Arnold Schwarzenegger
Governor

DATA SOURCES FOR CLIMATE CHANGE RESEARCH WITH A COMPUTABLE GENERAL EQUILIBRIUM (CGE) MODEL OF THE CALIFORNIA ECONOMY

PIER PROJECT REPORT

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Public Interest Energy Research Program

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June 2007
CEC-500-2006-080

California Climate Change Center
Report Series Number 2006-012

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Work Authorization 119

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Acknowledgments

The authors wish to thank the following individuals for their help clarifying certain questions related to the studies used as source data for the Computable General Equilibrium (CGE) model: Anne Choate and Diana Pape, ICF Consulting; Sandra Brown and Jonathan Winsten, Winrock International; and Ken Darrow, Energy and Environmental Analysis, Inc. We would also like to acknowledge the guidance and feedback we received from Guido Franco of the Energy Commission throughout this project.

Please cite this report as follows:

Murtishaw, S., and D. Roland-Holst. 2006. *Data Sources for Climate Change Research with a Computable General Equilibrium (CGE) Model of the California Economy.* California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-080.

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

The California Climate Change Center (CCCC) is sponsored by the PIER program and coordinated by its Energy-Related Environmental Research area. The Center is managed by the California Energy Commission, Scripps Institution of Oceanography at the University of California at San Diego, and the University of California at Berkeley. The Scripps Institution of Oceanography conducts and administers research on climate change detection, analysis, and modeling; and the University of California at Berkeley conducts and administers research on economic analyses and policy issues. The Center also supports the Global Climate Change Grant Program, which offers competitive solicitations for climate research.

The California Climate Change Center Report Series details ongoing Center-sponsored research. As interim project results, the information contained in these reports may change; authors should be contacted for the most recent project results. By providing ready access to this timely research, the Center seeks to inform the public and expand dissemination of climate change information; thereby leveraging collaborative efforts and increasing the benefits of this research to California's citizens, environment, and economy.

The work described in this report was conducted under the Assessing Potential Impacts of Climate Change on California contract, contract number 500-99-013, by Scott Murtishaw, Lawrence Berkeley National Laboratory and David Roland-Holst, University of California, Berkeley.

For more information on the PIER Program, please visit the Energy Commission's website www.energy.ca.gov/pier/ or contract the Energy Commission at (916) 654-5164.

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Appendix A. Scenarios Deferred for Later Analysis

Appendix B. CGE Model Scenarios in the Context of Other GHG Initiatives

Data Sources Used in the CGE Modeling for the UC Berkeley Climate Change Center Study *Managing Greenhouse Gas Emissions in California* (CACGE_Data.xls)

Abstract

To support California Environmental Protection Agency and Public Interest Energy Research (PIER) policy research initiatives, the Computable General Equilibrium (CGE) forecasting model of the California economy is being used to evaluate a variety of policies for mitigation of greenhouse gas (GHG) emissions. Because of the diversity and complexity of the policies being assessed, the research team undertook an exhaustive search for accurate and timely data to better calibrate the model. The report is a review of the most appropriate sources and provides a limited discussion about how they were incorporated into the CGE modeling facility. More details on the use of the data and the forecasting results are given in Roland-Holst (2006), but this project's objective was simply to document the sources of data used, their basic functional attributes, and adjustments made to the data to conform to the CGE modeling framework. Nearly all data used were obtained from official California sources or studies commissioned by state agencies, and these data cover a broad range of GHG reduction strategies. All data are less than three years old. The research team believes that it has assembled the most geographically relevant, timely, and accurate data available.

Keywords: Computable General Equilibrium model, CGE, California economy, greenhouse gas, GHG, climate change, general equilibrium model

Executive Summary

Introduction

California Executive Order S-3-05 established greenhouse gas (GHG) reduction targets for California and mandated that state agencies produce a biannual report on the impacts of climate change on California and policy options to mitigate climate change. The first report was published by the inter-agency Climate Action Team (CAT) in 2006. More recently the California Global Warming Solution Act of 2006 (AB32) requires that by 2020 the state's GHG emissions cannot be higher those emitted in 1990.

Purpose

This project's purpose was to characterize the economic impacts of the different GHG reduction options that PIER researchers have reported in the last few years, using a common framework. For example, PIER researchers that developed the estimated costs for carbon sequestration did not use exactly the same or similar assumptions as those used by researchers that estimated the costs associated with efforts designed to reduce non-carbon dioxide gases in California.

Project Objective

This project's objective was to generate the economic data that a macroeconomic model, such as the Computable General Equilibrium (CGE) forecasting model of the California economy, would need to evaluate a variety of policies for mitigation of GHG emissions—specifically, to document the sources of data used, their basic functional attributes, and adjustments made to the data to conform to the CGE modeling framework.

Project Outcomes

More than forty different policy scenarios were considered for inclusion in the CGE forecasting analysis. The report reviews the most appropriate sources and provides a limited discussion about how they were incorporated into the CGE modeling facility. Nearly all data used were obtained from PIER publications, and official California sources or studies commissioned by state agencies. All data were less than three years old.

Conclusions

The project team was able to incorporate eleven distinct sets of policies into the CGE framework for modeling purposes. Those results are shown in a study by Roland-Holst (2006). These policy scenarios were all supported by detailed analysis of their mitigation potentials, costs, and benefits. The scenarios used for the CGE analysis cover a diverse range of mitigation measure including building codes, vehicle emissions standards, refrigeration and cooling systems, afforestation, control of biogenic methane emissions.

Recommendations

A large number of innovative, and potentially significant, mitigation measures were requested by the California Climate Action Team for inclusion in the CGE forecasting runs. In many cases, these measures lacked the detailed cost and mitigation estimates necessary for adaptation in a CGE framework. Thus, several promising policies and measures await further research before meaningful assessment of their contribution to climate change mitigation can begin. Standardizing the discount rates and other cost parameters used in state-sponsored climate research would facilitate the inclusion of future research into CGE models or similar economic models.

Benefits to California

General equilibrium models enable policy makers to account for the otherwise unforeseen economic consequences of mitigation policies. The improvement and use of this economic analysis modeling tool can enable researchers to more closely estimate economic costs and benefits of potential GHG mitigation efforts in California, providing the state's decision makers with better information on which to base mitigation policy. A model that helps capture the ripple effects of government policies throughout the economy can help California to meet its mitigation targets in a least-cost manner that may bestow several economic benefits.

1.0 Introduction

On June 1, 2005 Governor Schwarzenegger signed Executive Order S-3-05, which established greenhouse gas (GHG) reduction targets for California. This Executive Order also mandated that state agencies, led by an inter-agency Climate Action Team (CAT), produce a biannual report on the impacts of climate change on California and policy options to mitigate climate change, with the first report being due in January 2006. In parallel to the CAT report, the Energy Foundation and the Hewlett Foundation commissioned a second study (Hanemann and Farrell eds. 2006) to provide additional expert analysis of the potential policies needed to meet the Governor's targets and the costs that these policies may entail.

One of the chapters of the Hanemann and Farrell (2006) report describes the results of GHG mitigation scenario analysis with a comparable California CGE (Roland-Holst 2006). The CGE model was used to capture upstream and downstream economic impacts of a wide range of climate change mitigation policies. Specific measures were drawn from a list generated by CAT (see Table B.1). In addition to work performed for the Hanemann and Farrell report, the CGE model may also be used for ongoing policy analysis on behalf of the Public Interest Energy Research (PIER) program managed by the California Energy Commission.

Detailed California-specific mitigation potential and cost data were needed to model the GHG reductions and economic impacts of various abatement measures in the CGE model. Most of the data were taken from recent studies conducted for state agencies. The research team had to adjust the results of some of these studies in order to produce data in a consistent format based on similar parameters and assumptions. In order to harmonize the results of these various studies, estimated costs and benefits were recalculated for some studies using a discount rate of 4% and tax rate of 0%, which correspond to the social cost parameters used in a report on mitigation of non-carbon dioxide (CO_2) gases produced by ICF Consulting (ICF 2005a). All dollar values were also converted to year 2003 constant dollars. See Murtishaw (2005) for a spreadsheet containing the adjusted data for several of the policy sets described below.

Each of the subsequent sections in this report describes the source and preparation of the data for a specific measure or policy analyzed in the CGE model. They are presented in the same order used in Roland-Holst (2006).

2.0 Building Energy Efficiency Standards

2.1. Scenario Description

This scenario and the one following it refer to a set of existing and proposed state initiatives to improve the energy efficiency of residential and commercial buildings in the state. Included among these are initiatives that are already being implemented or are scheduled for implementation and those that may be implemented pending approval.

2.2. Data Sources and Description

There are several strands of Energy Commission research that bear directly on this scenario set. For example, the 2005 Title 24 non-residential building standards are included in the Energy Commission forecasts. Although not explicitly incorporated in the Cal/EPA scenario list, new appliance standards have also been adopted in 2005, and these are included in the Energy Commission forecasts and will be incorporated in the CGE baseline runs. For this scenario, the research team used data synthesized from Energy Commission projections (Sanstad and Hallstein 2005) to calibrate baseline efficiency gains in gas and electricity use patterns. These data are timely and quite detailed (e.g., Residential, Commercial, Industrial, Mining, Agriculture, and Other). Original sources include CEC (2003, 2005a,b,c,d) and CPUC (2004a,b).

3.0 Building Energy Efficiency Standards

3.1. Scenario Description

Periodic updating of standards stringency as described in Section 2 above.

3.2. Data Sources and Description

See Section 2.

4.0 Energy Efficiency Programs

4.1. Scenario Description

This scenario refers to state initiatives to promote overall increases in residential and commercial energy efficiency, including substantial fiscal commitments to promote private technology adoption to achieve this goal. The basic scenarios were used to set this study's hypothetical annual trends in energy efficiency and estimated promotion costs.

4.2. Data Sources and Description

For this item, the initial results used here were obtained from an Energy Commission staff report by Mike Messenger (CEC 2003) in which new energy savings targets were proposed. This was followed by further analysis conducted jointly by CEC and CPUC, culminating in the adoption of new savings targets to 2013 by the CPUC (2004a, 2004b). The estimated savings for 2006–2008 only were incorporated in the California Energy Commission 2005 electricity and gas demand forecast (CEC 2005a). Note that the savings are in both electricity and natural gas demand.

5.0 Vehicle Tailpipe Efficiency

5.1. Scenario Description

This scenario evaluates AB 1493[1] (the Pavley bill of 2002), a bill that adopted GHG mitigation targets for automobiles sold in California.

5.2. Data Sources and Description

Data for all aspects of this scenario were obtained directly from published documents from the California Air Resources Board (CARB 2004a, 2004b). These include time series for vehicle adoption cost, GHG emissions reductions, and economic savings to owners of vehicles.

6.0 Heavy Duty Vehicle GHG Reduction Measures

6.1. Scenario Description

This scenario incorporates several possible measures, such as improved fuel economy, weight reduction, rolling and inertia resistance improvements, and an education program for heavy-duty vehicle operators.

6.2. Data Sources and Description

The primary data sources for this assessment were the petroleum dependence study (CEC-ARB 2003) and a study by the Center for Clean Air Policy (CCAP 2005a). The present analysis relies completely on ARB estimates of projected vehicle costs and savings in fuel and operating expense.

7.0 Hydrofluorocarbon (HFC) Reduction Strategy (bans on High GWP HFCs)

7.1. Scenario Description

The scenarios considered here cover refrigerant and cooling technologies in motor vehicle air conditioning systems (MVACs), with the overall objective of assessing economic effects of reducing HFC gas emissions. These emissions may not be large in volumetric terms, but the high global warming potential (GWP) values of HFC makes their mitigation a priority and a source of substantial CO_2 equivalent mitigation.

Three actual scenarios were examined:

- Improved HFC-134a in MVACs
- HFC-152a in MVACs
- CO_2 for New MVACs

[1] California Assembly Bill 1493 (AB 1493, Pavley, Chapter 200, Statutes of 2002)

7.2. Data Sources and Description

The HFC scenarios are calibrated to bottom-up data produced for the California Energy Commission by ICF Consulting provided in a report (ICF 2005a) and an accompanying spreadsheet (ICF 2005b). The report (ICF 2005a) assessed the cost and mitigation potentials of seven different categories of abatement measures related to the reduction of non-CO_2 GHGs. Data for several other measures incorporated in the CGE model, as described below, were also drawn from this report. The measures shown here were examined for the Pavley analysis (CARB 2004a). However, the CARB report does not provide individual cost information on the three measures in this set. ICF used the most current industry data available, which may differ from the Pavley analysis. ICF projects very little penetration of these technologies by 2010 but some appreciable impact by 2020. Expenditures are assumed to be borne by the automobile manufacturing industry for increased cost of equipment from air conditioning equipment providers. Detailed estimates of adoption costs and mitigation potential are given in the Refrigeration-AC spreadsheet of CACGE_Data.xls. The information provided in the ICF report readily enabled the estimation of key data points needed for the CGE model. Each section in the report, covering a different category of measures, includes a table of capital costs, annual costs, and annual benefits (where applicable) expressed in real 2000 dollars per annual metric ton of CO_2 equivalent avoided. Four additional tables display the annual reductions and break-even prices (calculated using the discounted abatement stream) for each measure. The four tables show the results using two sets of financial parameters (private cost, with a 20% discount rate and 40% tax rate; and social, with a 4% discount rate and 0% tax rate) for two different years (2010 and 2020). For the CGE model, the social cost tables were used. The product of expected annual reductions and the costs and benefits per ton yields the total capital outlay and total annual costs and benefits for each measure. As with the Winrock report, all costs and benefit figures in the ICF study were scaled from year 2000 dollars to real 2003 dollars.

8.0 HFC Reduction Strategy (Reduction of HFC Leakage and Releases)

8.1. Scenario Description

These scenarios extend the list in Section 3 above to stationary refrigeration systems.

Five specific scenarios were examined:

- Replace Direct Expansion (DX) with a Distributed System
- Secondary Loop
- Ammonia Secondary Loop
- Leak Repair
- Refrigerant Recovery

8.2. Data Sources and Description

Cost and reduction potential for these measures were drawn from the ICF (2005a, 2005b) report and spreadsheets described above. Three technologies for large stationary cold storage applications were examined: (1) distributed system coolers that use many compressors connected to a single cooling unit, (2) secondary loop systems with a short coolant loop that exchanges heat to a secondary loop with cooling fluid, and (3) a secondary loop with ammonia as the coolant. Two better practice measures were also analyzed: (1) leak reduction in large stationary systems, and (2) greater recovery of refrigerant during servicing and disposal of small equipment. Costs for these measures are assigned to the wholesale trade sector, because that is where most large stationary systems are located. Equipment revenues flow to the air conditioning equipment manufacturers. Calibration data are given (as in Section 3 above) in the Refrigeration-AC spreadsheet of CACGE_Data.xls.

9.0 Cement Industry Options

9.1. Scenario Description

The cement industry has levels of GHG emission that can be significantly mitigated by a small set of incentive compatible policies. These include increased use of limestone portland cement and blended cement, which account for 70% of the cumulative 38 million metric tons of CO_2 equivalent ($MMTCO_2eq$) reduction from all measures examined costing less than \$10/$MMTCO_2eq$. The use of waste tires as fuel accounts for an additional 10% of the reduction.

Fourteen measures were examined:

- Limestone Blended Cement
- Preventative Maintenance
- Process Control and Management
- Waste Tire Fuel
- Clinker Cooler Control
- On-line Kiln Feed Analyzer
- Kiln Shell Heat Loss Reduction
- Optimized Heat Recovery in Clinker Cooler
- Precalciner on Dry Preheater Kiln
- Planetary to Grate Cooler
- Seal Maintenance
- Blended Cements
- Long Dry to Preheater, Precalciner Kilns
- CemStar without License after 2014

9.2. Data Sources and Description

The primary data source is a report by the Center for Clean Air Policy (CCAP 2005b) and the spreadsheets that were used for their analysis (CCAP 2005c), detailing Marginal Abatement Cost (MAC) estimates for over thirty measures in the cement sector. Costs were expressed in 2003 dollars, so no adjustment for the CGE model was necessary. CCAP constructed three different MAC curves using discount rates of 4%, 7%, and 20%. To maintain consistency with the other types of measures used in the CGE model, the 4% rate scenario was used as the basis for this study's analysis. The stream of GHG savings was discounted for purposes of recalculating the annualized abatement costs in order to account for the reduced present value of the future carbon revenues. Because only three of the fourteen measures exhibit positive costs at the 4% discount rate, discounting does not have much impact on the adoption of these measures by the CGE model. Expenditures for equipment are mapped from the cement industry to the construction industry. Increased costs for improved maintenance procedures remain within the cement industry. In CACGE_Data.xls, the spreadsheet Cement contains the technical details derived from CCAP (2005a, b).

10.0 Blended Cement

10.1. Scenario Description

The CGE model project team was asked to analyze the impact of using of blended cement in order to reduce clinker fraction by 5% on average by 2020. Because a similar measure was included in the CCAP analysis (see Section 9), this scenario was not assessed separately.

10.2. Data Sources and Description

See Section 9.

11.0 Landfill and Manure Management

11.1. Scenario Description

Anaerobic decomposition of organic wastes or animal manure produces methane, a GHG with relatively high GWP. This gas can be captured with digester technologies in concentrated livestock production systems or landfill gas capture networks. The methane can then be flared, used for direct heat applications, or used to power generators to produce electricity. The objective of this scenario is to assess the economic effects of promoting such capture and dissipation strategies (e.g., the proposed San Joaquin Valley Rule 4570 to limit emissions of volatile organic compounds from confined animal facilities).

For Landfill Management, eleven scenarios are considered, depending on the scale of operation covered and the retention strategy:

Direct use of landfill gas – four scenarios

Scale by Landfill Capacity in Short Tons (WIP)	
> 1,000,000	Direct Gas
< 1,000,001	Direct Gas
< 500,001	Direct Gas
< 400,001	Direct Gas

Gas capture and electricity generation – seven scenarios

Scale by Landfill Capacity in Short Tons (WIP)	
> 1,000,000	Electricity
< 1,000,001	Electricity
< 500,001	Electricity
< 400,001	Electricity
< 300,001	Electricity
< 200,001	Electricity
< 100,001	Electricity

For Manure Management, eight measures in the dairy sector are included:

- Covered Lagoon, not Including Lagoon Cost – Large Dairy
- Covered Lagoon, Including Lagoon Cost – Large Dairy
- Plug Flow Digester – Medium Dairy
- 2-Stage Plug Flow Digester – Large Dairy
- Complete Mix Digester – Medium Dairy
- Covered Lagoon, not Including Lagoon Cost – Small Dairy
- Centralized Digester
- Covered Lagoon, Including Lagoon Cost – Small Dairy

11.2. Data Sources and Description

The ICF report provided the baseline data for this scenario (ICF 2005a), and the research team calibrated abatement using the MAC framework.[2] Methane emissions are measured in CO_2 equivalents; the demand for abatement technology is directed at the construction sector; captured gas and endogenous electricity from digesters and lagoons is consumed in the dairy sector (offsetting intermediate gas use in this sector); electricity is sold into the statewide grid; and digestate by-products are sold to the agricultural sector. The spreadsheets Manure Mgmt and Landfills in CACGE_Data.xls provides the calibration data, and additional background data are included in IMAC_Manure_Management_C.xls.

[2] Compare also EPA (1999).

12.0 Semiconductor Industry Targets (PFC Emissions)

12.1. Scenario Description

Measures to achieve the voluntary perfluorocarbon (PFC) reduction target set between the U.S. Environmental Protection Agency (EPA) and the Semiconductor Industry Association.

Five reduction measures were examined:

- Plasma Abatement
- Remote Clean
- Catalytic Abatement
- Capture/Recovery Using Membranes
- Thermal Destruction

12.2. Data Sources and Description

The ICF (2005a) report provides the baseline data for this scenario. ICF notes that U.S. semiconductor manufacturers (through a memorandum of understanding between the Semiconductor Industry Association and the EPA) have pledged to reduce PFC emissions to 10% below 1995 levels by 2010. Estimated PFC emissions from California semiconductor manufacturers were approximately 0.80 $MMTCO_2eq$ in 1995 (ICF 2005a). Assuming that California facilities decrease emissions in proportion to the national target, they could release only 0.72 $MMTCO_2eq$ in 2010. This amounts to a decrease of 78% below ICF's projected 2010 baseline. In the event of a future agreement that would seek to hold 2010 emissions constant through 2020, the California semiconductor industry would need to reduce PFC emissions by 91%, compared to ICF's 2020 baseline projections.

For the CGE model, this would mean that for 2010, the first three measures listed above need to be calibrated into the baseline and, for 2020, all semiconductor measures will be considered baseline. Increased costs for PFC abatement remain within the semiconductor manufacturing industry. The calibration data are included in the Semiconductor spreadsheet of CACGE_Data.xls.

13.0 Reforestation Projects

13.1. Scenario Description

Restoration of native tree cover in California.

13.2. Data Sources and Description

The primary data include MAC curves estimated by independent consultancies for the California Energy Commission (Energy Commission).[3] The main resource for the current estimation is a report by Winrock International (Winrock 2004), which provides extensive bottom-up data on sequestration potential from afforestation.

This study derived MAC estimates from total capital costs, opportunity costs of foregone grazing, and ongoing operation and maintenance (O&M) costs for any given afforestation measure. Calculations of carbon break-even prices were used to guide the choices of cost-effective measures to include in the CGE modeling runs.[4] The CGE model needs information on implementation expenditures for each measure, as well as what it costs to maintain it over time. To calibrate these costs in a dynamic setting, the research team attempted to derive the necessary data (for the three cost levels shown at $2.70, $5.50, and $13.60 per metric ton of CO_2) from Winrock (2004) using the cost data on pages 90 and 91, matched to Table S-1 and 2-6 and Figures 2-29 and 2-30. The original Winrock data do not discount carbon flows over time for purposes of calculating the break-even carbon price, so the research team ran the calculations both with and without discounting the future carbon sequestered.[5] Current estimates are posted in the Afforestation spreadsheet of the CGE model Excel spreadsheet data file (CACGE_Data.xls).

The costs given in Winrock (2004) are in year 2000 dollars. In order to make these costs compatible with the core economic data used by the CGE model, the research team converted these figures to 2003 dollars using a gross state product (GSP) deflator series compiled by the California Department of Finance (CDOF 2005) from the U.S. Bureau of Economic Analysis data. This deflator was applied to the costs for conversion, maintenance, measurement, and monitoring.

Annual opportunity costs, defined as the annual foregone profits from cattle grazing, are discussed in Winrock (2004) but are not shown for the specific break-even levels for which other data are given. These values were derived by balancing the equation for the break-even prices with the other parameters such that the sum of the present values of all costs divided by the expected total tons sequestered matched the break-even carbon prices shown in Table S-1 of the Winrock (2004) report. Expenditures for land conversion, maintenance, measurement, and monitoring are assumed to flow from the livestock cattle sector to the forestry sector.

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[3] MACs are surveyed in many sources in the economic literature. See, e.g., Baumol and Oates (1992) or McKitrick (1999).

[4] The break-even carbon price is the value per unit of avoided GHG emissions (generally per metric ton of CO_2 equivalent) at which present value lifetime benefits of GHG mitigation measure equal the present value of lifetime costs. Often this is calculated as the difference of the present value of costs and benefits divided by lifetime GHG savings.

[5] The rationale for discounting the stream of GHG savings in the denominator is to account for the fact that future revenues (or avoided taxes) from abating emissions are worth less in the present, due to discounting.

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Appendix A
Scenarios Deferred for Later Analysis

Scenarios discussed in the main body of this work are those that met empirical standards for modeling specification and short term data availability. These are only part of a much larger universe of issues appropriate to the CGE model policy simulation facility, however, and the model is expected to yield more extensive and intensive insights as the scope of its application increases. In particular, the research team hopes to extend the model to a series of scenarios about which Cal/EPA has already expressed interest. For the moment, however, more precise specification or data are needed before these experiments can be reliably conducted. The following annotated scenario list explains what would be needed to responsibly address the remaining policy questions posed by Cal/EPA.

1A Forest Management

1.1A Scenario Description

Harvest and regeneration of native trees. Unlike CalEPA-2 (described in Section 2.0 above), afforestation of rangeland, this policy calls for relatively complex adjustments in the state timber portfolio.

1.2A Specification Issues

Specification of heterogeneous timber stocks with stratification of harvest schedules.

1.3A Data Needs

Costs, benefits to mandating older harvest ages, reduced harvest yield tax for harvesting of older trees, cap and trade program. No targets or numbers were specified in the Winrock (2004) report, only activities.

2A Conservation Projects

2.1A Scenario Description

Prevention of conversion of native forests to non-forest use.

2.2A Specification Issues

Some set of alternative uses, defined in conformity with the social accounting matrix (SAM) sectoring scheme that can be used to establish opportunity costs for conservation and land set asides.

2.3A Data Needs

Costs, percent increase investment in conservation easements, cap and trade. No targets or numbers specified in the report, only activities. More detailed schedules of alternative uses and opportunity costs are also needed.

3A Biodiesel Blends

3.1A Scenario Description

Diesel fuel blending with renewal source fuels.

3.2A Specification Issues

Not significant.

3.3A Data Needs

More detailed adoption cost data.

4A Jet Fuel Reduction Options

4.1A Scenario Description

Institutional reforms and engineering innovations to improve jet fuel use efficiency. Includes improved communication and management systems, improved aerodynamics, reduced weight, increased maintenance, early retirement of aging planes. This scenario is mooted by lack of state authority to implement commercial aviation standards.

4.2A Specification Issues

Not too significant. Recalibration of existing productivity parameters in air transport.

4.3A Data Needs

Detailed cost information on reform, research and development, and technology adoption.

5A Road to Rail

5.1A Scenario Description

Increase dock-side rail access, improvements to efficiency to speed rail movement, I-5 corridor container movement.

5.2A Specification Issues

Recalibrate productivity parameters in the rail transport sector, as well as input-output flow coefficients between transport service modes.

5.3A Data Needs

Detailed cost estimates for implied infrastructure commitments.

6A Ethanol Fuel for Light Duty Vehicles

6.1A Scenario Description

Maximize use of ethanol to achieve GHG reductions (focus on biomass ethanol used in E85 vehicles)

6.2A Specification Issues

Not significant.

6.3A Data Needs

Detailed cost and efficiency information for alternative adoption scenarios.

7A Transport Refrigeration Units – Electric Standby

7.1A Scenario Description

Require all new Transport Refrigeration Units (TRUs) to have electric standby; require cold storage facilities to install electric infrastructure to support

7.2A Specification Issues

Not significant.

7.3A Data Needs

Detailed cost estimates for adoption and implied infrastructure commitments.

8A Port Electrification

8.1A Scenario Description

Phase in of vessels and infrastructure to support shore side power use

8.2A Specification Issues

Recalibration of productivity and input-output parameters.

8.3A Data Needs

Detailed cost estimates for adoption and implied infrastructure commitments.

9A Stationary Agricultural Engine Electrification

9.1A Scenario Description

Combination of regulatory and incentive approaches. Outreach to encourage replacement of diesel with electric.

9.2A Specification Issues

Not significant.

9.3A Data Needs

Detailed adoption cost and efficiency estimates.

10A Fuel Efficient Tire Program

10.1A Scenario Description

Fuel efficiency standards for vehicle tires.

10.2A Specification Issues

Not significant.

10.3A Data Needs

Engineering estimates of tire-fuel efficiency linkage. Adoption and R&D cost estimates.

11A Caltrans – Travel Reduction

11.1A Scenario Description

Additional travel reduction measures. Currently, this proposal is quite vague—not so much a specific proposal as a collection of concepts said to be considered under the governor's "Go California" transport initiative.

11.2A Specification Issues

Significant challenges to specifying the infrastructure-fuel efficiency linkage.

11.3A Data Needs

Technical and cost-effectiveness analyses are said to be "under way."

12A CA High Speed Rail Authority

12.1A Scenario Description

High-speed rail links from Sacramento to the San Francisco Bay to Los Angeles and San Diego.

12.2A Specification Issues

Not significant.

12.3A Data Needs

Extensive information on development, infrastructure, and adoption costs. A very far-reaching project with many spillovers and extensive specific data requirements.

13A Building, Transportation, and Housing Agency

13.1A Scenario Description

Reducing venting and leaks in oil and gas systems

13.2A Specification Issues

Not significant.

13.3A Data Needs

Need more cost information.

14A Smart Growth

14.1A Scenario Description

Integrated transport and land use planning to reduce number of vehicle miles traveled.

14.2A Specification Issues

Very challenging in the short run. Greater heterogeneity needs to be specified in the transport sector and locational modeling needs to be advanced.

14.3A Data Needs

Much more detailed data are needed than have been used for previous estimates (e.g., Bailie et al. 2004).

15A Industrial Carbon Policy

15.1A Scenario Description

A nebulous plan to develop a strategy to reduce carbon intensity in industrial production.

15.2A Specification Issues

The current scenario description lacks sufficient detail to be modeled.

15.3A Data Needs

Data requirements will be driven by the specification choice.

16A Pay-as-You-Drive Automobile Insurance

16.1A Scenario Description

Link insurance payments to miles driven, overcoming the current situation where insurance is largely not reflected in the marginal cost of driving

16.2A Specification Issues

Not too significant. Behavioral links between miles driven and marginal cost are empirically quite controversial, however.

16.3A Data Needs

Extensive data to calibrate coverage cost per mile across the CGE model income deciles.

17A Municipal Utility Combined Heat and Power Initiative

17.1A Scenario Description

Presented as a new, separate proposal, though it overlaps extensively with Scenario 30A. Different only in its focus on municipal utilities as opposed to investor-owned utilities.

17.2A Specification Issues

Similar to the allocation across sectors as described in Section 31.2A.

17.3A Data Needs

Cost data and penetration potentials as distinct from those analyzed for scenario 31A.

18A Accelerated Renewable Portfolio Standard

18.1A Scenario Description

20% renewable for all load serving entities by 2010, and 33% by 2020. 2010 number already included in 2003 Energy Action Plan and 2020 number in 2005 draft Energy Action Plan II.

18.2A Specification Issues

Requires more detailed specification of the electricity generation sector, where producer heterogeneity is very important to the adjustment process.

18.3A Data Needs

More extensive cost and efficiency data, particularly by scale and choice of technology.

19A Electricity Sector Carbon Policy

19.1A Scenario Description

Reduce electricity imports from out of state coal-fired generation.

19.2A Specification Issues

Not appropriate to a state economy model. Out of state effluent mix can be taken into account, but is exogenous to the model unless energy imports are differentiated by source.

19.3A Data Needs

Extensive cost-benefit data on out-of-state source technologies and adoption possibilities.

20A ARB – Natural Gas Flaring (ARB 2-15)

20.1A Scenario Description

The California Air Resources Board would help target GHG reductions through development of suggested control measures to be considered for adoption by the districts.

20.2A Specification Issues

Initial work needed to determine prevalence of venting and flaring of natural gas from crude oil production in California.

20.3A Data Needs

Extensive engineering and cost data needed.

21A Statewide 50% Recycling Goal

21.1A Scenario Description

Increase recycling to reduce GHG emissions associated with energy-intensive material extraction and production, as well as reduced methane emissions from landfills.

21.2A Specification Issues

The GHG savings seem very uncertain, and there are no reliable substitution estimates. Proposal lists 7 tasks to achieve the GHG reductions, with the last being measurement of the reductions.

21.3A Data Needs

Quantitative data linking recycled materials to a reduction of in-state production of virgin materials and the associated GHG impacts.

22A Zero Waste / High Recycling Strategies

22.1A Scenario Description

Companion measure to 50% recycling measure.

22.2A Specification Issues

As above, quite vague on technical and even programmatic details.

22.3A Data Needs

Recycling's links to GHG have very weak empirical support.

23A Alternative Fuels for Transportation

23.1A Scenario Description

Increase use of non-petroleum in the transport sector.

23.2A Specification Issues

New as a stand-alone proposal from the Energy Commission, but overlaps with ARB transport proposals. No specifics in the proposal, though the Energy Commission has analyzed the potential savings elsewhere.

23.3A Data Needs

Cost data and potential consumption.

24A Additional Publicly Owned Utility Energy Efficiency Programs

24.1A Scenario Description

Further energy efficiency programs—no specifics on how to achieve the reductions. Implementation is to be left to utilities, although the policy options are already well characterized.

24.2A Specification Issues

An allocation of efficiency targets by sector to enable modeling in the SAM framework.

24.3A Data Needs

These seem to be rough estimates of emissions benefits. Proposal notes that new data available in late 2005 will be used to reassess the savings. Additional data on implementation costs would be needed.

25A Energy Efficiency Programs (part of combined CPUC Climate Action Team (CAT) Workplan).

25.1A Scenario Description

Unlike the energy efficiency scenarios (Sections 2.0, 3.0, and 4) included in the current analysis, these measures still need clarification and more data development. Bailie et al. (2004) estimates are de-emphasized and PUC's own analysis added. The types of energy efficiency to be promoted are not explained, though the implication is that they are "cost effective," e.g., presumably have greater savings in energy costs than additional up front costs. These are cost-effective measures in principle, but much work is needed to assess them empirically.

25.2A Specification Issues

An allocation of efficiency targets by sector to enable modeling in the SAM framework.

25.3A Data Needs

Need extensive cost-benefit data.

26A Additional Energy Efficiency Programs (part of combined CPUC CAT Workplan)

26.1A Scenario Description

No substantive changes, though a new treatment of this proposal is included from the Energy Commission. Types of energy efficiency to be promoted not yet decided, though distinguished from measures described in Sections 2.0, 3.0, and 4 as not-cost effective.

26.2A Specification Issues

An allocation of efficiency targets by sector to enable modeling in the SAM framework.

26.3A Data Needs

Need extensive cost-benefit data.

27A Accelerating Renewable Development by Municipal Utilities

27.1A Scenario Description

Increase to 33% the amount of electricity generated from renewable sources for publicly owned utilities. Overlaps with scenario 28 below.

27.2A Specification Issues

Requires more detailed specification of the electricity generation sector, where producer heterogeneity is very important to the adjustment process.

27.3A Data Needs

More extensive cost and efficiency data, particularly by scale and choice of technology.

28A Accelerated Renewable Portfolio Standard (part of combined CPUC CAT Workplan)

28.1A Scenario Description

Some new discussion of implementation, but no new technical details – overlaps with scenarios 18A, 19A, and 27A.

28.2A Specification Issues

Requires more detailed specification of the electricity generation sector, where producer heterogeneity is very important to the adjustment process.

28.3A Data Needs

More extensive cost and efficiency data, particularly by scale and choice of technology.

29A Reduction of GHG Emissions through Water Use Efficiency Measures

29.1A Scenario Description

Reduced greenhouse gas emissions associated with water sector through conservation of water and investment in low energy intensity technology.

29.2A Specification Issues

Water resources are outside the scope of this year's CGE model development program.

29.3A Data Needs

Cost data and on the measures to be implemented and estimated energy savings.

30A Combined Heat and Power Initiative (new part of combined CPUC CAT Workplan)

30.1A Scenario Description

Promote commercial and industrial use of on-site power generation for both electricity and heat outputs. Overlaps with 17A and 31A.

30.2A Specification Issues

Similar to the allocation across sectors as described in Section 31.2A.

30.3A Data Needs

Cost data and penetration potentials as distinct from those analyzed for scenario 31A.

31A Combined Heat and Power Initiative

31.1A Scenario Description

Promote commercial and industrial use of on-site power generation for both electricity and heat outputs. (Reduces transmission losses and reduces demand for heat from other sources.) This scenario was not included in the latest analysis because the research team is still developing detailed data on patterns of adoption and displaced generation capacity.

Four technologies, each of various sizes were analyzed:

- Reciprocating Engines
- Microturbines ($\leq$ 70 kW)
- Fuel Cells
- Gas Turbines

31.2A Data Sources and Description

The main data components for these scenarios relate to sectoral patterns of combined heat and power (CHP) technology adoption and the way in which this adoption displaces incumbent capacity in the electricity generation sector. This study assumes that fuels used by CHP technologies are the same as those used by California generators (i.e., natural gas), although quantities used will differ, and from this, proceeds to develop adoption schedules by sector, as well as displacement schedules by type of generator, using data provided under Energy Commission contract by Energy and

Environmental Analysis, Inc. in collaboration with the Electric Power Research Institute (EEA 2005a, 2005b).

The data provided by EEA allocate the expected adoption of CHP capacity across 37 industry and service sector categories. These data were mapped over to the CGE model sectors to model the expenditure flows. EEA did not provide data on MACs of each measure per se. These were derived from EEA estimates of capital cost, incentive payment, O&M costs, fuel consumption, avoided boiler fuel consumption, and estimated CO_2 savings. Cost and benefits are discounted at 4% over the economic lifetime of the technology, shown in Appendix F of the report (EEA 2005a) (10 years for technologies with < 1 megawatt (MW) capacity and 15 years for technologies with ≥ 1 MW). Costs for this measure are dispersed across all 37 economic sectors on the basis of the relative shares of technical potential for CHP capacity. Expenditures flow from the industry installing the CHP to the construction sector.

EEA calculates CO_2 savings as the avoided boiler fuel that would be used by a standard boiler instead of the CHP unit, plus the fuel that would have been used to generate the offset electricity, minus the actual fuel used. The efficiency of boilers replaced by CHP units is assumed to be 80%. EEA assumes that gas-fired electricity is offset by on-site CHP generation. The emission rate used for determining the avoided emissions from reduced use of grid electricity is based on the average heat rate of gas generation in California (10,121 Btu/kWh) and 7% average transmission and distribution losses. Future use of the EEA data may use a more sophisticated representation of the emissions associated with grid-based electricity.

32A Solar PV Buildings Initiative

32.1A Scenario Description

This initiative is typified by a proposal for one million solar roofs on homes and businesses and increased use of solar thermal heating of air and water for residential and commercial use.

32.2A Data Sources and Description

Data sources consist of time trends for new housing starts and remodels, as well as data on new commercial real estate development. These are obtained from a combination of private gas and electric interests (e.g., PG&E) and state population and enterprise datasets.

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Appendix B
CGE Model Scenarios in the Context of Other GHG Initiatives

This study reports on a subset of the GHG mitigation scenarios under active consideration by state agencies. In subsequent work, the universe of CGE model applications will expand to include most policies covered in the CAT report (Cal/EPA 2005) and a variety of others being discussed elsewhere. This appendix makes more explicit the relationship between the CAT scenarios and our own, but in the medium term, the CGE model will also be applied to other areas, including:

- Cap and trade mechanisms
- Increased use of combined heat and power
- Carbon capture in agricultural soils
- Reduction of nitrous oxide (N_2O) emissions from farming operations
- Increased penetration of photovoltaic (PV) units
- Increased recycling requirements

The CGE model is calibrated to a variety of independently developed data sources reflecting the microeconomic characteristics of climate change policies. Most of this information was obtained from research commissioned by the Energy Commission, including a variety of sector studies that provide detailed bottom-up information on the costs of GHG abatement. It is important to make the relationship between the CGE model scenarios and those under evaluation by the Climate Action Team more transparent. As reflected in their December draft report, CAT looks at a larger number of scenarios than does the present CGE model application. For those policies that are common to both studies, CAT also appears to rely on different underlying data and prescribes different levels of GHG mitigation for most sectors considered.

To make the results more comparable, the research team produced two versions of each of the common scenarios described as "Necessary" by CAT (Table ES-3 in their report). In a first set of scenario runs, termed *Moderate* in scope, the CGE model was run to attain mitigation levels comparable to CAT prescriptions. Because most of the CGE model's bottom-up data sources indicate greater mitigation potential for the same scenarios, the team then ran a second scenario, termed *Ambitious,* to estimate its economic impacts. The two approaches are compared in Table A2.1 below, with an indication of the feasibility of generating CGE model estimates for the other CAT scenarios.

Table B.1 CAT and UC Berkeley Scenarios Compared

Strategy Name	CAT (Moderate)			BEAR (Ambitious)			
	2010[a]	2020	Percent of 2020[b]	2010	2020	Percent of 2020	Feasible to model
Other New Light Duty Vehicle Technology Improvements	**0**	**4**	**3%**				**Yes**
HFC Reductions	**3.4**	**8.5**	**7%**	**1**	**6**	**6%**	**Yes**
Transport Refrigeration, Off-Road and Port Electrification	**< 1**	**< 1**					
Manure Management	**0**	**1**	**1%**	**6**	**6**	**6%**	
Semiconductor Industry Targets (PFCs)	**2**	**2**	**2%**	**2**	**3**	**3%**	
Alternative Fuels: Biodiesel Blends	**< 1**	**< 1**					**Yes**
Alternative Fuels: Ethanol	**< 1**	**2.7**	**2%**				**Yes**
Heavy Duty Vehicle Emission Reductions	**0**	**3**	**3%**				**Yes**
Reduced Venting and Leaks in Oil and Gas Systems	**1**	**1**	**1%**				**Yes**
IOU Additional Energy Efficiency Programs/ Demand Response	**n.a.**	**6.3**	**5%**				
IOU Combined Heat and Power Initiative	**1.1**	**4.4**	**4%**				**Yes**
IOU Electricity Sector Carbon Policy	**1.6**	**2.7**	**2%**				**Not clear**
Landfill Methane Capture	**2**	**3**	**3%**	**9**	**8**	**7%**	
Zero Waste—High Recycling	**0**	**3**	**3%**				
Forest Management	**1–2**	**3–4**	**3–4%**				**Not clear**
Forest Conservation	**4.2**	**8.4**	**7%**				**Not clear**
Fuels Management/Biomass	**3.4**	**6.8**	**6%**				**Not clear**
Urban Forestry	**0**	**3.5**	**3%**				**Not clear**
Afforestation (planting trees)/ Reforestation	**0**	**12.5**	**11%**	**17**	**83**	**76%**	
Water Use Efficiency	**< 1**	**1.2**	**1%**				
Building Efficiency Standards	**TBD**	**TBD**					**Not clear**
Appliance Efficiency Standards	**TBD**	**TBD**					**Not clear**
Cement Manufacturing	**< 1**	**< 1**		**2**	**3**	**3%**	
Municipal Utility Energy Efficiency Programs/ Demand Response	**1**	**5.9**	**5%**				**Yes**
Municipal Utility RPS	**< 1**	**3.2**	**3%**				**Yes**
Municipal Utility Combined Heat and Power	**0**	**< 1**					**Yes**
Municipal Utility Electricity Sector Carbon Policy	**3**	**9**	**8%**				**Yes**
Alternative Fuels: Non-Petroleum Fuels	**TBD**	**TBD**					**Yes**
Transportation Policy Implementation	**"still being considered"**						
Measures to Improve Transportation Energy Efficiency	**1.8**	**9**	**8%**				**Yes**
Smart Land Use and Intelligent Transportation	**5.5**	**18**	**15%**				**Not clear**
Conservation Tillage/ Cover Crops	**TBD**	**TBD**					
Enteric Fermentation	**< 1**	**< 1**					
Total Potential Emission Reductions	**35–40**	**115–120**	**106–110**	**37**	**109**	**100**	

[a] Figures are reported in million metric tons of CO_2 equivalent.
[b] Shown as a percentage of the total 2020 Ambitious scenario GHG reductions.

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Data Sources Used in the CGE Modeling for the UC Berkeley Climate Change Center Study *Managing Greenhouse Gas Emissions in California*

CACGE_Data.xls