Research in Support of California's Greenhouse Gas Emission Reduction Registry

CONSULTANT REPORT

Prepared For:

California Energy Commission
Public Interest Energy Research Program

Prepared By:

Lawrence Berkeley National Laboratory

November 2003

500-04-008

Prepared By:
Lawrence Berkeley National Laboratory
Berkeley, California

Lynn Price
Jayant Sathaye
Chris Mamay
Ernst Worrell
Scott Murtishaw
Diane Fisher
Amol Phadke

Contract No. 500-00-021

Prepared For:
California Energy Commission

Guido Franco,
Contract Manager

Kelly Birkinshaw,
Program Manager
Energy-Related Environmental Research

Terry Surles,
PIER Program Director

Robert L. Therkelsen,
Executive Director

pier
PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

Acknowledgements

This work was supported by the California Energy Commission and the California Institute for Energy Efficiency (CIEE) using support from the California Energy Commission through the U.S. Department of Energy under Contract No. DE-AC03-76SF0098. This work does not necessarily represent the views of the California Energy Commission, its employees or the State of California. Publication of these research results does not imply CIEE endorsement of or agreement with these findings, nor that of any of its sponsors.

The authors express their thanks for the beneficial comments of reviewers on earlier drafts. The list of reviewers includes Guido Franco, Joe Loyer, Ross Miller, Adam Pan, and Jeff Wilson, all of the CEC; Dan Kirshner of Environmental Defense; and Neil Strachan of the Pew Center on Global Climate Change. We would also like to thank Dan Kirshner for his assistance with the Elfin model.

We would like to thank Dan Seif and Reed Content of Advanced Micro Devices (AMD) for their helpful assistance and review of the AMD case study. We would also like to thank Bill Tschudi of Lawrence Berkeley National Laboratory and Mary Jean Burer for their helpful comments on the AMD case study. We would like to thank Patrick Healy and Susanne Zechiel for the data and information they provided related to the Fetzer case study. Their insights and comments on draft versions of the case study were valuable. We would like to acknowledge the significant amount of work that Mary Jean Burer undertook in the research and preparation of the City of Berkeley case study. We would also like to thank Neal DeSnoo, Bill Ivie, and Matt Nichols of the City of Berkeley for the enormous amount of data they provided along with their helpful reviews of the Berkeley case study.

We would especially like to thank Diane Wittenberg and Jill Gravender of the California Climate Change Registry for their active involvement in this project, providing us with the Registry's perspective as well as requirements throughout the research.

Finally, we thank Jeff Wilson, Pierre duVair, and especially Guido Franco of the Energy Commission for their helpful guidance throughout this work.

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 six RD&D program areas:

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

What follows is the final report for the Greenhouse Gas Reduction Registry, 500-00-021, conducted by the Ernest Orlando Lawrence Berkeley National Laboratory. The report is entitled *Research in Support of California's Greenhouse Gas Emission Reduction Registry*. This work was supported by the California Energy Commission and the California Institute for Energy Efficiency (CIEE) using support from the California Energy Commission through the U.S. Department of Energy under Contract No. DE-AC03-76SF0098. This project contributes to the PIER program objectives of improving the environmental and public health costs/risks of California's electricity.

For more information on the PIER Program, please visit the Energy Commission's Web site at: http://energy.ca.gov/research/index.html or contact the Energy Commission's Publications Unit at 916-654-5200.

Table of Contents

Appendices

List of Tables

Executive Summary

The California Climate Action Registry, which was initially established in 2000 and began operation in fall 2002, is a voluntary registry for recording annual greenhouse gas (GHG) emissions. The purpose of the Registry is to assist California businesses and organizations in their efforts to inventory and document emissions in order to establish a baseline and to document early actions to increase energy efficiency and decrease GHG emissions. The State of California has committed to use its "best efforts" to ensure that entities that establish GHG emissions baselines and register their emissions will receive "appropriate consideration under any future international, federal, or state regulatory scheme relating to greenhouse gas emissions." Reporting of GHG emissions involves documentation of both "direct" emissions from sources that are under the entity's control and "indirect" emissions controlled by others. Electricity generated by an off-site power source is considered to be an indirect GHG emission and is required to be included in the entity's report.

Registry participants include businesses, non-profit organizations, municipalities, state agencies, and other entities. Participants are required to register the GHG emissions of all operations in California, and are encouraged to report nationwide. For the first three years of participation, the Registry will only require the reporting of carbon dioxide (CO_2) emissions,[1] although participants are encouraged to report the remaining five Kyoto Protocol GHGs.[2] After three years, reporting of all six Kyoto GHG emissions is required. The enabling legislation for the Registry (SB 527) requires total GHG emissions to be registered and requires reporting of "industry-specific metrics" once they have been adopted by the Registry.

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) was asked to provide technical assistance to the California Energy Commission (Energy Commission) related to the Registry in three areas: 1) establishing methods for calculating electricity CO_2 emission factors, 2) assessing the availability and usefulness of industry-specific metrics, and 3) evaluating various methods for establishing baselines for calculating GHG emissions reductions related to specific actions taken by Registry participants. Berkeley Lab conducted three case studies in order to explore issues related to both industry-specific metrics and baselines.

---

[1] While emissions are referred to as CO_2, quantities of emissions are reported in mass of equivalent carbon, where 1 kg C = 0.27 kg CO_2. We focus on CO_2 emissions since emissions of the other GHGs from utilities are comparatively negligible. In 1999, U.S. electric utilities released approximately 532.6 MtC, but only 2.3 MtCeq. of N_2O, and less than 0.1 MtCeq. of NH_4. Additionally, fugitive emissions of SF_6 are released from substations and circuit breakers in the electrical transmission and distribution system. These emissions equaled approximately 7 MtCeq. (U.S. EPA 2001).

[2] Methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

For the first area of research, the overall objective was to develop methods for estimating average emissions factors (AEFs) and marginal emissions factors (MEFs) in order to provide an estimate of the combined net CO_2 emissions from all generating facilities that provide electricity to California electricity customers. Berkeley Lab developed three methods for calculating California electricity emissions factors. The first uses the Elfin model to simulate plant operations and estimate emissions for 1990. The second is an accounting method that draws primarily from public data sources (PDS). The third, used for the 1999 test year, is a spreadsheet that applies a simplified load duration curve (LDC).[3] The electricity emissions factors derived take into account the location and time of consumption, direct contracts for power, which may have certain atypical characteristics (e.g., "green" electricity from renewable resources), resource mixes of electricity providers, import and export of electricity from utility-owned and other sources, and electricity from cogeneration. Using the three different methods to estimate annual AEFs, MEFs, and seasonal AEFs by utility power control areas (PCAs), Berkeley Lab found that using a simple annual statewide AEF could significantly under- or over-estimate an entity's emissions responsibility due to the large variation in generating resources among the utility service areas. Differentiating between MEFs and AEFs is essential to accurately estimate the CO_2 savings from reducing electricity use. Seasonal differences in AEFs due to fluctuations in hydro generation should be accounted for at the statewide level, and particularly for the Pacific Gas & Electric service area. Overall, Berkeley Lab's research demonstrated that there are significant differences in CO_2 emissions factors from electricity generation, depending upon whether the factor represents average emissions, marginal emissions, utility service districts, and various seasons. Programs that estimate total annual CO_2 emissions from electricity generation as well as programs that estimate CO_2 emissions reductions related to mitigation efforts should carefully choose the emissions factors that are used for calculating emissions from electricity.

For the second area of research, the overall objective was to evaluate the availability and usefulness of metrics that can be used to report GHG emissions trends for potential Registry participants. This research began with an effort to identify methodologies, benchmarking programs, inventories, protocols, and registries that use intensity-based metrics to track trends in energy use or GHG emissions in order to determine what types of metrics have already been developed. The next step in developing sector-specific metrics was to assess the availability of data needed to evaluate metric development priorities. Berkeley Lab also determined the relative importance of different potential Registry participant categories in order to assess the availability of sectoral or industry-specific metrics and then identified industry-specific metrics in use around the world. Berkeley Lab found that there are numerous methodologies, benchmarking programs, inventories, protocols, and registries that use industry-specific metrics to track trends in energy use or GHG emissions. However, Berkeley Lab did not identify an adequate metric to track GHG emissions while protecting proprietary data. As a result, Berkeley Lab recommends the development of a GHG intensity index as a new metric for reporting and tracking GHG emissions trends. Such an index would provide an industry-specific metric for reporting

[3] A load duration curve plots the amount of electric energy delivered or required at any specified point or points on a system in order of magnitude for power, rather than hourly variations.

and tracking GHG emissions trends that could accurately reflect year-to-year changes while protecting proprietary data. A GHG intensity index could be constructed using detailed production and GHG emissions data provided by Registry participants. Only the index, and not the detailed proprietary data, would be reported publicly. Such an index would provide Registry participants with a means for demonstrating improvements in their energy and GHG emissions per unit of production without divulging specific values.

For the third research area, Berkeley Lab evaluated various methods used to calculate baselines for documentation of energy consumption or GHG emissions reductions, noting those that use industry-specific metrics. Accounting for actions to reduce GHGs can be done on a project-by-project basis or on an entity basis. Establishing *project-related baselines* for mitigation efforts has been widely discussed in the context of two of the so-called "flexible mechanisms" of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Kyoto Protocol): Joint Implementation (JI) and the Clean Development Mechanism (CDM). Issues regarding the development of *entity-specific baselines*, which can be used by such entities as companies, municipalities, and organizations, have been explored in the context of baseline protection, emissions trading, credit for early action initiatives, and climate change registries. Berkeley Lab developed a baseline typology and assessed the complexity and robustness of each type of baseline vis-à-vis potential future emissions limits and/or emissions trading schemes. Berkeley Lab found that only an explicit future target from which to establish a baseline and an ex-post reconstructed baseline for retrofit projects were robust enough to be considered as a basis for granting credits for early actions. Of these two baseline types, the future target baseline is the easiest to construct; the ex-post reconstructed baseline is accurate because actual emissions are known and reductions can be verified by a third party, but it can be more complex and costly.

In the research related to electricity emissions factors, Berkeley Lab found that using a simple annual statewide AEF could significantly under- or over-estimate an entity's emissions responsibility due to the large variation in generating resources among the utility service areas. Differentiating between MEFs and AEFs is essential to accurately estimate the CO_2 savings from reducing electricity use. Seasonal differences in AEFs due to fluctuations in hydro generation should be accounted for at the statewide level, and particularly for the Pacific Gas & Electric service area. Overall, Berkeley Lab's research demonstrated that there are significant differences in CO_2 emissions factors from electricity generation, depending upon whether the factor represents average emissions, marginal emissions, utility service districts, and various seasons. Programs that estimate total annual CO_2 emissions from electricity generation, as well as programs that estimate CO_2 emissions reductions related to mitigation efforts, should carefully choose the emissions factors that are used for calculating emissions from electricity.

In the research related to industry-specific metrics, Berkeley Lab found that there are numerous methodologies, benchmarking programs, inventories, protocols, and registries that use industry-specific metrics to track trends in energy use or GHG emissions. Berkeley Lab also determined the relative importance of different potential Registry participant categories in order to assess the availability of sectoral or industry-specific metrics and then identified industry-specific metrics in use around the world. As a result of this review, Berkeley Lab recommends the development of a GHG intensity index as a new metric for reporting and tracking GHG emissions trends. Such an index would provide an industry-specific metric for reporting and tracking GHG emissions trends that could accurately reflect year-to-year changes while protecting proprietary data. A GHG intensity index could be constructed using detailed production and GHG emissions data provided by Registry participants. Only the index, and not the detailed proprietary data, would be reported publicly. Such an index would provide Registry participants with a means for demonstrating improvements in their energy and GHG emissions per unit of production without divulging specific values.

In the research related to baselines, Berkeley Lab evaluated various methods used to calculate baselines for documentation of energy consumption or GHG emissions reductions, noting those that use industry-specific metrics. Berkeley Lab developed a baseline typology and assessed the complexity and robustness of each type of baseline vis-à-vis potential future emissions limits and/or emissions trading schemes. We found that only a statutorily established future target baseline and an ex-post reconstructed baseline were robust enough to be considered as a basis for granting credits for early actions. Of these two baseline types, the future target baseline is the easiest to construct; the ex-post reconstructed baseline is accurate because actual emissions are known and reductions can be verified by a third party, but it can be more complex and costly.

Finally, Berkeley Lab conducted three case studies in order to explore issues related to both industry-specific metrics and baselines. These case studies were done for Advanced Micro Devices (AMD), Fetzer Vineyards, and the City of Berkeley. The case studies demonstrated numerous issues related to the use of metrics and recommended that industry-specific metrics be disaggregated to a certain degree, depending upon both the specific sector and data availability, in order to best capture the energy or GHG emissions trends experienced at the participant's facilities. The case studies also discussed various baseline issues and concluded that it is difficult to clearly identify any one baseline that is preferable to another based on the limited number of years of data available, but also due to the wide variation in the differences between the baselines and actual GHG emissions. Data availability, baseline complexity, baseline robustness, and the ultimate desired use of the baseline must all be considered when choosing a baseline upon which to measure future GHG emissions reductions.

Overall, the case studies showed that it is difficult to clearly identify any one baseline that is preferable to another based on the limited number of years projected, but also due to the wide variation in the differences between the baselines and actual GHG emissions. Thus, these case studies indicate that while there are many types of baselines that can possibly be used to determine GHG emissions reductions attributable to the early actions of a company, the decision on which baseline to choose can be best made by considering the baseline complexity and robustness in terms of the ultimate desired use of the baseline.

When choosing among baseline methods, various considerations related to baseline complexity and robustness must be taken into account. Frozen baselines simply show whether an entity is contributing more or less to GHG emissions overall. Intensity baselines do not offer the precision to be used as a basis for protecting early action, unless perhaps they are more complex and use highly disaggregated data. Otherwise, "intensity," as defined at more practical levels of detail, will be affected by factors that do not reflect true changes in efficiency. Project-based reconstructed baselines are the most defensible for the generation of credits. Although total emissions are reported at the entity-wide level, savings must be documented on a project-specific basis. Since the claimed savings are attributable to specific projects, they can be more realistically monitored and verified.

This research was undertaken to support the California Climate Action Registry by: 1) establishing methods for calculating electricity CO_2 emission factors, 2) assessing the availability and usefulness of industry-specific metrics, and 3) evaluating various methods for establishing baselines for calculating GHG emissions reductions related to specific actions taken by Registry participants.

By addressing each of those factors, this research provides information and analyses that the California Climate Action Registry can use to help ensure that voluntary CO_2 emissions reductions in the State are accurately tracked and that the participating entities receive appropriate credit for their emissions-reduction activities. As a result, California could reduce its production of greenhouse gases and benefit from cleaner air, while California entities that reduce those CO_2 emissions could benefit from financial and regulatory incentives based on CO_2 emissions reductions.

Abstract

The California Climate Action Registry, which was initially established in 2000 and began operation in fall 2002, is a voluntary registry for recording annual greenhouse gas (GHG) emissions. The purpose of the Registry is to assist California businesses and organizations in their efforts to inventory and document emissions in order to establish a baseline and to document early actions to increase energy efficiency and decrease GHG emissions. Reporting of GHG emissions involves documentation of both "direct" emissions from sources that are under the entity's control and "indirect" emissions controlled by others. Electricity generated by an off-site power source is considered to be an indirect GHG emission and is required to be included in the entity's report. The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) was asked to provide technical assistance to the California Energy Commission (Energy Commission) related to the Registry in three areas: 1) establishing methods for calculating electricity CO_2 emission factors, 2) assessing the availability and usefulness of industry-specific metrics, and 3) evaluating various methods for establishing baselines for calculating GHG emissions reductions related to specific actions taken by Registry participants. In addition, three case studies were conducted in order to explore issues related to both industry-specific metrics and baselines.

Regarding electricity emissions factors, Berkeley Lab found that there are significant differences in CO_2 emissions factors from electricity generation, depending upon whether the factor represents average emissions, marginal emissions, utility service districts, and various seasons. Regarding metrics, Berkeley Lab found that there are numerous methodologies, benchmarking programs, inventories, protocols, and registries that use industry-specific metrics to track trends in energy use or GHG emissions, but concluded that none of those identified could adequately fulfill the needs of the Registry and thus recommended the development of a GHG intensity index as a new metric for reporting and tracking GHG emissions trends. Regarding baselines, Berkeley Lab found that only an explicit future target from which to establish a baseline and an ex-post reconstructed baseline for retrofit projects were robust enough to be considered as a basis for granting credits for early actions. Finally, the case studies demonstrated numerous issues related to the use of metrics and recommended that industry-specific metrics be disaggregated to a certain degree, depending upon both the specific sector and data availability, in order to best capture the energy or GHG emissions trends experienced at the participant's facilities. The case studies also discussed various baseline issues and concluded that it is difficult to clearly identify any one baseline that is preferable to another based on the limited number of years of data available, but also due to the wide variation in the differences between the baselines and actual GHG emissions.

1.0 Introduction

1.1 Background and Overview

The California Climate Action Registry, which was initially established in 2000 and began operation in fall 2002, is a voluntary registry for recording annual greenhouse gas (GHG) emissions. The purpose of the Registry is to assist California businesses and organizations in their efforts to inventory and document emissions in order to establish a baseline and to document early actions to increase energy efficiency and decrease GHG emissions. The State of California has committed to use its "best efforts" to ensure that entities that establish GHG emissions baselines and register their emissions will receive "appropriate consideration under any future international, federal, or state regulatory scheme relating to greenhouse gas emissions." Reporting of GHG emissions involves documentation of both "direct" emissions from sources that are under the entity's control and "indirect" emissions controlled by others. Electricity generated by an off-site power source is considered to be an indirect GHG emission and is required to be included in the entity's report.

Registry participants include businesses, non-profit organizations, municipalities, state agencies, and other entities. Participants are required to register the GHG emissions of all operations in California, and are encouraged to report nationwide. For the first three years of participation, the Registry will only require the reporting of carbon dioxide (CO_2) emissions,[4] although participants are encouraged to report the remaining five Kyoto Protocol GHGs.[5] After three years, reporting of all six Kyoto GHG emissions is required. The enabling legislation for the Registry (SB 527) requires total GHG emissions to be registered and requires reporting of "industry-specific metrics" once they have been adopted by the Registry.

1.2 Project Objectives

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) was asked to provide technical assistance to the California Energy Commission (Energy Commission) related to the Registry in three areas: 1) establishing methods for calculating electricity CO_2 emission factors, 2) assessing the availability and usefulness of industry-specific metrics, and 3) evaluating various methods for establishing baselines for calculating GHG emissions reductions related to specific actions taken by Registry participants. Berkeley Lab conducted three case studies in order to explore issues related to both industry-specific metrics and baselines. These case studies were done for Advanced Micro Devices (AMD), Fetzer Vineyards, and the City of Berkeley. The objective of all of these areas of research was to provide information to assist the Energy Commission in making recommendations related to the design and structure of the California Climate Action Registry.

---

[4] See footnote 1.

[5] See footnote 2.

1.3 Report Organization

This report describes the project approach, project outcomes, and conclusions and recommendations for each of the three areas identified above, as well as for the case studies. This report is organized as follows:

Section 1.0	Introduction
Section 2.0	Project Approach
Section 3.0	Project Outcomes
Section 4.0	Conclusions and Recommendations
Section 5.0	References

There are two appendices, Appendix A, (Marnay et al. 2002), is a report on establishing methods for calculating electricity carbon dioxide emissions factors. Appendix B, (Price et al. 2003), is a report on two subjects: (1) assessing the availability and usefulness of industry-specific metrics, and (2) evaluating various methods for establishing baselines that can be used to calculate GHG emissions reductions resulting from specific actions taken by Registry participants. Appendix B also includes the three case studies.

Appendix A: Marnay, C., D. Fisher, S. Murtishaw, A. Phadke, L. Price, and J. Sathaye, 2002. *Estimating Carbon Dioxide Emissions Factors for the California Electric Power Sector*. Berkeley, CA: Lawrence Berkeley National Laboratory, LBNL-49945.

Appendix B: Price, L., S. Murtishaw, E. Worrell, 2003. *Evaluation of Metrics and Baselines for Tracking Greenhouse Gas Emissions Trends: Recommendations for the California Climate Action Registry*. Berkeley, CA: Lawrence Berkeley National Laboratory, LBNL-53027.

2.0 Project Approach

2.1 Establishing Methods for Calculating Electricity Carbon Dioxide Emissions Factors

The California electricity sector has undergone significant changes since 1990, and this poses daunting challenges for establishing a consistent method for estimating emissions factors over this period. In addition, publicly distributed data series have changed significantly over this decade. California is a particularly difficult state for calculating emissions factors for several reasons: California's fuel mix is among the most diverse in the nation; a large share of California's electricity—much of which is from combined heat and power (CHP)—is supplied by independent power producers;[6] several California utilities own shares of generating facilities in other states; California imports much of its electricity in addition to the power from these California-owned out-of-state resources; and direct retail access was in effect from 1998 to 2001.

Berkeley Lab developed three methods for calculating California electricity emissions factors. The first uses the Elfin model to simulate plant operations and estimate emissions for 1990. The second is an accounting method that draws primarily from public data sources (PDS). The third, used for the 1999 test year, is a spreadsheet that applies a simplified load duration curve (LDC). Table 1 compares these approaches and summarizes what is included in each approach.

The Elfin model was used to simulate plant operations and estimate emissions for 1990. This model was a widely used forecasting tool for utility power systems during the 1980s and early 1990s, roughly until publication of the last biennial CEC Electricity Report in 1996. Fortunately, old data sets that were compiled and publicly scrutinized during this period are still available in the public domain and can be used to replicate historic conditions. Data sets for six electricity utility service territories were provided by the CEC and all were run for 1990. Elfin has its own built-in algorithms for estimating emissions from cogeneration and imports. This model provides a great deal of versatility for determining emissions factors. In addition to providing annual average emissions factors (AEFs) and marginal emissions factors (MEFs) for the state and each power control area (PCA),[7] it also estimates emissions factors on a monthly basis as well as for other subperiods, such as for on- and off-peak hours.

---

[6] Total fuel consumption is reported by combined heat and power units on the Energy Information Administration survey forms, and several methodologies exist for determining how fuel consumption should be split between the heat and electric outputs. The approach used in this study assigned a fixed conversion efficiency of fuel input to useful thermal output and allocated the remaining fuel to electricity production.

[7] A *power control area* is defined as a grid region for which one utility controls the dispatch of electricity. Some smaller utilities are embedded in the power control areas of larger utilities.

Table 1. Comparison of Three Methods for Estimating Emissions Factors

Method	Year	Average Emission Factors	Marginal Emissions Factors	Includes Imports	Includes Exports	Includes CA-Owned Out-Of-State Generation	Excludes Specific Purchases[a]
Elfin Model	1990	Yes	Yes	Yes	No	Yes	N/A
Public Data Sources	1999	Yes	No	Yes[b]	No	Yes	Yes
Load Duration Curve	1999	Yes	Yes	Yes[b]	No	Yes	Yes/No[c]

[a] "Specific Purchases" refers to purchases of electricity by retailers for use in green power products. Generation and associated emissions for these products should be separated from the resources providing power for the general pool of grid electricity to avoid double counting.

[b] Imports are net imports. Thus, exports are not treated explicitly but are subtracted from import totals.

[c] The LDC approach could be modified to exclude specific purchases; however, this was not done for this report due to time limitations.

The second approach for deriving AEFs is an accounting method that draws primarily from U.S. Energy Information Administration (EIA) reporting forms, with some supplemental information from the CEC and the Federal Energy Regulatory Commission (FERC). This method was used to estimate emissions and derive AEFs for the 1999 test year.[8] Historical data on power plant generation and fuel consumption were used to determine plant-specific emissions. These were then aggregated into emission totals for each PCA as well as for the entire state.

Due to data limitations, several assumptions were made in order to calculate and assign emissions. One critical decision was that electricity was assumed to serve the load of the PCA where it was generated, an assumption that may not be very accurate with the deregulation of generation.[9] The shares of generation from out-of-state plants partially owned by California utilities were also assumed to serve these utilities' loads before other imports would be purchased. Another important assumption concerns the estimation of imports, which were calculated as the difference between PCA generation (including the out of state assets) and total loads. Emissions associated with the imported electricity were calculated by multiplying the quantity of imported electricity by the AEF of the region from which the electricity was assumed to originate.

Other important methodological steps were taken to avoid overestimating emissions from certain plants. In order to avoid allocating total emissions from CHP units, emissions were assigned to grid electricity using a method of deducting fuel input for heat based on a standard conversion efficiency of fuel to useful thermal output. Additionally, *specific*

[8] The absence of data on non-utility generation and monthly utility loads precluded the use of the PDS approach to calculate emissions factors for 1990.

[9] By late 1999, California's CAISO utilities had divested most of their thermal power plants to independent power producers; therefore, the relatively fixed relationship between customer load and the plant available to serve it no longer holds. For lack of precise sales data, a traditional fixed relationship is assumed in this report.

purchases of electricity for green power products and the associated emissions were subtracted from the totals of the PCA in which the electricity was generated.[10]

The third methodology, used for the 1999 test year, is a spreadsheet that utilizes a load duration curve (LDC), as many simulation models do (such as Elfin), albeit in a simplified form. The approach uses publicly available data from the National Energy Modeling System (NEMS) input files. The LDC model provides estimates of annual and monthly AEFs and MEFs by an approximation of the complex plant operation algorithms of more sophisticated models. In the LDC method, plants were placed in order of probable dispatch as follows: 1) nuclear plants, 2) non-thermal imports 3) renewables such as wind, geothermal, and biomass, 4) co-generation facilities, and 5) hydro. All remaining resources (thermal, non-cogeneration facilities) were then taken in order of their capacity factors, highest to lowest. The LDC model makes the same assumption as the PDS approach regarding electricity serving the load of the PCA in which it was generated, although some results for the combined load of the California Independent System Operator (CAISO) are also presented. This is equivalent to treating the three CAISO utilities—Pacific Gas & Electric (PG&E), Southern California Electric (SCE), and San Diego Gas & Electric (SDG&E)—as one PCA. Specific purchases have not been separated from the generation totals, but the model can be adapted to do so. Cogeneration did not require additional assumptions as the NEMS data files contain plant-specific heat rates for calculating fuel consumption for electricity generation from CHP plants.

2.2 Assessing the Availability and Usefulness of Industry-Specific Metrics

The enabling legislation for the California Climate Action Registry (SB 527) requires participating entities to register total GHG emissions and requires reporting of "industry-specific metrics" once such metrics have been adopted by the Registry (SB 527, Section 11). The legislation specifies that Registry "participants shall also report using industry-specific metrics once the registry adopts an industry-specific metric for the industry in question" (SB 527, Section 11). In support of this, the California Energy Commission is directed by the legislation to "Review…industry-specific greenhouse gas reporting metrics linked to or based on international or federal standards, as these become available periodically, and advise the registry of its opinion as to whether the adoption of sectoral or industry-specific metrics complement the reporting procedures" (SB 527, Section 16).

Sectoral and industry-specific metrics, also called *indicators,* are commonly used by businesses, governments, and analysts to track trends in GHG emissions or energy consumption.[11] These metrics, which are designed to measure improvements in CO_2 intensity or energy efficiency independent of economic growth or growth in production, use either an economic or a physical value for the denominator. For example, the energy

---

[10] *Specific purchases* are purchases of electricity by marketers or distribution companies for use in green power products, as defined in California Senate Bill 1305.

[11] For an extensive review of energy and carbon emissions indictors used by analysts, see Schipper et al. 2001.

intensity of cement production can be measured as energy use per dollar of value added by the cement industry (economic metric) or energy use per ton of cement produced (physical metric). Economic metrics are typically used when aggregating across heterogeneous entities that do not produce comparable products (e.g. the entire manufacturing sector). Physical metrics are typically used to compare entities that have similar production outputs.

Recent analyses have shown that there is great variability in economic metrics and that metrics based on physical values more accurately trace actual trends in emissions or energy intensity, although the heterogeneity of the industrial sector can make development of such metrics difficult for some industries (Freeman et al. 1996; Worrell et al. 1997). As a result, there have been increasing efforts to develop suitable physical metrics (Farla 2000; LBNL 1999; Nyboer and Laurin 2001a; Nyboer and Laurin 2001b; Phylipsen et al. 1996; Phylipsen et al. 1998).

The first step in developing industry-specific metrics was to identify methodologies, benchmarking programs, inventories, protocols, and registries that use intensity-based metrics to track trends in energy use or GHG emissions in order to determine what types of metrics have already been developed. Berkeley Lab identified such metrics through literature survey, Web-searching, and contacting other researchers or policy-makers who have experience with either registry projects or development of metrics for measuring and tracking GHG emissions.

The next step in developing industry-specific metrics was to assess the availability of data needed to determine metric development priorities. Such data are required to gain an understanding of the relative importance of specific building types, transport fleet modes, and industrial/manufacturing/agriculture facilities in California. Various industry-specific indices that have also been developed to track trends in energy use or GHG emissions were identified. Such indices can be helpful in situations where data confidentiality is an issue.

2.3 Evaluating Methods for Establishing Baselines for Calculating GHG Emissions Reductions Related to Specific Actions Taken by Registry Participants

Accounting for actions to reduce GHGs can be done on a project-by-project basis or on an entity basis. Establishing *project-related baselines* for mitigation efforts has been widely discussed in the context of two of the so-called "flexible mechanisms" of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Kyoto Protocol): Joint Implementation (JI) and the Clean Development Mechanism (CDM). Issues regarding the development of *entity-specific baselines*, which can be used by such entities as companies, municipalities, and organizations, have been explored in the context of baseline protection, emissions trading, credit for early action initiatives, and climate change registries.

The first step in evaluating methods for establishing baselines was to identify various baseline types that have either been proposed or used to calculate energy use or GHG emissions reductions. Berkeley Lab identified seven different types of baselines ranging from those that are project-specific to those that are entity specific.

The next step was to provide an overall typology for a number of baseline methods, categorizing them according to the way the baselines are calculated. First, the methods were divided into three major categories according to the basic approach used to calculate the baselines, and within these categories, variations of the methods are listed. Each of these variations was then rated on its complexity and robustness. ″Complexity″ is an indication of whether many calculations are necessary to establish the particular baseline. Baselines that are highly complex may necessitate the use of expertise outside of the Registry and will, therefore, be more costly to implement. "Robustness" is a measure of the likelihood that the method is rigorous enough to be accepted for early action credit or other tradeable credits.

2.4 Case Studies

In order to fully explore the issues surrounding the use of industry-specific metrics and to begin to understand the implications of using one type of baseline over another, Berkeley Lab conducted three case studies with entities representing a wide spectrum of activities that could be included in the California Climate Action Registry. These case studies were conducted for Advanced Micro Devices (AMD), Fetzer Vineyards, and the City of Berkeley.

For each case study, Berkeley Lab provided information on the sector background as well as an overview of the company or city. Berkeley Lab worked closely with representatives from each case study entity to gather energy use and GHG emissions data as well as data that could be used to construct metrics. Berkeley Lab then analyzed possible energy and GHG emissions metrics for each case study entity, identifying issues related to metric construction and use. Finally, Berkeley Lab evaluated various baselines to determine how baseline projections compare to actual trends for Fetzer Vineyards and AMD.[12]

[12] Baseline evaluation was not possible for the City of Berkeley due to funding limitations.

3.0 Project Outcomes

3.1 Establishing Methods for Calculating Electricity Carbon Dioxide Emissions Factors

The annual results of the three electricity emissions factor calculation approaches for the entire state and the four major California utilities are shown in Table 2. In terms of total electricity-related CO_2 emissions, the three methods produced similar results. The Elfin model methodology shows total CO_2 emissions of 26.1 MtC in 1990. Since the total state electricity load in 1999 was about 10 percent higher than in 1990, the larger total emissions of 29.5 MtC and 29.0 MtC yielded by the LDC and PDS methods, respectively, are to be expected. This ratio holds roughly true for the state and all PCAs but PG&E. The higher PG&E emissions reported by Elfin for 1990 are due largely to the fact that 1990 was a dry year, and gas plants were operated at greater capacity factors to compensate for lower hydro generation. For 1999, the PDS and LDC methods generated remarkably similar estimates for both the entire state and each PCA.

Table 2. Comparison of Annual Results from Three Electricity Emissions Factors Calculation Methodologies

	1990 - Elfin			1999 - LDC			1999 - PDS		
	Emissions (MtC)	AEF (kgC/kWh)	MEF (kgC/kWh)	Emissions (MtC)	AEF (kgC/kWh)	MEF (kgC/kWh)	Emissions (MtC)	AEF (kgC/kWh)	MEF (kgC/kWh)
SCE	11.8	0.132	0.165	12.9	0.131	0.215	12.9	0.132	N/A
SDG&E	2.2	0.132	0.201	2.8	0.146	0.181	2.6	0.140	N/A
LADWP	4.7	0.195	0.191	5.2	0.207	0.199	5.0	0.192	N/A
PG&E[a]	7.3	0.070	0.153	7.0	0.063	0.140	7.0	0.064	N/A
State[b]	26.1	0.110		29.5	0.105		29.0	0.108	

[a] LDC and PDS results for PG&E include Sacramento Municipal Utility District (SMUD).

[b] Includes irrigation districts and municipal utilities.

A principal finding was that the level of CO_2 associated with electricity usage varies considerably among the PCAs, although it comes as no surprise that these values are lower for PG&E than for the southern California companies. PG&E has a large share of carbon-free generation, such as hydro, nuclear, and predominantly hydro imports from the Pacific Northwest.

The LDC and Elfin models produced quite divergent MEFs for all the PCAs except the Los Angeles Department of Water & Power (LADWP). (MEFs were not calculated using the PDS methodology.) The difference in Elfin's 1990 and the LDC-derived 1999 MEFs for SCE is especially striking. The high 1999 MEF using the LDC method occurs because a large share of the gas-fired generation in this PCA is from cogeneration, which is assumed not to respond to changes in the load. Thus, the load-following resources consist largely of imports from the Southwest. The difference between the 1990 and 1999 MEFs is also large for PG&E, which has the greatest share of nuclear and hydro generation, two resources that are generally never curtailed to follow load. With the exception of LADWP, the MEFs are significantly higher than the corresponding AEFs. Since the MEFs of the PCAs other than LADWP range from 25 to over 200 percent greater than the corresponding AEFs, using AEFs to estimate the CO_2 savings from reducing electricity usage would significantly underestimate actual savings.

Table 3 disaggregates California electricity generation, CO_2 emissions, and average emissions factors in 1999 by their source, based on the PDS results. In-state electricity generation accounts for 63% of total California electric use, while 14% is out-of-state production owned by California utilities, and the remaining 23% is imported. Coal produces a negligible share of California's in-state electricity, but is by far the predominant source of energy in the Southwest U.S. Thus, imports from California-owned out-of-state coal plants and other utilities in the Southwest significantly increase California's CO_2 emissions and the statewide AEF. The emissions associated with the electricity from California-owned out-of-state plants alone raises the AEF by a third. Thus, a simple inventory approach that only counts emissions within California's borders underestimates the CO_2 emissions from electricity used by California consumers.

Table 3. Total 1999 California Electricity Generation, Electricity-Related CO_2 Emissions, and Average Emissions Disaggregated by Source[a]

	In-State	CA Owned Out-of-State[b]	Total In-State + CA Owned Out-of-State	SW Imports[c]	NW Imports[d]	Total CA
Generation (TWh)	170.14	37.16	207.30	42.80	19.76	269.86
CO_2 Emissions (MtC)	11.92	7.36	19.28	8.32	1.41	29.01
AEF (kgC/kWh)	0.070	0.198	0.093	0.194	0.071	0.108

[a] Calculated from public data sources as described in Section 3 of this report. These figures exclude specific purchases.

[b] This heading refers to the generation shares of out-of-state plants owned by California utilities.

[c] This category represents imports from the Southwest, a region that for purposes of this study includes Arizona, Nevada, New Mexico, Utah, and Colorado. The assumed share of imports from the Southwest is high due to the assumption that southern California utilities receive all imports from this region. Precise sales data would permit allocation of a greater share of imports to the Northwest, which would lower the state total emissions. If the shares were the same as those reported in CEC's California Electricity Generation 1983–2000 (roughly 53% from the Northwest) (CEC 2001), total emissions would be about 5% lower.

[d] The Northwest region is composed of Montana, Wyoming, Idaho, Washington, and Oregon.

The large share of seasonally varying hydro generation in California combined with typically hot late summer weather implies that AEFs may be higher when increased output from thermal generating sources must compensate for diminished hydro output. Conversely, as more thermal generation is used, the share of natural gas is likely to increase relative to coal, pushing down the AEF of thermal generation. Table 4 shows the AEFs calculated for May and October—months that usually have relatively high and low hydro generation. PG&E, the most hydro-dependent PCA, has by far the largest variation between the two months. This occurs both because more gas-fired generation is used within the PCA and more electricity is imported from the Northwest. The fall in hydro generation also causes the AEF of the imported power to increase, as more coal-fired electricity is used to replace the decline in hydropower. PG&E, being the largest PCA, is a large enough share of the statewide total load that the seasonal change in its resource mix significantly affects the statewide AEF. The variation in the other PCAs is much less pronounced and due as much to random changes in plant operations as to differences in hydro output. These results suggest that accounting for seasonal changes in resource mix, particularly for entities located in the PG&E service area, is important to accurately estimate emissions throughout the year.

Table 4. Seasonal Changes in Average Electricity Emissions Factors in California in 1999

Utility	May			October			Percent Difference Oct/May, PDS Total
	CA Generation, LDC[a]	CA Generation, PDS[a]	Total w/ Imports, PDS	CA Generation, LDC[a]	CA Generation, PDS[a]	Total w/ Imports, PDS	
PG&E	0.046	0.043	0.046	0.079	0.079	0.083	79%
SCE	0.086	0.083	0.122	0.111	0.105	0.132	8%
SDG&E	0.091	0.096	0.150	0.105	0.089	0.134	-11%
LADWP	0.205	0.194	0.192	0.208	0.184	0.184	-5%
CA[b]	0.082	0.074	0.098	0.113	0.103	0.117	19%

[a] Includes the shares of out-of-state plants owned by CA utilities.
[b] Includes only the PCAs listed in the table.

In summary, Berkeley Lab found that a statewide AEF could drastically misestimate an entity's emissions due to the large differences in generating resources among the service areas. Berkeley Lab also found that differentiating between marginal and average emissions is essential to accurately estimate the CO_2 savings from reducing electricity use. Finally, seasonal differences in AEFs due to fluctuations in hydro generation should be accounted for at the statewide level, and particularly for the PG&E area, a more careful effort should be undertaken to interpret and apply the Elfin files in a consistent fashion to obtain more accurate results than are derived here. This accounting will require better matching of historic data, better checking and standardizing of emission data, and better modeling of imports, exports, and trades, and the LDC approach proved promising and should be explored further. This approach can also be modified to consider variations in emissions by time-of-day, which could be of interest.

3.2 Assessing the Availability and Usefulness of Industry-Specific Metrics

In order to assess the availability and usefulness of industry-specific metrics, Berkeley Lab identified sector-specific metrics used in a number of international and national efforts aimed at understanding the underlying trends in GHG emissions, energy use and energy intensity. Table 5 presents a summary of the metrics identified. In addition to these metrics, Berkeley Lab found that hundreds, perhaps thousands, of companies worldwide have taken the initiative to report GHG emissions and/or energy use as part of the Environment, Health & Safety (EHS) reporting, often in response to corporate commitments to reduce GHG emissions or improve energy efficiency. While most companies report total GHG emissions, some companies also report either a GHG indicator or an energy intensity indicator. Intensity indicators vary by company. Some report energy intensity and some GHG intensity. Most use a physical measure of production, e.g. ton (or tonne) of product or number of products. Examples include Baxter International (energy use and GHG emissions/unit of production value), Dow Chemical (energy/lb product), Interface (energy use/unit of production), Holcim (GHG emissions/ton cement), Lafarge (energy/tonne cement), Miller Brewing (GHG emissions/barrel of beer produced), Pfizer (GHG emissions/$ of revenue), Rio Tinto (GHG emissions/unit of production), Rohm and Haas (energy use/lb output), SC Johnson (GHG emissions/lb product), Shell (energy use/ton product), St. Lawrence Cement (GHG emissions/ton cementitious product), ST Microelectronics (energy use/$ of production), Toyota (energy use/unit of production), and UTC (energy use/$ revenue) (Margolick and Russell 2001; U.S. EPA 2003).

Following the identification of metrics used in international and national programs, as well as those used by individual companies, Berkeley Lab then identified generic types of metrics for the buildings, transportation, and industry sectors.

Commercial and residential buildings in California consumed 865 TBtu of final energy in 1999. Berkeley Lab focused on commercial buildings only, however, because we expect commercial entities to be more likely participants in the Registry than residential building owners. When commercial buildings' electricity and natural gas use was combined, the largest share was found to be consumed in office-type buildings, followed by restaurants, retail stores, food stores, and warehouses, respectively. The survey of existing metrics for buildings found various metrics in use by international protocols, academic institutions, national governments, and businesses. Table 6 summarizes the buildings-related metrics used to measure GHG emissions and energy use. Physical metrics for measuring the intensity of GHG emissions or energy consumption in commercial buildings are generally based on building floor area (square feet or square meters). Emissions or energy use per occupant or employee can also be used, especially for office buildings where each additional employee typically requires conditioned space and office equipment. These metrics can be calculated by specific building types such as office buildings, restaurants, food stores, retail stores, and warehouses. Economic metrics are based on the economic value produced by the occupant of the commercial building. These metrics measure emissions or energy use per dollar of economic value produced.

Table 5. Sector-Specific Metrics Used for Commercial Buildings, Transportation, Industry, and Power

INTERNATIONAL	*Commercial Buildings*	*Transportation*	*Industry*	*Power*
Greenhouse Gas Protocol Initiative (GHGPI 2001)	• Sales/GHG emissions		• Production volume/GHG emissions • GHG emissions/function or service	• Tonnes of CO_2/electricity unit generated
UNEP GHG Indicator (Thomas et al. 2000)	• GHG emissions/unit of sales • GHG emissions/unit of value added • GHG emissions/number of employees		• GHG emissions/unit of value added • GHG emissions/unit of production	
International Council for Local Environmental Initiatives (ICLEI) (ICLEI 2001)	• Energy use/operating hours • Energy use/occupants • Energy use/floor space • Energy/commercial establishments • CO_2 eq. emissions/operating hours • CO_2 eq. emissions/occupants • CO_2 eq. emissions/floor space • CO_2 eq. emissions/commercial establishments	• Energy/vehicle kilometers traveled • Energy/vehicle • CO_2 eq. emissions/ vehicle kilometers traveled • CO_2 eq. emissions/vehicle	• Energy/floor area • Energy/industrial employees • Energy/industrial establishments • CO_2 eq. emissions/floor area • CO_2 eq. emissions/industrial employees • CO_2 eq. emissions/industrial establishments	
International Energy Agency (IEA 1997)	• Space heating energy use/square meter floor area • Electricity use/capita • Electricity use/unit of floor area • Electricity use/unit of service sector GDP • Electricity use/employee • Total primary energy/unit of service sector GDP • CO_2 emissions/capita • CO_2 emissions/unit of services GDP	• Energy use/passenger kilometer • Travel-related energy use/total national GDP • Tonnes of CO_2/capita • Energy use/tonne-kilometer of freight • Freight-related energy use/total national GDP • Freight CO_2 emissions/capita	• Energy use/tonne product • Energy use/$ value added • CO_2 emissions/unit of manufacturing energy use • CO_2 emissions/unit of manufacturing GDP	
European Commission Energy Efficiency Indicators Project (ODYSSEE 2001)	• Energy/value added • Energy/employee • Energy/floor area	• Freight energy/tonne km • Passenger energy/person km	• Energy/value added • Energy/tonne for energy-intensive industries	
International Network for Energy Demand Analysis in the Industrial Sector (LBNL 1999)			• Energy use/tonne product • CO_2 emissions/tonne of product	

Table 5. *continued*

NATIONAL	*Commercial Buildings*	*Transportation*	*Industry*	*Power*
Australia – Greenhouse Challenge (AGO 2003)	• CO_2 emissions/surface area • CO_2 emissions/transactions		• CO_2/tonne of product	• CO_2 emissions/kWh
Canada – Voluntary Challenge and Registry, Inc. (VCR-MRV, Inc. 1999)	• GHG emissions/total building area • GHG emissions/heated building area • GHG emissions/number of occupants or employees • Energy/square meter floor area		• CO_2 eq./cubic meter of oil eq. • CO_2 eq./unit of output • Energy/unit of output	• Total CO_2 emissions/TWh • Fossil CO_2 emissions/TWh
Canada – CIPEC (CIPEC 2001)			• Energy/tonne product • Energy/gross output • Energy/GDP • GHG emissions/tonne product • GHG emissions/gross output • GHG emissions/GDP	
Netherlands – Industrial Sector Agreements (Nuijen 1998)	• Climate-corrected energy use/unit of surface area (square meters)	• Energy use/person-kilometer		
Norwegian IEEN (Institute for Energy Technology 1998)			• Energy use/tonne product	

Table 6. Metrics for Buildings Energy Consumption and GHG Emissions

	Energy Consumption	GHG Emissions
Physical Metrics		
	Energy use/operating hours	Emissions/operating hours
	Energy use/occupants	Emissions/occupants
	Energy use/employee	Emissions/employee
	Electricity use/capita	Emissions/capita
	Electricity use/employee	Emissions/employee
	Energy use/floor space	Emissions/floor space
	Space heating energy use/floor area	Emissions/heated building area
	Electricity use/unit of floor area	
	Energy/commercial establishments	Emissions/commercial establishments
Economic Metrics		
	Electricity use/unit of services GDP	Emissions/unit of services GDP
	Energy/unit of value added	Emissions/unit of value added
	Primary energy/unit of services GDP	Emissions/unit of sales
		Emissions/transactions

Transportation is by far the largest energy-consuming and GHG-emitting sector in California, emitting almost 60% of total state GHG emissions in 1999 (California Energy Commission 2002). Transportation is broadly divided into travel or freight, but can also be divided into passenger transportation (local and interurban), freight transportation by motor vehicles, railroad transportation, water transportation, and air transportation.[13] Table 7 provides typical energy and GHG emissions metrics for the transportation sector.

Table 7. Metrics for Transportation Energy Consumption and GHG Emissions

	Energy Consumption	GHG Emissions
Physical Metrics		
	Energy/vehicle miles traveled	Emissions/ vehicle miles traveled
	Energy/vehicle	Emissions/vehicle
	Energy/passenger miles	Emissions/capita
	Energy/ton-miles of freight	Freight emissions/capita
	Freight energy/ton-mile	
	Passenger energy/person km	
Economic Metrics		
	Travel-related energy/total national GDP	
	Freight-related energy/total national GDP	

Industry in California consumed 1740 TBtu of final energy in 1999. Of the industrial electricity and natural gas use combined, the largest share was consumed by the oil and gas extraction sub-sector, followed by petroleum and coal products; food and kindred

[13] Statistics are also available for pipelines, transportation services, and the U.S. Postal Service, but have not been included in this report.

products; stone, clay, and glass products; and chemicals and allied products. Table 8 summarizes the industry-related metrics that are used by various governments, research institutions, and businesses to measure GHG emissions and energy consumption. Physical metrics for measuring the intensity of GHG emissions or energy consumption in industry are based on floor area (square feet or square meters), number of industrial employees, number of industrial establishments, or units of product produced. Metrics measuring emissions or energy use per unit of product can also be indexed in order to compare company performance to other companies or previous years. Such indexing can be designed to account for variations in products from year to year. Economic metrics are based on energy use per dollar of economic value or industrial output.

Table 8. Metrics for Industry Energy Consumption and GHG Emissions

	Energy Consumption	**GHG Emissions**
Physical Metrics		
	Energy/floor area	Emissions/floor area
	Energy/industrial employees	Emissions/industrial employees
	Energy/industrial establishments	Emissions/industrial establishments
	Energy use/unit of product	Emissions/unit of product
	Energy efficiency index (EEI)	Emissions/function or service
	Production Energy Intensity (PEI)	Carbon Energy Intensity (CEI)
	Energy Intensity Index (EII)	
	Production Energy Intensity Index (PEII)	Emissions/unit of manufacturing energy use
	Electricity/kg product	
Economic Metrics		
	Energy/$ gross output	Emissions/$ gross output
	Energy/GDP	Emissions/GDP
	Energy/$ commodity value	

Indexing is a means of providing information on a company's energy or emissions intensity (energy use per unit of product produced or emissions per unit of product produced) without revealing the actual underlying data to the public. In establishing an index, the base year intensity value for a company is set at 100 (or zero) and then intensity values for subsequent years are measured from the base year value. The calculation needs to take the company's product mix into account so that year-to-year changes in production will still result in a comparable annual index. Solomon Associates has developed an energy intensity index (EII), the Canadian Association of Petroleum Producers has developed a Production Energy Intensity Index (PEII), the international semiconductor industry has adopted a manufacturing index that normalizes for variations in production capacity and accounts for differences in manufacturing complexity, and the Dutch Long-Term Agreements (LTAs) on Energy Efficiency relied on the calculation of an energy efficiency index (EEI) to both set energy efficiency targets and as a metric to track progress toward realization of those targets. The calculation of the EEI uses physical activity indicators (e.g. ton of product, square meters of building space) in almost all sectors, as this more closely linked to actual energy use.

3.3 Evaluating Methods for Establishing Baselines for Calculating GHG Emissions Reductions Related to Specific Actions Taken by Registry Participants

Berkeley Lab identified seven types of baselines that can be constructed for calculating emissions reductions related to specific actions taken by registry participants. Table 9 provides an overview of the various baseline types that were identified by Berkeley Lab. These baselines are divided into those that are project-related and those that are entity-specific.

Project-related baselines are used to account for the GHG emissions that are reduced through specific mitigation projects. Baselines for calculating GHG emissions reductions from mitigation projects can be project-specific, multi-project, or can be based on the use of benchmark values. Project-specific baselines are determined on a project-by-project basis using specific measurements or assumptions. Multi-project, or standardized, baselines use existing or estimated emissions levels from a defined set of actual or projected projects to derive a baseline level (Ellis and Bosi 1999). Benchmark value baselines define business-as-usual or best-practice benchmark metrics that are used to set the baseline (Ellis et al. 2001).

Entity-specific baselines cover GHG emissions for an entire entity (e.g. corporation, municipality, organization) for a given period of time, typically yearly. Such baselines are developed in order to have a starting point for calculating GHG emissions reductions attributable to actions of the entity. Entity-specific reporting protocols have been developed by the World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD 2001) and for specific GHG emissions registries, such as the California Climate Action Registry (California Climate Action Registry 2002).[14] Entities are interested in accounting for their GHG emissions reduction activities in light of potential national (or state) GHG emissions-reduction commitments or for use within emissions trading regimes.[15] Entity-related baselines can be historical frozen baselines, business-as-usual projected baselines, future target baselines, or ex-post reconstructed baselines.

[14] In this section, we do not address the issue of modifying the baseline to account for ownership changes or changes in production within the entity.

[15] Emissions trading is a system in which participants can buy or sell GHG emissions allowances or credits. Emissions allowances are derived within a "cap-and-trade system," where there is an overall limit to emissions for a particular region or country and emissions allowances are distributed to participants. Emissions credits are generated through actions by entities that reduce their emissions below an established threshold. Entity-specific baselines are required in order to calculate these emissions credits (National Round Table on the Environment and the Economy 2002).

Table 9. Characteristics of Various Baselines Used to Calculate Energy Use or GHG Emissions Reductions

Baseline Focus	Type of Baseline	Baseline Used For	Use of Industry-Specific Metrics	Notes
Project-related	Project-specific	JI/CDM Emissions trading (credits) Registries	- Varies on a case-by-case basis	High transaction costs, high uncertainties (Begg et al. 1999; Ellis and Bosi 1999; Parkinson et al. 2001)
	Multi-project (standardized)	JI/CDM	- Energy use or GHG emissions/unit of output	Has been evaluated for the electricity, cement, steel sectors (Bosi 2000; Bode et al. 2000; Ellis 2000; Sathaye et al. 2001)
	Benchmark value	JI/CDM	- Energy use or GHG emissions/unit of output - Absolute energy use or GHG emissions/year	Ellis et al. 2001; Ministry of Economic Affairs 2000
Entity-specific	Historical frozen	Absolute targets or reductions Registries Credit for early action Emissions trading (credits)	Not used	
	Business-as-usual projected Growth baselines	Credit for early action Emissions trading (credits)	- Energy use or GHG emissions/unit of economic output - Energy use or GHG emissions/ unit of product produced	CCAP 1998; Nordhaus et al. 1998
	Future target	Credit for early action	- GHG emissions/year adjusted in a straight line downward from a base year to a designated reduction target in a future year	Nordhaus et al. 1998
	Ex-post reconstructed	Credit for early action Emissions trading (credits)	Not used	BPI 2002

As can be seen from the above discussion, many different baseline methods have been proposed, and some are currently in use by various registries or trading schemes. Table 10 provides an overall typology for a number of baseline methods, categorizing them according to the way the baselines are calculated. First, the methods are divided into three major categories according to the basic approach used to calculate the baselines, and within these categories, variations of the methods are listed. Each of these variations is then rated on its complexity and robustness. "Complexity" is an indication of whether many calculations are necessary to establish the particular baseline. Baselines that are highly complex may necessitate the use of expertise outside of the Registry and will, therefore, be more costly to implement. "Robustness" is a measure of the likelihood that the method is rigorous enough to be accepted for early action credit or other tradeable credits.

The first major group of baseline methods listed in Table 10 is *absolute baselines*, which are those that extrapolate a total level of emissions into the future. These methods are said to be static because they are not adjusted year to year to reflect an entity's output. While this type of baseline is the least subjective, the least costly, and the most easily implemented, it does not account for an entity's growth (Credit for Early Action Table 1999). Once these baselines are determined, they remain unchanged, unless they are adjusted to correct for a structural change, such as an acquisition or divestiture.

In contrast to absolute emissions baselines, *intensity baselines* estimate GHG savings according the emissions rate at which an entity produces its output. Thus, participants' early actions to reduce GHG emissions may be recognized even if growth in production causes overall emissions to rise, despite any improvements in emissions intensity that have occurred. These baselines are said to be dynamic because the estimated business-as-usual emissions to which the entity is compared depend on the entity's annual production and must be calculated from year to year. Intensity-derived baselines are linked to metrics, since a participant's rate of emissions for the base year(s) must be known in order to calculate future base case emissions. The emissions rate may be determined for one or more years in order to establish the baseline rate, or it may need to be monitored over several years in order to determine historic trends.

An *ex-post project-based baseline* tracks energy use or emissions from a starting year and is then determined on an annual basis by accounting for verifiable reductions attributed to specific mitigation actions. These are not truly baselines per se, but are simply the sum of an entity's actual emissions in a given year and the savings from specified mitigation actions. This approach is most accurate because actual emissions are known and reductions can be verified by a third party, but it can be more complex and costly (Credit for Early Action Table 1999). This type of baseline is used by the Baseline Protection Initiative (BPI) in Canada (BPI 2002).

Table 10. Typology and Qualitative Assessment of Baselines for Estimating Entity-Wide GHG Savings

Type of Baseline[a]	Calculation Method	Complexity[b]	Robustness[c]	Notes
Absolute: Static				
Fixed Base Year	Frozen base year absolute emissions projected into future	Low	Low	Used by the California Climate Action Registry
Fixed Multiyear Average	Multiyear average absolute emissions projected into future	Low	Low	Eliminates savings for all years used to construct the multiyear baseline
Future Target	Absolute emissions projected as a straight line between base year and future target	Low	Low/High	Robustness will be low with an arbitrary target and high if there is a national target
Historical Trend	Absolute emissions projected as a straight line based on historical trends	Low	Low	Will need to establish how many years are needed to constitute a trend
Intensity: Dynamic				
Fixed Base Year	Frozen base year intensity multiplied by actual production	Low	Low	Could be more complex and robust if structural changes are included
Fixed Multiyear Average	Multiyear average intensity multiplied by actual production	Low	Low	
Arbitrary Rate of Decline	Intensity declining at an arbitrary rate multiplied by actual production	Low	Low	Rates of decline may need to be negotiated.
Historical Trend - Entity	Entity historical intensity rate multiplied by actual production	Low	Mid	
Historical Trend - Industry	Industry-wide historical intensity rate multiplied by actual production	Low/High	Mid	Complexity is a function of the availability of regularly updated data on historical trends
Expert Judgment	Intensity rate decline based on expert judgment regarding industry multiplied by actual production	High	Mid	Expert judgment may be contested
Reconstructed: Dynamic				
Ex-Post Project-Based	Verified GHG emissions reduction project savings are added to actual GHG emissions trends to reconstruct the baseline	Mid/High	High	Project savings will need to be verified. Used by the Baseline Protection Initiative in Canada

Note: Baselines covered in this table are for existing facilities. Development of baselines for newly-constructed (greenfield) plants would require information on existing trends in the industry.

[a] *Static* or *dynamic* refers to whether total baseline emissions are projected into future years or are adjusted annually to reflect a participating entity's actual output.

[b] *Complexity* is an indication of how transparent a method is and to what extent outside expertise will probably be needed to calculate the baselines.

[c] *Robustness* indicates whether the resulting GHG emissions reductions are calculated using a methodology that could be strict enough to qualify for carbon credits under a cap-and-trade or other emissions trading scheme.

3.4 Case Studies

3.4.1 Advanced Micro Devices

Advanced Micro Devices (AMD) is a global supplier of microprocessors and other integrated circuit products. The company was founded in 1969 and is headquartered in Sunnyvale, California. In addition to the Sunnyvale campus, AMD owns two chip manufacturing facilities (one in Austin, Texas, the other in Dresden, Germany) and several test and assembly facilities located in various countries in Asia (AMD 2002). Since the California Climate Action Registry requires participants to report all emissions from activities in California and encourages them to report emissions from activities in other states, this case study focuses on the facilities in Sunnyvale and Austin.

AMD's publicly available data provide a manufacturing index (MI) that normalizes energy consumption, GHG emissions, and water consumption to varying levels of output. Berkeley Lab found that the energy-related GHG metrics, however, are subject to large fluctuations due to changes in capacity utilization. This approach undermines the purpose of the metrics, which is to track progress in reducing emissions per unit of output. Moreover, baselines derived from these metrics may be prone to unduly penalizing or rewarding manufacturers for factors beyond their control. The sensitivity to changes in capacity utilization may be due to the level of aggregation of energy data, where the more constant non-manufacturing energy consumption required to move air in the cleanroom and remove heat from the process tools is coupled with manufacturing-related energy consumption.

Perfluorocarbon (PFC) emissions, however, seem to be more closely correlated to production, and AMD has achieved relatively steady improvements in the emissions of PFCs per MI. Because the Registry's goal is to track real changes in GHG or energy intensity, it may be more informative to report the PFC and energy-related emissions metrics separately, as AMD currently does, but reporting the energy-related emissions at a more disaggregated level of end-use.

A suggested disaggregation that would not be too burdensome for Registry participants in this industrial sector might include the following metrics:

- Energy-related emissions from building energy use per square foot or square meter
- Energy-related emissions from clean room HVAC facilities per square foot or square meter
- Energy-related emissions from process tools and other productive end-uses per MI
- Non-energy-related emissions from manufacturing per MI

Separating the production-related emissions from the non-production-related emissions can be important for participants like AMD that have facilities with large fixed energy consumption requirements. Such metrics would allow the participants to clearly show the effect of energy-efficiency measures taken within the non-manufacturing facilities, such as offices and warehouses, separately from those taken within the manufacturing facilities. Within the manufacturing facilities, disaggregating the clean room HVAC from other end-uses will prevent changes in capacity utilization from masking the improvements in process efficiencies. Since the GWP-weighted emissions of PFCs can equal or exceed all the energy-related emissions combined, reporting them separately is imperative to account for the underlying reasons for changes in the GHG emissions.

If other electronics manufacturers participate in the Registry, and the Registry would like to maintain comparability among participants in similar industries, it will be important to work with the manufacturers to ensure that the normalization factors are defined consistently. For semiconductor manufacturing facilities, the Manufacturing Index described in this report is commonly employed in the industry. For R&D activities, however, this may be more complicated, as each manufacturer may have defined a normalization factor differently.

Regarding baselines, Berkeley Lab compared the actual GHG emissions and those emissions projected by the various baselines types in 2001 for AMD's Sunnyvale and Austin sites. In almost all cases, actual emissions are below the projected baselines. The only exceptions are for the fixed multiyear average rate baseline in the case of Sunnyvale and the historical trend baseline in the case of Austin where actual emissions are above the baseline values. For the Sunnyvale site, the three absolute baselines are very similar and as a result show very similar GHG emissions savings when compared to actual emissions in 2001. The intensity-based baselines provide a greater variation in projected 2001 values, none of which are similar to the absolute baseline values for that year. For the Austin site, the baselines and resulting GHG emissions reductions calculations vary widely.

3.4.2 Fetzer Vineyards

Fetzer Vineyards, headquartered in Hopland, California, was established in 1968. Currently, it is the sixth largest vineyard by total sales in the United States. Fetzer cultivates over 1,000 acres of grapes and produces approximately 200,000 cases of wine per year. Fetzer also engages in various service sector activities through its on-site restaurant and tasting facility, events center, and bed and breakfast operation (Fetzer 2001).

Fetzer Vineyards was able to provide production and energy consumption data at a level of disaggregation that made it possible to construct metrics for its two distinct operations of agricultural crop production (grape growing) and food processing (wine making). Other metrics that track energy use and GHG emissions from buildings and transportation activities would also need to be developed for a full accounting of GHG emissions; however, Fetzer Vineyards was unable to supply the production data for these activities at this time.

For both agricultural crop production and food processing, Berkeley Lab was able to construct meaningful metrics using physical measures of production. For agricultural crop production, the metrics constructed used either tons of grapes produced or acres as the denominator. Berkeley Lab found that using acres for a crop such as wine grapes can be problematic when new vineyards are planted, since it takes three to five years before the grapes are harvested but energy is still being expended to water and tend the field while the vines are maturing. Berkeley Lab found that a metric based on energy use per acre or energy use for productive acres per tons of grapes produced, with energy use for the "non-productive" acres subtracted from the total, would provide a better indication of trends.

Regarding baselines, Berkeley Lab found that the estimates of emissions vary widely depending on which baseline is chosen. In Fetzer Vineyard's case, it is important to note that the results would not differ so greatly if the absolute and intensity baselines were extrapolated from a year prior to 1999, when the switch to renewable electricity occurred. In practice, different baselines are useful for different purposes.

3.4.3 City of Berkeley

The City of Berkeley, located across the bay from San Francisco in northern California, has a population of 103,000. Municipal services provided by the City of Berkeley are similar to those provided by most large cities and include police and fire services, municipal libraries, refuse services, and public parks and recreation services. The City of Berkeley has set a goal to reduce its GHG emissions by 15% below projected baseline levels in 2010 (Energy Solutions 1998).

The City of Berkeley operates over 30 buildings; a municipal fleet of approximately 30 garbage trucks, 150 sedans, 100 light duty trucks, plus street sweepers and some heavy duty trucks; traffic signals at over 120 intersections, and approximately 40,000 streetlights (DeSnoo 2003; Silva 2003).

Berkeley Lab was able to develop metrics for the major sources of GHG emissions in the City of Berkeley for which data were available: buildings, vehicles, and traffic lights. Buildings contain a wide variety of energy uses, and the most precise metrics would measure energy consumed by each major end use, such as lighting, heating, cooling, and the use of various types of appliances and office equipment. However, each building is usually only fed by one gas meter and one electricity meter. Thus, obtaining data for more disaggregated uses would require the purchase of sub-metering equipment and an extensive data gathering effort. These data limitations largely prohibit the use of disaggregated metrics without elaborate efforts to estimate the electricity consumed by various end-uses. More aggregate indicators of intensity must be chosen. In this case study, energy consumption per square foot was used, correcting the natural gas consumption for climate, as the best overall indicator for buildings.

Even though data for specific end uses is not available, it may be useful to separately index natural gas and electricity. This is because the use of the two fuels is affected by different factors. For municipal buildings, natural gas will be used almost entirely for space heating. Therefore, the use of natural gas will be affected by the weather, and efforts to improve insulation will appear more clearly in a gas-only metric. Similarly, savings from lighting retrofits or acquisition of more efficient office equipment can be demonstrated in an electricity-usage metric.

Metrics for municipal vehicles can be based on the use of either gallon of fuel or GHG emissions from the fuel per vehicle mile traveled (VMT). Although a metric based on mileage is the most practical choice for municipalities and allows one to observe the most important changes in the fleet's GHG intensity over time, this metric does not capture the effect of shifting transport activity to non-motorized modes. For example, police officers and other staff use bicycles in some parts of Berkeley. While this reduces fuel consumption, it also reduces VMT, leaving the metric fairly constant.

For traffic signals, Berkeley Lab used a metric defined as GHG emissions per intersection for traffic signals. Data on traffic signal energy use for each year is provided by simulations from a traffic signal model designed by the City of Berkeley's Energy Commission (DeSnoo 2003). These data are then divided by the total number of intersections with traffic signals in use that year.

Development of metrics for the City of Berkeley highlighted a number of issues that may be common to many municipalities. First, since the denominator of building floor space was chosen as a more representative measure than number of municipal employees, it was important to obtain an accurate accounting of floor space. For the City of Berkeley, this task was difficult because of the significant building retrofits that were taking place during the case study period. In addition to having some buildings completely closed, these retrofit projects were problematic, because City employees moved to leased buildings, making it difficult to obtain both floor space and energy consumption, due to the various leasing arrangements.

Another finding from this case study was that while overall trends are apparent from a more aggregated metric such as GHG emissions per square foot (or meter) of building space, municipal energy managers may find tracking energy use and GHG emissions at a more disaggregated level to be more useful for evaluating specific actions taken to reduce municipal emissions. For example, disaggregating buildings or fleets by types or disaggregating by fuel use can highlight areas where savings have occurred or point out areas where potential savings may still be realized. For the City of Berkeley, such disaggregation shows that community centers have not reduced emissions per square foot at the rate experienced in other municipal buildings because they did not have energy efficiency retrofits that the other buildings had, that GHG emissions from the automobile fleet grew faster than those from the refuse fleet, and that retrofits of traffic signals significantly reduced emissions per intersection over the period of the case study.

4.0 Conclusions and Recommendations

In the research related to electricity emissions factors, Berkeley Lab found that using a simple annual statewide AEF could significantly under- or over-estimate an entity's emissions responsibility due to the large variation in generating resources among the utility service areas. Differentiating between MEFs and AEFs is essential to accurately estimate the CO_2 savings from reducing electricity use. Seasonal differences in AEFs due to fluctuations in hydro generation should be accounted for at the statewide level, and particularly for the Pacific Gas & Electric service area. Overall, Berkeley Lab's research demonstrated that there are significant differences in CO_2 emissions factors from electricity generation, depending upon whether the factor represents average emissions, marginal emissions, utility service districts, and various seasons. Programs that estimate total annual CO_2 emissions from electricity generation, as well as programs that estimate CO_2 emissions reductions related to mitigation efforts, should carefully choose the emissions factors that are used for calculating emissions from electricity.

In the research related to industry-specific metrics, Berkeley Lab found that there are numerous methodologies, benchmarking programs, inventories, protocols, and registries that use industry-specific metrics to track trends in energy use or GHG emissions. Berkeley Lab also determined the relative importance of different potential Registry participant categories in order to assess the availability of sectoral or industry-specific metrics and then identified industry-specific metrics in use around the world. As a result of this review, Berkeley Lab recommends the development of a GHG intensity index as a new metric for reporting and tracking GHG emissions trends. Such an index would provide an industry-specific metric for reporting and tracking GHG emissions trends that could accurately reflect year-to-year changes while protecting proprietary data. A GHG intensity index could be constructed using detailed production and GHG emissions data provided by Registry participants. Only the index, and not the detailed proprietary data, would be reported publicly. Such an index would provide Registry participants with a means for demonstrating improvements in their energy and GHG emissions per unit of production without divulging specific values.

In the research related to baselines, Berkeley Lab evaluated various methods used to calculate baselines for documentation of energy consumption or GHG emissions reductions, noting those that use industry-specific metrics. Berkeley Lab developed a baseline typology and assessed the complexity and robustness of each type of baseline vis-à-vis potential future emissions limits and/or emissions trading schemes. We found that only a statutorily established future target baseline and an ex-post reconstructed baseline were robust enough to be considered as a basis for granting credits for early actions. Of these two baseline types, the future target baseline is the easiest to construct; the ex-post reconstructed baseline is accurate because actual emissions are known and reductions can be verified by a third party, but it can be more complex and costly.

Finally, Berkeley Lab conducted three case studies in order to explore issues related to both industry-specific metrics and baselines. These case studies were done for Advanced Micro Devices (AMD), Fetzer Vineyards, and the City of Berkeley. The case studies demonstrated numerous issues related to the use of metrics and recommended that industry-specific metrics be disaggregated to a certain degree, depending upon both the specific sector and data availability, in order to best capture the energy or GHG emissions trends experienced at the participant's facilities. The case studies also discussed various baseline issues and concluded that it is difficult to clearly identify any one baseline that is preferable to another based on the limited number of years of data available, but also due to the wide variation in the differences between the baselines and actual GHG emissions. Data availability, baseline complexity, baseline robustness, and the ultimate desired use of the baseline must all be considered when choosing a baseline upon which to measure future GHG emissions reductions.

Overall, the case studies showed that it is difficult to clearly identify any one baseline that is preferable to another based on the limited number of years projected, but also due to the wide variation in the differences between the baselines and actual GHG emissions. Thus, these case studies indicate that while there are many types of baselines that can possibly be used to determine GHG emissions reductions attributable to the early actions of a company, the decision on which baseline to choose can be best made by considering the baseline complexity and robustness in terms of the ultimate desired use of the baseline.

When choosing among baseline methods, various considerations related to baseline complexity and robustness must be taken into account. Frozen baselines simply show whether an entity is contributing more or less to GHG emissions overall. Intensity baselines do not offer the precision to be used as a basis for protecting early action, unless perhaps they are more complex and use highly disaggregated data. Otherwise, "intensity," as defined at more practical levels of detail, will be affected by factors that do not reflect true changes in efficiency. Project-based reconstructed baselines are the most defensible for the generation of credits. Although total emissions are reported at the entity-wide level, savings must be documented on a project-specific basis. Since the claimed savings are attributable to specific projects, they can be more realistically monitored and verified.

4.1 Benefits to California

This research was undertaken to support the California Climate Action Registry by: 1) establishing methods for calculating electricity CO_2 emission factors, 2) assessing the availability and usefulness of industry-specific metrics, and 3) evaluating various methods for establishing baselines for calculating GHG emissions reductions related to specific actions taken by Registry participants.

By addressing each of those factors, this research provides information and analyses that the California Climate Action Registry can use to help ensure that volutnary CO_2 emissions reductions in the State are accurately tracked and that the participating entities receive appropriate credit for their emissions-reduction activities. As a result, California could reduce its production of greenhouse gases and benefit from cleaner air, while California entities that reduce those CO_2 emissions could benefit from financial and regulatory incentives based on CO_2 emissions reductions.

5.0 References

Advanced Micro Devices (AMD), 2002. *2001 Sustainability Progress Report*. http://www.amd.com/us-en/Corporate/AboutAMD/0,,51_52_531,00.html.

Australian Greenhouse Office (AGO), 2003. *Greenhouse Challenge*. http://www.greenhouse.gov.au/challenge/index.html.

Baseline Protection Initiative (BPI), 2002. *Baseline Protection Initiative Reference Manual*. http://nccp.ca/NCCP/pdf/media/news/manual_e.pdf.

Begg, K., S. Parkinson, T. Jackson, P-E. Morthorst, and P. Bailey, 1999. *Overall Issues for Accounting for the Emissions Reductions of JI Projects*. Presented at the Workshop on Baselines for CDM, Tokyo, February 25–26, 1999.

Bode, J-W., J. de Beer, K. Blok, and J. Ellis, 2000. *An Initial View on Methodologies for Emission Baselines: Iron and Steel Case Study*. OECD and IEA Information Paper.

Bosi, 2000. *An Initial View on Methodologies for Emission Baselines: Electricity Generation Case Study.* OECD and IEA Information Paper.

California Climate Action Registry, 2002. *General Reporting Protocol*. Los Angeles: California Climate Action Registry. http://198.104.131.213/docs/PROTOCOLS/general_reporting_protocol_102102.pdf.

California Energy Commission (CEC), 2002. *Inventory of California Greenhouse Gas Emissions and Sinks: 1990–1999*. Sacramento, CA: California Energy Commission.

California Energy Commission, 2001. *California Electricity Generation, 1983 to 2000*. http://www.energy.ca.gov/electricity/ELECTRICITY_GEN_1983-2000.XLS.

Canadian Industry Program for Energy Conservation (CIPEC), 2001. http://oee.nrcan.gc.ca/cipec/ieep/cipec/index.cfm.

Center for Clean Air Policy (CCAP), 1998. *Growth Baselines: Reducing Emissions and Increasing Investment in Developing Countries*. Washington, DC: CCAP. http://www.ccap.org/pdf/grow-int.pdf.

Credit for Early Action Table, 1999. *Report of the Credit for Early Action Table*. http://www.nccp.ca/html/tables/pdf/options/CEA_Report_May99.pdf.

DeSnoo, N., 2003. Personal communication with Neal DeSnoo, City of Berkeley.

Ellis, J., F. Missfeldt, M. Bosi, J. Painuly, 2001. *Possibilities for Standardised Baselines for JI and the CDM.* Background paper for UNEP/OECD/IEA workshop on baseline methodologies. Paris: Organisation for Economic Co-operation and Development and International Energy Agency. http://www.uccee.org/baselineworkshop/BackgrdPaper.doc.

Ellis, J., 2000. *An Initial View on Methodologies for Emission Baselines: Cement Case Study*. OECD and IEA Information Paper.

Ellis, J. and M. Bosi, 1999. *Options for Project Emissions Baselines*. OECD and IEA Information Paper. Paris: Organisation for Economic Co-operation and Development and International Energy Agency.

Energy Solutions, 1998. *City of Berkeley Resource Conservation and Global Warming Abatement Plan,* Berkeley, CA: Energy Solutions.

Farla, J., 2000. *Physical Indicators of Energy Efficiency*. Utrecht, The Netherlands: Utrecht University.

Fetzer Vineyards, 2001. *Come Visit Us.* http://www.fetzer.com/comevisit/index.html.

Freeman, S. L., M. J. Neifer, J. M. Roop, 1996. *Measuring Industrial Energy Efficiency: Physical Volume Versus Economic Valu*e. Richland, WA: Pacific Northwest National Laboratory (PNNL-11435).

GHGPI (Greenhouse Gas Protocol Initiative). 2001. http://www.ghgprotocol.org/.

Institute for Energy Technology, 1998. *Norwegian Industrial Energy Efficiency Network*. Kjeller, Norway: Institute for Energy Technology.

International Council for Local Environmental Initiatives (ICLEI), 2001. http://www.iclei.org/.

International Energy Agency, 1997. *Indicators of Energy Use and Efficiency: Understanding the Link Between Energy Use and Human Activity*. Paris: OECD/IEA.

Lawrence Berkeley National Laboratory (LBNL), 1999. *International Network for Energy Demand Analysis in the Industrial Sector.* Berkeley, CA: Lawrence Berkeley National Laboratory (LBID-2297).

Margolick, M. and D. Russell, 2001. *Corporate Greenhouse Gas Reduction Targets*. Washington, DC: Pew Center on Global Climate Change.

Marnay, C., D. Fisher, S. Murtishaw, A. Phadke, L. Price, and J. Sathaye, 2002. *Estimating Carbon Dioxide Emissions Factors for the California Electric Power Sector.* Berkeley, CA: Lawrence Berkeley National Laboratory, LBNL-49945.

Ministry of Economic Affairs, 2000. *Operational Guidelines for Baseline Studies, Validation, Monitoring, and Verification of Joint Implementation Projects*. Volume 2a: Baseline Studies, Monitoring, and Reporting – A Guide for Project Developers. Netherlands: MEA.
http://www.ceruleanconsultants.com/docs/Dutch%20MERV%20guidelines.pdf.

National Roundtable on the Environment and the Economy, 2002. *The ABCs of Emissions Trading: An Overview.* Ottawa, Canada: NRTEE. http://www.nrtee-trnee.ca/EmissionsTrading/en/ABCs-EmissionsTrading-e.pdf.

Nordhaus, R., S. Fotis, and V. N. Feldman, 1998. *Analysis of Early Action Crediting Proposals*. Prepared for the Pew Center on Global Climate Change. Washington, DC: PEW.

Nuijen, W., 1998. "Long Term Agreements on Energy Efficiency in Industry," in Martin et al. (eds.) *Industrial Energy Efficiency Policies: Understanding Success and Failure: Proceedings of a Workshop Organized by the International Network for Energy Demand Analysis in the Industrial Sector*. Utrecht, The Netherlands, June 11–12, 1998, LBNL-42368.

Nyboer, J. and A. Laurin, 2001a. *Development of Energy Intensity Indicators for Canadian Industry: 1990 to 1999*. Prepared for Canadian Industry Program for Energy Conservation and Natural Resources Canada. Vancouver: Canadian Industry Energy End-use Database and Analysis Center, Simon Fraser University.

Nyboer, J. and A. Laurin, 2001b. *Development of Greenhouse Gas Intensity Indicators for Canadian Industry: 1990 to 1999.* Prepared for Environment Canada and the Canadian Industry Program for Energy Conservation. Vancouver: Canadian Industry Energy End-use Database and Analysis Center, Simon Fraser University.

ODYSSEE, 2001. Web site of the ODYSSEE Database maintained by Enerdata S.A.: http://www.enerdata.fr/enerdata_UK/indexa.html (accessed November 13, 2001).

Parkinson, S., K. Begg, P. Bailey, and T. Jackson, 2001. "Accounting for Flexibility Against Uncertain Baselines: Lessons from Case Studies in the Easter European Energy Sector," *Climate Policy* 1(2001): 55–73.

Phylipsen, G. J. M., J. Nyboer, J. T. Oliver, A. Pape, E. Worrell, and K. Blok, 1996. *Proceedings of a Workshop on Methodologies for International Comparisons of Industrial Energy Efficiency*. April 1–2, 1996; Simon Fraser University, Vancouver, British Columbia.

Phylipsen, G. J. M., K. Blok, and E. Worrell, 1998. *Handbook on International Comparisons of Energy Efficiency in the Manufacturing Industry*, Utrecht, The Netherlands: Department of Science, Technology and Society, Utrecht University.

Price, L., S. Murtishaw, E. Worrell, 2003. *Evaluation of Metrics and Baselines for Tracking Greenhouse Gas Emissions Trends: Recommendations for the California Climate Action Registry*. Berkeley, CA: Lawrence Berkeley National Laboratory, LBNL-53027.

Sathaye, J., L. Price, E. Worrell, and M. Ruth, 2001. *Multi-Project Baselines for Evaluation of Industrial Energy-Efficiency and Electric Power Projects*. Berkeley, CA: Lawrence Berkeley National Laboratory, LBNL-48242.

Schipper, L., F. Unander, S. Murtishaw, and M. Ting, 2001. "Indicators of Energy Use and Carbon Emissions: Explaining the Energy Economy Link," *Annual Review of Energy and the Environment* 26: 49–81.

Silva, E., 2003. Personal communication with Ed Silva, City of Berkeley Public Works.

Thomas, C., T. Tennant, and J. Rolls, 2000. *The GHG Indicator: UNEP Guidelines for Calculating Greenhouse Gas Emissions for Businesses and Non-Commercial Organizations*. Geneva: United Nations Environment Programme. http://www.climnet.org/pubs/Unepghg.pdf.

U.S. Environmental Protection Agency (EPA), 2003. Climate Leaders: Partner GHG Goals. http://www.epa.gov/climateleaders/goals.html.

U.S. Environmental Protection Agency, 2001. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–1999*. Washington, DC: U.S. EPA. http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BMQ95/$File/2001-inventory.pdf.

VCR-MRV, Inc. 1999. *Registration Guide 1999*.

World Resources Institute/World Business Council for Sustainable Development, 2001. *The Greenhouse Gas Protocol: A Common Corporate Accounting and Reporting Standard*. http://www.ghgprotocol.org/standard/ghg.pdf.

Worrell, E., L. Price, N. Martin, J. Farla, and R. Schaeffer, 1997. "Energy Intensity in the Iron and Steel Industry: A Comparison of Physical and Economic Indicators," *Energy Policy* 25(7-9): 727–744.

Appendix A

Estimating Carbon Dioxide Emissions Factors for the California Electric Power Sector

Appendix B

Evaluation of Metrics and Baselines for Tracking Greenhouse Gas Emissions Trends: Recommendations for the California Climate Action Registry