Draft CEC PIER-EA Discussion Paper

Economics of Mitigation and Adaptation

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Disclaimer

The purpose of this paper is to inform discussions among CEC staff, other state agency staff, non-governmental representatives, representatives of academia and other stakeholders regarding the state of the research on the economics of greenhouse gas (GHG) mitigation and climate change adaptation in California. In particular, this discussion paper will identify gaps in our understanding and recommendations for future research initiatives with the end goal of supporting informed and systematic planning for climate change. Note that this paper is not intended as a research proposal and should not include recommendations regarding specific research projects.

1.0 Description of Research Topic

In the past several years, the State of California has undertaken an unprecedented set of initiatives to reduce its emissions of carbon dioxide and other greenhouse gases (GHGs) in the near and long term. Economic methods and information are core components of the analysis supporting this multi-agency, multi-stakeholder effort. At the same time, it is now well established that climate change will pose risks to California's natural and engineered environment over the coming century that under certain conditions could result in substantial economic costs to the state's households and businesses. Understanding these risks, and determining how best to address them, also requires the application of economic methods, in conjunction with those of the natural sciences and engineering.

To date, California's GHG mitigation and climate change adaptation planning and policy-making has drawn upon, among other sources, the results of PIER-supported research, which has itself built upon a large knowledge base in basic and applied environmental and energy economics developed over several decades. The need to enlarge and refine this knowledge base continues to grow as policy-making evolves and as scientific understanding of climate change increases.

2.0 Summary of PIER Program Research and Accomplishments to Date on the Economics of Mitigation and Adaptation

The economics component of the 2003 PIER climate change research plan identified the following nine topics as priority research areas in the economics of GHG mitigation and climate change adaptation in California (Sanstad, 2003):

- Computational modeling and decision analysis, emphasizing uncertainty analysis and robust decision-making.
- Climate change impacts and adaptation, emphasizing risks from potential abrupt and/or extreme events.
- Economics of energy efficiency.

- Technological change.
- Information technology and energy.
- Revenue recycling, i.e., the use of proceeds from GHG emissions taxes or the auctioning of tradable emissions permits.
- Air quality and GHG abatement.
- Regional permit trading.
- Cost estimation for the abatement of non-CO_2 GHGs.

Overall, PIER has successfully planned and implemented a research portfolio encompassing projects in most of these categories. A number of these projects have provided timely and valuable results for California state agencies' GHG mitigation and climate change adaptation policy-making. The following section summarizes PIER's accomplishments in key areas.

Computational economic modeling

An existing computable general equilibrium (CGE) model of the California economy, the "EDRAM" (Environmental Dynamic Revenue Analysis Model) model, was enhanced to improve its applicability to GHG mitigation analysis; this work focused on developing a new comprehensive database (called a "social accounting matrix") for the model, including energy flows (Berck et al., 2008). Simultaneously, a new California CGE model, "BEAR" (Berkeley Energy and Resources), was created to expand the set of tools available to California policy makers for formulating GHG mitigation policies (Murtishaw and Roland-Holst, 2007). A preliminary assessment was conducted of the aggregate economic effects of statewide GHG reduction policies, including the potential benefits from recycling of revenues from a hypothetical California GHG emissions trading system (Roland-Holst, 2006).

Regional emissions permit trading

Existing examples of emissions trading systems—in California, nationally, and in Europe—were reviewed to draw key lessons for the design and implementation of a GHG emissions trading policy in California (Farrell, 2005a). The detailed evolution of a specific system—for the control of nitrogen oxide emissions from electric power plants in the Northeastern United States—was analyzed for the applicability of its design to a California electricity GHG trading scheme (Farrell, 2005b).

Climate change impacts and adaptation

Dale et al. (2005) analyzed the historical relationship between the reliability of agricultural water supply and the value of irrigated farmland in California; this work provided evidence that changes in water reliability patterns may be a key mechanism by which climate change could affect the state's agricultural output and economic viability. Dale et al. (2006) conducted a scenario study of the implications of a specific global GHG emissions scenario on California's water supply (the "A2" scenario from the *Special Report on Emissions Scenarios* of the Intergovernmental Panel on Climate Change); this work provided a partial analysis of the potential economic costs to Central Valley agricultural water users and South Coast urban water users from a climate change-induced reduction in water supply. In another study (Vicuña et al., 2006), the potential economic costs of increased levee-failure probability due to climate change were

analyzed, taking account of the joint economic effects of levee failures and droughts. Finally, another project examined the climate change-related information environment of California's coastal managers, who will play a central, if not paramount, role in planning for potential impacts of sea-level rise (Moser and Tribbia, 2007). Among other findings was the need for new resources, institutional mechanisms, and methods to provide these managers with usable information, and to better apply climate science to support them.

Technological change

Several studies were conducted of the complex interplay among government policy, market forces, and technological innovation related to energy and pollution control (Taylor et al., 2006; 2007). The first study examined how government actions have spurred innovation in selective catalytic reduction for controlling nitrogen oxide emissions from electric power plants and in wind power technology. The second study focused on policy and innovation in photovoltaic cells, solar thermal electric power, and solar water heating.

Non-CO_2 gases

Costs and benefits were estimated for 59 reduction options for non-CO_2 gases, under varying assumptions regarding discount and tax rates and planning horizons (Choate et al., 2005).

Carbon sequestration

Cost curves were constructed for sequestering carbon through forest management, rangeland afforestation, and agricultural practices in California (Brown et al., 2004). A lower bound was estimated for the cost of forest sequestration across several management options. Conservation tillage was identified as offering the highest potential for agricultural sequestration. A follow-up study refined the analysis with enhanced data and methods, and assessed the carbon-reducing possibilities of hazardous fuel reduction (Petrova et al., 2006). The approach taken in these studies was subsequently extended to analyses focusing on Oregon and California (Dushku et al., 2007a; 2007b), as well as on a detailed assessment of sequestration potential in Shasta County, California (Martin et al., 2007; Winrock International, 2007). Concurrently, a comprehensive assessment was conducted of primary sources and potential sinks for terrestrial sequestration in the West Coast Regional Carbon Sequestration Partnership (WESTCARB) region, including estimation of sequestration cost curves for California (Herzog et al., 2007).

Decision-making under uncertainty

An innovative decision-support system for optimal management of Northern California reservoirs under uncertainty was developed and underwent prototyping and feasibility testing (Georgakakos et al., 2005; 2007). This system integrated probabilistic climate and meteorological information, water demand forecasting, economic inputs, and other information in a decision analysis framework.

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3.0 Non-PIER Accomplishments in this Area and Opportunities for Collaboration

Basic and applied research on the economics of GHG mitigation and climate change impact adaptation is proliferating rapidly as governments and other entities around the world accelerate their efforts to address the risks of global climate change. The following is by no means an exhaustive list of non-PIER activities, but is a selection of those that are particularly relevant to PIER.

Energy efficiency

To support its emerging initiatives for substantially increased deployment of energy efficiency in California, the California Public Utilities Commission (CPUC) is sponsoring research on consumer behavior in relation to adoption of efficient technology and the design and effectiveness of utility demand-side management programs. This program is being administered by the University of California Office of the President's California Institute for Energy & Environment, which has also begun co-organizing and sponsoring annual conferences on "Behavior and Climate Change." Broadly speaking, these efforts are aimed at reviving the research area of non-economic social science energy analysis that emerged in the 1970s and 1980s but significantly attenuated thereafter.

In 2006, Stanford University inaugurated the Precourt Institute for Energy Efficiency to organize and support multi-disciplinary research to promote energy efficient technology and practices. (It should be noted that research funding from the Institute is restricted to Stanford faculty and students.) The Institute's areas of activity include buildings, transportation, and energy systems, and encompass both economic and engineering research, among other approaches.

Information technology and energy demand

While currently addressed primarily to demand response and system reliability goals, California's Advanced Metering Initiative has potentially significant longer-term implications for energy consumption and the technological, market, and regulatory environment for GHG emissions abatement policies. Among the ongoing relevant efforts are those of the Load Management Standards Proceeding (Docket # 080-DR-01), which among other activities, is studying consumer decision-making in relation to energy-applied information technology. In addition, California investor-owned utilities and other private firms are pursuing development and demonstration projects on the deployment of such technology in households and businesses.

Uncertainty analysis and modeling

In the course of preparing the 2007 Integrated Energy Policy Report (IEPR), the Energy Commission conducted several innovative studies applying uncertainty modeling to GHG mitigation in the electric power sector and to power planning under policy requirements. One of these was a multiple scenario analysis of combinations of options for meeting electricity GHG emissions reduction targets in the year 2020 (Jaske, 2007). The other was a portfolio analysis of long-run utility procurement plans (Ringer, 2007).

In its Proceeding # 08-02-007, the CPUC begun a multi-party assessment of options for addressing uncertainty related to GHG emissions and policies in investor-owned utilities' long-term procurement and resource adequacy planning. Uncertainty

modeling and analysis is also being considered by the Energy Commission as a possible focus in the 2009 IEPR. A group of Northern California research institutions has developed an approach to long-run GHG mitigation analysis that both addresses key uncertainties and exploits the capabilities of existing modeling tools (Sanstad, 2007). A forthcoming report under the auspices of the multi-agency U. S. Climate Change Science Program (CCSP) is also of interest; currently in the review phase, the report will focus on incorporating uncertainty into climate-related decision-making. A related report of the CCSP recently addressed both scenario methodology and integrated assessment of global CO_2 stabilization scenarios, and directly and indirectly dealt with uncertainty in long-run analyses of climate change and GHG mitigation economics (CCSP, 2007).

Impact assessment and adaptation analysis

Increasing recognition of the inevitability of some climate change effects on biophysical systems and human society is being reflected in work around the world to support decision-makers in assimilating uncertainty information on potential climate change impacts and mitigation or coping strategies. One noteworthy example is a study of the increased vulnerability of New York City to storms and sea-level rise resulting from climate change (Gornitz et al., 2006). This study included the provision of probabilistic information to stakeholders evaluating coastal infrastructure options for impact mitigation. The CCSP has recently released a comprehensive assessment of the state-of-knowledge of potential climate change impacts and adaptation issues related to climate sensitive ecosystems and resources nationally and regionally (CCSP, 2008).

Quantitative decision support

An innovative project of the CPUC has developed and applied a GHG emissions analysis and cost-effectiveness model of the Western electric power system that is a "reduced form" of an extremely detailed planning and operations model (E3, 2007). This reduced form (designated the "GHG Calculator") is designed to be accessible to non-specialists, flexible, and relatively transparent while incorporating the maximum possible range of information in simplified form.

4.0 Research Underway/Committed to via PIER Process

PIER has underway or is committed to a number of research projects that extend or complement its previous efforts. These are primarily focused on GHG mitigation, and include the following:

Carbon sequestration

Carbon sequestration potential in Central Valley agricultural soils will be quantified using a biophysical soil model previously developed, validated, and applied to Yolo County with co-funding from PIER. This analysis will be extended to other counties, and will yield supply curves associated with different management practices.

Combined Heat and Power (CHP) and GHG emissions

Emissions reduction potential from accelerating deployment of CHP technologies in California's small commercial, residential, and light industrial sectors will be analyzed using a micro-scale optimization model.

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Energy efficiency codes and standards

Improved estimates of the historical effects of efficiency codes and standards on electricity consumption in California's residential sector will be calculated. These estimates will support current regulatory analysis for expanding and strengthening codes and standards to meet GHG mitigation targets.

Quantitative decision support

A computational and decision analysis framework for economic simulation model assessment and multi-model integration will be developed and prototyped. This framework will support joint agency Assembly Bill 32 (AB 32) implementation planning.

Sectoral-specific mitigation

In-depth case studies of GHG emission reduction options available to different sectors of the state economy will be conducted, applying an interdisciplinary technical and economic approach and identifying implementation barriers and strategies for overcoming them. A co-benefit will be proof-of-concept demonstration of the utility of case studies for policy formulation in California.

5.0 Gaps in Research/Knowledge Relevant to California

There are several dimensions of knowledge or research gaps relevant to California in the area of economics. As the implementation of AB 32 and other emissions mitigation policies proceeds, there is an ongoing and indeed expanding need for detailed data on the emissions reduction potential and costs of abatement technologies, measures, and programs in specific sectors and sub-sectors. However, it is also the case that PIER alone cannot fill this need completely within its budgetary and mission constraints, and that other agencies and stakeholders are increasing their efforts to develop this kind of information. In addition, new research frontiers are emerging as scientific knowledge progresses and the needs of policy making increase.

The most relevant knowledge or research gaps are those that PIER is uniquely positioned to address by virtue of its role as a publicly-sponsored research entity (as opposed to an applied policy-making entity), and given the expanding resources available elsewhere for developing specific elements of the knowledge base. The following topics are consistent with this criterion.

The highest priority economics research topic identified in the 2003 PIER Strategic Plan was "Computational and Decision Analysis Tools for Integrated Risk Assessment," the discussion of which concluded in part with the following statement:

> "In summary, there is a critical need for research to develop different theoretical and computational possibilities for an integrated modeling capability that allows for both conventional and deep uncertainty, the analysis of robust strategies, and computationally intensive scenario analysis combining market and non-market elements" (Sanstad, 2003; p. 14).

The 2003 discussion of issues and recommendations remain valid today; indeed, developments in modeling and policy analysis during the intervening years have provided even further evidence for the importance of this research area. In the field of economic model-based GHG mitigation analysis, there remain significant and

unresolved inter-model differences in cost estimates, among other outputs—even after more than three decades of economic model development and engineering cost studies focused on energy and GHG emissions. This uncertainty has become a matter of considerable practical import, as the U. S. Congress and Executive Branch administrative agencies attempt to formulate long-run, national emissions reduction policy. As Fischer and Morgenstern (2006) point out, first-order uncertainty in the prospective costs of policies impedes progress towards emissions mitigation, as decision-makers are understandably reluctant to commit significant societal resources when the potential economic consequences are so imperfectly understood.

In reviewing six economic modeling studies of the potential costs of Senate bill S. 2191 (the Lieberman-Warner Climate Security Act of 2007), Parker and Yacobucci (2008) observe that

> "It is difficult (and some would consider it unwise) to project costs up to the year 2030, much less beyond...***Long-term cost projections are at best speculative, and should be viewed with attentive skepticism***" (emphasis in original).

The most important characteristic of climate change and GHG-related long-run economic issues is pervasive and fundamental uncertainty, in both physical changes in the climate and the evolution of society and the economy. There is no method or technique that can eliminate either short- or long-run uncertainty in the economics of GHG mitigation and climate change adaptation. The research challenge is instead to develop new approaches to address this uncertainty and to enable policy-makers to formulate and implement mitigation and adaptation strategies that take it into account. Moreover, *it is essential to recognize that the treatment of uncertainty cannot in general be simply "added on" to existing models or analysis;* new frameworks, models, and information are required.

Methods for long-range analysis and planning

A first example of these issues is the significant and immediate need to develop or co-develop new methods for long-range (i.e., beyond two decades) planning and analysis, for both GHG mitigation and climate change adaptation. To date, PIER-funded and other California researchers working on long-run economic issues have largely applied the standard method of deterministic "scenario" analysis. While providing initial order-of-magnitude and illustrative results and insights, in general, this methodology does not provide the type of information that is needed for actual policy design and implementation, particularly at geographically-specific levels or in economic sub-sectors. In terms of the above discussion, long-run climate and GHG economic policy issues are problems in *risk assessment* and *risk management*. To address the risks involved, decisions regarding long-lived investments in both mitigation measures and adaptation options must take full account of uncertainties, and be made with methods that are appropriate for hedging against those uncertainties and for generating outcomes that are robust against different potential climate, technological, and other future events. Most commonly, scenario analysis—including its applications with economic simulation and other numerical models—does not address these issues.

Integrative decision support for GHG emissions mitigation

The overall California mitigation effort has seen a rapid expansion in the number of data sources, models, and specific policy analyses that must be coordinated and integrated. To date, the *de facto* integrating method at the overall, statewide planning level has been to use the CGE models noted above; these are now being combined with other models. While this type of modeling is an essential component of mitigation policy analysis, its limits as the primary integrating tool are becoming clear. Individual models are increasingly complex, difficult for non-specialists to understand, and generally not designed or implemented for comprehensive sensitivity or robustness analysis. Combining these and other models with different origins, structures, and input-output configurations can significantly exacerbate these limitations, and create substantial hurdles to the flexibility, accessibility, and robustness that is required for sound policy-making.

There is, therefore, an increasing need for new analytical and quantitative decision support methods and tools to integrate and apply empirical data, models and model outputs, and other sources of information in a systematic fashion that is rigorous but also flexible and accessible to a heterogeneous stakeholder community. In essence, this describes a decision and policy analysis architecture that encompasses simulation modeling and other elements, but is defined at a higher level.

Multi-disciplinary impact adaptation analysis

Adaptation to and coping with unavoidable climate change impacts in California are now recognized as core elements of the state's response to the risks of climate change. Research and applied work on impact assessment adaptation is at a much earlier stage of development than methods for GHG mitigation analysis. In part as a consequence, there is a degree of fragmentation in adaptation research that impedes both further intellectual progress and the provision of useful information and tools to policy-makers and planners. Economics, non-economic social sciences, engineering, natural science, and other disciplines all have a role in adaptation analysis and planning, but have different paradigms and yield results that are in many cases difficult to combine or reconcile. This problem is rendered more acute by the fact that adaptation planning characteristically entails a degree of institutional and political complexity that is categorically greater than is involved in GHG mitigation, in which a relatively small number of institutions have primary responsibility and authority. The need in this area is for applied research that integrates methods and practices from multiple disciplines in the context of the existing governmental and other institutions that bear responsibility and authority for climate change impact planning.

Data development and other policy inputs

In addition to the above methodological research areas, there is an ongoing need for support of the state's climate-related policy process in the form of basic information—such as cost estimates—on the economics of GHG mitigation and climate change adaptation. PIER is in certain cases best positioned to fill this need and, indeed, has thus far generated invaluable information of this type, such as PIER's work on the costs of carbon sequestration and of mitigating non-CO_2 gases.

6.0 Conclusions and Recommendations

6.1 Conclusions

PIER has developed and implemented a wide-ranging portfolio of research projects on the economics of climate change adaptation and GHG mitigation in California. A key metric for the success of this enterprise is the use of many of its outputs in the multi-agency state planning and regulatory process for mitigation and adaptation. This is a solid foundation on which to both expand key elements of the existing portfolio and develop innovative new research.

At the same time, the acceleration of regulatory and other stakeholder activities in the mitigation and adaptation arenas imply that the policy and Research, Development and Demonstration (RD&D) strategic planning context for PIER has changed significantly since 2003. Other state agencies are enlarging their policy efforts as well as their funding for supporting research. But private entities are also playing an increasingly large role, with a key example being the dramatic recent expansion of venture capital devoted to "clean energy." These developments pose both a challenge and an opportunity for PIER; while more coordination is warranted to maximize PIER's value-added to the overall RD&D effort, PIER may also be able to more narrowly target its resources to achieve even greater gains in the areas in which it can make unique contributions.

6.2 Recommendations

The following recommendations are based on the information and discussion in this document and meet the following programmatic criteria according to which PIER allocates its research funding: (1) relevance to PIER objectives (i.e., concerning the energy sector); (2) likelihood of generating scientifically and/or policy-relevant results within no more than four-to-five years; (3) potential applicability to California policy-making related to climate change; (4) technical quality and potential to advance scientific understanding; (5) potential to generate "co-benefits" (i.e., in science or policy not directly related to climate change); (6) likelihood of eventually securing co-funding from other agencies; and (7) the clear need for state support to reach the level of funding necessary to address these issues adequately.

The recommendations below are assigned equal priority. The first two should be interpreted as updating and refining the "Computational and Decision Analysis Tools for Integrated Risk Assessment" recommendation in the 2003 PIER climate and GHG economics strategic planning document.

Methods for long-run analysis and planning

- New theoretical, computational, and empirical methods should be developed or co-developed for dealing with multi-decadal problems in GHG mitigation and climate change impacts and adaptation. These would be "next generation" approaches and, in particular, would be designed to overcome limitations of standard scenario methods by addressing multiple sources of uncertainty—both probabilistic and otherwise—in an adaptive risk management framework. This research should include practical implementation, at a minimum in prototype form, in one or more selected state energy and environmental policy or regulatory processes.

Integrated quantitative GHG mitigation decision support

- New methods should be developed for integrating existing modeling, data, and other inputs to the state's ongoing near-term GHG mitigation planning. These methods would define a decision analysis framework and architecture that could encompass multiple and disparate information sources in a goal-directed format. This framework would be *supra* the economic models that are currently used as integrating platforms.

Multi-disciplinary economic, institutional, and scientific adaptation analysis

- In a case-study or similar configuration that targets specific impact and adaptation categories, cross-cutting analyses and planning exercises should be conducted, with the aim of creating detailed and practical recommendations, timelines, and other resources tailored to appropriate decision-makers and/or agencies.

Data generation, case studies, and other policy-relevant activities

- In selected areas, PIER should continue its ongoing applied work on estimating mitigation potentials, costs, and other detailed information on GHG mitigation options, including both technologies and practices, as appropriate. This work should continue to be focused on topics that uniquely require and can benefit from publicly-supported research, such as carbon sequestration and non-CO_2 gases.

References

Berck, Peter, David Roland-Holst, Ryan Kellog, Lingyun Nie, and Stephen Stohs. 2008. *Policy Options for Greenhouse Gas Mitigation in California: Preliminary Results from a New Social Accounting Matrix and Computable General Equilibrium (CGE) Model*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-091, January.

Brown, Sandra, Timothy Pearson, Aaron Dushku, John Kadyzewski, and Ye Qi (Winrock International). 2004. *Carbon Supply from Changes in Management of Forest, Range, and Agricultural Lands of California*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-04-068F, March.

CCSP. 2007. *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations (Part A) and Review of Integrated Scenario Development and Application (Part B)*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Clarke, L., J. Edmonds, J. Jacoby, H. Pitcher, J. Reilly, R. Richels, E. Parson, V. Burkett, K. Fisher-Vanden, D. Keith, L. Mearns, C. Rosenzweig, M. Webster (Authors)]. Department of Energy, Office of Biological & Environmental Research, Washington, DC, USA, 260 pp.

CCSP. 2008. *Preliminary review of adaptation options for climate-sensitive ecosystems and resources*. A Report by the U. S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius, S. H., J. M. West (eds.), J. S. Baron, B. Griffith, L. A. Joyce, P. Kareiva, B. D. Keller, M. A. Palmer, C. H. Peterson, and J. M. Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA, 873 pp.

Choate, Anne, Ravi Kantamaneni, Dan Lieberman, Pam Mathis, Beth Moore, Diana Pape, Lauren Pederson, Marian Van Pelt, and John Venezia (ICF International). 2005. *Emission Reduction Opportunities for Non-CO_2 Greenhouse Gases in California*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-121, July.

Dale, Larry, Anthony Fisher, Michael Hanemann, Wolfram Schlenker, Kimberly Fujita, and Dev Millstein. 2005. *Economic Impacts of Climate Change on Agricultural Water Use in California*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-054, March.

Dale, Larry, Sebastian Vicuña, Damian Bickett, and Caitlin Dyckman. 2006. *The Economic Cost of Climate Change Impact on California Water: A Scenario Analysis*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-003, July.

Dushku, Aaron, Sandra Brown, Silvia Petrova, Timothy Pearson, Nick Martin, Jonathan Winsten, and John Kadyszewski. 2007a. *Carbon Sequestration through Changes in Land Use in Oregon: Costs and Opportunities*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2007-074, October.

Dushku, Aaron, Sandra Brown, Silvia Petrova, Jonathan Winsten, Nick Martin, Timothy Pearson, and John Kadyszewski. 2007b. *Carbon Sequestration Through Changes in Land Use in Washington: Costs and Opportunities*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2007-075, October.

E3. 2007. GHG Calculator v.1a Reference. Energy and Environmental Economics, Inc., San Francisco.

Farrell, Alexander E. 2005a. *Review of Market-Based Incentives for Consideration of Applications in California*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-025, March.

Farrell, Alexander E. 2005b. *Emissions Markets – Characteristics and Evolution*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-024, March.

Fischer, Carolyn, and Richard D. Morgenstern. 2006. Carbon Abatement Costs: Why the Wide Range of Estimates? *The Energy Journal* 27 (2):73–86.

Georgakakos, K. P., N. E. Graham, T. M. Carpenter, A. P. Georgakakos, and H. Yao. 2005. Integrating Climate-Hydrology Forecasts and Multi-Objective Reservoir Management for Northern California. *EOS* 86(12), March 22.

Georgakakos, Konstantine, Nicholas Graham, and Aris Georgakakos. 2007. *Integrated Forecast and Reservoir Management (INFORM) for Northern California: System Development and Initial Demonstration* [and Appendices A to I]. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-109, April.

Gornitz, V., R. Horton, A. Siebert, and C. Rosenzweig. 2006. Vulnerability of New York City to storms and sea level rise. *Geol. Soc. Amer. Abstr. Programs* 38(7):335.

DRAFT

Herzog, Howard, Weifeng Li, Hongliang Zhang, Mi Diao, Greg Singleton, and Mark Bohm. 2007. *West Coast Regional Carbon Sequestration Partnership: Source Sink Characterization and Geographic Information System-Based Matching*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2007-053, October.

Jaske, Michael R. 2007. *Scenario Analyses of California's Electricity System: Preliminary Results for the 2007 Integrated Energy Policy Report*. California Energy Commission, Staff Draft Report. CEC-200-2007-010-SD, June.

Martin, Nick, Sandra Brown, Silvia Petrova, Timothy Pearson, Aaron Dushku, and John Kadyszewski. 2007. *Pilot Project Opportunities for Carbon Sequestration in Shasta County, California*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-072, September.

Moser, Suzanne C., and John Tribbia. 2007. *More Than Information: What California's Coastal Managers Need to Plan for Climate Change*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2007-046, October.

Murtishaw, Scott, and David Roland-Holst. 2007. *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-500-2007-099, September.

Parker, Larry, and Brent Yacobucci. 2008. *Climate Change: Costs and Benefits of S. 2191*. Congressional Research Service Report for Congress. Order Code RL34489, May 15.

Petrova, Silvia, Nick Martin, Sandra Brown, and John Kadyszewski. 2006. *Carbon Supply from Changes in Management of Forest, Range, and Agricultural Lands in California: Forest Fuel Reduction (ADDENDUM to PIER report # P500-04-068)*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-093-AD, September.

Ringer, Mike. 2007. *Portfolio Analysis and its Potential Application to Utility Long-Term Planning*. California Energy Commission, Final Staff Report. CEC-200-2007-012-SF, September.

Roland-Holst, David. 2006. *Economic Growth and Greenhouse Gas Mitigation in California*. UCB-1000-2007-008, August.

Sanstad, Alan H. 2003. *The Economics of Climate Change Mitigation and Adaptation in California*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-03-023FA-VI. Attachment VI of Franco, Guido, Robert Wilkinson, Alan H. Sanstad, Mark Wilson, and Edward Vine. 2003. *PIER-EA Climate Change Research, Development and Demonstration Plan*. 500-03-025FS, April.

Sanstad, Alan H. 2007. *A Stochastic Framework for Analyzing Long-Run CO_2 Abatement Strategies: A Project of the California Energy Modeling and Analysis Consortium (CEMAC)*. Paper presented at the 4th Annual California Climate Change Conference, Sacramento, September 12.

DRAFT

Taylor, Margaret, Dorothy Thornton, Gregory Nemet, and Michael Colvin. 2006. *Government Actions and Innovation in Environmental Technology for Power Production: The Cases for Selective Catalytic Reduction and Wind Power in California*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-053, August.

Taylor, Margaret, Greg Nemet, Michael Colvin, Loida Begley, Cyrus Wadia, and Tyler Dillavou. 2007. *Government Actions and Innovation in Clean Energy Technologies: The Cases of Photovoltaic Cells, Solar Thermal Electric Power, and Solar Water Heating*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2007-012, February.

Vicuña, Sebastian, Michael Hanemann, and Larry Dale. 2006. *The Economic Cost of Delta Levee Failure Due to Climate Change: A Scenario Analysis*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-004, July.

Winrock International. 2007. *Summary of the Rangelands Suitable for Terrestrial Carbon Sequestration in Shasta County*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2007-101, October.

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