1
7041	Membership-Basis Organization Hotels	40	6.9	6.8
7215	Coin-Operated Laundries and Cleaning	78	6.2	15.9
7217	Carpet and Upholstery Cleaning	91	6.1	1.9
7219	Laundry and Garment Services	78	6.9	8.4
7231	Beauty Shops	78	6.2	3.7
7241	Barber Shops	78	6.9	5.0
8231	Libraries	44	6.9	3.3
8351	Child Day-Care Services	78	5.9	4.4
8361	Residential Care	49	5.8	3.1
8641	Civic and Social Associations	71	8.6	5.8

SIC = Standard Industrial Classification code; N/A = data are not available for this industry

[9] The share of small businesses is calculated using California Employment Development Department data. California Size of Business. Number of Businesses by Employment Size, Industry, and County. Available at http://www.labormarketinfo.edd.ca.gov/?pageid=138 (accessed 10/23/10).

Table N-10: Range of Impact on Average Percentage of Revenue Spent on Energy (%)

SIC	Business Category	Energy Expenditures/ Revenue	Expected Price Range		Reserve Prices		
			$15	$30	$60	$67	$75
7215	Coin-Operated Laundries and Cleaning	22.1	1.4	2.7	5.6	6.2	7.0%
7219	Laundry and Garment Services	15.3	0.8	1.5	3.2	3.6	4.0%
8641	Civic and Social Associations	14.4	0.6	1.2	2.5	2.8	3.1%
7021	Rooming and Boarding Houses	14.3	0.6	1.3	2.7	3.1	3.5%
7041	Membership-Basis Organization Hotels	13.7	0.6	1.3	2.7	3.0	3.4%
7033	Trailer Parks and Campsites	13.3	0.5	1.1	2.2	2.5	2.8%
7241	Barber Shops	11.9	0.5	1.0	2.1	2.4	2.7%
6719	Holding Companies	11.8	0.5	1.0	2.1	2.4	2.7%
7011	Hotels and Motels	11.3	0.5	1.0	2.0	2.3	2.6%
7032	Sporting and Recreational Camps	11.0	0.3	0.7	1.5	1.7	1.9%
8351	Child Day-Care Services	10.3	0.4	0.9	1.8	2.1	2.3%
8231	Libraries	10.2	0.4	0.7	1.6	1.7	2.0%
5461	Retail Bakeries	10.1	0.3	0.7	1.5	1.7	1.9%
5813	Drinking Places	10.0	0.4	0.8	1.6	1.8	2.0%
7231	Beauty Shops	9.9	0.4	0.8	1.6	1.8	2.1%
8361	Residential Care	8.9	0.3	0.7	1.4	1.6	1.8%
4941	Water Supply	8.7	0.3	0.6	1.3	1.5	1.6%
7217	Carpet and Upholstery Cleaning	8.0	0.2	0.5	1.0	1.2	1.3%
5441	Candy, Nut, and Confectionery Stores	7.8	0.2	0.5	1.0	1.1	1.3%

SIC = Standard Industrial Classification code

H. Model Details

1. ENERGY 2020

A description of the ENERGY 2020 model is provided here, and additional detail can be found in the assumptions book for ENERGY 2020 and the ENERGY 2020 technical documentation posted on the ARB website.[10]

ENERGY 2020 is an integrated multi-region energy model that provides complete and detailed simulations of the demand and supply picture for all fuels. The model simulates demand by three residential categories, over 40 North American Industrial Classification System (NAICS) commercial and industrial categories, and three transportation services. There are approximately six end-uses per category and six technology/mode families per end-use. Currently the technology families correspond to six fuel groups (oil, gas, coal, electric, solar, and biomass) and 30 detailed fuel products.

Supply sectors include electricity, oil, natural gas, refined petroleum products, ethanol, landfill gas, and coal supply. For electricity, the model includes endogenous (i.e., calculated by the model) simulation of capacity expansion/construction, rates/prices, load-shape variation due to weather, and changes in regulation. For the other supply sectors the prices are set exogenously. The model includes pollution accounting for combustion (by fuel, end-use, and sector), non-combustion, and non-energy (by economic activity) for six GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).

The model simulates decisions by energy users for each end-use, including: fuel choice; investment in end-use efficiency (e.g., by purchasing devices that are more efficient than the minimum required by standards); and end-use utilization (i.e., how much the device is used). End-use-specific choices are simulated as needed, such as mode choice for freight movement and passenger transportation. Choices are simulated based on costs (e.g., increased capital costs versus the value of fuel saved) as well as on non-price attributes (e.g., convenience or the acceptance of the technology). Past purchasing behavior is used to calibrate the non-price choice parameters for each end-use.

ENERGY 2020 can provide insight into the following:

- Changes in fuel prices associated with allowance prices
- Emissions reductions by year and sector
- Changes in fuel expenditures by year and sector
- Changes in investment by year and sector

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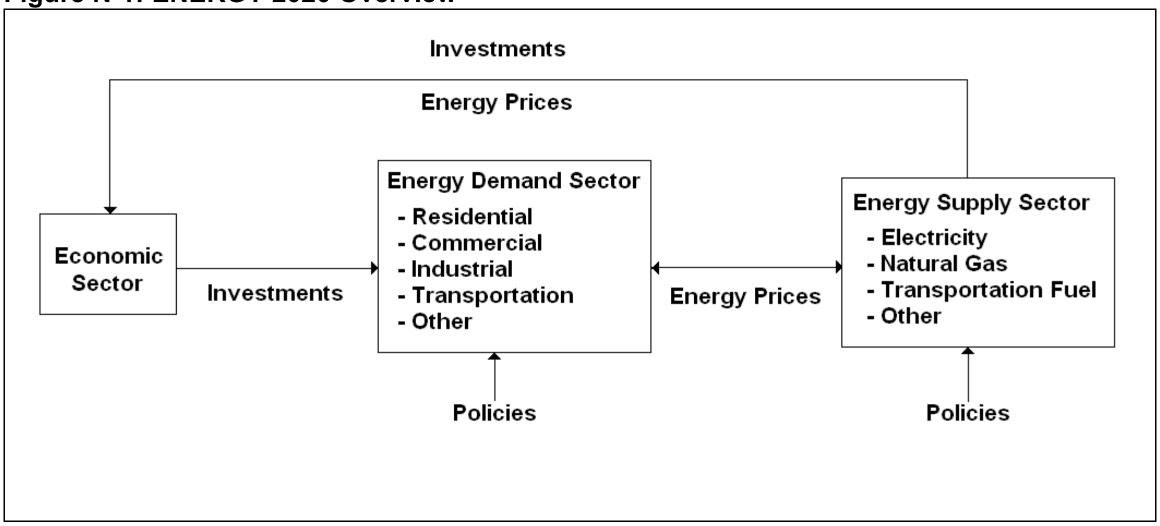
[10] See http://www.arb.ca.gov/cc/scopingplan/economics-sp/models/models.htm (accessed on 10/23/10).

ENERGY 2020 does not estimate changes in state output, income, employment, or the redistribution of potential allowance revenue. These questions are addressed using the E-DRAM model, discussed below.

The general structure of ENERGY 2020 is provided in Figure N-1N-1. The Energy Demand Sector interacts with the Energy Supply Sector to determine the equilibrium levels of demand and energy prices. The Energy Demand Sector is driven by the Economic Sector, but it also feeds back inputs to the Economic Sector in terms of investments (in energy-using equipment and processes) and energy prices. The model has a simplified Economic Sector so as to capture the linkages between the energy system and the overall economy. However, the model is best run when combined with a macroeconomic model.

Figure N-1: ENERGY 2020 Overview



The model assumes that energy demand results from using capital stock in the production of output. For example, the industrial sectors produce goods, which require energy for production; the commercial sectors require buildings in order to provide services; and the residential sector needs housing. The amount of energy consumed in any end-use is based on energy efficiencies. For example, the energy efficiency of a house, along with the efficiency of the furnace, determines how much energy the house uses to provide the desired warmth.

The model simulates investment in energy-using capital (e.g., 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 therefore the 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 tradeoffs between changing fuel costs and efficiency determine the capital cost of the chosen technology.

These tradeoffs are dependent on perceived energy prices, capital costs, operating costs, risks, access to capital, regulations, and other imperfect information.

The model formulates the energy-demand causally using historical relationships of output, energy demand, and technology. Rather than using price elasticities to determine how demand reacts to changes in price, the model explicitly identifies the multiple ways in which price changes influence the economics of alternative technologies and behaviors, which in turn determine consumers' demand. The model accurately recognizes that price responses vary over time, depending on factors such as the rate of investment, age and efficiency of the capital stock, and relative prices of alternative technologies.

The energy requirement embodied in the capital stock can be changed only by new investments, retirements, or retrofitting. The efficiency with which capital uses energy has a limit determined by technological or physical constraints. The efficiency of the new capital purchased depends on the consumer's perception of the trade-off between efficiency and other factors such as capital costs. For example, as fuel prices increase, the efficiency that 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. 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.

a. Reference Case Description

The cap-and-trade program is compared to an established Reference case to measure the economic impact. The constructed reference case is based on exogenous forecasts of key drivers, including economic growth, fuel use, and regulatory structure. The reference case reflects GHG emissions and expenditures expected to occur in the absence of a cap-and-trade program but with the inclusion of several other emissions-reduction measures. The data primary inputs and sources are shown in Table N-11.[11]

[11] *Data* refers both to historical data and projections of future inputs.

Table N-11: Reference Case Primary Data Inputs

Data Input	Source
Population and economic growth	*2009 Integrated Energy Policy Report;* California Energy Commission, Dec. 2009
Fuel prices	U.S. Energy Information Administration 2008 Revision
Energy consumption	*2009 Integrated Energy Policy Report;* California Energy Commission, Dec. 2009
Emissions	California Greenhouse Gas Emissions Inventory
Electricity generation capacity and operation	Federal Energy Regulatory Commission (FERC)

The forecasts of energy use and emissions do not include other policies to reduce emissions that have been adopted or are planned pursuant to AB 32. The existing or planned measures that are assumed to have a significant effect on the emissions and their targets are described in Table N-12. The inclusion of these measures in ENERGY 2020 has limited effect on the emissions reductions from cap-and-trade. However, it is necessary to compute the investment changes from these policies to include in the economy-wide analysis.

Table N-12: Existing or Planned GHG Measures

Measure	Metric	Modeled Target
Advanced Clean Cars	New vehicle fleet efficiency	42 mpg
Low-Carbon Fuel Standard (LCFS)	Ethanol share: Biodiesel share:	18% 15%
Renewable Electricity Standard	Renewable Share of Electricity Sales	33%

2. EDRAM Model

The Environmental Dynamic Revenue Assessment Model (E-DRAM) is a static computable general equilibrium (CGE) model of the California economy.[12] Computable general equilibrium models are standard tools of empirical analysis, and they are widely used to analyze the aggregate impacts of policies whose effects may be transmitted through multiple markets. The E-DRAM model was developed by Dr. Peter Berck of the University of California, Berkeley, in collaboration with the California Department of Finance and the Air Resources Board. The current model includes 188 distinct sectors: 120 industrial sectors, 2 factor sectors (labor and capital), 8 household sectors, 9 consumption sectors,

[12] *Static* in this respect means that E-DRAM solves for a single year and that the solution in that year is not tied to decisions made in previous years.

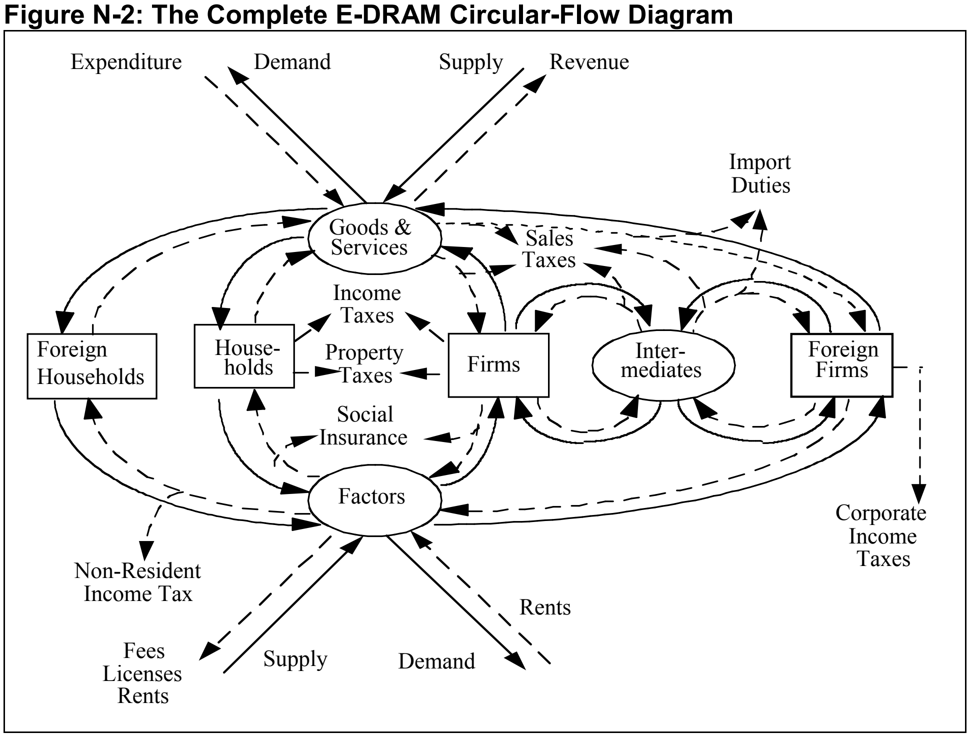
1 investment sector, 45 government sectors, and 1 sector that represents the rest of the world.

The E-DRAM model does not a produce a forecast of the future. Rather, it constructs a future-year reference case from existing forecasts of income, population, and energy use. Together, income and energy growth imply an estimate of technical progress. In this analysis, growth in E-DRAM has been set so that it is in agreement with the growth assumptions used in ENERGY 2020.

The model solves for the set of commodity and factor prices, and the levels of industry activity and household income that clear all markets in the economy, given aggregate factor endowments, households' consumption technologies (specified by their utility functions), and industries' transformation technologies (specified by their production functions). The model derives a price for the output of each of the 120 industrial sectors, a price for labor (called the "wage"), and a price for capital services (the "rental rate").

The basic relationships in E-DRAM are shown in the circular-flow diagram in Figure N-2. 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 dashed lines, are monetary flows.

Figure N-2: The Complete E-DRAM Circular-Flow Diagram



Households buy goods and services from the goods-and-services markets and give up their expenditure as compensation. They sell capital and labor services on the factor markets and receive income in exchange. There are eight separate household types distinguished by California marginal personal income tax brackets. A detailed description of the demand for goods and services is given in Chapter III of the DRAM report.[13]

Firms supply goods and services to the goods-and-services market in return for revenues. Firms demand capital and labor from the factor markets and in return pay wages and rents. Firms also purchase intermediate goods from other firms. 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 on a national input-output table.

California is an open economy, which means that it trades goods, services, labor, and capital readily with other states and countries. In this model, all agents outside California are aggregated into one group, called "Rest of World." That is, no distinction is made between the rest of the United States and foreign countries. California interacts with two types of rest-of-world agents: foreign consumers and foreign producers.

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. 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 are described in Chapter VIII of the DRAM Reports.

Finally, government is considered by combining the taxing and spending effects of the three levels of government (federal, state, and local). Government buys goods and services and gives up expenditures. 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. And government makes transfers to households, which are not shown in the diagram. Chapter II of the DRAM Report includes a detailed description of the government activities in the model.

3. ENERGY 2020 in Combination with E-DRAM

Results from ENERGY 2020 are used in combination with the E-DRAM model to further examine the potential economic impacts of the cap-and-trade program. Figure N-3 provides a summation of the information presented in the previous sections and highlights how further analysis can be preformed using ENERGY 2020 together with E-DRAM.

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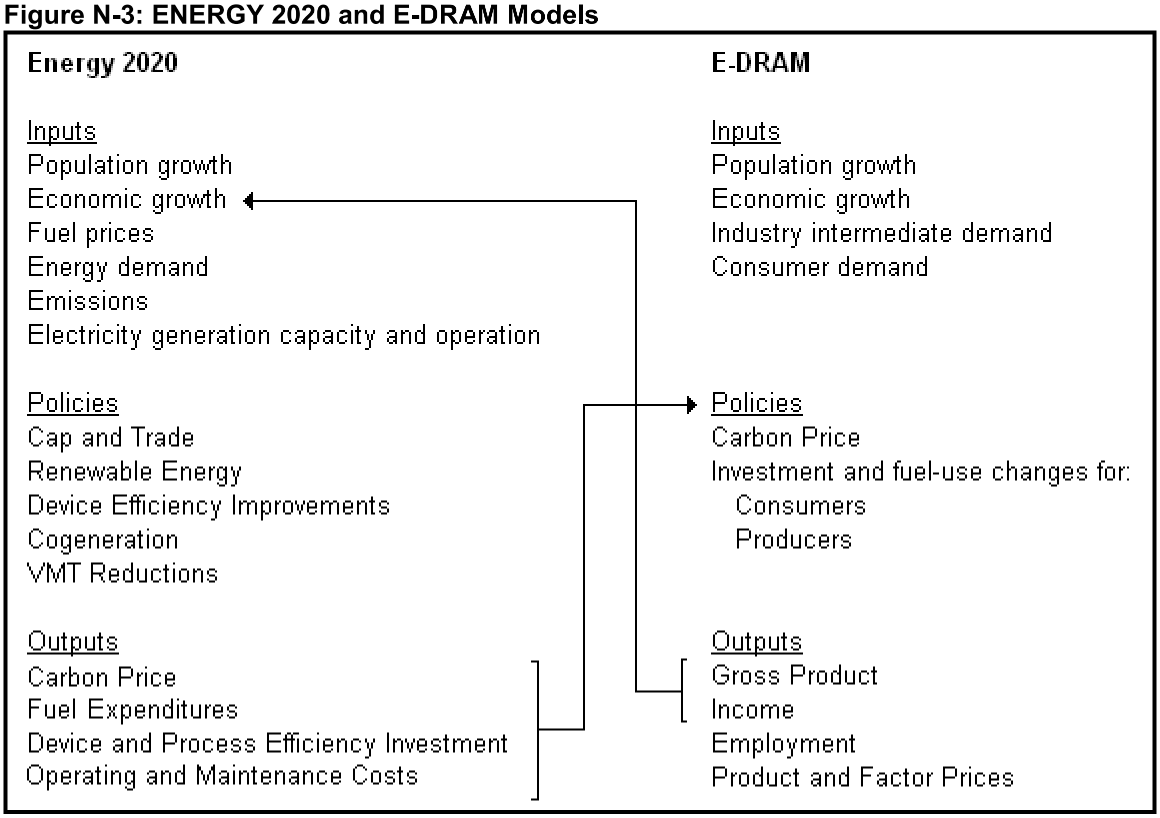
[13] Berck, P., E. Golan, and B. Smith. 1996. *Dynamic Revenue Analysis for California.* California Department of Finance. Available at http://www.dof.ca.gov/HTML/FS_DATA/DYNA-REV/DYNREV.HTM (accessed 10/23/10).

As shown, both models rely on some of the same input data, but ENERGY 2020 focuses more on energy supply and demand, while E-DRAM focuses on the economic relationships between producers, consumers, and government. The intent of this portion of the analysis is to use the information produced by the detailed energy model to further investigate the broader economic impacts of the cap-and-trade program, which are better estimated in E-DRAM.

The ENERGY 2020 model results that are passed on to E-DRAM include:

- CO_2 allowance price
- Changes in device and process efficiency investment
- Changes in operating and maintenance costs
- Changes in fuel expenditures

Figure N-3: ENERGY 2020 and E-DRAM Models



CO_2 Allowance Price. The allowance price is represented in E-DRAM by increasing the prices of electricity, natural gas, and transportation fuel by amounts that reflect the average carbon content of each fuel at a given allowance price. For this analysis, all allowance value is assumed to remain in-state and is returned to households as income. The return of income in this manner would be similar, though not exactly equivalent to, an adjustment to taxes on wages.

Investment and Fuel Expenditure Changes. The changes in investment and fuel expenditure generated by ENERGY 2020 are captured in the E-DRAM model as changes in technology and consumer-expenditure patterns.

The ENERGY 2020 model simulates energy demand and investment at the end-user, or consumer, level. Therefore, all ENERGY 2020 results are applied in E-DRAM at the consumer level. The consumer in this respect is both a household that consumes finished goods and a producer that consumes intermediate goods in the production process.

Figure N-4 provides a picture of the ENERGY 2020 to E-DRAM model-to-model mapping of expenditures. Column 1 indicates the ENERGY 2020 expenditure category that will be passed on to E-DRAM. Column 2 indicates the level of aggregation that will be used in both models. The two models each have considerable detail, but to make the sharing of information tractable, it is preferable to deal with aggregations. In this analysis, the ENERGY 2020 investment and fuel-expenditure changes are applied in E-DRAM to six broad sector aggregations. These groupings are Residential, Commercial, Energy-Intensive Industrial, Other Industrial, Passenger Transportation, and Freight Transportation.[14] Column 3 provides information about the ENERGY 2020 end-uses, which are useful for determining the appropriate E-DRAM categories that are on the receiving end of the expenders (shown in Column 4).

For example, the Residential sector demands energy to operate different devices. Implementing the cap-and-trade program in ENERGY 2020 causes expenditures by the Residential sector on these devices, and thereby the fuel needed to power these devices to change. In E-DRAM, these changes are represented as increases or decreases in spending by the Residential sector to the appropriate E-DRAM device and fuel sectors.

These expenditure changes are implemented in E-DRAM by adjusting the model's Social Accounting Matrix (SAM), which represents all of the economic transactions that take place within a regional economy during a particular benchmark period. The entries along a row in the SAM show each payment received by a particular sector. The entries down a column in the SAM show the expenditures made by a particular sector. For accounting purposes, a SAM must balance—that is, each row sum and corresponding column sum must be equal. This balancing ensures that all money received by firms is spent and that no money leaks out of the economy. The original SAM provides the basis for what the reference-case economy looks like, and the altered SAM indicates what the economy looks like with the imposition of a cap-and-trade program.

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[14] *Industrial sectors* are the goods-producing sectors, while *commercial sectors* are the non-goods-producing sectors such as wholesale trade, retail trade, or services.

Figure N-4: ENERGY 2020 Mapping to E-DRAM

Expenditure	Energy Consumer	End-use	E-DRAM Sector
Device	Residential Commercial	Air Conditioning Lighting Refrigeration Space Heating Water Heating Other Non-Subs* Other Subs**	Refrigeration and Air Conditioning Wholesale Durable Goods Machinery Manufacture
	Industrial - Energy-Intensive - Other	Motors Process Heat Other Subs Off Road Miscellaneous	Refrigeration and Air Conditioning Wholesale Durable Goods Machinery Manufacture
	Transportation - Passenger - Freight	Vehicle type	Retail Vehicles and Parts Automobile Manufacturing
Process	Residential Commercial Industrial - Energy-Intensive - Other	Building Efficiency	Retail Building Materials
Operating and Maintenance	Residential Commercial Industrial - Energy-Intensive - Other		General increase in all intermediate goods
Fuel	Residential Commercial Industrial - Energy Intensive - Other Transportation - Passenger - Freight	All end-uses	Electrical Power Distribution Natural Gas Distribution Retail Gasoline Stations

* Other Non-Subs = Other devices that operate only on electricity
** Other Subs = Other devices that operate on multiple fuel types

As shifts in expenditures are made, the SAM is rebalanced so that the sum of the rows equals the sum of the columns. In particular, the increase in Consumer Transportation sector spending for automobiles has the effect of reducing expenditures on all other Consumer Transportation goods. The decrease in fuel expenditures has the effect of increasing expenditures on all other Consumer Transportation goods. The model is then resolved for a new set of commodity and factor prices, and the levels of industry activity and household income that clear all markets—and their impacts—are measured as the change from the original SAM reference solution.