The Costs and Financial Benefits of Green Buildings

A Report to California's
Sustainable Building Task Force

October 2003

Principal Author: Greg Kats, Capital E

Contributing Authors: Leon Alevantis, Department of General Services
Adam Berman, Capital E
Evan Mills, Lawrence Berkeley National Laboratory
Jeff Perlman, Capital E

This report was developed for the Sustainable Building Task Force (Task Force), a group of over 40 California state government agencies. Funding for this study was provided by the Air Resources Board (ARB), California Integrated Waste Management Board CIWMB), Department of Finance (DOF), Department of General Services (DGS), Department of Transportation (Caltrans), Department of Water Resources (DWR), and Division of the State Architect (DSA). This collaborative effort was made possible through the contributions of Capital E, Future Resources Associates, Task Force members, and the United States Green Building Council.

October 3, 2003

Dear Colleagues,

This study, *The Costs and Financial Benefits of Green Building,* represents the most definitive cost benefit analysis of green building ever conducted. It demonstrates conclusively that sustainable building is a cost-effective investment, and its findings should encourage communities across the country to "build green."

In August 2000, Governor Davis issued Executive Order D-16-00, establishing sustainable building as a primary goal for state construction and tasking the State and Consumer Services Agency with its implementation. Our agency established the Sustainable Building Task Force, a unique partnership among more than 40 governmental agencies, whose combined building, environmental, and fiscal expertise has produced outstanding results, including funding for this report.

Since its inception, the Sustainable Building Task Force has worked diligently to incorporate green building principles into California's capital outlay process. Our many successes include:

- Building the first LEED Gold state owned office building in the country, the Education Headquarters Building, which is saving taxpayers $500,000 a year in energy costs alone;
- Including sustainable building performance standards, such as energy efficiency, in over $2 billion of state construction and renovation contracts;
- Constructing many high visibility state "leadership buildings," which are models of sustainability, including the Caltrans District 7 Office building in Los Angeles;
- Promoting on-site renewable energy, such as the installation of over an acre of photovoltaic panels on the roof of the Franchise Tax Board Building in Rancho Cordova – which is the largest array on any state office building in the country;
- Assisting the Chancellor of the new 10th University of California campus, UC Merced, in her goal to construct the greenest campus in the country with an initial target of LEED Silver for all construction; and
- Impacting the sustainability of K-12 bond funded school construction throughout the state by providing funding and technical assistance to support the work of the Collaborative for High Performance Schools (CHPS), including the construction of 13 demonstration high performance schools.
- Confirming through rigorous emissions testing that the careful selection of building materials in concert with environmentally responsive cleaning practices results in cleaner and healthier indoor environments.

While the environmental and human health benefits of green building have been widely recognized, this comprehensive report confirms that minimal increases in upfront costs of 0-2% to support green design will result in life cycle savings of 20% of total construction costs -- more than ten times the initial investment. In other words, an initial upfront investment of up to $100,000 to incorporate green building features into a $5 million project would result in a savings of $1 million in today's dollars over the life of the building. These findings clearly support the work of the Sustainable Building Task Force and reinforce our commitment to build the greenest state facilities possible.

This report was funded by several Sustainable Building Task Force member agencies, including the Air Resources Board, the Department of Finance, the Department of General Services, the Department of Transportation, the Department of Water Resources, the Division of the State Architect, and the Integrated Waste Management Board. Their resources and staff support have helped to increase our collective knowledge of the true costs and benefits of green building. In addition, I would like to recognize the contributions of Undersecretary Arnold Sowell and Senior Consultant Amanda Eichel of the State and Consumer Services Agency. Their leadership, as well as their commitment to this subject, made this project possible.

With the signing of Executive Order D-16-00 by Governor Davis, California embarked on a road to sustainability. Since that time many cities, counties, and school districts, as well as the Board of Regents for the University of California, have established similar sustainable building goals. It is extremely rewarding not only to note the major accomplishments of this Task Force, including this first of a kind study documenting the cost-effectiveness of green building, but also to witness the national impact of these extraordinary interagency efforts.

Best regards,

Aileen Adams
Secretary

TABLE OF CONTENTS

Executive Summary

Integrating "sustainable" or "green" building practices into the construction of state buildings is a solid financial investment. In the most comprehensive analysis of the financial costs and benefits of green building conducted to date, this report finds that an upfront investment of less than two percent of construction costs yields life cycle savings of over ten times the initial investment. For example, an initial upfront investment of up to $100,000 to incorporate green building features into a $5 million project would result in a savings of at least $1 million over the life of the building, assumed conservatively to be 20 years.[1]

The financial benefits of green buildings include lower energy, waste disposal, and water costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased productivity and health. These benefits range from being fairly predictable (energy, waste, and water savings) to relatively uncertain (productivity/health benefits). Energy and water savings can be predicted with reasonable precision, measured, and monitored over time. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy.

There is now a very large body of research, reviewed in this report, which demonstrates significant and causal correlation between improvements in building comfort and control measures, and worker health and productivity. However, these studies vary widely in specific measured correlations. Further, there has been relatively little work completed to evaluate specific, measurable benefits from green building design in California. Clearly, the benefits are significant and not zero, but the data supports a broad range of calculated benefits – in contrast to the more precisely measurable energy, water, and waste savings.

The financial benefits conclusions in this report should therefore be understood in this context. Energy, waste, and water savings as well as emissions reductions can be viewed as fairly precise, reasonably conservative estimates of direct benefits that alone significantly exceed the marginal cost of building green. Health and productivity benefits can be viewed as reasonably conservative estimates within a large range of uncertainty. Further research is necessary to better quantify and capture the precise savings associated with these benefits. Additional studies might include such measures as evaluating green building effects on insured and uninsured health effects, employee turnover, worker well being and, where relevant (e.g. in schools), test scores.

Background

"Green" or "sustainable" buildings use key resources like energy, water, materials, and land much more efficiently than buildings that are simply built to code. They also create healthier work, learning, and living environments, with more natural light and cleaner air, and contribute to improved employee and student health, comfort, and productivity. Sustainable buildings are cost-effective, saving taxpayer dollars by reducing operations and maintenance costs, as well as by lowering utility bills.

---

[1] Although this report was written with specific regard to California state buildings, data is national in scope and conclusions are broadly applicable to other types of buildings and for other public and private sector entities.

Over the last few years, the green building movement has gained tremendous momentum. The United States Green Building Council (USGBC), a national non-profit organization, has grown dramatically in membership. The USGBC's Leadership in Energy and Environmental Design (LEED) rating system has been widely embraced both nationally and internationally as the green building design standard. Public and private sector entities, including the cities of Santa Monica, San Diego, San Francisco, San Jose, Long Beach, Los Angeles, Seattle, and Portland; the University of California; the Department of the Navy; the federal General Services Administration; and the States of Oregon, New York and Maryland have all adopted green building policies and clean energy standards. In addition, corporate entities, including Steelcase, Herman Miller, Johnson Controls, Interface, IBM, PNC Financial Services, Southern California Gas Company, Toyota, and Ford Motor Company, have constructed green buildings.

Recognizing the tremendous opportunity for California state government to provide leadership in the area of exemplary building design and construction methods, several years ago Governor Davis issued two Executive Orders that address the siting and building of state facilities:

- Executive Order D-16-00 establishes the Governor's sustainable building goal: "to site, design, deconstruct, construct, renovate, operate, and maintain state buildings that are models of energy, water, and materials efficiency; while providing healthy, productive and comfortable indoor environments and long-term benefits to Californians...The objectives are to implement the sustainable building goal in a cost effective manner…; use extended life cycle costing; and adopt an integrated systems approach.[2]"
- Executive Order D-46-01 provides guidance on the process the Department of General Services will use to locate and lease space, including such considerations as proximity to public transit and affordable housing, preserving structures of historic, cultural, and architectural significance, opportunities for economic renewal; and sensitivity to neighborhood and community concerns.[3]

The Issue of Cost

To implement the Executive Orders, the Secretary of the State and Consumer Services Agency, Aileen Adams, formally convened an interagency Sustainable Building Task Force (Task Force) comprised of over 40 state agencies, including representatives with energy, environmental, fiscal, construction, property management, and historic preservation expertise. As the Task Force set about its implementation work, the uncertainty about the "cost" of green buildings became an issue of growing importance and increased discussions.

While there seems to be consensus on the environmental and social benefits of green building, there is a consistent concern, both within and outside the green building community, over the lack of accurate and thorough financial and economic information. Recognizing that the cost issue was becoming more and more of a prohibitive factor in the mainstreaming of green building not only within California but across the country, several members of the Task Force funded an Economic Analysis Project to determine more definitively the costs and benefits of sustainable

[2] State of California, Governor's Executive Order D-16-00. August 2000. Available at: http://www.governor.ca.gov/state/govsite/gov_homepage.jsp.
[3] State of California, Governor's Executive Order D-46-01. October 2001. Available at: http://www.governor.ca.gov/state/govsite/gov_homepage.jsp.

building.[4] Sustainable buildings generally incur a "green premium" above the costs of standard construction. They also provide an array of financial and environmental benefits that conventional buildings do not. These benefits, such as energy savings, should be looked at through a life cycle cost methodology, not just evaluated in terms of upfront costs. From a life cycle savings standpoint, savings resulting from investment in sustainable design and construction dramatically exceed any additional upfront costs.

It is generally recognized that buildings consume a large portion of water, wood, energy, and other resources used in the economy. Green buildings provide a potentially promising way to help address a range of challenges facing California, such as:

- The high cost of electric power.
- Worsening electric grid constraints, with associated power quality and availability problems.
- Pending water shortage and waste disposal issues.
- Continued state and federal pressure to cut criteria pollutants.
- Growing concern over the cost of global warming.
- The rising incidence of allergies and asthma, especially in children.
- The health and productivity of workers.
- The effect of the physical school environment on children's abilities to learn.
- Increasing expenses of maintaining and operating state facilities over time.

Benefits include some elements that are relatively easy to quantify, such as energy and water savings, as well as those that are less easily quantified, such as the use of recycled content materials and improved indoor environmental quality. Prior to this report, no comprehensive analysis of the actual costs and financial benefits of green buildings had been completed, although there are a number of studies that do begin to address this very important issue.

- In October 2002, the David and Lucille Packard Foundation released their Sustainability Matrix and Sustainability Report, developed to consider environmental goals for a new 90,000 square foot office facility. The study found that with each increasing level of sustainability (including various levels of LEED), short-term costs increased, but long-term costs decreased dramatically.[5]

- A second, older study conducted by Xenergy for the City of Portland identified a 15% lifecycle savings associated with bringing three standard buildings up to USGBC LEED certification levels (with primary opportunities to save money associated with energy efficiency, water efficiency and use of salvaged materials).[6]

---

[4] Funding agencies include the Air Resources Board (ARB), California Integrated Waste Management Board (CIWMB), Department of Finance (DOF), Department of General Services (DGS), Department of Transportation (CalTrans) Department of Water Resources (DWR), and Division of the State Architect (DSA).

[5] "Building for Sustainability: Six Scenarios for the David and Lucille Packard Foundation Los Altos Project," prepared for the David and Lucille Packard Foundation, October 2002. Available on-line at: http://www.packard.org/pdf/2002Report.pdf.

[6] "Green City Buildings: Applying the LEED Rating System," prepared for the Portland Energy Office by Xenergy, Inc and SERA Architects, June 18, 2000. Available at: http://www.sustainableportland.org/CityLEED.pdf.

In addition, a number of other studies document measurable benefits for enhanced daylighting, natural ventilation, and improved indoor air quality in buildings. Benefits associated with these "green" features include enhanced worker and student productivity, as well as reduced absenteeism and illness.
For example:

- One study performed by the Heschong-Mahone group looked at students in three cities and found that students in classrooms with the greatest amount of daylighting performed up to 20% better than those in classrooms that had little daylight.[7]
- A study at Herman-Miller showed up to a 7% increase in worker productivity following a move to a green, daylit facility.[8]
- A Lawrence Berkeley National Laboratory study found that U.S. businesses could save as much as $58 billion in lost sick time and an additional $200 billion in worker performance if improvements were made to indoor air quality.[9]

Report Methodology and Format

This report is the first of its kind to fully aggregate the costs and benefits of green buildings. Specifically, the bulk of this report reviews and analyzes a large quantity of existing data about the costs and financial benefits of green buildings in California. Several dozen building representatives and architects were contacted to secure the cost of 33 green buildings compared to conventional designs for those buildings. The average premium for these green buildings is slightly less than 2% (or $3-5/ ft^2, see *Implications for California,* pg.18), substantially lower than is commonly perceived. The majority of this cost is due to the increased architectural and engineering (A&E) design time necessary to integrate sustainable building practices into projects. Generally, the earlier green building gets incorporated into the design process, the lower the cost.

A literature review conducted for this report revealed that there is sufficient data from which to construct reasonable estimates about the value of many green building attributes. Historically, both private firms and public agencies do not recognize the full financial value of green buildings. They usually acknowledge some benefits from lower energy and water use, but completely ignore or critically undervalue other, often significant, financial benefits of green buildings during the design and construction decision-making process.[10] For most of these benefits, such as emissions reductions and employee productivity, there are multiple methods that can be used to derive values of benefits, as well as a large range of values that can be assigned to them. In most cases, there is no single "right" answer. Nonetheless, the report underscores that based on the body of

---

[7] Heschong Mahone Group, "Daylighting in Schools: An Investigation into the Relationship Between Daylight and Human Performance," 1999. Available at: http://www.h-m-g.com; Follow up studies verified the rigor of analysis and subsequent research continues to show positive correlation between daylighting and student performance.
[8] Judith Heerwagen, "Do Green Buildings Enhance the Well Being of Workers?" *Environmental Design and Construction Magazine*. July/August 2000. Available at: http://www.edcmag.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,4118,19794,00.html.
[9] William Fisk, "Health and Productivity Gains from Better Indoor Environments," summary of prior publications (see Appendix J), with figures inflation-adjusted for 2002 dollars and rounded.
[10] See, for example "CEC Environmental Performance Report." Available at: http://www.energy.ca.gov/reports/2001-11-20_700-01-001.PDF. 2003 EPR will be finalized and available in October 2003 as part of the *Integrated Energy Policy Report*.

existing data, it is possible to determine reasonable, conservative estimates of financial benefits for a range of green building attributes.

The report also reveals the need for further research and analysis. In all areas, consistently conservative assumptions were made in view of data limitations. Additional research will help to refine cost and benefit estimates and likely lead to increased financial benefit calculations for green building. Additionally, throughout the report, the reader is directed to online databases and publications for the most accurate and relevant information. In many instances, these referenced documents are available online, and URLs are provided in the footnotes.

Conclusion

The benefits of building green include cost savings from reduced energy, water, and waste; lower operations and maintenance costs; and enhanced occupant productivity and health. As Figure ES-1 shows, analysis of these areas indicates that total financial benefits of green buildings are over ten times the average initial investment required to design and construct a green building. Energy savings alone exceed the average increased cost associated with building green.

Additionally, the relatively large impact of productivity and health gains reflects the fact that the direct and indirect cost of employees is far larger than the cost of construction or energy. Consequently, even small changes in productivity and health translate into large financial benefits.

Figure ES-1. Financial Benefits of Green Buildings Summary of Findings (per ft^2)

Category	20-year NPV
Energy Value	$5.79
Emissions Value	$1.18
Water Value	$0.51
Waste Value (construction only) - 1 year	$0.03
Commissioning O&M Value	$8.47
Productivity and Health Value (Certified and Silver)	$36.89
Productivity and Health Value (Gold and Platinum)	$55.33
Less Green Cost Premium	($4.00)
Total 20-year NPV (Certified and Silver)	**$48.87**
Total 20-year NPV (Gold and Platinum)	**$67.31**

Source: Capital E Analysis

Despite data limitations and the need for additional research in various areas, the findings of this report point to a clear conclusion: building green is cost-effective and makes financial sense today.

Acknowledgements

Fifty members of the Sustainable Building Task Force provided guidance and significant staff and research time to shape this work. The leadership of Arnie Sowell, Undersecretary of the California State and Consumer Services Agency, made this report possible. Amanda Eichel, Senior consultant with the California State and Consumer Agency, provided invaluable research and organizational support.

The US Green Building Council served as a partner in this effort, providing critical data, insights and support throughout the project. Principal author Greg Kats serves as Chair of the Energy and Atmosphere Technical Advisory Group for LEED and serves on LEED's steering committee.[11]

Other members of the Capital E team - Hank Habicht, Jim Rogers and Joe Romm - provided valuable insights, edits and support.

Vivian Loftness and the Carnegie Mellon University's Department of Architecture provided invaluable information and data on the productivity benefits from improved indoor air quality.

A group of California and national leaders served on the Green Building Valuation Advisory Group, and provided invaluable guidance and information throughout the project.

Green Building Valuation Advisory Group

Gregg Ander	Chief Architect, Southern California Edison
Bob Berkebile	Principal, BNIM Architects
Anthony Bernheim	Principal, SMWM
Steve Castellanos	California State Architect
Christine Ervin	President, US Green Building Council
Vivian Loftness	Head, Department of Architecture, Carnegie Mellon University
Roger Platt	VP and Counsel, Real Estate Roundtable
Bill Reed	VP Integrative Design, Natural Logic
Art Rosenfeld	Commissioner, California Energy Commission
Beth Shearer	Director, Federal Energy Management Program, US DOE

The authors were greatly helped by the kind assistance and advice from a large range of experts in state agencies, architectural firms and elsewhere, particularly:

Hashem Akbari, Lawrence Berkeley National Laboratory
Dan Burgoyne, California Department of General Services
Bill Browning, Rocky Mountain Institute
John Boecker, Robert Kimball & Associates
Amanda Eichel, California State and Consumer Services Agency
Charles Eley, Eley Associates & The Collaborative for High Performance Schools
Randy Ferguson, California Department of General Services
William Fisk, Lawrence Berkeley National Laboratory
Kathy Frevert, California Integrated Waste Management Board

[11] Lead author contact information: gkats@cap-e.com, www.cap-e.com, or 202 463-8469. For purposes of disclosure, Greg Kats co-founded and until 2001 served as Chair of the IPMVP, the national standard for monitoring and managing building energy and environmental performance. LEED and IPMVP are referred to frequently in this report.

David Gottfried, WorldBuild and the US Green Building Council
Nigel Howard, US Green Building Council
Wendy Illingworth, Economic Insights, Inc.
Pat McAuliffe, California Energy Commission
Daryl Mills, California Energy Commission
Gregg Morris, Future Resources Associates
Brendan Owens, US Green Building Council
Rubin Tavares, California Energy Commission
Jim Tilton, California Department of Finance
Robert Watson, Natural Resources Defense Council
Robert Wilkinson, University of California Santa Barbara, Department of Environmental Studies
John Wilson, California Energy Commission

In addition, valuable assistance and/or draft review comments were provided by:

Lucia Athens	City of Seattle Green Building Program
Sam Baldwin	US Department of Energy
Panama Bartholomy	California Department of General Services, Division of the State Architect
John Blue	California Integrated Waste Management Board
Bob Boughton	California Department of Toxic Substances Control
Marilyn Brown	Oak Ridge National Lab
Ty Carson	US Green Building Council
Tom Deitsche	US Green Building Council
Sean Dockery	California Department of General Services, Division of the State Architect
William Dougherty	Tellus Institute
Beverly Dyer	US Department of Energy, Federal Energy Management Program
Simon Esching	California Department of Water Resources
Gary Estrada	California Department of General Services, Office of Risk and Insurance Management
Karen Finn	California Department of Finance
Doug Grandy	California Department of General Services
Dave Hasson	City of Portland, Environmental Services
Tom Hicks	US Environmental Protection Agency, Energy Star Program
Ray Hoagland	California Department of Water Resources
Tom Hoff	National Renewable Energy Lab
Steve Kasower	US Bureau of Reclamation, Southern California
Matt Layton	California Energy Commission, Systems Assessment & Facilities Siting
Dale Lessick	Irvine Ranch Water District
Hal Levin	Lawrence Berkeley National Laboratory
Joe Loyer	State Energy Siting Division, Environmental Unit
Amory Lovins	Rocky Mountain Institute
Fred Luzzi	California Department of General Services, Real Estate Services Division, Buildings and Property Management Branch
Lisa Maddaus	California Urban Water Conservation Council
Nadav Malin	Environmental Building News
Gary Matteson	Mattesons and Associates
Lisa Matthiessen	Davis Langdon Adamson
Mike Meredith	California Department of General Services, Real Estate Services Division

Jeff Morris	Sound Resource Management
Peter Morris	Davis Langdon Adamson
Jim Ogden	3D/I
Aya Ogishi	UC Berkeley, Department of Agricultural and Resource Economics
Tom Phillips	California Air Resources Board
Steve Prey	California Department of Transportation
Jack Safely	Metropolitan Water District of Southern California
Chris Schmidle	California Integrated Waste Management Board
Jennifer Seal	Rocky Mountain Institute
Dave Sharky	California Department of General Services, Real Estate Services Division, Buildings and Property Management Branch
Lisa Skumatz	SERA, Inc.
Arnie Sowell	California State and Consumer Services Agency
Gail Sturm	Cushman & Wakefield
Scott Tomeshevski	California Energy Commission
James Toothaker	Formerly of the Governor's Green Government Council, Pennsylvania
Barbara Van Gee	California Integrated Waste Management Board
Jed Waldeman	California Department of Health Services
Clark Williams	California Integrated Waste Management Board
Alex Wilson	Environmental Building News
Gary Wolff	Pacific Institute
Hank Zaininger	Zaininger Engineering

I. Overview of Project

In September 2002, California's Sustainable Buildings Task Force (SBTF)[12] – composed of representatives from over 40 state agencies – with funding from seven of its constituent agencies,[13] hired a team, lead by Capital E, to undertake an economic analysis project to aid in the effort to evaluate the cost and benefits of sustainable building.

This report is intended to provide immediately useful analytic support for making informed and cost-effective building design decisions. Identification of gaps and recommendations for additional research are mentioned throughout the text and compiled in Section XII – Recommended Next Steps. These are intended to provide guidance to the SBTF in identifying opportunities to further improve understanding of the full costs and benefits of green buildings.

What is a Green Building?

"Green" or "sustainable" buildings are sensitive to:

- Environment.
- Resource & energy consumption.
- Impact on people (quality and healthiness of work environment).
- Financial impact (cost-effectiveness from a full financial cost-return perspective).
- The world at large (a broader set of issues, such as ground water recharge and global warming, that a government is typically concerned about).

California's Executive Order D-16-00 establishes a solid set of sustainable building objectives: "to site, design, deconstruct, construct, renovate, operate, and maintain state buildings that are models of energy, water and materials efficiency; while providing healthy, productive and comfortable indoor environments and long-term benefits to Californians." [14] This green building Executive Order requires consideration of externalities, economic and environmental performance measures, life cycle costing, and a whole building integrated systems approach when making sustainable building funding decisions. These objectives for sustainable building design include not only tangible savings associated with energy, water and waste efficiencies, but also "softer" benefits, such as human health and productivity, impact on the environment and incorporation of recycled content materials.

---

[12] See: http://www.ciwmb.ca.gov/GreenBuilding/TaskForce/, State of California Sustainable Building Task Force website.

[13] The seven CA state agencies that funded this study are the California Air Resources Board (ARB), California Integrated Waste Management Board (CIWMB), Department of Finance (DOF), Department of General Services (DGS), Department of Transportation (Caltrans), Department of Water Resources (DWR), and Division of the State Architect (DSA).

[14] State of California, Governor's Executive Order D-16-00. August 2000. Available at: http://www.governor.ca.gov/state/govsite/gov_homepage.jsp.
The goals of sustainable building practice in California, according to one recent article, are to: a) enhance indoor air quality; b) improve occupant health and productivity; c) increase the efficiency of material, energy, and water resource usage; and d) reduce the environmental impacts associated with the production of raw materials and the construction, deconstruction and long-term operation of buildings. Alevantis et al., "Sustainable Building Practices in California State Buildings," *Proceedings of Indoor Air 2002: The 9th International Conference on Indoor Air Quality and Climate*. Monterey, CA, June 30 – July 5, 2002. Vol. 3, pp. 666-671, Indoor Air 2002, Inc. Available at: http://www.indoorair2002.org.

In December 2001, the SBTF released the report, *Building Better Buildings: A Blueprint for Sustainable State Facilities*,[15] the first in a series of reports that will document the progress of California state government in implementing the Governor's sustainable building goals. The Blueprint notes that sustainable buildings are often called green or high performance buildings. The US Green Building Council (USGBC)[16] uses the term "green" to define a building with the same objectives as those described in the *Blueprint*. Other initiatives, such as New York's High Performance Building Design Guidelines,[17] use the term "high performance" to describe virtually the same set of building characteristics. The High Performance Guidelines draw particular attention to the use of advanced technology, or "smart infrastructure," and its impact on tenant ability to control key building comfort measures (such as temperature and light levels) to increase performance.[18]

This report will use the terms "sustainable" and "green" synonymously and interchangeably.

Sustainable design practices have been applied in American buildings for millennia, as evidenced in the exquisite structures of the Hopi Indians a thousand years ago. However, the term sustainable or green architecture as a modern, integrated design philosophy appears to be very recent. The first references to "green architecture" and "green building label" reportedly appeared in the British publication *The Independent* in London in early 1990, followed by the first American use of the term "green architecture" in mid-1990, on the editor's page of *Architecture* magazine.[19] The American Institute of Architect's Committee on the Environment started in 1989.[20] In 1991, the city of Austin established the first green building program in the United States[21] – there are now dozens of such programs nationally.[22] The Green Building committee of the American Society for Testing and Materials (ASTM) also formed in 1991.[23] Thus, the modern green building movement appears to be little over a decade old. It is therefore impressive that there is already an emerging national consensus on the definition of a green building and a rapidly increasing number of green projects in both the public and private sectors.

While there is no exactly "correct" weighting of green attributes, there is a broad consensus both with regard to the general attributes that constitute greenness, as well as the approximate

---

[15] California State and Consumer Services and Sustainable Building Task Force. "Building Better Buildings: A Blueprint for Sustainable State Facilities," December 2001. Available at: http://www.ciwmb.ca.gov/GreenBuilding/Blueprint/.

[16] See: http://www.usgbc.org, United States Green Building Council website.

[17] New York City Department of Design and Construction. "High Performance Building Guidelines*."* April 1999. Available at: http://home.nyc.gov/html/ddc/html/highperf.html.

[18] See, for example: Alan Traugott, "Green Building Design = High Performance Building Design," *Consulting-Specifying Engineer*, January 1999, pp. 68-74.

[19] Nathan Engstrom, "The Rise of Environmental Awareness in American Architecture: From the Bruntland Commission to LEED," *Platform* (A publication of the School of Architecture at the University of Texas at Austin), Fall 2002. Available at: http://www.ar.utexas.edu/csd/documents/stu-papers/engstrom-1.pdf.

[20] See: http://www.aia.org/cote, American Institute of Architect's Committee on the Environment (COTE) website.

[21] See: http://www.ci.austin.tx.us/greenbuilder/, The City of Austin Green Building Program.

[22] For a useful summary table (with URLs) of two dozen green building programs in the US, see:
Peter Yost, "Green Building Programs – An Overview," *Building Standards*, March – April 2002, p. 13. Available at: http://www.buildingscience.com/resources/articles/default.htm.
The Table was adapted from a longer article in *Environmental Building News*.

[23] See: http://www.astm.org, ASTM "Sustainability" Subcommittee E06.71 of Committee E06 "Performance of Buildings."

weighting that these different attributes should receive.[24] However, the definition of a sustainable building is innately subjective. There is no universally accepted way to compare such diverse green attributes as, for example, improved human health, reduced water pollution and reduced forest cutting. Different green building programs balance various dimensions of "greenness" through a necessarily subjective weighting. For example, Green Globes, a US online assessment tool for benchmarking the greenness of building performance, attributes 34% of the weighting of building greenness to energy use, more than the USGBC's Leadership in Energy and Environmental Design (LEED) Rating System's 29%.[25] Because of the wide range of "green" attributes considered, no single scientific denominator exists, and weighting reflects consensus best judgment rather than scientific determination.

The range of definitions of what constitutes a green or sustainable building includes:

- The British Research Establishment Environmental Assessment Method (BREEAM) was launched in 1990 and is increasing in use.[26]
- Canada's Building Environmental Performance Assessment Criteria (BEPAC) began in 1994.[27] This system was never fully implemented due to its complexity.
- The Hong Kong Building Environmental Assessment Method (HK-BEAM) is currently in pilot form.[28]
- The US Green Building Council (established in 1993) began development of the Leadership in Environmental and Energy Design (LEED) Green Building Rating System™ in 1994. Version 2.0 of the LEED standard was formally released in May 2000; Version 2.1 was released in November 2002.[29]

US state or regional green building guidelines include:

- New York's High Performance Building Guidelines (1999).[30]
- Pennsylvania's Guidelines for Creating High Performance buildings (1999).[31]

---

[24] For an elegant review of green building design evolution, see:
"Building for Sustainability: Six Scenarios for the David and Lucille Packard Foundation Los Altos Project," October 2002. Available on-line at: http://www.packard.org/pdf/2002Report.pdf.
This comprehensive study evaluates the life cycle cost of six increasingly green designs, each built to a different standard of sustainability. Increases in initial capital costs are weighed against decreases in operating costs to determine net present value (NPV) for each building type over a 30, 60 and 100 year period. The study concludes, even without taking into account most externalities, that life cycle cost for a green building is considerably lower than for a conventional one.

[25] Green Globes – Environmental Assessment of Buildings. Energy Criteria. Available at: http://www2.energyefficiency.org/crit-energy.asp; US Green Building Council's LEED Rating System Energy Criteria. Slide 28, LEED™ Point Distribution, http://www.usgbc.org/Docs/About/usgbc_intro.ppt.

[26] British Research Establishment. BREEAM Environmental Assessment Tool. Information Available at: http://products.bre.co.uk/breeam/.

[27] See: http://www.bepac.dmu.ac.uk/, BEPAC website.

[28] HK-BEAM Society. Hong Kong Building Environmental Assessment Method, Version 4/03 Pilot. May 2003. Available at: http://www.bse.polyu.edu.hk/Research_Centre/BEP/hkbeam/main.html.

[29] US Green Building Council. LEED™ Version 2.1Rating System. November 2002. Available at: http://www.usgbc.org/Docs/LEEDdocs/LEED_RS_v2-1.pdf.

[30] New York City Department of Design and Construction High Performance Building Guidelines. April 1999. Available at: http://home.nyc.gov/html/ddc/html/highperf.html.

[31] State of Pennsylvania Guidelines for Creating High Performance Buildings, 1999. Available at: http://www.gggc.state.pa.us/publictn/gbguides.html.

In addition, there are a dozen or more local applications of LEED, generally adding more stringent requirements as part of state certification. Federal work on green buildings, coordinated by DOE's Federal Energy Management Program, has also developed important programs and resources on green building best practices. [32]

LEED as the US Green Building Standard

The United States Green Building Council (USGBC), a national non-profit entity, developed the Leadership in Energy and Environmental Design (LEED) Green Building Rating System™[33] to rate new and existing commercial, institutional, and high-rise residential buildings according to their environmental attributes and sustainable features. The LEED system utilizes a list of 34 potential performance based "credits" worth up to 69 points, as well as 7 prerequisite criteria, divided into six categories:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation & Design Process

LEED allows the project team to choose the most effective and appropriate sustainable building measures for a given location and/or project. These "points" are then tallied to determine the appropriate level of LEED certification. See Appendix A for a full list of LEED Version 2.1 prerequisites and credits.

Four levels of LEED certification are possible; depending on the number of criteria met, and indicate increasingly sustainable building practices:

LEED Certified	26-32	points
LEED Silver	33-38	points
LEED Gold	39-51	points
LEED Platinum	52+	points

There is a general perception that LEED is becoming the standard for US green building design. As the industry magazine *Health Facilities Management* described in October 2002, "LEED has become the common benchmark for sustainability."[34] Although imperfect and still evolving, LEED has rapidly become the largest and most widely recognized green building design and certification program in the US, and probably in the world.

LEED was first introduced through a Pilot Program, and twelve buildings received version 1.0 certification in March 2000. Version 2.0 was released shortly thereafter for use as a design and

[32] See for example: "Greening Federal Facilities", second edition, May 2001, produced by BuildingGreen, Inc. See: http://www.eere.energy.gov/femp/techassist/green_fed_facilities.html.
[33] US Green Building Council. LEED Rating System, Version 2.1. November 2002. Available at: http://www.usgbc.org/Docs/LEEDdocs/LEED_RS_v2-1.pdf.
[34] Craig Applegath and Jane Wigle, "Turning Green," *Health Facilities Management*, October 2002, pp. 22-27.

certification tool. At the end of 2000, about 8 million square feet of buildings were undergoing LEED certification. By early 2003, this number had jumped to over 100 million square feet. As of December 2002, of all new construction projects in the United States, an estimated 3% had applied for LEED certification, including 4% of schools, 16.5% of government buildings and 1.1% of commercial projects.[35] In addition, many buildings use LEED as a design tool without going through the certification process.[36] LEED's use and impact is therefore more pervasive than the figures suggest. All indications are that this explosive growth will continue. Despite its limitations, the strength and likely future durability of LEED and its definition of green buildings derives from several factors:

- LEED is broad and democratic in nature, currently with 3000 organizations representing all sectors of the building industry. Membership has roughly doubled annually over the last three years. [37]
- LEED continues to change through large, professional, voluntary committees, and a staff that is responsive to the evolving needs of its large and diverse membership. New products are being developed, including: LEED for Existing Buildings, LEED for Commercial Interiors, LEED for Core and Shell, LEED for Homes, LEED for Neighborhood Developments, and LEED for Multiple Buildings.[38]
- The USGBC spends millions of dollars each year to support LEED in a number of ways, including: an extensive training program; the LEED Accredited Professional exam; a Resource guide; LEED templates; an extensive LEED website for registered projects, technical data and scientific committees; and a growing staff of professionals dedicated to LEED.

States and municipalities can create local applications of LEED, generally adding more stringent regional requirements. This approach has been used in Portland, Oregon[39] and Seattle, Washington.[40] These programs require buildings to receive LEED certification, but are tailored to meet the specific resource concerns of the region.[41]

---

[35] US Green Building Council, Urban Land Institute and The Real Estate Roundtable. "Making the Business Case for High Performance Green Buildings." 2002. Available at: https://www.usgbc.org/Docs/Member_Resource_Docs/makingthebusinesscase.pdf.
All percentages based on square footage not on number of buildings. For total LEED square footage see also: www.usgbc.org.

[36] See for example: Larry Flynn, Senior Editor, "Sustainability," *Building Design and Construction*, April 2001.

[37] US Green Building Council. USGBC Member Directory. 2003. Available at: https://www.usgbc.org/Members/members_directory.asp.

[38] LEED™ Green Building Rating System Committees, US Green Building Council. 2003. Available at: https://www.usgbc.org/Members/member_committees.asp.

[39] Portland Office of Sustainable Development, Green Building Division. "City of Portland Supplement to the LEED Rating System." 2002. Available at: http://www.sustainableportland.org/portland_leed.pdf.

[40] City of Seattle Green Building Team. "City of Seattle CIP Supplements to the LEED Green Building Rating System™." 2001. Available at: http://www.cityofseattle.net/sustainablebuilding/Leeds/docs/LEEDSupplements.PDF.

[41] Darren Bouton and Geof Syphers, "Creating Green Building Criteria for Local Governments: Recommendations for San Jose LEED," paper presented at the USGBC International Green Building Conference, October 2002.
Available at: http://www.usgbc.org/expo2002/schedule/documents/DS509_Bouton_P324.pdf.

Many other jurisdictions are currently creating LEED-based guidelines and ordinances. Some have developed guidelines that closely follow LEED but are not viewed as LEED compatible, such as the High Performance Guidelines of North Carolina's Triangle Region.[42] The USGBC's recent publication, *Making the Business Case for High Performance Green Buildings*, co-produced with the Urban Land Institute and The Real Estate Roundtable, provides a useful overview of green building benefits as well as a list of cities, states and other entities that have adopted LEED.[43]

LEED in California

There are more LEED registered projects within California – over 140 as of August 2003[44] – than in any other state. In 2001, in support of state greening efforts, California's Sustainable Building Task Force developed the LEED Supplement for California State Facilities.[45] This regionalized supplement to LEED V.2.0 is intended for guidance purposes and is not required for use in state projects. It provides information on California codes, policies and practices and is hosted on the CIWMB's website[46] for public use, though it has not been officially adopted.

On the local level, LEED has been adopted in a number of California municipalities. The city of San Jose,[47] San Francisco city and county,[48] the city of San Diego,[49] the city of Santa Monica,[50] and Los Angeles city and county[51] have all made commitments to LEED. The city of Oakland[52] and Alameda County[53] and have developed their own LEED-based green building guidelines. The city of Pleasanton recently passed an ordinance requiring both public and private buildings to meet the standards of LEED Certified level, subject to a few modifications.[54]

As an interim step towards the adoption of LEED at the state level, the California Sustainable Building Task Force, in collaboration with the Department of General Services, has developed

---

[42] Triangle J Council of Governments. "High Performance Guidelines: Triangle Region Public Facilities." September 2001. Available at: http://www.tjcog.dst.nc.us/hpgtrpf.htm.
[43] USGBC. 2002. Op. Cit.
[44] LEED Registered Project List, US Green Building Council, April 2, 2003. https://www.usgbc.org/LEED/Project/project_list_registered.asp.
[45] For California application of LEED, see: http://www.ciwmb.ca.gov/GreenBuilding/Design/LEEDforCA.doc.
[46] See: http://www.ciwmb.ca.gov/GreenBuilding/, California Integrated Waste Management Board Green Building Website.
[47] City of San Jose. "Green Building Policy." 2001. Available at: http://www.ci.san-jose.ca.us/esd/gb-policy.htm.
[48] City and County of San Francisco. "Resource Efficient City Buildings Ordinance." 1999. Available at: http://www.sfgov.org/sfenvironment/aboutus/policy/legislation/efficient.htm.
[49] City of San Diego. "Policy No. 900-14: Sustainable Building Practices." 2002. Available at: http://clerkdoc.sannet.gov/RightSite/getcontent/local.pdf?DMW_OBJECTID=09001451800850ad.
[50] City of Santa Monica. "Green Building Guidelines." 1997. Available at: http://greenbuildings.santa-monica.org/introduction/introduction.html.
[51] City of Los Angeles. "Sustainable Building Initiative: An Action Plan for Advancing Sustainable Design Practices." 2001. Available at: http://www.lacity.org/SAN/lasp/sbi-draft-nov2001-300.pdf.
[52] City of Oakland. "Oakland Sustainable Design Guide." 2001. Available at: http://www.oaklandpw.com/greenbuilding/.
[53] Alameda County Waste Management Authority. "New Construction Green Buildings Guidelines." 2001. Available at: http://www.stopwaste.org/nhguide.html.
[54] City Council of the City of Pleasanton. "Ordinance No. 1873." Adopted December 2002. Available at: http://www.ci.pleasanton.ca.us/pdf/greenbldg.pdf.

two lists of technologies that are intended to guide development of new buildings.[55] The Tier 1 list includes many green technologies – such as "cool roofs" (described below) – that have been predetermined as cost-effective by the Department of Finance and are expected to be included in new construction. The Tier 2 list includes technologies that should be included in new designs as long as they are cost justified, and as the project budget allows.

In reality Tier 1 and Tier 2 technologies are inconsistently included in construction. Part of the reason is that the benefits of green design are best achieved when green technologies and practices are adopted as part of an integrated design rather than on a piecemeal basis. An integrated green building design approach – such as LEED – provides a way to incorporate green technologies and practices in a way that is more likely to be cost-effective. [56]

In addition to LEED, another rating system has been developed specific to K-12 schools in California. The Collaborative for High Performance Schools, or CHPS, is a diverse group of government, utility, and non-profit organizations with a unifying mission to improve the quality of education for California's children.[57] The goal of the CHPS is to create a new generation of high performance school facilities in California. The focus is on public schools and levels K-12, although many of the design principals apply to private schools and higher education facilities as well. High performance schools are healthy, comfortable, resource efficient, safe, secure, adaptable, and easy to operate and maintain. They promote higher test scores, help school districts retain quality teachers and staff, reduce operating costs, increase average daily attendance (ADA), reduce liability, and promote environmental stewardship and joint use opportunities.

CHPS has developed a three volume Best Practices Manual for High Performance Schools, including a set of design criteria to "rate" CHPS schools.[58] Different from LEED, CHPS is self-certifying, and CHPS schools must score 28 out of 81 possible points for eligibility.

---

[55] State of California, Real Estate Services Division,"Exhibit C – Tiers: Energy Efficiency and Sustainable Building Measures," July 1, 2002. Available at: http://www.ciwmb.ca.gov/GreenBuilding/Design/Tiers.pdf.
[56] The benefits and process of green design are extensively documented in RMIs "Green Development: Integrating Ecology and Real Estate." See www.rmi.org.
[57] See: http://www.chps.net, The Collaborative for High Performance Schools website.
[58]The Collaborative for High Performance Schools. "CHPS Best Practices Manual, Volumes I-III, 2002." Available at: http://www.chps.net/manual/index.htm#score.

II. Important Assumptions

Life Cycle Assessment (LCA)

This report uses a life cycle costing (LCC) approach to evaluate and integrate the benefits and costs associated with sustainable buildings. Life cycle costing, often confused with the more rigorous life cycle assessment (LCA) analysis, looks at costs and benefits over the life of a particular product, technology or system. LCA, in contrast, involves accounting for all upstream and downstream costs of a particular activity, and integrating them through a consistent application of financial discounting. The result – if data is available -- is a current "cradle to grave" inventory, impact assessment and interpretation (e.g., a net present value estimate). However, the art and science of calculating true life cycle impacts and costs of green buildings is still evolving and is generally not practiced. Currently, decisions on whether or not to invest in a green building are typically based only on first costs plus, in some cases, a discounted value of lowered energy and water bills. This report seeks an approach that draws on the discipline of LCC practices to identify and clearly document the benefits and costs of the most important green building attributes, including some that are generally not explicitly considered in building investment decisions.

There are a number of international green building assessment programs that provide tools for evaluating building performance across a large range of green performance criteria.[59] European LCA work is extensive and some of it ties into the internationally accepted ISO quality certification process.[60] A popular Canadian core and shell assessment tool – Athena [61] – was recently used in designing the Clearview Elementary School in Pennsylvania[62] and the Battery Park City residential construction project in New York City.[63] BEES, a building materials selection tool developed by the U.S. Government's National Institute of Standards and Technology (NIST), is useful for specifying materials and can be used with Athena to create a whole building life cycle analysis.[64] Some of the most rigorous science-based LCA tools are not available in English – these include LEGOE from Germany, an LCA program that runs in the background with CAD software,[65] and EcoQuantum from Holland.[66]

Altogether, there are a dozen or more life cycle tools each with various strengths and limitations – Athena, for example, despite its strengths, is currently based only on Canadian data.[67]

---

[59] For an extensive international listing of green building evaluation and life-cycle related tools and programs with related URLs, go to: http://buildlca.rmit.edu.au/links.html.
[60] For European life cycle work see: http://www.ecotec.com/sharedopet/password/rhrsum13.htm.
[61] Athena Version 2.0 Environmental Impact Estimator. 2003. Available at: See http://www.athenasmi.ca/.
[62] Clearview Elementary School Athena Model Output, 7Group. Available at: http://www.sevengroup.com/pdf/Athena.PDF.
[63] The Athena Sustainable Materials Institute Members Newsletter. Volume 3, Number 1. June 2002. See: "Updates Green Building Challenge 2002." Available At: http://www.athenasmi.ca/news/down/Ath_vol_3_1.pdf.
[64] BEES 3.0 Software Download available at: http://www.bfrl.nist.gov/oae/software/bees.html.
[65] Available only in German at: http://www.legoe.de.
[66] Available only in Dutch from the Environmental Institute at the University of Amsterdam (IVAM). A demo of an older version is available in English at: http://www.ivambv.uva.nl/uk/index.htm.
[67] For a valuable recent review of life cycle tools, see: Gregory Norris and Peter Yost, "A Transparent, Interactive Software Environment for Communicating Life-Cycle Assessment Results," *Journal of Industrial Ecology*, 2002, Volume 5, Number 4. For a good overview of international life cycle development, see: "Evolution and Development of the Conceptual Framework and Methodology of Life-

This report does not use any of these specific tools. Rather, it follows the general life cycle approach in evaluating a broad spectrum of costs and benefits using the limited data available. There are many substantial information gaps preventing a full life cycle cost assessment of green buildings. To cite just two examples: data on the full cost of water is incomplete, and available data on emissions from energy use should (but generally does not) reflect the life cycle emissions from energy extraction, transportation, use and disposal, as well as from energy generation. The objective of this report is to aggregate the available data about green buildings, and to develop a reasonable net present value estimate of their future associated costs and benefits.

Use of Present Value (PV) and Net Present Value (NPV)

The overarching purpose of this report is to answer the following question: Does it make financial and economic sense to build a green building? Green buildings may cost more to build than conventional buildings, especially when incorporating more advanced technologies and higher levels of LEED, or sustainability. However, they also offer significant cost savings over time.

This report will seek to calculate the current value of green buildings and components on a present value (PV) or net present value (NPV) basis. PV is the present value of a future stream of financial benefits. NPV reflects a stream of current and future benefits and costs, and results in a value in today's dollars that represents the present value of an investment's future financial benefits minus any initial investment. If positive, the investment should be made (unless an even better investment exists), otherwise it should not.[68] This report assumes a suitable discount rate over an appropriate term to derive an informed rationale for making sustainable building funding decisions. Typically, financial benefits for individual elements are calculated on a present value basis and then combined in the conclusion with net costs to arrive at a net present value estimate.

Net present value can be calculated using Microsoft's standard Excel formula:

$$NPV = \sum_{i=1}^{n} \frac{values_i}{(1+rate)^i}$$

The formula requires the following:

- **Rate**: Interest Rate per time period (5% real)
- **Nper (n)**: The number of time periods (20 years)
- **Pmt (values):** The constant sized payment made each time period (annual financial benefit)

This provides a calculation of the value in today's dollars for the stream of 20 years of financial benefits discounted by the 5% real interest rate. It is possible to calculate the net present value of the entire investment - both initial green premium and the stream of future discounted financial benefits - by subtracting the former from the latter.

Cycle Assessment," *SETAC Press*, January 1998. Available as an addendum to *Life-Cycle Impact Assessment: The State-of-the-Art*. See: http://www.setac.org. Environmental Building News, Dec 2002, p 14, by Nadav Malin (BEES review), and Environmental Building News, Nov 2002, p 15, by Nadav Malin (ATHENA review).

[68] See: http://www.investorwords.com/cgi-bin/getword.cgi?3257.

Discount Rate
To arrive at present value and net present value estimates, projected future costs and benefits must be discounted to give a fair value in today's dollars. The discount rate used in this report is 5% real. This rate is stipulated for use by the California Energy Commission[69] and is somewhat higher than the rate at which the state of California borrows money through bond issuance.[70] It is also representative of discount rates used by other public sector entities.[71]

Term
California's Executive Order D-16-00, committing California to provide energy efficiency and environmental leadership in its building design and operation, stipulates that "a building's energy, water, and waste disposal costs are computed over a twenty-five year period, or for the life of the building."[72] Buildings typically operate for over 25 years. A recent report for the Packard Foundation shows building life increasing with increasing levels of greenness. According to the Packard study, a conventional building is expected to last 40 years, a LEED Silver level building for 60 years and Gold or Platinum level buildings even longer.[73] In buildings, different energy systems and technologies last for different lengths of time – some energy equipment is upgraded every 8 to 15 years while some building energy systems may last the life of a building. This analysis conservatively assumes that the benefits of more efficient/sustainable energy, water, and waste components in green buildings will last 20 years, or roughly the average between envelope and equipment expected life.

Inflation

This report assumes an inflation rate of 2% per year, in line with most conventional inflation projections.[74] Unless otherwise indicated, this report makes a conventional assumption that costs (including energy and labor) as well as benefits rise at the rate of inflation – and so present value calculations are made on the basis of a conservative real 5% discount rate absent any inflation effects. In particular, energy costs are relatively volatile, although electricity prices are less volatile than primary fuels, especially gas.

[69] California Energy Commission. "Life Cycle Cost Methodology: 2005 California Building Energy Efficiency Standards." March 2002. Available at: http://www.energy.ca.gov/2005_standards/documents/2002-04-02_workshop/2002-03-20_LIFE_CYCLE.PDF.
[70] See for example: "Analysis of GARVEE Bonding Capacity, Attachment D: Detailed Assumptions for Sensitivity Analysis." California State Treasurer's Office. Prepared for California Department of Transportation. 2003. Available at: http://www.treasurer.ca.gov/Bonds/garvee.pdf.
[71] The Wall Street Journal lists discount rates daily, dependent upon credit rating. See Market Data and Resources. Available at: http://online.wsj.com/public/site_map?page=Site+Map.
[72] California Executive Order D-16-00, August 2000. Op. Cit.
[73] A conventional building design for the Packard Foundation envisages a building life of 40 years. A silver building is expected to last 60 years, gold rated building is designed to last 80 years, while a platinum or "living building" – an extremely sustainable design – is projected to last for 100 years. See *"Building For Sustainability Report: Six Scenarios for The David and Lucile Packard Foundation,"* Los Altos Project, October 2002. Available at: http://hpsarch.com/TitlePageSpecial/2002-Report.pdf.
[74] See, for example: http://oregonstate.edu/Dept/pol_sci/fac/sahr/cf166503.pdf and http://www.jsc.nasa.gov/bu2/inflateGDP.html.

LEED as a Basis

Although this report will look at the lessons offered from a range of green design programs, LEED is used as the common basis for comparison because it has become the dominant definition of green buildings in the United States. For example, in seeking to quantify a building's "greenness," it will be described by its LEED level or equivalent (e.g., LEED Silver, representing 33 to 38 points).

A Note about Data Sources

The last few years have seen the emergence of meta-studies that screen, select, and provide up-to-date and well-linked compilations of important data sets related to green building benefits. For example, the Carnegie Mellon BIDS program has screened over one thousand studies to come up with approximately 90 of the most rigorous studies on the productivity impacts from green and high performance building designs.[75] Similarly, the US Green Building Council keeps a regularly updated list of all the cities and municipalities that use LEED or some version of LEED. Some areas, notably water and waste, lack comprehensive on-line databases. A brief annotated review of sources is included as an appendix for these two sections (Appendix L).

In many cases there is no recent reliable California data. For example, there appears to be no California-specific study on the environmental benefits of waste reduction. Similarly, in the last decade there have been no publicly available, comprehensive studies on California that calculate the full benefits (such as avoided transmission and distribution costs) of reduced energy demand, e.g., from measures such as on-site generation and energy efficiency. These gaps are noted in the text and are reflected in recommendations at the end of the report for additional research.

[75]Carnegie Mellon University Department of Architecture. Building Investment Decision Support Tool. 2002. Available at: http://www.arc.cmu.edu/cbpd/.

III. The Cost of Building Green

The Problems of Determining Cost

There has been a widespread perception in the real-estate industry that building green is significantly more expensive than traditional methods of development. A half dozen California developers interviewed in 2001 estimated that green buildings cost 10% to 15% more than conventional buildings.[76] The Sustainable Building Task Force *Blueprint*[77] identifies several obstacles to sustainable buildings, including:

- Incomplete integration within and between projects.
- Lack of life cycle costing.
- Insufficient technical information.

The *Blueprint* notes that because of these barriers, "many sustainable building applications are prematurely labeled as 'unproven' or 'too costly.'"[78] *Consulting – Specifying Engineer* echoed this view in its October 2002 issue, indicating that: "the perception that green design is more expensive is pervasive among developers and will take time to overcome" and "inhibiting green design is the perception that 'green' costs more and does not have an economically attractive payback."[79]

There is a growing body of performance documentation and online resources related to green building. For example, a new online source developed through a partnership of the US Department of Energy, Environmental Building News, the US Green Building Council, Rocky Mountain Institute, and the AIA Committee on the Environment includes 42 green building case studies, 13 of which are located in California.[80] Despite these advances, there is still little published data about actual cost premiums for green buildings. This information gap is compounded by the fact that the USGBC does not require that cost information be included with submissions for LEED certification.

Many developers keep cost information proprietary. In addition, even if developers are willing to share their cost data, determining a precise "green premium" for a given project is often very difficult for several reasons:

- Developers typically only issue specifications and costs for the designed building, not for other green options. Individual green items are sometimes priced out in comparison to non-green ones, but this is not the norm and does not provide a basis for cost comparison between green and conventional whole building design.

---

[76] Berman, Adam. "Green Buildings: Sustainable Profits from Sustainable Development," unpublished report, *Tilden Consulting*. July 30, 2001. Available from the author: adam@isabellafreedman.org.
[77] California State and Consumer Services Agency and Sustainable Building Task Force, December 2001. Op. Cit.
[78] *Ibid*, p. VI.
[79] Scott Siddens, Senior Editor, "Verdant Horizon," *Consulting –Specifying Engineer*, October 2002, pp. 30-34. Available at: http://www.syska.com/Sustainable/news/index.asp.
[80] US Department of Energy, Office of Energy Efficiency and Renewable Energy. High Performance Buildings Database. Available at: http://www.eere.energy.gov/buildings/highperformance/case_studies.

- Some green buildings being built today are showcase projects that may include additional and sometimes costly "finish" upgrades that are unrelated to greenness but that nonetheless are counted toward the green building cost increase.
- The design and construction process for the first green building of a client or design/architectural firm is often characterized by significant learning curve costs, and design schedule problems such as late and costly change orders.
- The relative newness of green technologies and systems can make designers, architects and clients conservative when using them. They may oversize green building systems and not fully integrate them into the building, thereby reducing cost savings and other benefits. Similarly, cost estimators may add uncertainty factors for new green technologies they are not familiar with, and these can compound, further inflating cost estimates.

National Green Building Leaders

Although more members and registered projects are located in California than in any other state, Pennsylvania, Massachusetts, Washington and Oregon have the most extensive, documented experience with green building and LEED.[81] Therefore, despite the general deficiency of published data on the cost of building green, there is substantial recent evidence from these and other entities to indicate that building green is less expensive than many developers think. In particular, this data comes in part from two municipalities with extensive experience building LEED projects: Pennsylvania and Seattle, WA.

Pennsylvania

Over the past several years, the state of Pennsylvania has constructed five LEED registered projects (three will be completed in 2003). Pennsylvania's green building experience now enables it to build LEED Silver buildings that cost virtually the same as traditional buildings.[82] The state's first LEED Gold level green building, a 40,000 square foot office building in Cambria, PA, was built at $90 per square foot, just under comparable market rates for conventional buildings (See Appendix C).[83] Much of Pennsylvania's success comes from the state's ability to negotiate better prices from green manufacturers. Most green materials used in this project cost the same or less than the traditional alternative, reinforcing the fact that green design has matured and broadened into the mainstream and is no longer a cutting edge trend.[84]

Seattle, WA

Seattle was the first municipality in the nation to adopt a LEED Silver requirement for larger (over 5000 ft^2 occupied space) construction projects. The city currently has 11 LEED registered projects.

[81] Pennsylvania, Oregon and Washington have more projects per capita, per Gross State Product, and per Construction Gross State Product than California or other states across the country. See Appendix B for a Graphical Representation.

[82] Governor's Green Government Council, State of Pennsylvania. See: "Building Green in Pennsylvania," CD-ROM available at http://www.gggc.state.pa.us.

[83] Commonwealth of Pennsylvania Department of Environmental Protection, Cambria Office Building. 2001. Available at: http://www.gggc.state.pa.us/building/Cambria/2300DEPCambriaDOBldg.pdf.

[84] Governor's Green Government Council, State of Pennsylvania. "Building Green in Pennsylvania: Making the Case." Video available at: http://www.greenworks.tv/green_building/archives.htm.

Detailed cost data from these projects has not yet been released, but according to a draft report, LEED Silver certification should not add cost to a project provided the following: [85]

- LEED Silver is made a requirement in the Request for Qualification for the Design Team and embedded within the construction documents, building construction, and commissioning.
- The selected Design Team has sustainable design embedded within the firm's design culture.
- Contractors, Property Managers, Real Estate Analysts, Budget Analysts, Crew Chiefs and Custodians are included on the Design Team.
- Selected sustainable design strategies are "whole system" in nature and integrated design solutions are pursued that cannot be peeled off from the base project as "add alternates."

A Cost Analysis of 33 LEED Projects

Cost data was gathered on 33 individual LEED registered projects (25 office buildings and 8 school buildings) with actual or projected dates of completion between 1995 and 2004. These 33 projects were chosen because relatively solid cost data for both actual green design and conventional design was available for the same building.

Virtually no data has been collected on conventional buildings to determine what the building would cost as a green building. And, surprisingly, most green buildings do not have data on what the building would have cost as a conventional building. To be useful for this analysis, cost data must include both green building and conventional design costs for the same building. Typically this data is based on modeling and detailed cost estimates. (As indicated elsewhere, LEED does not currently require that cost data for both conventional and green design be submitted. This report recommends that the USGBC consider making this a prerequisite or offer part of a credit for providing this data).

Attempts to compare the cost of a specific green building – such as a school – with other buildings of similar size and function in a different locality provide little help in understanding the cost of green design. The added cost impact of designing green may be very small compared with other building costs such as the cost of land and infrastructure. Therefore, a meaningful assessment of the cost of building green requires a comparison of conventional and green designs for the same building only.

Consequently, there is very little solid data on the additional costs associated with green design. Information for this report was collected primarily through a broad literature review; from several dozen interviews with architects and other senior building personnel; written and verbal communications with California's Sustainable Building Task Force members, USGBC staff, attendees at the Austin green building conference, and members of the Green Building Valuation Advisory Group; through a query posted in the Environmental Building News; and from others.

---

[85] Lucia Athens and Gale Fulton, "Developing a Public Portfolio of LEED™ Projects: The City of Seattle Experience." Electronic copy received from authors on December 20, 2002. Available at: http://www.usgbc.org/expo2002/schedule/documents/DS509_Athens_P126.pdf.

A resulting table containing each project name, location, building type, date of completion, green premium and certification level or equivalent can be found in Appendix C. Note that many of these buildings have not yet been certified by the USGBC. In these cases, the LEED level indicated is an assessment by the architect and/or client team reflecting very detailed analysis and modeling – this is viewed as a relatively accurate prediction of final LEED certification level.

While the size of the data set is not large, analysis provides meaningful insights into the cost premium for green buildings. Figures III-1 and III-2 show that, on average, the premium for green buildings is about 2%. The eight rated Bronze level buildings had an average cost premium of less than 1%. Eighteen Silver-level buildings averaged a 2.1% cost premium. The six Gold buildings had an average premium of 1.8%, and the one Platinum building was at 6.5%. The average reported cost premium for all 33 buildings is somewhat less than 2%.[86]

Figure III-1. Level of Green Standard and Average Green Cost Premium

[86] See Appendix C for a complete list of the 33 projects, their LEED levels, and green premiums.

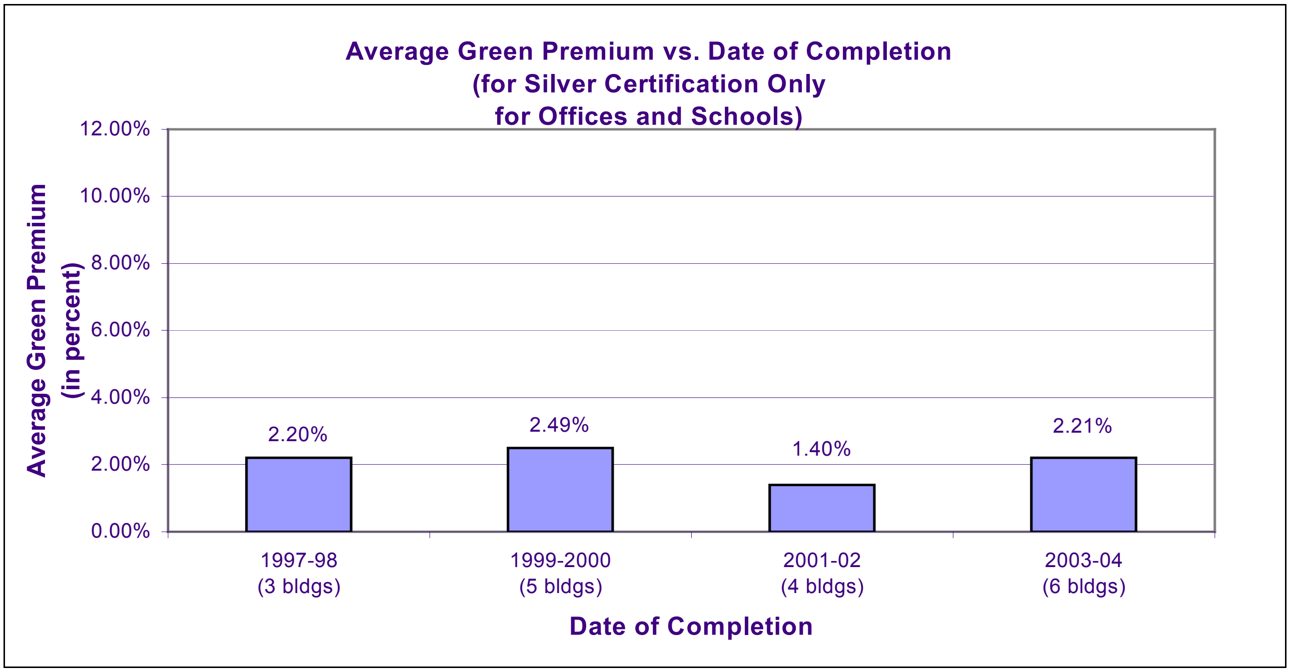
Figure III-2. Average Green Cost Premium vs. Level of Green Certification

Source: USGBC, Capital E Analysis

Figure III-3. Year of Completion and Average Green Cost Premiums for Buildings with Silver Certification

Year of Completion	Average Green Cost Premium
1997-1998	2.20%
1999-2000	2.49%
2001-2002	1.40%
2003-2004	2.21%
Avg. of 18 Silver buildings	2.11%

Figure III-4. Average Green Cost Premium vs. Date of Completion for Buildings with Silver Certification



Source: USGBC, Capital E Analysis

There is evidence that building green gets less expensive over time, with experience. However, an expected downward cost trend of the green cost premium is not clear in this data. The green premium is lowest for the most recently completed buildings (2001-02) and higher for buildings projected to be completed in 2003 and 2004. This data reflects two things. First, 2003-2004 buildings costs are projections and these tend to be slightly high (conservative). It can be expected that as these buildings are completed, the actual cost premium will, on average be lower than projected in this data. Second and perhaps more importantly, the reported data includes both first time green buildings and buildings that may be the third or fourth green building by the same owner/designer builder team. Thus the data includes both relatively higher cost first timers and the efforts of experienced teams that generally achieve lower cost premiums.

The trend of declining costs associated with increased experience in green building construction has been experienced in Pennsylvania,[87] as well as in Portland and Seattle. Portland's three reported completed LEED Silver buildings (see Appendix C) were finished in 1995, 1997, and

[87] Data provided by John Boecker, L. Robert Kimball and Associates, A/E Firm for the Pennsylvania Department of the Environment Cambria Office Building, Ebensburg, PA, the PA Department of Environmental Protection Southeast Regional Office. Norristown, PA, and the Clearview Elementary School, York, PA.
See: http://www.lrkimball.com/Architecture%20and%20Engineering/ae_experience_green.htm.

2000. They incurred cost premiums of 2%, 1% and 0% respectively.[88] Seattle has seen the cost of LEED Silver buildings drop from 3-4% several years ago to 1-2% today.[89]

A second data anomaly is that reported cost levels for LEED Gold buildings are slightly lower than for Silver buildings, whereas the higher performance level requirements to achieve Gold would be expected to cost more than Silver levels. In part, this anomaly reflects the small data set – the Gold premium is an average across only six buildings. As additional green building data is assembled, costs are likely to more closely follow the rising cost levels associated with more rigorous levels of LEED. Nonetheless, the data indicates that it is possible to build Gold level buildings for little additional cost. The higher performance levels associated with Gold buildings (described below in Health and Productivity and other sections), combined with their potentially low cost premiums – as indicated in this small data set – suggest that, based on available data, LEED Gold may be the most cost effective design objective for green buildings.

Implications for California

The conclusions above indicate that while green buildings generally cost more than conventional buildings, the "green premium" is lower than is commonly perceived. As expected, the cost of green buildings generally rises as the level of greenness increases, while the premium to build green is coming down over time. Importantly, the cost of green buildings tends to decline with experience in design and development, as clients and their design and architecture teams move beyond their first green building. This trend suggests that California develop policies and procedures to favor the hiring of more experienced green building teams, and that this experience be embedded throughout the design team. Additionally, development of multiple green buildings within a particular California state agency or university can be expected to result in declining costs per building to that organization.

Assuming conservative, relatively high California commercial construction costs of $150/ft^2$ to $250/ft^2$,[90] a 2% green building premium is equivalent to $3-5/ft^2$. Use of lower, more average construction costs in these calculations would tend to increase the reported cost effectiveness of green construction.

The rest of this report will attempt to quantify the size of financial benefits as compared with the costs of building green buildings.

---

[88] Data provided by Heinz Rudolf, BOORA Architects. See Portfolio/Schools at: http://www.boora.com/

[89] Lucia Athens, Seattle Green Building Program, Nov. 2002. See: http://www.cityofseattle.net/light/conserve/sustainability/.
The city is expected to soon release a review of over a dozen green Seattle buildings and specific costs premiums for these buildings.

[90] This is a reasonable, somewhat high (e.g. conservative) estimate as confirmed by Oppenheim Lewis Inc. and Anthony Bernheim, Principal, SMWM. Includes hard and soft costs (including design fees) associated with construction, but not land acquisition.

IV. Energy Use

Energy is a substantial and widely recognized cost of building operations that can be reduced through energy efficiency and related measures that are part of green building design. Therefore, the value of lower energy bills in green buildings can be significant. The average annual cost of energy in state buildings is approximately $1.47/ft^2.[91] On average, green buildings use 30% less energy than conventional buildings[92] – a reduction, for a 100,000 ft^2 state office building, worth $44,000 per year, with the 20-year present value of expected energy savings worth over half a million dollars.[93]

A detailed review of the 60 LEED rated buildings, including 5 LEED rated buildings in California, clearly demonstrates that green buildings, when compared to conventional buildings, are:

- On average 25-30% more energy efficient (compared with ASHRAE 90.1-1999 and, for California buildings, Title 24 baselines);[94]
- Characterized by even lower electricity peak consumption;
- More likely to generate renewable energy on-site; and
- More likely to purchase grid power generated from renewable energy sources (green power and/or tradable renewable certificates.

Although the environmental and health costs associated with air pollution caused by non-renewable electric power generation and on-site fossil fuel use are generally externalized (not considered) when making investment decisions, the energy reductions realized through the design and construction of green buildings reduce pollution and lower the environmental impact of conventional power generation.[95] This report seeks to quantify some of the benefits, including the value of peak power reduction (in this section) and the value of emissions reductions (in Section V) associated with the energy strategies integrated into green building design.

---

[91] Over 95% of primary energy use in California state buildings is electricity, with the balance natural gas. Data provided by California Department of General Services, Real Estate Services Division, Building Property Management Brach. "Energy Cost Estimates," December 2002. See also *Appendix I*. 2002 energy costs were estimated at $1.60/ft^2/yr, but average California electricity rates are conservatively projected to drop from $0.12/kWh to $0.11/kWh. Energy use and cost data come directly from utility bills.
[92] Note: As a result of the energy crisis in California and various Flex-Your-Power energy efficiency campaigns, the State has already reduced electricity use in most buildings by close to 20%. Absolute energy savings typical of green buildings will be lower for energy efficient state buildings, which have already realized much of the benefit associated with energy efficiency. However the percentage reduction in energy use in these buildings is comparable to less efficient buildings – see subsequent data and discussion.
[93] Using 5% real discount rate over 20 year term, as discussed above. While both improved energy efficiency and on site generation result in lower energy bills, the reduced energy costs only capture a portion of the benefits accrued to the state. See for example: CEC Environmental Performance Report, http://www.energy.ca.gov/reports/2001-11-20_700-01-001.PDF.
[94] Based on analysis of Energy and Atmosphere Credit 1 – Energy Optimization points awarded to all LEED-NC v2 Certified projects.
[95] See: Lovins et al., "Small is Profitable," RMI, 2002. Available at: http://www.rmi.org.

Data on green buildings is somewhat limited because of the relative youth of a quantifiable definition of 'green' (this report uses the U.S. Green Building Council's LEED Green Building Rating System), a limited data set (69 LEED rated Buildings), incomplete reporting and/or insufficient reporting requirements (of the 69 LEED rated buildings, 19 were Certified under the LEED v1.0 Pilot which had different reporting requirements), and client preference for non-disclosure of data. All these limitations are evident in the small data set of five LEED rated buildings in California, including:

- Toyota Motor Sales South Campus Office Development, Torrance – LEED v2.0 Gold, 630,000 ft^2, completed in 2002.
- Ford Motor Company Premier Automotive Group North American HQ, Irvine – LEED v2.0 Certified, 253,000 ft^2, completed in 2001.
- William and Flora Hewlett Foundation Headquarters, Menlo Park - LEED v2.0 Gold, 48,000 ft^2, completed in 2002.
- Capital Area East End Complex 225, Sacramento – LEED v2.0 Gold, 479,000 ft^2, completed in 2003.
- UCSB Donald Bren School of Environmental Science and Management, Santa Barbara – LEED v1.0 Platinum, 90,000 ft^2, completed in 2000.

Data on energy use in these buildings was obtained directly from the USGBC,[96] and included a detailed review of the Energy Cost Budget documents required for award of LEED energy performance. Because some project teams have requested that their project data be kept confidential the data is presented in a format that ensures that the performance characteristics of specific buildings are masked. These California LEED rated buildings on average demonstrate energy efficiency commensurate with the 25-30% national average reduction for green buildings.[97] Energy efficiency (relative to a California Title 24 baseline) improvements for the five buildings (in order of lowest to highest) are 22%, 30%, 30%, 35%, 40%.

The Price of Energy

Calculating the current financial value of lower future energy consumption requires estimating future energy costs, and this is complicated by the rapidly changing tariff structures of California's utilities. California electricity rates have climbed steeply over the past several years, in large part due to surcharges mandated by the CPUC in response to the recent electricity crisis. As indicated in Figure IV-1, peak electricity prices are as high as $0.34 per kWh for buildings (including most state buildings) that are on time-of-use rates. At this time, it is not clear what future electricity prices will be.[98]

---

[96] Data provided by the US Green Building Council, December 2002 (Brendan Owens, LEED Engineer).

[97] Because the energy performance baseline in California is Title 24, which is more rigorous than the prevailing national ASHRAE standard, it might be expected that energy reduction in California green buildings would be less than for LEED buildings nationally. This does not appear to be the case. Several reasons for this may include relatively high California energy prices (and recent price increases) that would tend to increase incentives for aggressive energy reduction measures, and the existence of California standards in areas other than energy – such as recycling and indoor environmental quality - that provide a higher baseline for non-energy performance for California sustainable buildings, and that may make energy improvements below the Title 24 baseline not more costly *relative* to other dimensions of green design.

[98] McAuliffe, Pat. California Energy Commission, Office of Commissioner Art Rosenfeld, December 2002.

The majority of California state buildings are on tariffs with time-of-use rates. These include relatively high electricity prices during periods of peak grid-wide electricity use, in an attempt to reduce peak consumption. The Pacific Gas & Electric (PG&E) commercial tariff, in Figure IV-1 below, is typical of these time-of-use commercial rates.

Figure IV-1. PG&E A-6 Time of Use Rate Schedule (simplified)

Customer Charge	**Season**	**Time-of-Use Period**	**Energy Charge** (per kWh)	**1/4/01 Energy Surcharge** (per kWh)	**6/1/01 Energy Surcharge** (per kWh)	**Total Energy Charge** (per kWh)	**"Average" Total Rate** (per kWh)
Single phase service per meter/day =$0.26612; Polyphase service per meter/day =$0.39425. Plus Meter charge =$0.22341 per day for A6 or A6X; =$0.06571 per day for A6W	**Summer**	On peak	$0.23258	$0.01000	$0.10064	**$0.34322**	$0.14487
		Part Peak	$0.10288	$0.01000	$0.04551	**$0.15839**	
		Off Peak	$0.05618	$0.01000	$0.03551	**$0.10169**	
	Winter	Part Peak	$0.11562	$0.01000	$0.04551	**$0.17113**	
		Off Peak	$0.07169	$0.01000	$0.03551	**$0.11720**	

Source: http://www.pge.com/tariffs/CommercialCurrent.xls

PG&E's average commercial rate is currently about $0.15 per kWh.[99] San Diego Gas & Electric (SDG&E)[100] and Southern California Edison (SCE)[101] have similar rates. Other utilities, such as Sacramento Municipal Utility District (SMUD) have slightly lower average commercial rates. The current average cost of electricity for state buildings is about $0.12/kWh, reflecting a concentration of state buildings in lower tariff utility districts, such as SMUD.[102] This rate is likely to drop by the end of 2003 as a substantial temporary surcharge (intended to help California utilities regain solvency) is dropped. However, there may be an additional bond surcharge of about $0.005/kWh imposed in 2003. In addition, the CPUC may implement a $0.50+/kWh "super peak" surcharge on the peak hours of 15 of the hottest (and highest peak electricity use) days in the year.[103] The CEC believes that at end of 2003 rates may drop to about $0.11/kWh,

[99] For PG&E rates, see: http://www.pge.com/tariffs/CommercialCurrent.xls and http://www.pge.com/tariffs/GNR2_Current.xls.

[100] For SDG&E rates see: http://www.sdge.com/tariff/elec_commercial.shtml, and http://www.sdge.com/tm2/pdf/GN-3.pdf.

[101] For SCE Rates, see: http://www.sce.com/NR/sc3/tm2/pdf/ce87-12.pdf and http://www.sce.com/sc3/005_regul_info/005a_tariff_book/005a3_rates/005a3b_biz_rates.htm.

[102] Data provided by the California Energy Commission, Office of the Supervisor of Rates, December 2002. See also: Electricity in California. California Energy Commission. Available at: http://www.energy.ca.gov/electricity/index.html#rates.

[103] California Energy Commission. Office of Energy Commissioner Art Rosenfeld. November 2002.

and that this is a good, conservative estimate for future average commercial electricity prices (Note: Higher electricity rates would increase the benefits of green buildings).[104]

This report therefore assumes a real average commercial electricity price for 2003 and beyond of $0.11/kWh. This rate is used for calculations involving schools as well, even though schools are more evenly distributed through higher tariff utility districts (benefits accruing to green schools may therefore be understated in this analysis). Projected future electricity savings are discounted at the 5% (real) rate. However, calculating the full benefits of lower energy costs from green buildings is more complex than this because green buildings tend to use disproportionately less energy during peak times, when electricity is more valuable and expensive.

Cutting Peak Power

The unique integrated design and construction process that green buildings typically follow considers the building holistically. Interactions between competing building systems (lighting vs. cooling, fresh air vs. humidity control, etc.) are therefore analyzed simultaneously, allowing the building designers to reduce peak power demand by downsizing building systems, particularly air conditioning and lighting loads, while providing a comfortable indoor environment. For most of California (except the generally foggy northern coast) and much of the US (especially in the South and Midwest) air conditioning is the dominant energy user during peak load. The largest and third largest electricity demands, respectively, in California during a typical 50,000 MW peak load period are commercial air conditioning – representing 15% of peak load, and commercial lighting – representing 11% of peak load.[105] By encouraging integrated design and awarding credit for optimization of building energy systems, LEED provides strong incentives to cut both of these peak demand uses.

LEED encourages:

- *Integrated design*: Project teams consider building systems in total to optimize competing demands.
- *High Performance Lighting*: Incorporation of more efficient lights, task lighting, use of sensors to cut unnecessary lighting, use of daylight harvesting and other advanced lighting techniques and technologies. These measures can significantly reduce power demand from electric lights. In hot weather, this reduction has the added advantage of reducing cooling loads in a building, which in-turn reduces required air conditioning.
- *Increased Ventilation Effectiveness*: Helps cut air conditioning load during peak through improved system optimization.
- *Underfloor Air Distribution Systems*: Use of a plenum below a raised floor to deliver space conditioning. Typically cuts fan and cooling loads, substantially lowering air conditioning load (see "Underfloor Air" in Section IX).

---

[104] Data provided by the California Energy Commission, Office of the Supervisor of Rates, December 2002. See also: California Energy Commission. "2002-2012 Electricity Outlook Report." February 2002. Available at: http://www.energy.ca.gov/reports/2002-02-14_700-01-004F.PDF.

[105] John Wilson, Art Rosenfeld and Mike Jaske, "Using Demand Responsive Loads to Meet California's Reliability Needs," paper presented at 2002 ACEEE summer conference. Available from: jwilson@energy.state.ca.us. Note: the number two user of electricity in California is residential air conditioning.

- *Commissioning* (see "Commissioning" in Section IX): A systematic process to ensure that building systems are designed, installed and operating as planned. Incorporation of commissioning tends to increase building system performance and cut energy use, helping to ensure that design objectives and performance targets are met (and that energy savings persist).
- *Heat Island Reduction Measures*: By increasing the reflectivity of roofs and other typically dark surfaces, it is possible to lower building and urban temperatures, in turn reducing air conditioning loads and peak demand.
- *On-site Generation*: Two of the eight LEED Gold level buildings reviewed use photovoltaics (PV) to generate 20% of their power on site. PV is coincident with peak power usage, and so contributes to peak demand reduction.

Although peak demand reduction data is not provided or is incomplete for some buildings (LEED certification requirements do not currently require peak reduction information), California LEED rated buildings, like non-California buildings, generally show larger reductions in peak demand than in overall energy use. For the three California LEED rated buildings for which peak reduction data was submitted, electricity for space cooling and lighting (of conditioned space) varied widely but indicated an average electricity peak demand reduction of 17%. This average includes a shift from electricity to natural gas for most space cooling in one of the buildings. The fuel switch from electricity to natural gas artificially inflates the electric peak demand reduction in this building. A fourth California LEED building, for which incomplete data was submitted, indicates a 13% reduction in total building energy use by implementing natural ventilation strategies rather than relying solely on mechanical HVAC.

The very limited California data set indicates that peak demand reduction in California green buildings is significant and consistent with a preliminary estimate of 10% peak demand reduction below average energy reduction in green buildings. The correlation between peak demand reduction in green buildings evident in the limited data set warrants further research. Preliminary discussions, between report authors and the USGBC, are underway to modify LEED credit requirements to require peak demand reduction data in LEED documentation.

It is important to emphasize that there is not yet sufficient data to exactly predict peak demand reduction from green buildings. Uncertainties result from a limited data set, inconsistencies in documentation, incomplete documentation, technical issues such as fuel switching, and the large variability between building designs. Nonetheless the available green building data is significant and collectively indicates that green buildings - including green buildings in California - on average provide peak demand reduction that is significantly larger than average energy reduction.

LEED places a high priority on building energy performance. Energy efficiency (including building commissioning, renewable energy and green power) is the single largest LEED credit category and represents 27% of the total points available in the LEED Green Building Rating System. LEED rated buildings, on average, use 30% less energy than those that meet the standard energy requirements of Title 24 (for California buildings) or ASHRAE 90.1 (in the rest of the country). Additional confirmation comes from analysis of USGBC data for 21 LEED rated buildings (including 6 buildings in California) - 8 Certified buildings, 5 Silver buildings and 8 Gold buildings. Both analyses (looking at a partially overlapping set of buildings) indicate that Gold buildings are generally the most energy efficient and Certified buildings the least efficient.[106] On a weighted average basis, green buildings are 28% more efficient than

[106] This building data is from USGBC from buildings that have completed the LEED certification process.

conventional buildings and generate 2% of their power on-site from photovoltaics (the large majority of green buildings do not have on-site generation and the 2% on site generation average reflects significant on-site generation from a few green buildings).

Figure IV-2. Reduced Energy Use in Green Buildings as Compared with Conventional Buildings

	Certified	Silver	Gold	Average
Energy Efficiency (above standard code)	18%	30%	37%	28%
On-Site Renewable Energy	0%	0%	4%	2%
Green Power	10%	0%	7%	6%
Total	**28%**	**30%**	**48%**	**36%**

Source: USGBC, Capital E Analysis

Evaluation of LEED certification documentation for over a dozen buildings,[107] including four California buildings, indicates an approximate average reduction in energy use of 30%, but an average peak reduction of about 40%.[108] While the data set is limited, it nonetheless indicates that green buildings reduce peak demand to a greater degree than total energy consumption: green buildings have proportionately larger reductions in peak demand.

Energy Star, administered by the US EPA and DOE, is the best known national energy performance rating program. It recognizes buildings for superior energy performance – defined as the 25% most energy efficient portion of the market – based on actual energy usage. Unfortunately, like LEED, the Energy Star program does not evaluate peak demand reduction.[109] Both USGBC/LEED and EPA/Energy Star should gather and publish data on the peak demand reduction of, respectively, green and energy efficient buildings.

Value of Peak Power

Utility transmission and distribution (T&D) systems generally run at less than 50% capacity.[110] However, during periods of peak electricity use, the generation and T&D systems may be close to overloaded. The benefits of reduced consumption are largest during periods of peak power consumption – avoided congestion costs, reduced power quality and reliability problems, reduced pollution, and additional capital investment to expand generation and T&D infrastructure. The value of peak reduction is not just in avoided purchase of electricity, but also in avoided capacity

[107] Data provided by the USGBC, analysis by Capital E with USGBC. November and December, 2002

[108] Because USGBC does not require that peak load reduction data be submitted, the data quality is mixed and includes some buildings that specify peak load demand reduction and some building data that indicates this indirectly (e.g., through large reductions in air conditioning load). Additional building information reviewed provided no useful data on peak demand reductions.

[109] US EPA. Energy Star Technical Description for the Office Model. 2001. Available at: http://www.energystar.gov/ia/business/evaluate_performance/technicaldescription.pdf.

[110] Electricity generation and distribution assets are less than half utilized most of the time. See: Amory Lovins et al, "Small is Profitable," RMI, 2002. http://www.smallisprofitable.org/.

and T&D costs.[111] Thus, energy benefits of green buildings need to be quantified not solely based on reduced energy use but also on reduced peak electricity demand.

Approaches for determining the value of peak demand reduction include: 1) marginal cost as imposed in time-of-use rates, and 2) the actual marginal cost of peak power – the cost of building peaking power plants, T&D required to deliver additional power, and related costs such as congestion costs.

An alternative, more elegant approach to calculating the full value of energy reduction in green buildings (including reduced peak demand reduction) would be to match energy reduction by time of use to the value of incentives being developed to reduce marginal load through demand reduction for three periods – baseload, shoulder periods and peak periods (up to 1000 hours per year). The California Energy Commission report, "Discussion of Proposed Energy Savings Goals for the Energy Efficiency Programs in California" evaluates the potential to achieve substantial energy efficiency savings by providing per kWh financial incentives for these three periods of $0.058/kWh, $0.10/kWh, and $0.167/kWh, respectively. [112] This spread between peak and average prices is used to estimate peak value below. Green building documentation does not provide energy use modeling data that would be required to precisely match green building energy use profiles to these marginal efficiency cost targets.

It appears that there is no recent, comprehensive, and publicly available analysis of the value of peak reduction in decreasing T&D, congestion, and related costs.[113] The most recent robust data, consisting of eleven utility studies, including four in California, is eight to ten years old. Summarized in Appendix D, these studies calculate the value to the grid of reduced peak demand due to on-site electricity generation.[114] On-site generation and on-site energy efficiency are functionally equivalent since both avoid the cost of additional central power generation, distribution facility capacity, and T&D.

These utility studies indicate an average T&D-related peak reduction value of $600 per kW (see Appendix D for calculations). To be very conservative, this report will reduce this value by 50%, providing an estimated value of T&D related benefits of $300/KW. This is almost certainly quite low and warrants further research. Gas peaking plants in California now have a capital cost of

---

[111] McAuliffe, Pat. California Energy Commission. October 2002. See also: Amory Lovins et al, "Small is Profitable," RMI, 2002. http://www.smallisprofitable.org/.

[112] Mike Messenger, "Discussion of Proposed Energy Savings Goals for Energy Efficiency Programs in California," *CEC Staff Paper*, September 2003. See: http://www.energy.ca.gov/reports/2003-09-24_400-03-022D.PDF

[113] Based on research and a range of interviews with experts at the CEC, PUC, utilities and elsewhere.

[114] As indicated, this data has limitations, which may both exaggerate and undervalue estimates. For example:

1) Only 4 out of 11 studies are from California, and these indicate an average T&D benefit of $510 per kW, lower than the average of $605.
2) The data is 8 to 10 years old. Benefits and costs are likely to have changed somewhat – for example, NIMBY (Not In My Back Yard) concerns and the resulting need to run a larger portion of additional transmission capacity underground have generally increased grid congestion and line expansion costs, indicating that current numbers would probably be higher than those calculated here.
3) Other benefits – described in great detail in the new publication, "Small is Profitable, the Hidden Cost Economic Benefits of Making Resources the Right Size" (RMI, 2002) – were not included in these studies and would tend to increase the value of T&D and related benefits.

On balance these issues would tend to make a comprehensive valuation of T&D and related benefits higher today than these studies indicate.

approximately \$600/kW.[115] Combining the current cost of new marginal generating facilities with \$300 T&D costs results in an estimated total value of \$900/kW for reduced peak demand.

Because of increasing congestion and more cumbersome construction restrictions, T&D and related costs are probably more expensive today than when these studies were done. For example, San Diego Gas & Electric has been planning to build a 31 mile, 500,000 volt transmission line in south Riverside County at an expected cost of \$300 million, or nearly \$10 million per mile –higher than historical costs for large transmission line extensions. However, a PUC administrative law judge recently ruled that the line is not cost-justified over the next five years based on projected electricity demand growth.[116] The explicit recognition of the link between projected electricity demand growth and approval of costly new power lines highlights the potential value of green buildings in reducing or even eliminating the large capital costs of line expansion.

Calculation

As discussed above, green buildings provide an average 30% reduction in energy use, as compared with minimum energy code requirements. For energy costs of \$1.47/ft^2/yr, this indicates savings of about \$0.44/ft^2/yr,[117] with a 20-year present value of \$5.48/ft^2. Energy savings alone exceed the average additional cost of green over conventional construction.

In addition, green buildings provide reduction in peak demand. An important area of research is to develop data needed to better calculate average peak demand reduction. Similarly, USGBC should consider requiring or encouraging that this data be provided in LEED certification documentation. USGBC does not currently require peak capacity analysis to be provided in LEED certification submissions, but output data from several commercially available energy models does provide this information. This report does not calculate savings based on peak capacity reduction. Instead, this report develops a peak reduction value based on data provided on peak energy demand reduction. As discussed above, the limited available data set of green building peak demand reduction for both California and non-California LEED rated buildings indicates a peak demand reduction of 10%.

The value of peak demand reduction can be approximated in several ways, including:

1) Based on California state building experience, a 10% reduction in peak demand for one million square feet of state prisons, hospitals or office buildings amounts to 200 kW, or about \$24,000 per year. On a per ft^2 basis this rule of thumb[118] works out to about \$0.024/ ft^2 per year.[119]

2) On the basis of an average energy use of 14kWh/ft^2 per year in state buildings and an average spread in cost between average and peak demand price indicated in recent

[115] California Energy Commission. "Comparative Cost of California Central Station Electricity Generation Technologies." *Final Staff Report*. June 2003. Available at: http://www.energy.ca.gov/reports/2003-06-06_100-03-001F.PDF, esp. Appendix C.
[116] "SDG&E's Plan for Power Line Dealt Blow," *Energy Info Source, California Energy Report* 10/21/02-11/03/02. Available at: http://www.energyinfosource.com/.
[117] 30% of \$1.47/ft^2/yr total energy costs at 5% discount rate over 20 year term – see Appendix I.
[118] Data provided by the California Department of General Services, November 2002.
[119] Data provided by the California Department of General Services, December 2002.

> California Energy Commission estimates for incentives required to reduce marginal load (described above) of \$0.067/kWh, it is possible to estimate annual savings from lowered peak power consumption. Assuming peak demand is 8% of all hours, it is estimated, conservatively, that a 1kWh shift from peak power, is worth \$0.05 per ft^2 per year.

The two estimates – \$0.024/ft^2/yr and \$0.05/ft^2/yr – represent a substantial spread, and indicate the need for better data gathering and more detailed modeling.[120] Adopting a conservative estimated annual savings of \$0.025/ft^2 results in the 20-year present value of the peak demand reduction attribute of green buildings at \$0.31/ft^2 (\$0.025/year, at 5% real discount rate over 20 years). It is important to emphasize that these are preliminary approximations based on limited data and that more rigorous and thorough modeling should be conducted as a larger data set develops. Despite these limitations, the conclusion indicates that green building energy reduction values include both lowered energy costs and some value of peak demand reduction. The value of peak demand and peak capacity reduction may be higher than estimated here.

Conclusion

Green building energy savings primarily come from reduced electricity purchases, and secondarily from reduced peak energy demand. The financial benefits of 30% reduced consumption at an electricity price of \$0.11/kWh are about \$0.44/ft^2/yr, with a 20-year present value of \$5.48/ft^2. The additional value of peak demand reduction from green buildings is estimated at \$0.025/ft^2/yr, with 20-year present value of \$0.31/ft^2. Together, the total 20-year present value of financial energy benefits from a typical green building is \$5.79/ft^2. Thus, on the basis of energy savings alone, investing in green buildings appears to be cost-effective.

Comment on Green Buildings and Demand Responsive Pricing

California's shift to dynamic electricity pricing and demand responsive buildings indicates an important future role for green buildings in helping to reduce energy and environmental costs. Several utilities across the country, including Georgia Power Company and Gulf Power have successfully provided financial incentives to customers to cut power consumption as a way to reduce and flatten load and avoid or delay the cost of building and/or operating additional generating capacity. However, California has become the national leader, and is developing dynamic pricing policies and programs to cut costs, increase system efficiency, and create a more intelligent and efficiently used electricity grid.[121]

California is helping residents and businesses install metering and control systems to support increased response to price signals to cut power usage through such measures as load shifting, moving air conditioning to before peak periods, and demand reduction measures such as lowering lighting levels. These measures, now proven ways to cut energy costs by rewarding price responsive customer load management, are being expanded to increase customer, utility, and state benefits. Green buildings are ideal candidates for demand responsive load management because

[120] Modeling by Gregg Morris of Future Resources Associates based on A-6 Schedule (Figure IV-1) indicates a range of \$0.026 -\$0.039/ft2/year, indicating that the \$0.025/ft/year estimate is conservative (this analysis is available upon request, gmorris@emf.net).

[121] See: Arthur Rosenfeld, Michael Jaske and Severin Borenstein, "Dynamic Pricing, Advanced Metering and Demand Response in Electricity Markets", Hewlett Foundation Energy Series, October 2002. See: http://ef.org/energyseries_dynamic.cfm

they already typically include relatively advanced metering and energy management systems. If, as seems likely, green building continues to grow very rapidly, these buildings should comprise an important part of California's strategy to expand demand responsive load management. In addition, the USGBC should consider adopting policies that encourage green buildings to include metering and energy management systems. These systems allow buildings to more readily participate in and secure the financial benefits of demand responsive power pricing and grid management.

V. Emissions from Energy

Energy use in California state buildings is over 95% electricity (See Appendix I). The generation of electricity, particularly from fossil fuels, creates a number of harmful emissions.

As discussed in the previous section, green buildings use an average of 30% less purchased energy than conventional buildings. In addition, green buildings are more likely to purchase "green power" for electricity generated from renewable energy sources. Green power purchases can take two forms:

- Customers can purchase green power directly from their utility or from a local green power provider. In this case customers are paying for electricity generated from renewable energy sources, typically by a local provider in the state or utility jurisdiction. About 40% of US electricity customers have this option.
- Customers can purchase green certificates, or green tags. In purchasing green certificates, a customer is buying ownership of the reduced emissions (and by implication the environmental and health benefits) associated with renewable power, even though the green generating facility is frequently not in the customer's vicinity. All electricity consumers have this option.

For 21 green buildings on which USGBC has collected data, 6% of the electricity purchased was green.[122] Two factors need to be considered in determining the net impact that green power purchases by green buildings have on emissions. First, a small and growing portion – slightly less than 1/2% of the general population – already buys green power.[123] This suggests that adoption of LEED provides a 5.5% net increase in green power purchases compared with conventional buildings. Secondly, LEED recently modified its green power purchase requirement to allow purchase of green certificates. With this change, 100% of LEED buildings now have the ability to get LEED credit for buying green power, providing virtually universal availability. This is in contrast to direct green power purchases, which are currently available in areas containing only 40% of the population. This broadening of the green power credit will therefore significantly increase the portion of LEED buildings that buy green power (an issue that should be explored in more detail).

Because all buildings are now able to buy green power, in the form of certificates, this report assumes that the portion of green power purchased by LEED green buildings will rise from 6% to 9% - an increase proportionally less than the doubling in buildings that can buy green power and receive LEED credit for it. A conservative estimate is that the future difference between average green building green power purchase and total average building green power purchase will rise from 5.5% (cited above) to 8.5%. Note that this is equal to 6% of total electricity use in an average non-green building.

This report therefore assumes that an average green building in the near future will purchase 9% of its electricity from green sources, or about 8.5% more than an average conventional building. Since a green building uses only 70% of the electricity that a conventional building does, the emissions reduction value of green power purchases by a green building is effectively reduced to about 6%. Adding emissions reductions from green power purchases to overall electricity

[122] Data provided by the USGBC. Capital E analysis with USGBC, November and December 2002.
[123] Jan Hamrin. Center for Resource Solutions, communication January 12, 2003. This number includes business as well as residential consumers.

consumption reduction provides a total emissions reduction of 36% compared to conventional buildings.

Value of Pollution Associated with Energy

Energy use in California state buildings and schools is predominantly electricity. Reduction in electricity use means lower emissions of pollutants (due to avoided burning of fossil fuels to generate electricity) that are damaging to human health, to the environment and to property.[124]

Air pollutants that result from the burning of fossil fuels include:

- Oxides of Nitrogen (NOx) – a principal cause of smog.
- Particulates (including PM10) – a principal cause of respiratory illness (with associated health costs) and an important contributor to smog.
- Sulfur Dioxide (SO2 or SOx) – a principal cause of acid rain. (SOx and SO2 are functionally the same for the purposes of this report.)
- Carbon Dioxide (CO2) – the principal greenhouse gas and the principal product of combustion.

Additional fossil fuel related pollutants include reactive organic compounds (ROC) and carbon monoxide (CO). These pollutants are not evaluated here because California power plant emissions represent 0.24% and 0.33%, respectively, of the statewide emissions totals and their values in other building aspects are small.[125] Volatile Organic Compounds (VOCs) may have significant value but are not calculated in this report. A more comprehensive analysis should evaluate the costs of a fuller set of these additional pollutants, including mercury.

There are at least three ways of valuing the costs of air pollution associated with burning fossil fuels:

1) The direct costs of pollution effects on property, health and environment can be calculated and then allocated on a weighted or a site-specific basis.
2) The cost of avoiding or reducing these pollutants can be used as a way to determine market value of pollutants.
3) The market value of pollutants can be used if there is an established trading market.

Each of these approaches has limitations and no one is universally "correct."

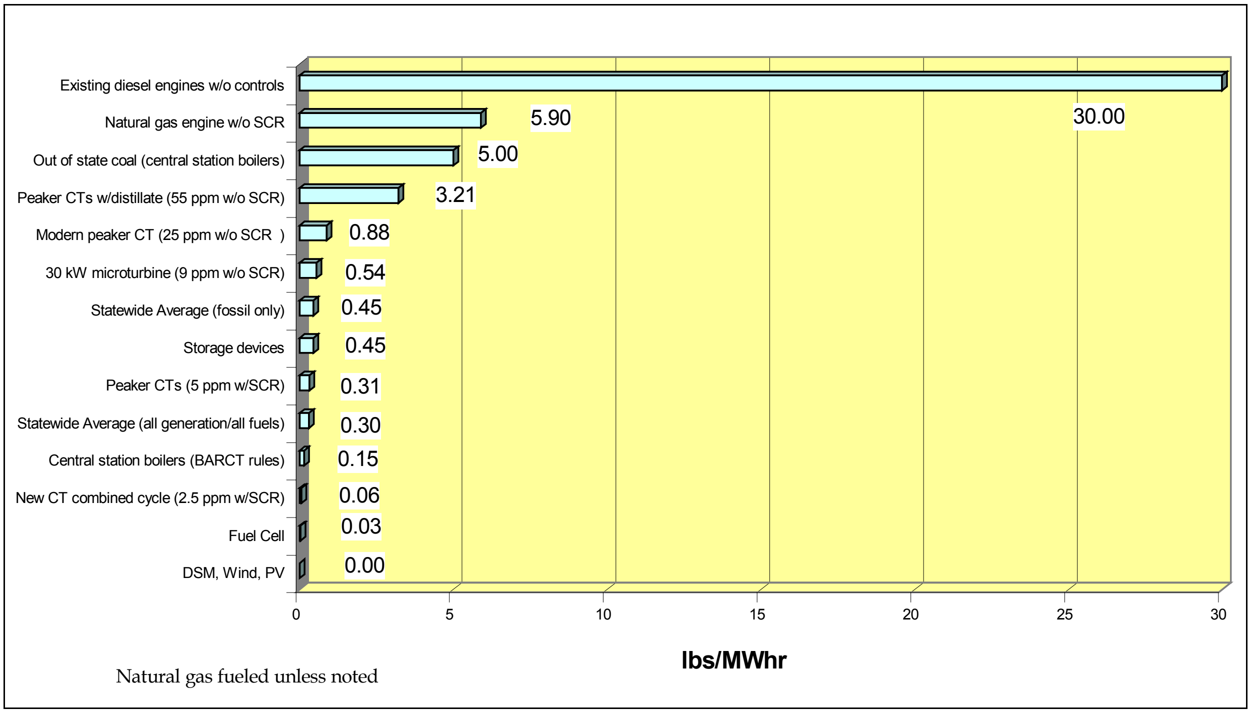
[124] Other forms of power, such as nuclear and hydro, also have environmental costs, though it is not within the scope of this report to evaluate these issues. Note that emissions intensity can vary by time of day, by season and other factors such as peak vs. baseload power (an issue that is addressed elsewhere in this report), although emissions impact is roughly proportional to energy use.

[125] California Energy Commission, "Environmental Performance Report of California's Electric Generation Facilities," July 2001. Available at: http://www.energy.ca.gov/reports/2001-06-28_700-01-001.html.

Emissions from Energy Use

The emissions reduction from decreased energy use depends on when reduction occurs and what energy source is displaced. Some of the most harmful emissions include NOx, SOx, particulates, and CO2. As indicated in Figure V-1 below, emissions vary vastly from back-up dirty diesel generators (of which the state has 3500 MW[126]) that produce 30 lb of NOx/MWhr,[127] down to zero emissions from renewable energy.[128]

Figure V-1. Generation Technologies Comparative NOx Emissions (lb/MWhr)



Source: "Performance Report of California's Electric Generation Facilities," CEC, July 2001.

Figure V-1 demonstrates that different sources of power are responsible for very different levels of pollution, and consequently different levels of associated health, environmental and property related costs. Benefits derived from the reduction in emissions from green buildings depend in part upon when reductions occur and what type of power (clean or dirty) is displaced. Emissions can vary substantially between California utilities, by season, and by time of use. This report uses an average California emissions factor for electricity to determine the financial value of emissions reductions associated with green buildings. Green buildings also tend to reduce peak consumption even more than they reduce overall demand. A more precise estimate would factor in the energy use profile of green buildings and match this to time-of-day power generation and associated pollution. However, this is beyond the scope of this analysis. It should be noted that green buildings can contribute to reducing grid congestion and power reliability and availability

[126] *Ibid.*
[127] *Ibid.*
[128] It should be noted that zero emissions for renewable energy – PV, wind, fuel cells, hydro, etc – refers only to the operation of these generating devices and not to their manufacture.

problems and can help reduce use of dirty backup/standby generating units. This could be examined in a more detailed analysis.

For a number of reasons – new technology, a shift to renewable energy, improvements in power plant efficiency, emissions control technologies and plant retrofits – emissions of NOx and SOx have dropped sharply and are expected to continue dropping. The CEC Environmental Performance Report notes that, "between 1975 and 2000, NOx and PM10 emissions from power generation declined by 79% and 83% respectively." [129] This decline is summarized in Figure V-2 below.

Figure V-2. Comparison of California Statewide Emissions with Emissions from Power Generation (tons/day)

Pollutant	Source of Emissions	1975	1980	1985	1990	1995	2000	2005 (est.)	2010 (est.)
NO_x	From All Sources	4,761	4,947	4,950	4,929	4,207	3,570	3,008	2,573
	From Power Generation	385	341	161	141	107	79.0	66.5	65.1
	% Power Generation	8.1%	6.9%	3.3%	2.9%	2.5%	2.2%	2.2%	2.5%
PM_{10}	From All Sources	1,864	2,018	2,004	2,240	2,177	2,313	2,467	2,612
	From Power Generation	49.6	29.1	5.7	11.8	8.1	8.62	9.63	9.8
	% Power Generation	2.7%	1.4%	0.28%	0.53%	0.37%	0.37%	0.39%	0.38%

Source: California EPA, Air Resources Board, Emission Reduction Offset Transaction Cost Summary Report for 2001

The State of California accounts for CO2 inconsistently – the California Inventory of Greenhouse Gas Emissions does not require inclusion of out-of-state generation, whereas the California Emissions Inventory Improvement Program does.[130] Typically, California emissions factors calculated by the Energy Information Administration and others reflect only in-state generation. California imports about 20% of its power from out-of-state, and this power has much higher pollution levels. Total coal generation in 2002 for California was 6220 MW, although 3065 MW or slightly less than 50% was imported.[131] In Los Angeles Department of Water and Power territory, coal imports are even more significant: total coal generation owned by LADWP, for example, is 2,235 MW – although almost all of it located out-of-state but sold in the California market.[132]

[129] State of California, California Environmental Protection Agency, Air Resources Board, "Emission Reduction Offset Transaction Cost Summary Report for 2001," April 2002, Table 1. Available at: http://www.arb.ca.gov/erco/erc01web.pdf.
[130] Lynn Price et al., "The California Climate Action Registry: Development of Methodologies for Calculating Greenhouse Gas Emissions From Electricity Generation," presented at *Green Building International Conference,* November 2002. Available at: http://eetd.lbl.gov/ea/EMS/reports/50250.pdf.
[131] California Energy Commission. "California Gross System Power for 2002 In Gigawatt-Hours (GWh)." 2002. Available at: http://www.energy.ca.gov/electricity/gross_system_power.html.
[132] Information provided by the California Energy Commission, Systems Assessment and Facilities Siting Division. January 2003. (Matt Layton) See also: LADWP. Power Content Label. Available at: http://www.ladwp.com/power/pwrcontentlbl.pdf; US DOE. Energy Efficiency and Renewable Energy. GreenPower Network. 1999. "LA's New 'Green Power' Program Will Save Customer's Money." Available at: http://www.eere.energy.gov/greenpower/ladwp_599_pr.html.

Figure V-3. California Power Emissions Factors from the Tellus Institute (CO2 Modified)

	Emission Factors (short tons per GWh)		
Pollutant	**1999**	**2010**	**2020**
Carbon Dioxide	308	308	308
Sulfur Dioxide	0.32	0.281	0.244
Nitrogen Oxides	0.404	0.448	0.399
PM-10	0.235	0.2	0.186

Source: Tellus Institute, 2002, modified by Capital E.

Tellus Institute has undertaken analysis of California power emissions, including out-of-state generation. Modified Tellus estimates are used here, principally because they include all power used in California, not just power generated in-state.[133]

These emissions factors developed by Tellus reflect the likely future average mix of electricity generating technologies and fuels used by the California market. They also reflect likely future trends in emission factors under the EIA's projected business as usual scenario through 2020. The Tellus Institute emissions estimates change over time, including a significant increase in CO2 intensity in 2010 and 2020, to 452 and 490 tons per GWh, respectively. Given California's continuing concerns about pollution, including global warming, and the state's recent commitment to expanded use of renewable energy, it appears that CO2 intensity is more likely to remain flat than rise, so this report uses the 1999 CO2 emissions factor throughout the period of calculation. Use of the higher Tellus numbers would indicate larger financial benefits of green buildings.

Estimated Costs Associated with Pollution from Power Generation

Air pollution from burning fossil fuels to generate electricity imposes very large health, environmental and property damage costs. Demonstrated health costs include increased mortality and increased respiratory ailments.[134] The health, environmental and property damages associated with pollution from burning fossil fuels – commonly referred to as externalities – are only partially reflected in the price of energy. Estimating the costs of externalities is technically difficult, politically problematic, and overall an inexact science. There have been dozens of

[133] William W. Dougherty, Senior Scientist, "Characterization of Criteria Air Pollutant and Greenhouse Gas Emission Factors Associated with Energy use in the USA: Sources, Assumptions, Methodology," based on Reference Case of the EIA's AEO200, Tellus Institute, 2002. See also: US Department of Energy, "Carbon Dioxide Emissions from the Generation of Electric Power in the United States," July 2000. Available at: http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2emiss.pdf; U.S. Department of Energy, Energy Information Administration, "Updated State-level Greenhouse Gas Emission Factors for Electricity Generation," Washington, D.C. See DOE EIA site: http://www.eia.doe.gov/env/utility.html.

[134] See, for example: "The Benefits and Costs of Clean Air Act 1990 to 2010," 1991. Available at: http://www.epa.gov/air/sect812/1990-2010/fullrept.pdf and Jonathan Samet et al., "The National Morbidity, Mortality, and Air Pollution Study – Part II: Morbidity and Mortality From Air Pollution In the United States," Health Effects Institute, 2000. Available at: http://www.healtheffects.org/Pubs/Samet2.pdf.

attempts to estimate the external costs of power generation, but these efforts have not produced consensus. [135]

The California Board of Energy Efficiency (CBEE) developed estimates for environmental adders of $0.0072/kWh, or about 3/4 of one cent per kWh.[136] The CEC sought to determine the damage functions (for health, property and environmental impacts) in their Electricity Reports of 1992 and 1994.[137] In the reports, the CEC expressed reservations about use of this data. Given the lack of consensus on the value of externalities, and changing generation profiles (including steep reductions in some pollutants since the CEC analysis), this report will not rely on these damage functions to calculate the value of emissions reductions.

Instead, this report will rely on market values for traded emissions as the least imperfect of the options available for determining emissions values. These prices reflect actual marginal cost of emissions reductions in relatively liquid and well-established trading markets covering the majority of California's population. For some pollutants, including NOx and SOx, there is a well-established, liquid market and these market prices serve as our best measure of both the marginal cost of emissions reductions and the value society places on them. It is important to note that because the current market for emissions is driven by caps set by regulations, and not the morbidity effects of emissions, it does not directly reflect the externalities of health impacts, and therefore the value of reductions may be significantly understated. Some pollutants, including NOx and PM10, have substantial vehicular sources, and it is possible that the true value of reduced emissions for stationary sources is the same as for mobile ones (although this discrepancy is not recognized in the emissions market). In addition, important pollutants, such as mercury and smaller particulates (e.g. PM2.5) have large adverse health effects that are not addressed in this report. A more comprehensive evaluation of a fuller set of pollutants would end to increase the estimated financial benefits associated with lower conventional energy used in green buildings.

The California Air Resources Board (ARB) compiles and publishes annual data on emissions offset transactions[138] from 35 districts. Figure V-4 contains the reported prices for these offsets.[139] The average value of offsets was used in calculations.

[135] For a valuable introduction and overview of past California and national studies on externality cost and costs of emissions reductions, see Jonathan Koomey and Florentin Krause, "Introduction to Externality Costs," LBNL, 1997. Available at: http://enduse.lbl.gov/Info/Externalities.pdf .

[136] Nick Hall and Jeff Riggert, "Beyond Energy Savings: A Reviews of the Non-Energy Benefits Estimated for Three Low-Income Programs," *ACEEE Conference Proceedings, Program Measurement and Evaluation* – 10.111.

[137] California Energy Commission. "1994 Electricity Report." Available at: http://www.energy.ca.gov/reports/ER94.html.

[138] Prior annual compilations of the offset transactions in California that occurred from 1993 through 2000 can be found at http://www.arb.ca.gov/erco/erco.htm.

[139] California Environmental Protection Agency, Air Resources Board, "Emission Reduction Offset Transaction Cost Summary Report for 2001,"April 2002, Table 1. Available at: http://www.arb.ca.gov/erco/erc01web.pdf. See also: http://www.arb.ca.gov/cgi-bin/swish/search.pl.

Figure V-4. 2001 Prices Paid in Dollars Per Ton for California-based Offsets

	NOx	PM10	SOx
Average (mean)	$ 27,074	$ 46,148	$12,809
Median	$ 22,000	$ 25,000	$ 7,500
High	$104,000	$126,027	$82,192
Low	$ 774	$ 400	$ 15

Source: California EPA Air Resources Board

Because there is no cap on CO2 emissions and no California CO2 market, CO2 price-indexes are not compiled and included. To determine CO2 value it is necessary to look at alternative sources.

The Cost of Carbon: Putting a Price on CO2 Emissions

The vast majority of the world's climate change scientists have concluded that anthropogenic emissions – principally from burning fossil fuels – are the root cause of global warming.[140] The United States is responsible for about 22% of global greenhouse gas (GHG) emissions. Of this 22%, the US building sector is responsible for about 35% of US CO2 emissions. CO2 is the dominant global warming gas, equal to about 9% of global anthropogenic emissions. As a recent study notes, US buildings alone are responsible for more CO2 emissions than those of any other country in the world except China.[141]

A report published in July 2002 for the United Nations Environmental Program's Finance Initiatives Climate Change Working Group, *Climate Change and the Financial Services Industry*, warns of the large risks posed by global warming. The report concludes that the "increasing frequency of severe climatic events, coupled with social trends, has the potential to stress insurers, reinsurers and banks to the point of impaired viability or even insolvency." [142] John Fitzpatrick, CFO and Member of the Executive Board of Swiss Re, maintains, "climate change and substantial emissions reductions – like any other strategic global business challenge – ultimately become a financial issue." [143] The United Nations estimates the potential cost of global warming at over $300 billion per year, and insurance firms are becoming concerned about the possibility of lawsuits due to damage from human-induced global warming.[144]

Global warming is recognized as a potentially very costly issue for California, implying a significant value for CO2 reductions in this state. Projected changes in rainfall patterns and snowmelt will likely reduce both available freshwater supplies and the effectiveness of the state's

---

[140] Intergovernmental Panel on Climate Change. World Meterological Association and United Nations Environmental Program. "IPCC Third Assessment Report – Climate Change 2001." Available at: http://www.ipcc.ch/.

[141] Kinzey et al., "The Federal Buildings Research and Development Program: A Sharp Tool for Climate Policy," *2002 ACEEE proceedings*, Section 9.21.

[142] Innovest, for the United Nations Environmental Program. Finance Initiatives Climate Change Working Group. "Climate Change and the Financial Services Industry," 2002. Available at: http://www.unepfi.net/.

[143] "Climate Change Related Perils Could Bankrupt Insurers," *Environmental News Service*, October 7, 2002. Available at: http://www.campaignexxonmobil.org/news/News.OneWorld100802.html.

[144] Katharine Q. Seeley, "Global Warming May Bring New Variety of Class Action", *New York Times*, September 6, 2001. Available at: http://www.commondreams.org/headlines01/0906-03.htm.

hydropower infrastructure. If California experiences below average rainfall, it could cut the amount of power that the state gets from hydroelectricity, currently 20% of total power, by up to half.[145]

California's new climate change legislation, passed in October 2002[146] establishes global warming as an issue of legitimate state concern. In addition, previous legislation requires that the value of emissions reductions be considered in developing a present value assessment of solar energy systems for California state buildings.[147] California's building investment and construction programs should reflect this, probably by assigning a dollar value to avoided GHG emissions achieved through better building design. Even if this value is not based on a single, determinative methodology and even if it is low, recognizing the cost of global warming by assigning a dollar value of some amount is preferable to the current practice of assigning no value – effectively $0 – to CO2 reductions. It is also economically efficient for the state to explicitly recognize a value for CO2 in order to ensure a more cost-effective decision making process about building design choices.

It is important to note that because California is a relatively energy efficient state with relatively clean electricity generation, the emissions associated with energy use in California buildings are relatively low. Balancing this, the value of emissions traded in California markets is high relative to the rest of the US.

Market trading rules for CO2 are not yet established and there is no accepted cap on emissions to drive the creation of a California market. Therefore a range of approaches for determining a fair value for CO2 reductions is discussed below.

Assigning a Cost to Carbon

The large energy use of buildings (more than one third of energy used in the economy) has led to extensive analysis of strategies to cut CO2 emissions from this sector. Countries such as Holland are developing specific programs to reduce energy use and associated greenhouse gas emissions from their buildings sector.[148] Innovative legislation passed in 1997[149] in Oregon mandates that new power plants in the state offset a significant portion (roughly 17%) of their CO2 emissions either by avoiding, sequestering or displacing emissions or by funding projects that do the same.[150] To date, this program has funded projects (including those currently under negotiation)

[145] William Keese, "Electricity Supply/ Reliability 2000 to 2002," Report for the joint hearing to the California Senate, August 10, 2000. Available at: http://www.energy.ca.gov/papers/2000-08-10_KEESE_TESTIMONY.PDF.

[146] State of California Assembly Bill 1493. Chapter 200, Statutes of 2002. Available at: http://www.leginfo.ca.gov/pub/01-02/bill/asm/ab_1451-1500/ab_1493_bill_20020722_chaptered.pdf. For more on CO2 issues in California, see: http://www.arb.ca.gov/gcc/gcc.htm.

[147] State of California Senate Bill 82, Chapter 10, Statutes of 2001-2002, 2nd Extraordinary Session. Available at: http://www.leginfo.ca.gov/pub/01-02/bill/sen/sb_0051-0100/sbx2_82_bill_20011007_chaptered.pdf.

[148] Kool et al., "Development of Policy to Reduce CO2 emissions from the Dutch Building Sector," *ACEEE conference proceedings*, 2002, Section 9.23.

[149] State of Oregon House Bill 3283. Oregon Revised Statutes of 1997. Oregon Administrative Rules, Chapter 345, Division 24. Available at: http://www.climatetrust.org/housebill.html.

[150] The Climate Trust. "Funding Innovative Projects to Counter Rapid Climate Change." October 2002. Available at: http://www.climatetrust.org/CTBrochureOct2002.pdf; "2001 Annual Report," Available at: http://www.climatetrust.org/2001AnnualReport.pdf.

that will result in approximately 3.5 million metric tons of CO2 offsets.[151] Within California, legislation has established the California Climate Action Registry, a voluntary registry for businesses and organizations within California to record annual greenhouse gas emissions and track reductions over time.[152] However, there is currently no mandate for state agencies to participate in the Registry. For California, models indicate that achieving a slowdown in growth of CO2 emissions resulting from building energy use would require state taxes on CO2 of $5 per ton in 2005, rising to $14 per ton in 2020.[153]

Determining a value for CO2 reduction is a difficult proposition. For example, a recent Intergovernmental Panel on Climate Change (IPCC) report cites a range of values between $5 and $125 per ton of CO2.[154] CO2 trading programs in the US are emerging,[155] with the value of trades typically ranging from under $1 up to $16 per ton, with most trades at under $5 per ton, but with a general trend of prices rising. The World Bank has participated in 26 emissions reduction projects, with CO2 trading at $3 to $4 per ton.[156] BP has used a price of $10 per ton for internal trading of CO2.

Despite the wide range of current prices for CO2, there is a widespread perception that CO2 prices will rise as the market demand continues to grow, as more private firms and public entities participate, and as the least expensive tons get bought up first. Many macro models project that to meet significant CO2 reduction targets, CO2 prices must be in the $25-$50 per ton range. The exact clearing price depends to a large extent on the size of emissions reductions sought – a political issue that has yet to be resolved. The EU estimates that to achieve the Kyoto Protocol CO2 targets, CO2 cost will need to be about $30 per ton.[157]

A 2002 A.D. Little (ADL) study for the CEC and the ARB includes a detailed analysis of the value of CO2. This study summarizes CO2 values from four emissions trading firms active in the US and two emissions trading institutions, with prices ranging from $0.10 up to $70 per ton. The individual averages of the six institutions are between $2 and $35, with the average of these averages at $13 per ton of CO2 (note that most trades were at lower prices).

---

[151] The Climate Trust. "The Climate Trust Fact Sheet." 2003. Available at: http://www.climatetrust.org/aboutus.html.
[152] State of California Senate Bill 527, Chapter 769, Statutes of 2001. Available at: http://www.leginfo.ca.gov/pub/01-02/bill/sen/sb_0501-0550/sb_527_bill_20011012_chaptered.pdf.
[153] Kool et al. (all in 1999 dollars) Op. Cit.
[154] IPCC Working Group III, "Summary for Policymakers: The Economic and social Dimensions of Climate Change," 2001. Available at: http://www.ipcc.ch/pub/sarsum3.htm.
[155] Carbon Trade Watch. "Briefing No. 1: The Sky is Not the Limit: The Emerging Market in Greenhouse Gases." January 2003. Available at: http://www.tni.org/reports/ctw/sky.pdf. For a list of existing registry and emissions reductions programs, see also: http://www.nescaum.org/Greenhouse/Registry/state_matrix.html.
[156] "World Carbon Credit Trading Could Triple," *CNN*, October 22, 2002. Available at: http://www.evworld.com/databases/shownews.cfm?pageid=news221002-02.
[157] P. Capros and L. Mantzos, "The Economic Effects of EU-Wide Industry-Level Emission Trading to Reduce Greenhouse Gases," May 2000. Available at: http://europa.eu.int/comm/environment/enveco/climate_change/primes.pdf.

The ADL report concludes by recommending that California adopt a value of $25 per ton of CO2. The CEC estimated that $11 (2002 dollars) must be spent on reforestation to grow enough trees to absorb one ton of carbon dioxide each year.[158] A more recent report, completed by TIAX, LLC for the ARB and CEC completes a similar analysis, but recommends a value of $15 per ton of CO2 emissions.[159]

Given the large range of prices assigned to CO2 by emissions trading markets, policy makers, analysts and others, there is no exactly "right" price per ton of CO2. This analysis recommends that California state agencies adopt a value of $5 or $10 per ton when valuing CO2 emissions. Both of these prices are reasonable figures. These prices are above most current CO2 trades, but well below most medium term estimates for CO2 reduction costs, and below specific price estimates and projections for California. Additional analysis is recommended to arrive at a more thorough valuation of CO2, and this might, for example, include a range of values with probability assigned to each different value. Despite the uncertainties and large credible range of possible prices, some value per ton should be assigned to CO2 for the purposes of calculating the benefits of green buildings, and the relatively conservative prices estimates of $5 and $10 are modeled below.

Conclusion

The average California state building uses electricity at a rate of about 10 $kWh/ft^2/yr$.[160] Converting this to GWh, multiplying by the emissions factors for 2010 from Figure V-3, and then multiplying again by the average prices-per-ton from Figure V-4, yields yearly emissions costs per square foot (Figure V-5). Figure V-6 shows the 20-year PV of a 36% reduction in emissions of the four pollutants discussed above.

Figure V-5. Estimated Annual Cost of Emissions (/ft^2)

Pollutant	Emission Factors (short tons per GWh)	Dollars/ton		Annual Cost of Emissions for 10 kWh	
Carbon Dioxide	308	$5	$10	$0.015	$0.031
Sulfur Dioxide	0.281	$12,809		$0.036	
Nitrogen Oxides	0.448	$27,074		$0.121	
PM-10	0.2	$46,148		$0.092	

Source: Tellus Institute, California ARB, Capital E Analysis

[158] California Energy Commission, Committee Order for Final Policy Analysis, Docket No. 88-ER-8, March 27, 1990, as reported in the Tellus *Packaging Stud,* Report #4, "Impacts of Production and Disposal of Packaging Materials – Methods and Case Studies," p. 1-5. CPI adjusted from $8 in 1990 dollars.

[159] TIAX, LLC, "Benefits of Reducing Demand for Gasoline and Diesel," Report to the CARB and CEC, May 2003. Available at: http://www.energy.ca.gov/fuels/petroleum_dependence/documents/2003-05-07_600-03-005A1.PDF.

[160] Data provided by the California Department of General Services, Real Estate Services Division, Building Property Management Brach. See Appendix I. Energy use and cost numbers come directly from utility bills.

Figure V-6. 20-Year PV of 36% Pollution Reduction for California Buildings (/ft^2)

	CO2 PRICE	
Pollutant	**$5/ton**	**$10/ton**
NOx	$0.54	$0.54
PM10	$0.41	$0.41
SOx	$0.16	$0.16
CO2	$0.07	$0.14
Total	**$1.18**	**$1.25**

Source: Capital E Analysis

This report will assume the lower $5 per ton value of carbon, indicating a 20-year PV of $1.18/ft^2 for emissions reductions from green buildings.

VI. Water Conservation

California is facing substantial water shortages that are expected to worsen. Drought years can be particularly difficult on Californians. Urban water users have experienced mandatory rationing, small rural communities have seen wells go dry, agricultural lands have been fallowed, and environmental water supplies have been reduced. Without additional facilities, all of these conditions will only deteriorate with California's projected population increase.[161] Thus, water conservation not only saves money for the end user through reduced utility expenditures, but also saves state water districts the costs of facilities construction and expansion and prevents potential environmental damage.

Green building water conservation strategies typically fall into four categories:

- Efficiency of potable water use through better design/technology.
- Capture of gray water – non-fecal waste water from bathroom sinks, bathtubs, showers, washing machines, etc. – and use for irrigation.
- On-site storm water capture for use or groundwater recharge.
- Recycled/reclaimed water use.

Taken together, these strategies can reduce water use below code/common practice by over 30% indoors and over 50% for landscaping.[162] Of 21 reviewed green buildings submitted to the USGBC for LEED certification (including 6 California buildings) all but one used water efficient landscaping, cutting outdoor water use by at least 50%. Seventeen buildings, or 81%, used no potable water for landscaping. Over half cut water use inside buildings by at least 30%.[163]

Current Practice in California State Commercial and Institutional Buildings[164]

The state's current strategy for water conservation in new or renovated buildings generally does not include measures that exceed federal codes. However, the SBTF has developed a 2-tiered list of sustainable building measures, which includes a number of water efficiency elements.[165] While in theory, new projects should include all feasible water efficiency technologies and strategies, in practice this is not done in most projects.[166] Additionally, state projects are not

---

[161] California Department of Water Resources, "California Water Plan Update BULLETIN 160-98," 1998, Volume 2, Chapter 6, p. 6-2. Available at: http://rubicon.water.ca.gov/. A more current update is expected from DWR in 2003.

[162] US Green Building Council LEED Reference Package, Version 2.0, June 2001, p. 65, and analysis of green buildings submitted to USGBC. Available for purchase at: http://www.usgbc.org/LEED/publications.asp.

[163] Data provided by USGBC.

[164] "Commercial" refers to water use at state office buildings and other commercial facilities. "Institutional" refers to water use at schools, colleges, universities and other non-office government facilities.

[165] California Department of General Services. Real Estate Services Division. "Tier 1 and Tier 2 Energy Efficiency and Sustainable Building Measures Checklists." July 1, 2002. Available at: http://www.ciwmb.ca.gov/GreenBuilding/Design/Tiers.pdf.

[166] California Department of General Services. Real Estate Services Division, Project Management Branch. "Energy Efficiency and Sustainable Building Measures Capital Projects Summary." August 8, 2002.

mandated to follow California's Model Water Efficient Landscape Ordinance of 1993, even when a project is located in an area where the local utility has adopted it. It is therefore assumed that most state buildings are no more water efficient than other private sector commercial projects in California, and that typical strategies employed to reduce water consumption in private sector projects have a similar impact on California state buildings.

The Cost-Effectiveness of Water Conservation and Demand Reduction Strategies[167]

The potential cost savings of water conservation has been documented in the commercial and institutional sectors. Two 1997 studies – one by the Metropolitan Water District (MWD) and one by the US EPA and the California Department of Water Resources (DWR) attempted to estimate this potential specifically in California.[168] The MWD study found that commercial water use volume could be cost-effectively reduced (average payback – 1.7 years) by approximately 23%. The DWR study came to similar conclusions, finding that a 22% reduction in water use could be cost-effectively generated through conservation strategies. Projected savings by building type include: office buildings - 40%, schools - 21%, and hospitals - 22%.[169] In both studies, the authors note that estimates are conservative, and only include relatively simple technologies and/or implementation strategies and short term paybacks.

Water conservation can take several forms. In an urban commercial or institutional setting, significant savings can be achieved through reductions in outdoor water use – with efficient landscape and irrigation design, automatic rain sensors, and landscape water audit programs to ensure that reductions are met – as well as indoors – with better leak detection, more efficient appliances, and aggressive audits (simply ensuring compliance with existing standards and regulations could result in a 3% demand reduction across the commercial, industrial and institutional sectors).[170]

The cost of urban water conservation programs is typically $500-$750/af of conserved water (1 af = 1 acre-foot = 325,851 gallons).[171] Water can also be conserved by increasing the efficiency of the distribution system. Reducing distribution system losses to 5% through full metering, annual water audits, and systematic leak detection and repair programs would cost an estimated $300/af.[172]

---

[167] Cost-effectiveness is described earlier in the assumptions section, and is consistent with the definition in "BMP Costs and Savings Study: A Guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices," prepared for the California Urban Water Conservation Council by A & N Technical Services, Inc, March 31, 1999. It states, "Cost-effectiveness analysis (CEA) is the comparison of costs of a conservation device or activity with its benefits expressed in physical units (for example, $Costs per AF of savings). Cost-benefit analysis (CBA) is the comparison of costs of a conservation device or activity with its benefits, also expressed in dollar terms (for example, $Net Benefits = $Benefits - $Costs)."

[168] Charles Pike, "Study of Potential Water Efficiency Improvement in Commercial Business," US EPA/DWR, April 1997.

[169] Jon Sweeten and Ben Chaput, "Identifying the Conservation Opportunities in the Commercial, Industrial, and Institutional Sector," paper delivered to the AWWA, 1997, p.8.

[170] BULLETIN 160-98, p. 6-10. Op. Cit.

[171] A&N Technical Services. "BMP Costs and Savings Study: A Guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices." July 2000. Available for purchase at: http://www.cuwcc.org/publications.

[172] BULLETIN 160-98, p. 6-10, 6-11. Op. Cit.

Estimated Actual Cost of Water from the State Perspective

A recent empirical study in Canada estimated that the price charged for fresh water was only one-third to one-half the long-run marginal supply cost, and that prices charged for sewage were approximately one-fifth the long-run cost of sewage treatment.[173] Commonly uncounted components of the long-run marginal supply cost include: new marginal water supply expansion and treatment, new marginal wastewater capacity and treatment, and the economic costs caused by environmental damage. Given anticipated population growth and concomitant escalating water demand, these costs are likely to be significant. (For a brief description of California's current water situation including demand, forecasted growth rates, and supply constraints, please see Appendix F). These factors make conservation and demand reduction, as encouraged in green building, all the more attractive – water saved does not need to be treated or disposed.

The California Urban Water Conservation Council (CUWCC) has designed a model to account for all of these factors in determining the total savings of water conservation. Called the Total Society Cost Model,[174] it requires inclusion of all avoided future economic, environmental, and social costs in order to determine a true avoided cost of urban water conservation. It has yet to be implemented by a single agency, perhaps reflecting the fact that determining the true marginal cost of water is difficult.

The following factors contribute to the complexity of determining the true marginal cost of water:

- *Regional Differences*. The current and projected future cost of supplying, treating, delivering and disposing of water vary drastically between and within regions.
- *Future Cost of Water.* To value a water conservation measure today, it is necessary to predict future marginal water costs over the lifetime of the measure. The marginal cost of water in 2012 depends on multiple factors including: demographic changes, weather patterns and public policy choices.
- *Perspective.* Marginal cost depends on perspective. A private building owner, a local utility, a regional utility and a state will all have different marginal cost assumptions.
- *Hard-to-Quantify Environmental Costs*. Although attempts have been made to value some environmental costs (e.g., complying with anticipated regulations), the economic impacts of damages (e.g., habitat destruction, fish losses, local air pollution, greenhouse gas emissions, increased delta salinity, etc.) are generally more difficult to quantify.
- *Unpredictable Political Landscape*. For more than 20 years, California has been taking as much as one million acre-feet per year (1 maf/yr) from the Colorado River above an existing legal limit of 4.4 maf/yr. In January 2003, the Bush administration announced that California would no longer be entitled to this extra water. In 2003, this could mean California will lose as much as 650,000 af of anticipated water supply.[175] This decision will likely increase southern California's marginal cost of water.

---

[173] Steven Renzetti, "Municipal Water Supply and Sewage Treatment: Costs, Prices, and Distortions," *Canadian Journal of Economics*, v32, i3, May 1999, p. 688.
[174] This approach is described in "Guidelines for Preparing Cost-Effectiveness of Urban Water Conservation Best Management Practices," a publication of the CUWCC, Sept. 1996, pp.1-7.
[175] Dean Murphy, "The Politics of Water: California Water War Takes New Turn," *San Francisco Chronicle*, 2003. Available at: http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2003/01/05/MN169799.DTL.

- *Climate Change Impacts*. Recent studies suggest that global warming will have a significant impact on California's water resources. It appears there is no available study that projects the impact of climate change on the cost of future water supplies.

Notwithstanding these challenges, two comprehensive studies have been released over the past several years that attempt to determine appropriate marginal water costs for the state. The more recent, *Urban Water Conservation Potential*, was produced by Gary Fiske and Associates for the California Urban Water Agencies (CUWA) in August 2001.[176] It assigns marginal cost numbers to every region of the state for each year from 2000 – 2040.[177]

Figure VI-1 below shows the present value of avoided marginal water costs over a 20 year period based on the CUWA study. *Supply* is the present value of the marginal price the utility would pay to obtain or develop an acre-foot of water each year. *Wastewater* is the present value of the average cost savings - $73.50/af - from the delay of new wastewater facilities construction over the same time period. *Wastewater O&M* is the present value of the average avoided cost to treat new supplies - $13.50/af - over the specified time period. The *Weighted Average Value* is based on anticipated population growth for each region of the state (see Appendix G for calculations).

Figure VI-1. 20-Year Net Present Value of Avoided Marginal Water Supply and Wastewater Treatment Costs to Local Water Agencies in 2003

	Supply (/af)	Wastewater (/af)	Wastewater O&M	Total (/af)
Bay Area	$8,392	$953	$201	$9,546
Central Coast	$4,423	$953	$201	$5,576
Sacramento	$629	$953	$201	$1,783
San Joaquin	$1,944	$953	$201	$3,098
South Coast	$7,920	$953	$201	$9,074
S. Lahontan	$3,683	$953	$201	$4,837
Tulare	$2,046	$953	$201	$3,200
Average	$5,075	$953	$201	
			Weighted Average Value:	**$6,299**

Source: Gary Fisk and Associates for CUWA, Capital E Analysis

The CUWA study highlights the large differences in marginal water costs between regions (Sacramento's current low cost reflects historical access to low cost water sources) and provides a potential baseline for regional marginal water cost analysis.

A second study, *Economic Evaluation of Water Management Alternatives*, was developed by CALFED in October 1999.[178] It makes predictions of marginal water costs in certain regions of California only for the year 2020, and is thus less useful for determining 20-year PV and yearly

[176] Gary Fiske and Associates, "California Urban Water Agencies Urban Water Conservation Potential*." Final Report*, August 2001.

[177] It is assumed that wastewater capacity expansion costs would not begin to accrue until 2005 as projects currently being developed should be counted as fixed, sunk costs.

[178] "Economic Evaluation of Water Management Alternatives," prepared for the CALFED Bay-Delta program, October 1999. Available at: http://calwater.ca.gov/Archives/WaterManagement/adobe_pdf/EconomicEvaluationofWaterManagementAlternatives_Oct99.pdf.

marginal water costs than the CUWA study. The "Unconstrained" scenario, CALFED's preferred/expected option of the seven analyzed, is presented in Figure VI-2 below:[179]

Figure VI-2. Marginal Cost Expectations for One Acre-foot of Water in 2020[180]

	CALFED	CUWA
South Coast	$1,045	$628
San Francisco Bay	$1,123	$867
San Joaquin River	$130	$138
Tulare Lake	$211	$143

Source: CALFED, CUWA

While the CALFED numbers are higher than those from CUWA, a more comprehensive assessment of California's water situation would probably reflect marginal cost numbers higher than both for most regions of the state. The California Water Plan Update from 1998[181] cites a number of water development projects and their costs.[182] According to this report, dam construction alone can cost $2.3 billion to deliver an average of 620,000 af/yr from the San Joaquin River. This excludes property, utility relocation and mitigation costs, as well as maintenance and other water delivery costs. Seawater desalinization, often viewed as the upper bound of economically feasible water, costs $1000-2000/af.[183] The following important factors should be included in order to accurately estimate marginal water cost.

Perspective. The marginal cost numbers from the CUWA study are equal to the price the agency pays for water. From the state's perspective, however, there are additional costs of developing new supplies and delivering water to the end user. These costs can be significant. For example, MWD has now begun accepting proposals from its member agencies to develop desalinization facilities. MWD will pay up to $250/af to subsidize the local construction of desalinization plants.[184] From the perspective of the MWD, the marginal cost of this water is $250/af. However, the actual development cost to the local agencies can be up to $2000/af.[185] Assuming an average annual cost of $1150/af suggests a 20-year PV of $14,332/af of new water capacity construction avoided, or more than 2 times higher than the weighted average cost for California indicated Figure VI-1.

Wastewater Treatment Costs. The authors of the CUWA study acknowledge that their wastewater treatment numbers could be refined.[186] The CUWA study assumes that the marginal cost of wastewater treatment will grow at the rate of inflation, as it has, on average, over the past

---

179 *Ibid.* Table 8.1.

180 San Joaquin and Tulare Lake Region numbers are much lower than the Bay Area and South Coast for two primary reasons. First, their marginal need is for agriculture, and agricultural water is much less expensive to develop, treat, and dispose of than urban water. Second, both of these regions are closer to the water sources than the Bay Area and South Coast, sharply reducing pumping costs. Costs include amortized capital and O&M costs for supply measures, plus estimated retail cost components for treatment, distribution and administrative overhead.

181 BULLETIN 160-98, Volume 2. Op. Cit.

182 "California Water Plan Update BULLETIN 160-98," Volume 2, Chapter 6. Download at: http://rubicon.water.ca.gov/pdfs/v2/v2ch6.pdf.

183 *Ibid*, p.6-34.

184 CUWA study. Op. Cit.

185 CUWA study. Op. Cit.

186 Illingworth, Wendy. Economic Insights, Inc., Oct 15, 2002.

ten years. However, a recent study released by the EPA suggests that future costs will likely rise much more rapidly than in the past.[187] The city of Portland, Oregon, for example, expects wastewater rates to rise by about 7% annually over the next decade, significantly higher than the 2-3% annual increase experienced over the past several years.[188]

Proposition 50 Supply Projects. This initiative, from the November 2002 ballot, requires California to issue $3.4 billion worth of bonds to fund a variety of water projects over the next several years. A portion of the funds is intended for new supply and advanced treatment projects including desalination and reclaimed water.[189] These relatively expensive projects were not included in the marginal cost assumptions in the CUWA study.

Projections of Environmental Costs. Environmental costs beyond those attributed to anticipated regulatory requirements are difficult to quantify. Not surprisingly, the authors of the CUWA study made no attempt to estimate them. Nevertheless, both water supply expansion and marginal consumption have significant potential environmental impacts. These include: wildlife habitat destruction, fish losses, local air pollution and climate change impacts, among others.[190]

In addition, multiple studies suggest that global warming will likely alter precipitation patterns in the state. A recent report by the Pacific Institute summarized the results of nearly 1,000 peer-reviewed studies on climate change. The report states "with very high confidence":

> *It is likely that reductions in snowfall and earlier snowmelt [caused by global warming] and runoff would increase the probability of flooding early in the year and reduce the runoff of water during late spring and summer. Basins in the western United States are particularly vulnerable to such shifts*.[191]

According to the California Climate Change Registry, climate change in California will also likely cause the following: a sea level rise of 4-35 inches by 2100, severe salt-water intrusion into coastal aquifers, and greater air pollution.[192]

Exclusion of Reclaimed Water Projects. Reclaimed water projects provide an increasingly large share of "new" water supply. In the Bay Area, for example, reclaimed water is expected to

---

[187] The EPA reports that the expected gap between future revenues (based on historical price increase) and infrastructure needs will be approximately $148 billion over the next twenty years. See: US Environmental Protection Agency. "The Clean Water and Drinking Water Infrastructure Gap Analysis," August 2002. Available at: http://www.epa.gov/owm/gapfact.pdf.

[188] Data provided by the City of Portland, Environmental Services Department. October 2002.

[189] Proposition 50 allocates up to $200 million for desalination, treatment capacity expansion, and recycled water projects. "The Official Voter Information Guide to the November 2002 California Elections*."* http://www.ss.ca.gov.

[190] See, for example, "Proceedings of a Workshop on Economic Non-Market Evaluation of Losses to Fish, Wildlife and Other Environmental Resources," Bay Institute of San Francisco, May 1987.

[191] Peter Gleick, "Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States," September 2000, p. 4.
Available at: http://www.gcrio.org/NationalAssessment/water/water.pdf. A similar UCS study finds that more precipitation will fall as rain, rather than snow, causing massive flooding in the spring and droughts by late summer. Reduced summer runoff of fresh water would also increase summer salinity in San Francisco Bay, requiring less diversion in order to meet ecosystem and bay water quality needs. Christopher Field, "Confronting Climate Change in California: Ecological Impacts on the Golden State*,"* *Union of Concerned Scientist*, 1999.
Available at: http://www.ucsusa.org/publication.cfm?publicationID=7.

[192] See: http://www.climateregistry.org/.

account for 50% of new supply over the next twenty years.[193] Reclaimed water projects typically cost \$600-\$1100/af – higher than the marginal costs numbers presented in the CUWA study in *every* region of the state. At an average cost of \$850/af, the 20-year PV for avoiding new reclaimed water projects is about \$10,593/af, or almost 2 times larger than CUWA estimates for the Bay Area.

This report will assume that actual costs are two times higher than indicated by CUWA data, for a state average 20-year PV of \$12,598/af. For the reasons described above, even this adjusted cost estimate is likely to be low. Additional work needs to be conducted to obtain more accurate full cost numbers.

Conclusion

Green buildings are designed to conserve water. Taking the avoided cost of water to be only the average retail price paid by state agencies to local utilities, the literature suggests that there is considerable potential for cost-effective water conservation strategies in new and renovated building projects in many regions of the state. However, the actual value of water conservation to the state is not the avoided cost of retail water rates. Rather, it is the region-specific added cost of new marginal water supplies.

The CUWA study cited above advances knowledge of the marginal costs of new water supplies. But it is clear that additional work needs to be done to determine more realistic numbers. More comprehensive assumptions will likely yield higher marginal costs, and thus higher potential savings. Nevertheless, the CUWA study is a good basis for determining average statewide costs, and can be adjusted upward to reflect actual recent water costs.

The modified CUWA findings were applied to a hypothetical new state building project to determine potential savings and include this and a cost doubling to reflect the higher actual costs discussed above. This provides a 20-year PV of \$0.51/ft^2 for water savings from green buildings. These costs are very likely conservative (low) for reasons discussed above. Please see Appendix G for the detailed calculations.

This investigation provides a conservative estimate for the value of water savings from green building, but also indicates that more research and analysis needs to be done.

193 "Water Conservation Master Plan Annual Report," FY02, East Bay Municipal Utility District. 2002. p.4.

VII. Waste Reduction

Nearly 60% (over 21 million tons in 1998) of waste in the State of California comes from commercial (i.e. non-residential) buildings.[194] Additionally, 57% of the construction and demolition (C&D) debris nationally comes from the non-residential sector.[195] California state buildings generally fall within this category.

Waste reduction strategies such as reuse and recycling, as promoted in green buildings, help to divert some waste from being disposed of in landfills. Diversion strategies result in savings associated with avoided disposal costs as well as in reduced societal costs of landfill creation and maintenance. In addition to diverting waste from landfills, recycling and reuse can catalyze further economic growth in industries that reprocess diverted waste and use recycled raw materials.

Green building waste reduction strategies can occur at time of construction and throughout the life of the building.

Construction waste reduction options include:

- Reuse and minimization of construction and demolition (C&D) debris and diversion of C&D waste from landfills to recycling facilities.
- Source reduction, e.g., (1) use of building materials that are more durable and easier to repair and maintain, (2) design to generate less scrap material through dimensional planning, (3) increased recycled content, (4) use of reclaimed building materials, and (5) use of structural materials in a dual role as finish material (e.g. stained concrete flooring, unfinished ceilings, etc.).
- Reuse of existing building structure and shell in renovation projects.

Building lifetime waste reduction includes:

- Development of indoor recycling program and space.
- Design for deconstruction.
- Design for flexibility through the use of moveable walls, raised floors, modular furniture, moveable task lighting and other reusable building components.

Together, these strategies can have a dramatic impact on reducing landfill disposal. C&D diversion rates have reached as high as 97% on individual State of California projects, and are typically at least 50-75% in green buildings.[196] C&D waste impacts vary greatly depending on the type of building project and whether it is new construction, renovation, or construction on already developed land.

---

[194] California Integrated Waste Management Board. "Statewide Waste Characterization Study: Results and Final Report." December 1999. p. ES-2: commercial and self-haul commercial values combined

[195] US Environmental Protection Agency Municipal and Industrial Solid Waste Division, Office of Solid Waste. "Characterization of Building-related Construction and Demolition Debris in the United States." June 1998. p. 2-11, Table 8.

[196] California State and Consumer Services Agency and Sustainable Building Task Force. "Building Better Buildings: A Blueprint for Sustainable State Facilities." December 2001. P.16.

Of 21 green buildings submitted to USGBC for certification, seventeen, or 81%, reduced construction waste by at least 50%, while 38% reduced construction waste by 75% or more.[197] Renovated projects can often utilize 75-100% of a building envelope and shell (excluding windows) and up to 50% of non-shell elements (walls, floor systems, etc.).[198]

Designing indoor recycling systems encourages recycling as part of a building's operational practices. Moveable walls, raised floors, modular furniture, and moveable task lighting can reduce the costs and wastes associated with reconfiguring office spaces (similar to saved churn costs of "Underfloor Air" – see Section IX).

It is clear that green buildings recycle and divert substantially higher levels of waste, and incorporate greater amounts of recycled or "re-used" materials than conventional buildings. However estimating the relative increases in waste recycling, diversion and use of green buildings compared with conventional buildings is difficult and tenuous.

Current Practice in California State Commercial and Institutional Buildings

Currently, there is no standard practice for incorporating all the waste reduction elements into state construction projects, although efforts are underway in each individual category.

C&D diversion requirements are incorporated into state contracts through the use of building performance standards and the Tier sustainable building measures checklists, which specify technologies that should be or can be used in new buildings. Tier 1 requires that all projects develop a recycling plan that results in the diversion of 50% or more of C&D materials, and Tier 2 encourages project teams to consider diverting 75% or more (if economically feasible). Although required, there is little evidence to date that indicates either is regularly done for state projects.[199]

The Tier 1 list also requires projects to "provide for dedicated space in and outside the building for the collection, storage, and loading of recyclable materials." Unfortunately, information is not readily available to indicate how often dedicated recycling space is actually included in space designs. AB 75 does require state agencies and large state facilities (college campuses and prisons) to divert 25% of generated solid waste from landfills by January 1, 2002 and to achieve a 50% diversion rate by January 1, 2004.[200] Regardless of whether or not dedicated space is included in design, state agencies are required to implement recycling programs and many recycling programs are in place and being enhanced to reach this goal.

With respect to the purchase of recycled content products, there is a state mandate through the State Agency Buy Recycled Campaign[201] (SABRC) that requires state agencies to meet recycled content requirements for products in each of 12 categories.[202] Contractors for state agencies must also supply recycled content products that meet the SABRC requirements. Although SABRC has

[197] Data provided by USGBC.
[198] LEED Reference Package. Version 2.0. US Green Building Council. June 2001. pages 170 - 180.
[199] Information provided by the California Integrated Waste Management Board, Green Building Section. November 2002. (Kathy Frevert).
[200] California Assembly Bill 75 (Strom-Martin) Statues of 1999, Chapter 764. Available at: http://www.leginfo.ca.gov/pub/99-00/bill/asm/ab_0051-0100/ab_75_bill_19991010_chaptered.html.
[201] See: http://www.ciwmb.ca.gov/BuyRecycled/StateAgency.
[202] See: http://www.ciwmb.ca.gov/BuyRecycled/StateAgency/Buying.htm.

been in place for approximately 14 years, Block 225 of the Capitol Area East End Project was the first construction project to attempt to implement the mandate. While not all materials used in Block 225 were SABRC compliant, this project was invaluable in helping the state to develop specification language, reporting procedures, and forms that will assist future state projects in their efforts to increase the use of recycled content products.[203] The Tier 1 list does include requirements for the use of recycled content products, promoting the incorporation of these materials into projects when appropriate. Because the checklists were developed considering only material first costs, those products deemed cost-effective are fairly limited.

Since the enactment of the 1989 California Integrated Waste Management Act (AB 939),[204] waste diversion in California has been steadily increasing – from 17% in 1990, to 25% in 1995, to 48% in 2002.[205]

The Retail Cost of Disposal and Diversion

Retail collection and removal fees in California currently range from $90 – $150/ton for disposal (including an average tipping fee of $34/ton)[206] and from $120 – $200/ton for recycling.[207] These are the fees paid by customers to waste management companies for waste collection and removal, and are associated with curbside recycling, not generally applicable to many commercial businesses. Higher fees for recycling collection probably result from the necessity to sort and collect separately different types of recycled waste. The range reflects many factors including: tipping fees, type of recycled material, recycled product markets and infrastructure, labor costs, and subsidies. Additionally, hauling costs may be higher for diversion/recycling because the waste must be transported farther in order to be processed.

Because of the relative high quality of many recovered building materials, well established markets, and lower collection costs, C&D recycling is generally less expensive per ton than curbside residential or commercial service. For example, C&D recyclers in the Sacramento region will accept concrete and asphalt for free and clean wood waste for less than $10 per ton,[208] while the Sacramento County Landfill charges $26 per ton[209] (hauling costs are not included in these figures). In this instance where the first cost of recycling is less than the first cost of disposal there is a direct financial incentive to divert materials for recycling and reuse.

---

[203] Information provided by CIWMB, Recycling Technologies Branch. September 2003 (Clark Williams, JoAnne Jaschke)

[204] California Assembly Bill 939, Sher, Chapter 1095, Statutes of 1989. Public Resources Code (PRC) sections 42920–42928 Available at: http://www.leginfo.ca.gov/cgi-bin/displaycode?section=prc&group=42001-43000&file=42920-42928.

[205] CIWMB, "Solid Waste Generation and Diversion, 1989-2002." Available at: http://www.ciwmb.ca.gov/lgcentral/Rates/Diversion/RateTable.htm

[206] CIWMB, "Active Landfill Profiles," 2003. Available at: http://www.ciwmb.ca.gov/Profiles/Facility/Landfill/Default.asp.

[207] Conversation with Aya Ogishi, Department of Agricultural and Resource Economics, UCB, November 6, 2002. (John Blue, CIWMB).

[208] Telephone inquiry: *California Concrete Crushing and Recycling* (916) 387-5050 and *Allied Waste-Elder Creek Transfer & Recovery Facility* (916) 387-8425)

[209] CIWMB. "2000 Solid Waste Tipping Fee Survey." Available at: http://www.ciwmb.ca.gov/landfills/TipFees/2000/

Estimated Actual Cost and Benefits of Landfill Diversion

From the perspective of the state, the value of diverting materials from landfills should include all quantifiable benefits that accrue to the state. These include direct economic benefits as well as avoided environmental costs.

Direct Economic Value

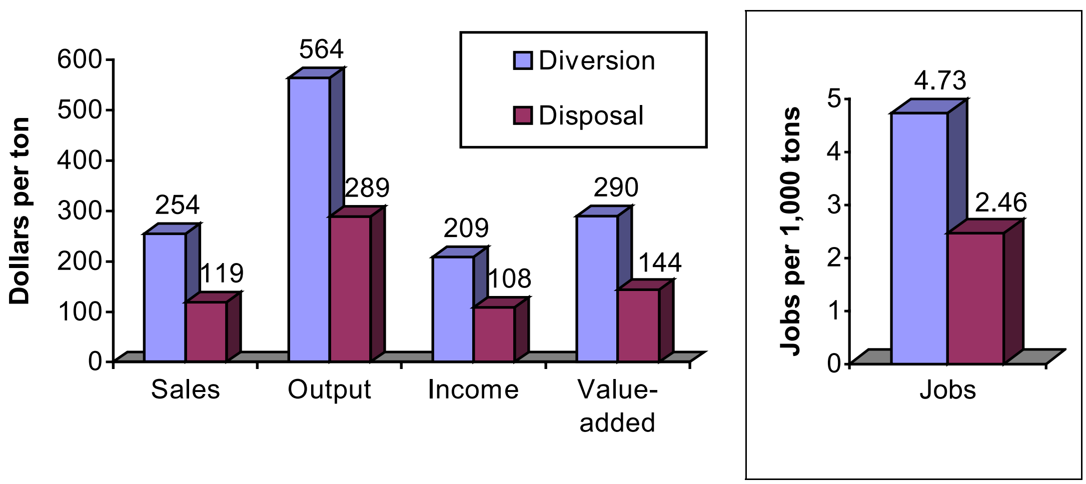
Two recently published studies have quantified the economic costs and benefits of landfill disposal and diversion in California. The Department of Agriculture and Resource Economics at UC Berkeley (UCB), in conjunction with the California Integrated Waste Management Board (CIWMB), published the first study in April 2001.[210] The second, conducted by the National Recycling Coalition (NRC), was released in July 2001.[211] It is important to note that these studies deal with the economic impacts of waste diversion in general and are not specific to C&D diversion. These studies have been included to show the positive economic impact of diversion as compared to disposal.

The UCB study used 1999 data to compare the economic impacts of waste disposal to diversion in six California regions. For both disposal and diversion, the study calculated Total Sales generated from waste and four multiplier effects:

- *Total Output* – a measure of how the disposal/diversion sector influences total economic activity including direct (e.g., collection of wastes), indirect (e.g., collection/recycling equipment manufacturers, other support businesses) and induced impacts (e.g., engineers/consultants) – not including environmental costs.[212]
- *Total Income* – a measure of the total income earned by all persons in the economy attributed to disposal/diversion.
- *Total Value Added* – a measure of the increase in the value of goods sold by all sectors of the economy, minus the costs of inputs.[213]
- *Number of Jobs* – the number of jobs created by disposal/diversion activities.

[210] *Ibid.*
[211] "California Recycling Economic Information Study (REI)," prepared for CIWMB by the National Recycling Coalition in association with R.W. Beck, Inc, July 2001. Available at: http://www.ciwmb.ca.gov/agendas/mtgdocs/2002/01/00007124.pdf.
[212] Total Output includes both Total Income and Value Added.
[213] Value Added also includes tax revenues.

Figure VII-1. Value of Diversion vs. Disposal in UCB Study



Source: Goldman and Ogishi, April 2001

In general, the UCB study found that total economic impacts from diversion are nearly twice as large as the impacts from disposal. One additional ton of waste disposed in a landfill in California generates $289 of total output in the state economy. One additional ton of waste diverted as recyclables generates an average of $564. Figure VII-1 above shows that only 2.46 jobs are created for every 1,000 tons of waste disposed, while 4.73 jobs are created for waste diverted as recyclables. The study also found that regional variation is significant. The Central Valley's total output impacts are nearly $350 per ton greater when waste is diverted, while the Eastern region is the only place in the state where, due to currently limited infrastructure to support recycling businesses, the average economic impacts for diversion are less than the impacts for disposal.[214]

The NRC study has a broader scope than the UCB study. It compares diversion to other sectors of the economy and shows how the economic impacts from diversion in California fit within the nationwide economy. It also uses different assumptions, input data and methodologies. Despite the differences, the resulting economic impacts per diverted ton are quite similar.

Averaging the results of the two diversion studies show that when material is diverted rather than disposed in a landfill, the marginal impacts are worth:[215]

- $325 per ton in Output Impact
- $70 per ton in Income Impact
- $111 per ton in Value Added Impact
- 2.15 jobs per 1,000 tons

[214] George Goldman and Aya Ogishi, "The Economic Impact of Solid Waste Disposal and Diversion in California." Paper presented at the *Western Agricultural Economic Association Meeting*, Logan Utah, July 20, 2001, p. 14. Available at: http://are.berkeley.edu/extension/EconImpWaste.pdf.

[215] These numbers are based on data from "Two Studies on the Economic Impacts for Diversion: A Brief Review by Board Staff" (unpublished document from the CIWMB).

The figures are intended to quantify the economic impacts for the period of one year – the year in which the waste is either disposed of or diverted. They are not 20-year PV numbers. Both studies may under-estimate the full marginal value of diversion. In the Berkeley study, for example, only data from manufacturers that use recycled materials extensively (as identified by the 1997 Census of Manufacturers) were included. In addition, the Census data set does not include all industries. The value of source reduction and reuse were also not included in the study, nor was the value of some common materials such as tires. Consideration of these factors would likely increase the value of diversion.

Avoided Environmental Costs

While no study completed to date has examined and quantified the environmental benefits of recycling in California, several have investigated the subject in other states. The most comprehensive study was conducted in Massachusetts in 2000. The study found average total net environmental benefit of recycling at $63 per ton. According to the study, diversion has two primary benefits compared to disposal:[216]

1) Fewer hazardous substances and greenhouse gases are emitted when products are manufactured with recycled materials instead of virgin wood, metal and petroleum resources.[217]
2) Fewer hazardous substances and other pollutants are released when materials are collected for recycling instead of landfill disposal or incineration.

Just as the economic impact described in the UCB and NRC studies must be further refined to create a more meaningful number, this environmental estimate should be adjusted to reflect California-specific conditions. In addition, projected costs for long-term maintenance of environmental hazards associated with landfill degradation should also be considered.

Conclusion

As discussed above, estimating financial benefits of waste reduction, diversion and recycling from green buildings relative to existing buildings is difficult. At present, the AB75 baseline for waste diversion for California state agencies is 25%, set to increase to 50% in 2004. Although this does not apply directly to specific building construction projects, construction and demolition debris diversion do factor into the overall state agency calculation. Currently, no data exist to indicate whether or not these goals are being met relative to construction projects. However, diversion rates in excess of 75% are commonly met on projects where project managers enforce the Tier 1 & 2 requirements for waste diversion. Improved reporting of diversion and disposal data for state projects would significantly improve the ability to estimate the waste reduction benefits of green buildings.

---

[216] Lisa Skumatz and Jeffrey Morris, "Massachusetts Recycle 2000: Baseline Report," prepared for the Commonwealth of Massachusetts Executive Office of Environmental Affairs (EOEA) Recycle 2000 Task Force, December 1998.

[217] Estimates of net benefits of GHG reductions are based on US EPA, "Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste, Final Report," September 1998, Exhibit ES-4. Available at: http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BVP7P/$File/r99fina.pdf.

It is possible, with a set of tentative assumptions, to estimate waste benefits associated with green buildings. This report uses the numbers from the UCB and NRC/REI studies, combined with the environmental benefit from the Massachusetts study, to calculate rough conservative values for C&D diversion in for new construction as well as demolition of pre-existing structure before construction:

- $0.03/ft^2 or $3,000 per 100,000 ft^2 building for construction only.
- $0.14/ft^2 or $14,000 per 100,000 ft^2 building for construction preceded by demolition.

Since green buildings attempt to use some of the pre-existing building envelope, it is probable that diversion percentages for the second case will be higher than estimated in this analysis. The details of these calculations are included in Appendix H.

Because these numbers include an estimate of environmental benefits from waste diversion, this value therefore will accrue to the state as a whole. A reduced, though still positive value of waste diversion and recycling will benefit individual offices and/or developers.

In the absence of good data on present rates of waste diversion in green and conventional buildings during both their construction and operation, it is impossible to quantify the relative advantages of either one. However, it is possible that the green building waste reduction advantage would not exceed about $0.50/ft^2, because of California's already aggressive waste reduction targets (as set forth in AB 75 and AB 989) – the effectiveness of which is evidenced by the increase in waste diversion from 17% in 1990 to 48% in 2002. [218]

A more thorough study is needed to obtain more realistic financial cost estimates of diversion versus disposal and to generate a California-specific value for the environmental benefits of construction and demolition waste diversion and recycling.

[218] CIWMB, "Solid Waste Generation and Diversion, 1989-2002." Available at: http://www.ciwmb.ca.gov/lgcentral/Rates/Diversion/RateTable.htm

VIII. Productivity and Health

California's Executive Order D-16-00, which established the Governor's sustainable building goals, includes the statement that sustainable building practices should "enhance indoor air quality; and improve employee health, comfort and productivity,"[219] indicating that health and productivity benefits should be explicitly recognized in the state's building design and funding decisions.

This section contains a brief overview of what is known about health, human comfort and productivity in relation to green building design and operation. The conclusion contains a reasonable and conservative estimate for the monetary value of productivity gains in green buildings. Health and productivity issues, often addressed separately, are combined here because both relate directly to worker well-being and comfort and both can be measured by their impacts on productivity.

The relationship between worker comfort/productivity and building design/operation is complicated.[220] There are thousands of studies, reports and articles on the subject. This report relies in large part on recent meta-studies that have screened tens or hundreds of other studies and have evaluated and synthesized their findings.

Potential Savings

The cost to the state of California for state employees is ten times larger than the cost of property. The following chart (Figure VIII-1) and supporting data (see Appendix I) represent state costs for 27,428 state employees in 38 state-owned buildings. Note that operations and maintenance (O&M) costs are allocated 44% for labor and 56% for property related expenses.[221] Average annual employee costs ($66,478 in salary and benefits - $65,141 - plus allocated operations and maintenance costs - $1,337), are 10.25 times larger than the cost of space per employee ($6,477).[222] Thus, measures that increase employee costs by 1% are equivalent, from a state cost perspective, to an increase in property related costs of about 10%. *In other words, if green design measures can increase productivity by 1%, this would, over time, have a fiscal impact roughly equal to reducing property costs by 10%.*

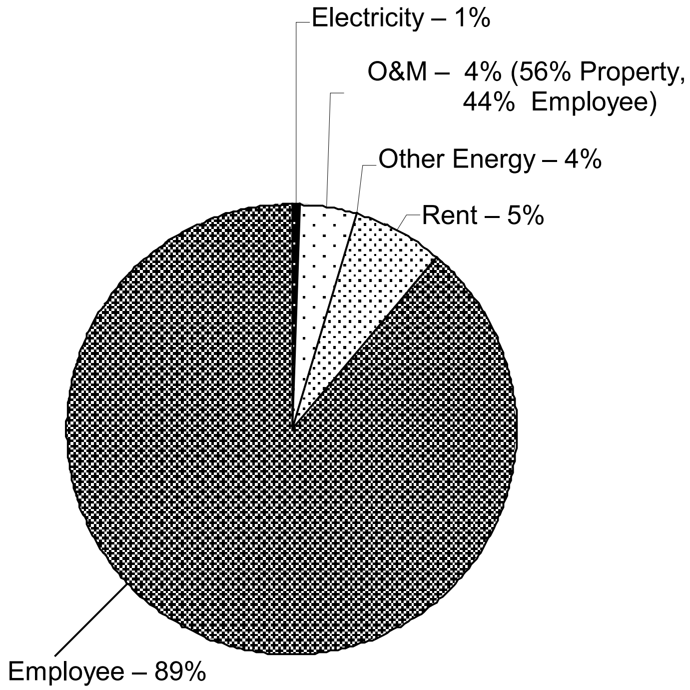
[219] State of California. Governor's Executive Order D-16-00, August 2000. Available at: http://www.governor.ca.gov/state/govsite/gov_homepage.jsp.

[220] One approach to address this complexity is offered by comprehensive building performance scoring tools for evaluating building design and operation benefits. One example of this type of scoring methodology is called the Balanced Scorecard. This approach evaluates four categories of building performance: Financial Results (cost of absenteeism, turnover, etc), Business Processes (innovation, product quality, etc), Customer Satisfaction (stakeholder relations - including public image and local economic impact), and Learning and Growth (human capital development - including work satisfaction and productivity). These kinds of broad systems approaches are valuable for explicitly demonstrating how green buildings support health, productivity and other benefits and meeting larger corporate objectives. However, these types of approaches are less helpful for quantifying the benefits of green building design. See for example: http://www.balancedscorecard.org/bscand/bsckm.html.

[221] Operations and Maintenance cost ($3,039) are allocated 44% for labor and 56% for property related expenses. Data provided by the California Department of General Services, Real Estate Services Division. December 2002.

[222] See Appendix I.

Figure VIII-1. Costs in California State Employee-Occupied Office Buildings
(December 2001 - September 2002 with projections for November-December 2002)



Source: Real Estate Services Division of Department of General Services.[223]

Increased productivity is closely linked to improved worker health. Companies with a demonstrably healthier work environment can also experience reduced insurance premiums – a topic covered in Section X.

The Building-Productivity Link

There is growing recognition of the large health and productivity costs imposed by poor indoor environmental quality (IEQ) in commercial buildings – estimated variously at up to hundreds of billions of dollars per year. This is not surprising as people spend 90% of their time indoors, and

[223] Data provided by the California Department of General Services. November 2002. Note that these include state owned buildings leased to state agencies and that on average these rental rates are slightly below market average – perhaps by about 10%. The data were not adjusted to account for this (by about 3%) because doing so has no significant effect on calculations or conclusions. Conditioned area per employee is assumed to be 225ft^2 – the number indicated by the California Department of General Services, Real Estate Services Division. This is significantly below the aggregate data summarized in Appendix I, provided by DGS, reflecting the fact that a substantial portion of building space is not conditioned occupied. Annual average energy cost is about $1.60, conservatively projected to decline to $1.47/ft^2. (Also see discussion of this data in Energy Use section.)

the concentration of pollutants indoors is typically higher than outdoors, sometimes by as much as 10 or even 100 times.[224]

Measuring the exact financial impact of healthier, more comfortable and greener buildings is difficult. The costs of poor indoor environmental and air quality – including higher absenteeism and increased respiratory ailments, allergies and asthma – are hard to measure and have generally been "hidden" in sick days, lower productivity, unemployment insurance and medical costs.

The discussion of IEQ and productivity issues in industry publications has expanded rapidly in the last decade to become a common theme, and has spilled over into popular media. Business Week's cover for its June 5, 2000 issue features a picture of a large menacing office building to accompany the feature story: "Is Your Office Killing You? The Dangers of Sick Buildings." [225] The article cites potential benefits of up to $250 billion per year from improved indoor air quality in US office buildings.

There are now hundreds of published testimonials about the health and productivity benefits that result from adopting green design strategies. For example:

- William Pape, the cofounder of VeriFone, reports that eighteen months after VeriFone employees began working in a building retrofitted to cut indoor pollutants and improve indoor environmental quality, absenteeism rates were down 40% and productivity was up by more than 5%. Pape notes that healthy workplaces have "done more to boost productivity than all the bandwidth in the world." [226]
- Gary Jay Saulson, the Senior VP and Director of Corporate Real Estate for PNC Realty Services, describes the benefits of the LEED Silver PNC Firstside Center building in Pittsburgh as follows: "people want to work here, even to the point of seeking employment just to work in our building. Absenteeism has decreased, productivity has increased, recruitment is better and turnover less." Two business units experienced 83% and 57% reductions in voluntary terminations after moving into the new Firstside facility.[227]

The relationship between green building strategies and productivity has been studied and documented extensively. There are number of substantial databases that aggregate and screen studies on the relationship between specific building performance attributes and productivity and worker well-being.[228]

---

[224] US Environmental Protection Agency, "Indoor Air Quality," January 6, 2003. Available at: http://www.epa.gov/iaq/.

[225] Michelle Conlin, "Is Your Office Killing You?" *Business Week*, June 5, 2000, http://www.businessweek.com/2000/00_23/b3684001.htm.

[226] William Pape, "Healthy, Wealthy, and Wise," *Inc*, 1998, No. 2, pp. 25-26. Available at: http://www.inc.com/articles/ops/office_management/office_design/1075-print.html. See also William Browning, "Boosting Productivity with IEQ Improvements," *Buildings Design & Construction*, April 1997.

[227] Compared with a control group that experiences an 11% reduction. "Shades of Green: 2002 Report of the Pittsburgh Green Building Alliance," http://www.gbapgh.org. This report provides a clear overview of green building benefits and valuable references and quotes on productivity and related green building benefits. See also: William Browning, "Successful Strategies for Planning a Green Building" *Planning for Higher Education*, Society of College and University Planners, March-May 2003, pp. 78-86.

[228] The Rocky Mountain Institute has been a pioneer in developing and publishing studies on green buildings and productivity, including both original research and reviews of studies on the impact of green buildings on productivity, sales and other worker performance measures. See Rocky Mountain Institute website, "Buildings & Land," Available at: http://www.rmi.org/sitepages/pid174.php. These include:

What Do Tenants Want?

Given the large impact that poor IEQ has on the health and comfort of office workers, it is not surprising that recent surveys of workers suggest that IEQ is one of the most important components of job satisfaction. For example, the study, *What Office Tenants Want: 1999 BOMA/ULI Office Tenant Survey Report*[229] is based on questionnaires from 1800 office tenant surveys in 126 metropolitan areas. Conducted by the Building Owners and Managers Association (BOMA) and the Urban Land Institute, the study affirms that office tenants highly value comfort in office buildings. Survey respondents attributed the highest importance to tenant comfort features, including comfortable air temperature (95%) and indoor air quality (94%). Office temperature and the ability to control temperature are the only features that were both "most important" and also on the list of things with which tenants are least satisfied. The BOMA/ULI study found that the number one reason that tenants move out is because of HVAC heating/cooling problems.

The BOMA/ULI survey found that office tenants also highly value intelligent building features. These include modern energy-efficient HVAC systems and automatic sensors for lighting. According to the BOMA/ULI study, over 75% of office buildings do not have these intelligent features. The survey found that 72% of tenants who want an intelligent feature would be willing to pay additional rent to have the feature made available.

This and other studies make it clear that a high percentage of office tenants are dissatisfied with the indoor air quality (IAQ) and comfort of their work environment and express a willingness to pay for a greener, more comfortable and productive one.

California has developed its own requirements for IAQ that differ from and are in some ways more stringent than IAQ prerequisites contained in LEED. Although the new California IAQ requirements have been adopted for use in the East End complex, they are not required in new construction and have, as yet, not been generally applied. Until these new standards are incorporated, the LEED approach to IAQ offers a significant improvement over current California practices.

"Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design," a compilation of widely quoted original research and review of 20 case studies on documented productivity gains, (Joseph Romm and Bill Browning, "Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design," RMI, 1994. Available at: http://www.rmi.org/images/other/GDS-GBBL.pdf. See also: Joseph Romm, "Cool Companies," *Island Press*, 1999 for a useful set of business case studies), and "Green Development: Integrating Ecology & Real Estate," a general overview of green building case studies with a focus on productivity and health in green buildings (Excerpts from "Green Development: Integrating Ecology & Real Estate" available at: http://www.rmi.org/sitepages/pid219.php).
Some good general databases on the subject include: http://www.ciwmb.ca.gov/GreenBuilding/Basics.htm; http://www.gbapgh.org/On%20Green%20Building/ogb_economic_benefits.html; http://www.conservationeconomy.net/content.cfm?PatternID=30; and http://www.ci.sf.ca.us/sfenvironment/aboutus/greenbldg/gb_productivity.pdf.
See also EPA's excellent database on indoor air quality: http://www.epa.gov/iaq/largebldgs/i-beam_html/bibliography.htm.

[229] "What Office Tenants Want: 1999 BOMA/ULI Office Tenant Survey Report." To order, call 1-800-426-6292, or order on-line at www.boma.org, item #159-TENANT-029.

While the full range of design practices encouraged by LEED is available in Appendix A, the following are some relevant attributes common in green buildings that promote healthier work environments:

1) Much lower source emissions from measures such as better siting (e.g., avoiding locating air intakes next to outlets, such as parking garages, and avoiding recirculation), and better building material source controls (e.g., required attention to storage). Certified and Silver level green buildings achieved 55% and Gold level LEED buildings achieved 88% of possible LEED credits for use of the following:[230]

    a. less toxic materials
    b. low-emitting adhesives & sealants
    c. low-emitting paints
    d. low-emitting carpets
    e. low-emitting composite wood
    f. indoor chemical & pollutant source control

2) Significantly better lighting quality including: more daylighting (half of 21 LEED green buildings reviewed provide daylighting to at least 75% of building space [231]), better daylight harvesting and use of shading, greater occupancy control over light levels and less glare.
3) Generally improved thermal comfort and better ventilation – especially in buildings that use underfloor air for space conditioning (see Section IX).
4) Commissioning, use of measurement and verification, and CO_2 monitoring to ensure better performance of systems such as ventilation, heating and air conditioning (see Section IX).

The links between specific LEED credits and productivity are reviewed in other publications.[232]

One of the most authoritative studies to date quantifying potential health and productivity benefits from improved indoor environments was undertaken by William Fisk, head of the Indoor Environment Department at Lawrence Berkeley National Laboratory, and colleagues. Their findings, estimated across the US, are summarized below and reflect analyses and syntheses of a large number of prior studies. Fisk et al. divided the health benefits provided by better buildings into four principal areas: acute respiratory illness, allergies and asthma, sick building syndrome symptoms, and direct productivity gains. A summary of the rationale and supporting data and assumptions underlying Fisk's calculations is included as Appendix J.

---

[230] Capital E analysis of USGBC data (based on analysis of points actually achieved in building performance data submitted to USGBC), November and December 2002. For more detail on achievable reductions from some of these indoor emissions sources, please see: Hodgson AT. "Common Indoor Sources of Volatile Organic Compounds: Emissions Rates and Techniques for Reducing Consumer Exposures." University of California, Lawrence Berkeley National Laboratory. 1999.
Prepared for California Air Resources Board.
Available at: http://www.arb.ca.gov/research/apr/past/indoor.htm#Toxic%20Air%20Contaminants.

[231] Capital E analysis of USGBC data, November and December 2002.

[232] See for example: Jonathan Weiss, Kath Williams and Judith Heerwagen, "Human Centered Design for Sustainable Facilities," Available from authors: j.heerwagen@att.net or williams@global.net.

Figure VIII-2. Potential Productivity Gains from Improvements in Indoor Environments

Source of Productivity Gain	Potential Annual Health Benefits	Potential U.S. Annual Savings or Productivity Gain (2002 dollars)
1) Reduced respiratory illness	16 to 37 million avoided cases of common cold or influenza	$7 - $16 billion
2) Reduced allergies and asthma	8% to 25% decrease in symptoms within 53 million allergy sufferers and 16 million asthmatics	$1 - $5 billion
3) Reduced sick building syndrome symptoms	20% to 50% reduction in SBS health symptoms experienced frequently at work by ~15 million workers	$10 - $35 billion
4) Sub-total		*$18 - $56 billion*
5) Improved worker performance from changes in thermal environment and lighting	Not applicable	$25 - $180 billion
6) Total		*$43 - $235 billion*

Adapted from: William Fisk, "Health and Productivity Gains from Better Indoor Environments"[233]

The first two sources of productivity gain outlined in Figure VIII-2 are only partially attributable to the work environment, so this report assumes that potential health benefits are therefore reduced to a range of $12 to $45 billion annually. Productivity benefits from both health improvement and from improvement in thermal environment and lighting are reduced to a range of $35 to $225 billion. Note that there are other, less substantial sources of potential health related benefits that are not included in Figure VIII-2, making these estimates of benefits potentially low.

Assuming a low value of $25 billion, this translates into $385 in direct health improvement potential for each of the 65 million full time office workers and teachers in the US.[234] If one third of these benefits can be achieved in a green building, this translates into about $130 per year in health-related financial benefits. With 225 ft^2 in average space per worker, this suggests a potential annual productivity gain of $0.58/$ft^2$.

If we assume a mid-range value of $140 billion in potential productivity benefits (line 6 in Figure VIII-2), and assume that 1/3 of these benefits could be achieved from respiratory health benefits

---

[233] William Fisk, "Health and Productivity Gains from Better Indoor Environments," summary of prior publications (see Appendix J), with figures inflation-adjusted for 2002 dollars and rounded.
See also:
W.J. Fisk, "Health and Productivity Gains from Better Indoor Environments and Their Relationship with Building Energy Efficiency," *Annual Review of Energy and Environment* 25(1): pp. 537-566.
W.J. Fisk and A.H. Rosenfeld. "Estimates of Improved Productivity and Health from Better Indoor Environments," *Indoor Air* 7(3), 1997: pp. 158-172.

[234] Adjusted up from 63.5 million in Fisk. Note that Fisk includes ½ of military personnel, who are assumed to be office workers. For more on the size and composition of the US workforce, see: *Statistical Abstract of the United States*, US Census Bureau, 2001.
Available at: http://www.census.gov/prod/2002pubs/01statab/stat-ab01.html.

and thermal and lighting improvements in green buildings, this translates into about $718 per worker per year. This suggests a potential annual productivity gain of \$3.19/ft^2 per worker, or slightly over 1% per year.

A review published by ASHRAE compares commonly used measures of productivity with HVAC system performance. In the study, the authors evaluate 262 references and feature the 53 most rigorous and significant ones. These demonstrate a positive correlation between measures common to green buildings and productivity, absenteeism, and related issues.[235]

A National Science and Technology Council project entitled *Indoor Health & Productivity* was established to collect and communicate research findings relating workplace attributes – including lighting, thermal comfort, air quality and ventilation – to human health and productivity. The database contains over 900 papers from more than 100 journals and conferences. There are abstracts for about 700 of these articles, and the entire database is searchable by fields such as author and category (e.g., acoustics, humidity, ventilation) or by keywords such as sick building, visual comfort or HVAC.[236] There is a very large body of technically sound studies and documentation linking health and productivity with specific building design operation attributes – e.g., indoor air quality and tenant control over work environment, including lighting levels, air flow, humidity and temperature. It is clear that green building measures that improve these attributes increase worker comfort, health, well-being and measured productivity.

Two studies of over 11,000 workers in 107 European buildings analyzed the health effect of worker-controlled temperature and ventilation. They found significantly reduced illness symptoms, reduced absenteeism and increases in perceived productivity over workers in a group that lacked these features.[237]

Seattle City Light has compiled over 30 projects that document productivity, increased retail sales and increased student learning resulting from incorporation of green design elements.[238] The program intends to create a database documenting the impact of green features on worker comfort, health, productivity and related measures for all municipal buildings that meet or exceed LEED Silver level and is preparing to release a study of a dozen Seattle green buildings, including costs and benefits.

Productivity Benefits for Specific Worker Control/Comfort Upgrades

One of the leading national centers of expertise on the benefits of high performance buildings is the Center for Building Performance at Carnegie Mellon University. The Center's Building Investment Decision Support (BIDS) program has reviewed over 1000 studies that relate

---

[235] Sensharma et al., "Relationships Between the Indoor Environment and Productivity: A Literature Review," published in *ASHRAE Transactions* 1998, Vol. 104.

[236] An online bibliography as well as more information about this project can be found at http://www.dc.lbl.gov/IHP/. The website includes 5 useful brief reviews of key findings in the area of health, productivity and school test scores that were published in ASHRAE Journal, May 2002.

[237] Judith Heerwagen, "Sustainable Design Can Be an Asset to the Bottom Line - expanded internet edition," *Environmental Design & Construction*, Posted 07/15/02. Available at: http://www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,80724,00.html.

[238] See "High Performance Building Delivers Results," *The Sustainable Demand Project – A Project of the Urban Consortium Energy Task Force of Public Technology*, City of Seattle, Seattle City Light, December 2000. Available at: http://www.cityofseattle.net/light/conserve/sustainability/SDPFRa.pdf.

technical characteristics of buildings, in areas such as lighting and ventilation, to tenant responses, such as productivity. Of these studies, the Center has identified 95 that are sufficiently rigorous and quantitative to meet their criteria for inclusion in the BIDS database and decision making tool, making it perhaps the most valuable database of its kind.[239]

Collectively, these studies demonstrate that better building design and performance in areas such as lighting, ventilation and thermal control correlate to increases in tenant/worker well-being and productivity. The BIDS data set includes a number of controlled laboratory studies where speed and accuracy at specific tasks was measured in low and high performance ventilation, thermal control and lighting control environments. These studies used a range of speed and accuracy performance measures including: typing, addition, proof reading, paragraph completion, reading comprehension, and creative thinking.[240]

Increases in tenant control over ventilation, temperature and lighting each provide measured benefits from 0.5% up to 34%, with average measured workforce productivity gains of 7.1% with lighting control, 1.8% with ventilation control, and 1.2% with thermal control. Additionally, measured improvements have been found with increased daylighting, as discussed in the following section.

Figures VIII-3, VIII-4 and VIII-5 on the subsequent pages were supplied by the Department of Architecture at Carnegie Mellon University. They represent ongoing research, and as such should be considered interim.[241]

---

[239] Vivian Loftness et al., "Building Investment Decisions Support (BIDS)," *ABSIC Research 2001-2002 Year End report.* See: http://nodem.pc.cc.cmu.edu/bids. Carnegie Mellon's BIDS™, for Building Investment Decision Support, is a case-based decision-making tool that calculates the economic value added of investing in high performance building systems, based on the findings of building owners and researchers around the world.
[240] Communication with Vivian Loftness, CMU, February 2003.
[241] Data extracted from BIDS™. Carnegie Mellon University Department of Architecture. February 2003. (Vivan Loftness).

Figure VIII-3: Increased Ventilation Control

The 13 studies summarized below by CMU show a consistently significant positive correlation between increased control over ventilation and increased productivity – ranging between 0.5 % and 11%, with most studies clustering around 1% and an average of 1.8%.

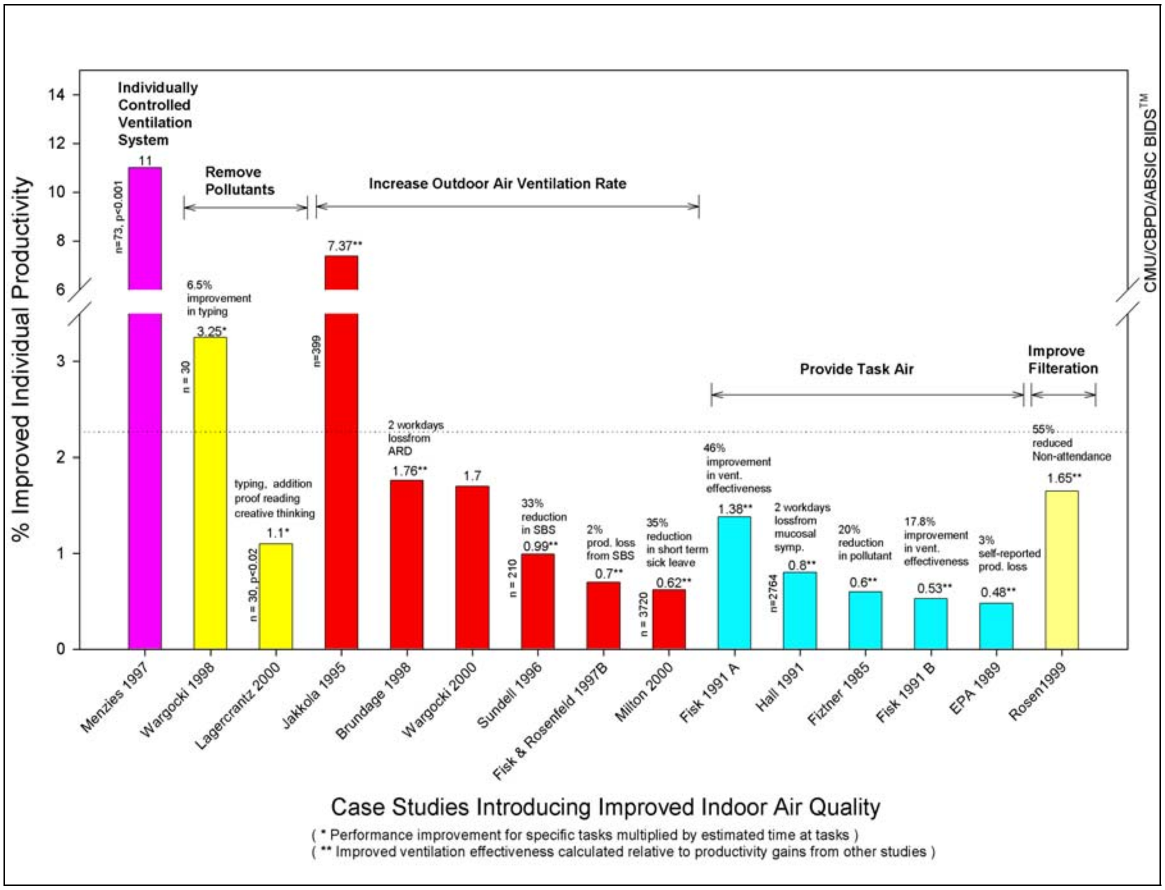


Figure VIII-4: Increased Temperature Control

The Center also looked at studies examining productivity impacts of worker control over temperature. As noted earlier, the BOMA/ULI study found that lack of control over temperature was one of only two features considered by respondents as both most important and of lowest tenant satisfaction. The mean productivity increase for temperature control in these seven studies is 1.2%.

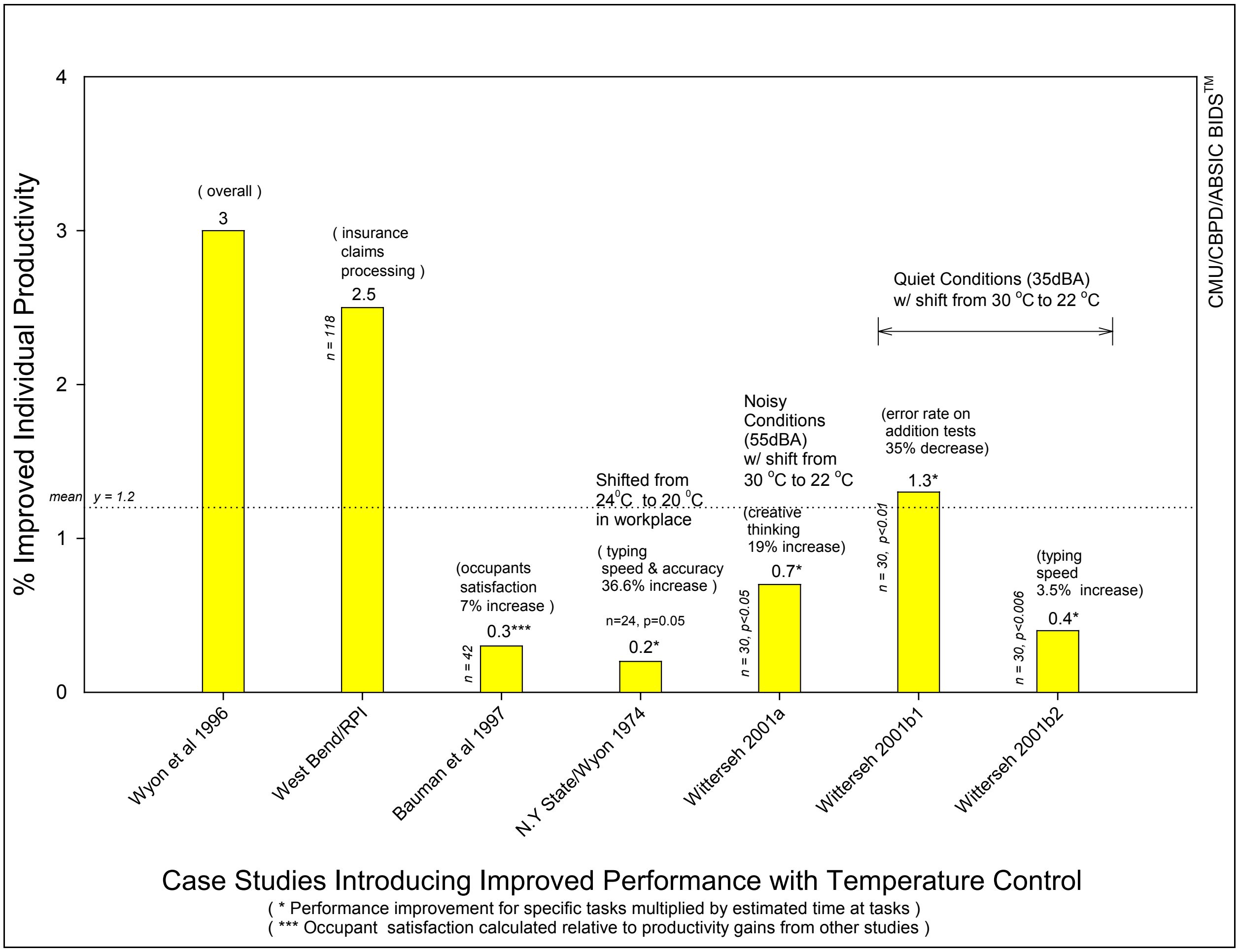
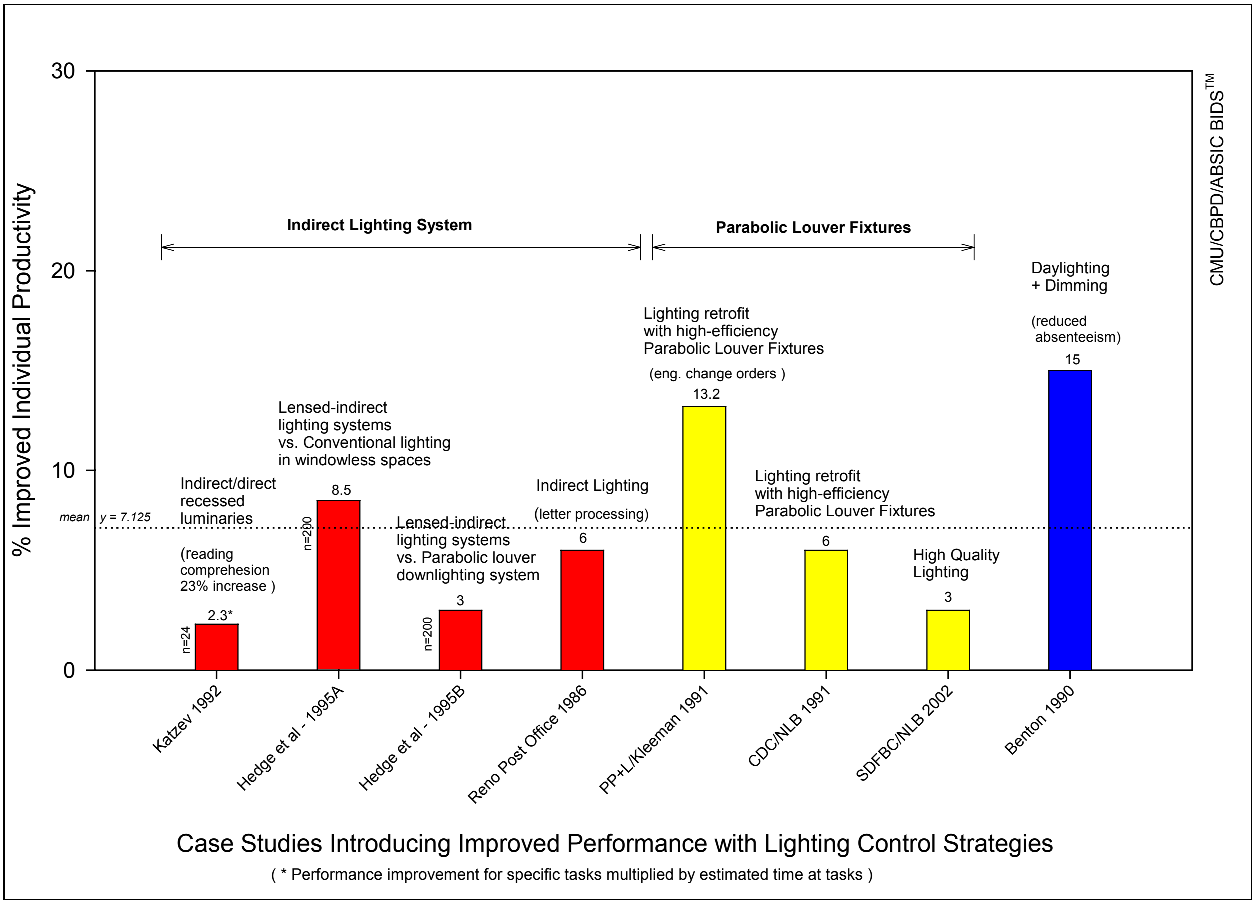


Figure VIII-5: Increased Lighting Control

Eight studies measured the relationship between increased lighting control and productivity, finding productivity gains ranging from 3% up to 34%, with a mean of 7.1%.



Increased Daylighting

A study by the Heschong Mahone Group evaluated the test score performance of over 21,000 students in three school districts in San Juan Capistrano, CA; Seattle, WA; and Fort Collins, CO. The study found that in classrooms with the most daylighting, students' learning progressed 20% faster in math and 26% faster in reading than similar students in classrooms with the least daylighting. The overall findings show that increased daylighting and generally improving quality of lighting significantly improves student test performance.[242] The study's results have been widely quoted, although the large impact of daylighting quality surprised some people and raised questions about the technical thoroughness of the report. To ensure the study's validity, California's Public Interest Energy Research (PIER) program, administered by the CEC, funded a follow up study, employing an independent technical advisory group to reanalyze the data. The reanalysis confirmed the initial study's findings with a 99.9% confidence level.[243]

The kind of work done by "knowledge workers" – most state employees – is very similar to the work students do. Tasks include: reading comprehension, synthesis of information, writing, calculations, and communications. Large-scale studies correlating daylighting with student performance on standard tests therefore provide relevant insight about the impact of increased daylighting on state employees.

This study is important for its size, rigor and the large measured impact of lighting quality on standardized test performance. Note that the study compares performance between students with the greatest amount of daylighting and those with the least daylighting – two extremes. Therefore it is difficult to use this study to predict benefits of enhanced daylighting common in green buildings relative to conventional buildings. The productivity benefits that could conservatively be expected are much less than 26% (which reflects extremes in daylighting), perhaps on the order of 2% to 6%.

Sick Building Syndrome

Following (see text box, *The cost of sick building syndrome for California state and school employees,* below) are the results of an analysis of the cost of sick building syndrome (SBS) for California state and school employees.[244] It assumes a "conservative" 2% productivity decrease due to SBS symptoms. By comparison, a 2000 evaluation of three buildings with a total of over 600 occupants for the Portland Energy Office estimated a 1% increase in productivity and noted that this is "a very conservative estimate." [245] A National Energy Management Institute (NEMI) study entitled *Productivity and Indoor Environmental Quality*, estimates that productivity gains

---

[242] Heschong Mahone Group, "Daylighting in Schools: An Investigation into the Relationship Between Daylight and Human Performance," 1999. Available at: http://www.h-m-g.com; Follow up studies verified the rigor of analysis and subsequent research continues to show positive correlation between daylighting and student performance.
[243] Heschong Mahone Group. 2002. "Daylighting in Schools Re-Analysis." Available at: http://www.newbuildings.org/pier/index.html.
[244] Original report by Leon Alevantis, Deputy Chief of Indoor Air Quality Section, California Department of Health Services, updated for this report by the author.
[245] "Green City Buildings: Applying the LEED Rating System," prepared for the Portland Energy Office by Xenergy, Inc and SERA Architects, June 18, 2000.
Available at: http://www.sustainableportland.org/CityLEED.pdf.

of 1.5% in "generally healthy" buildings are possible and even conservative.[246] As part of the State of California's Block 225 Capitol Area East End project, the Center for the Built Environment will be conducting a productivity analysis of workers related to indoor environmental quality efforts in that building. However, results from this study are not expected for approximately 2-3 years.[247]

The cost of sick building syndrome for California state and school employees
By Leon Alevantis, California Department of Health Services

SBS symptoms are most commonly reported by office and classroom workers. These workers make up about half of the state workforce. The impact of SBS to California office and classroom workers may be calculated as follows:

California office and classroom workers:

A telephone-based, state-wide survey of 14,729 adults (18 years or older) conducted in 1999 on behalf of the California Department of Health Services (DHS),[1] found that 54% of the adult population worked indoors. According to the 1999 California Current Population Survey, there were about 24 million adults living in California. Therefore, in 1999 there were about 13 million adults working indoors. Of those working indoors, according to the DHS survey, 54% or 7 million worked in an office or a classroom. This is about 44% of the annual average employment for 1999 (which was about 16 million).

SBS costs to California office and classroom workers:

Multiplying the number of California office and classroom workers by an annual average compensation of $43,000 (which was the annual average for these professions in 1998 according to data from the California Employment Development Department, excluding benefits and allocated O&M costs) and an estimated conservative decrease of 2% in productivity caused by SBS symptoms[2] the resulting cost of SBS symptoms to California is about $6 billion. Assuming that the average cost for benefits plus allocated O&M costs is an additional 50% of each worker's annual compensation, the resulting overall cost of SBS to California employers is about $9 billion.

Furthermore, published data indicate that 23% of office workers and teachers reported two or more frequent symptoms that improve when they leave their workplace. This implies that about 2 million California office workers and teachers are frequently affected by at least two SBS symptoms.

[1] California Department of Health Services, "1999 California Tobacco Surveys (CTS)."
[2] W.J. Fisk, "Health and Productivity Gains From Better Indoor Environments and Their Relationship with Building Energy Efficiency," *Annual Review of Energy and the Environment,* 25 (1): 537-566.

[246] Thomas Kelly, "Measuring the ROI of IAQ", *Buildings*, March 1999. And see: http://www.nemionline.org/.
[247] Field Study of Capitol Area East End Complex. Center for the Built Environment. See: http://www.cbe.berkeley.edu/research/briefs%2Deastend.htm.

Conclusion

There is no standard for estimating the exact productivity impact of a green building. Each green building has a different set of technologies and design attributes, and each building population has different health attributes and comfort needs.

However, four of the attributes associated with green building design – increased ventilation control, increased temperature control, increased lighting control and increased daylighting – have been positively and significantly correlated with increased productivity. Additionally, there is a large range in potential productivity and health gains from improved indoor environmental quality summarized in Figure VIII-2.

There are also quantifiable green building gains in attracting and retaining a committed workforce – an aspect beyond the scope of this report. Attracting and retaining the best employees can be linked to the quality of benefits that workers receive, including the physical, environmental and technological workplace. Green buildings are designed to be healthier and more enjoyable working environments. Workplace qualities that improve the environment of knowledge workers may also reduce stress and lead to longer lives for multi-disciplinary teams.[248]

It is beneficial for the State of California to maximize health and productivity benefits across a large number of employees and a large number of buildings. The studies cited above indicate significant and measured productivity benefits across a large population of workers and multiple green buildings. Productivity impacts could be even greater in California schools, which often exhibit poor environmental health conditions and a lack of adequate maintenance (and associated maintenance budgets).[249] Therefore improvements in air quality in schools could have significant economic and human health benefits.

LEED rated buildings all address some combination of measures that help reduce the pollutants that cause sickness and increase health care costs; improve quality of lighting and increase use of daylighting; and increase tenant control and comfort. A review of LEED prerequisites and credits (see Appendix A) indicates that LEED is designed to specifically address the materials, designs and operations affecting productivity and health issues discussed above. Credits directly relating to productivity are included in the Indoor Environmental Quality section with two prerequisites and 15 credits (about 22% of total credits available). A preliminary review of green buildings submitted for USGBC certification confirms that these buildings consistently include a range of material, design and operation measures that directly improve human health and productivity. Gold and Platinum level LEED buildings are more comprehensive in applying IEQ-related measures and therefore should be viewed as providing larger productivity and health benefits than Certified or Silver level green buildings.

Calculation

Given the studies and data reviewed above, this report recommends attributing a 1% productivity and health gain to Certified and Silver level buildings and a 1.5% gain to Gold and Platinum level buildings. These percentages are at the low end of the range of productivity gains for each of the

[248] Communication with Vivian Loftness, CMU, February 2003.
[249] California Air Resources Board and California Department of Health Services. Draft Revised Report to the California Legislature: "Environmental Health Conditions in California's Portable Classrooms." 2003. Available at: http://www.arb.ca.gov/research/indoor/pcs/pcs.htm.

individual specific building measures – ventilation, thermal control, light control and daylighting – analyzed above. They are consistent with or well below the range of additional studies cited above.

For state of California employees, a 1% increase in productivity (equal to about 5 minutes per working day) is equal to $665 per employee per year, or $2.96/ft^2 per year.[250] A 1.5 % increase in productivity (or a little over 7 minutes each working day) is equal to $998 per year, or $4.44/ft^2 per year. At $4.44 per year, over 20 years and at a 5% discount rate (assuming that state employee salaries are unchanged with respect to inflation), the PV of the productivity benefits is about $36.89/ft^2 for Certified and Silver level buildings, and $55.33/ft^2 for Gold and Platinum level buildings. Assuming a longer building operational life, such as 30 or 40 years, would result in substantially larger benefits.

Note on Education [251]

LEED is broadly applicable to most commercial type buildings, and in most cases aspects of LEED will translate easily into other infrastructure areas. However, there are several issues that are specific to education buildings, particularly classrooms and laboratories. The US Environmental Protection Agency and the Department of Energy have collaborated to develop the Laboratories for the 21st Century or Labs21[252] program, which outlines a series of Environmental Performance Critera specific to laboratories. The USGBC is working with Labs21 in the hopes of developing a joint "LEED for Labs." K-12 classrooms also present a special case not specifically addressed by LEED.

California's Collaborative for High Performance Schools (CHPS)[253] has already had a substantial and very positive impact on California schools. For example, the Los Angeles Unified School District is one of five districts throughout the state that have adopted CHPS for all new K-12 school construction.[254] The CHPS program has developed a three volume Best Practices Manual outlining a range of green design technologies and practices.

CHPS and LEED are very compatible, with limited differences between the two programs. CHPS is self-certifying whereas USGBC is responsible for LEED certification. CHPS addresses acoustics, requires greater attention to on-site toxics and requires a higher level of energy performance. LEED includes several measures not in CHPS, including post occupancy requirements such as measurement and verification.[255] CHPS focuses just on schools. While there is currently no direct interchangeability between the CHPS and LEED rating systems, CHPS is working with the USGBC to develop a Memorandum of Understanding, which would formally establish the relationship between CHPS and the USGBC. Internally, the USGBC has

---

[250] Average 2002 California employee compensation is $66,469 and average space per employee is 225 ft^2. Both numbers are discussed earlier in this section.
[251] This note on education was reviewed by Nigel Howard, VP of USGBC and Charles Eley, Executive Director of CHPS.
[252] Labs 21 Environmental Performance Criteria, Version 2.0. October 2002. Available at: http://labs21.lbl.gov/EPC/intro.htm.
[253] See page 7 for a more thorough discussion of CHPS. Also see: http://www.chps.net/ and http://www.dsa.dgs.ca.gov/Sustainability.
[254] Los Angeles Unified School District. Board of Education. "Resolution on the Design and Construction of High Performance Schools," November 2002. Available at: http://chps.net/chps_schools/pdfs/LAUSD_res.pdf. See also: http://chps.net/chps_schools/districts.htm.
[255] Discussion with Charles Eley, Eley & Associates, March 26, 2003. See also CHPS Criteria. Available at: http://chps.net/manual/index.htm#vol3.

considered developing a LEED for schools application guide. However, much of this work has already been completed through the development of CHPS performance criteria. Establishing consistency between LEED and CHPS, perhaps with CHPS serving the basis for a national LEED for schools application guide, will help ensure these two complementary programs work together.

Green building and sustainability has also started to influence construction of higher education facilities. In early 2002, the Los Angeles Community College District Board of Trustees committed to a 25% renewable energy standard and adopted a minimum LEED Certified level target for future construction. They allocated $35 million of an overall budget of $1.2 billion, or almost 3%,[256] for green construction.

Most recently, in July of 2003, the University of California Board of Regents, informed in part by an early draft of this report, adopted a green building and clean energy policy for all future new construction on campuses system wide.[257]

It is worth noting that:

- 6.2 million children, teachers and administrators – one fifth of California's population – spend their day inside schools.
- Only 43% of high-volume chemicals have been tested for potential human toxicity, and only 7% have been tested for their effect on children's development.[258]
- Asthma is the leading cause of admission of urban children into hospitals and the leading cause of days absent from school.[259]

LEED Gold design can be expected to provide a significant level of protection against potentially toxic chemicals and against a rising incidence of asthma and allergies. Gold level green buildings typically achieve much higher levels of compliance with LEED IEQ enhancement measures than Certified or Silver buildings. This could include the use of low emitting materials for adhesives and sealants, paints, carpets, and composite woods as well as establishing indoor chemical and pollution source control. As noted in the productivity section, 13 Certified and Silver level green buildings reviewed achieved an average of about 55% of these LEED measures, while 8 Gold level LEED buildings achieved 88% of these credits.

This report recommends that higher education systems target the LEED Gold level, as it will likely be cost-effective to do so. Savings could be expected in energy, waste, and water, and – critically – substantial gains can be expected in student health and productivity.

Several recent studies have begun to address the impact of high performance school facilities on student learning and teacher performance:

- As discussed earlier, the Heschong Mahone study examined student performance improvement on standardized tests for 22,000 students in 2000 classrooms in California,

---

[256] Los Angeles Community College District. "Proposition A Sustainable Building Principles and Energy Policy." Available at: http://www.propositiona.org/PropAInfo/SustainableBuildingPrinciples.asp.
[257] See: http://ucop.edu/regents/aar/julyd.pdf.
[258] Philip Landrigan et al, "Environmental Pollutants and Disease in American Children: Estimates of morbidity, Mortality, and Costs of Lead Poisoning, Asthma, Cancer and Developmental Disabilities," *Environmental Health Perspectives*, Volume 110, Number 7, July 2002.
Available at: http://ehpnet1.niehs.nih.gov/docs/2002/110p721-728landrigan/abstract.html.
[259] *Ibid.*

Colorado and Washington. Data from California schools (which is considered the most detailed) shows with a 99% statistical certainty that students with the most daylight progressed 20% faster in math and 26% faster in reading than students with the least daylighting.[260]

- A study of Chicago and Washington, DC schools found that better school facilities can add 3-4 percentage points to a school's standardized test scores, even after controlling for demographic factors.[261] This and other studies reviewed in the productivity section confirm a widely held, common sense perception that the physical quality of the classroom environment greatly affects how well children learn.
- An analysis of two school districts in Illinois, one small and one large, found that student attendance improved by 5% after incorporating cost effective indoor air quality improvements – regardless of school size (specifically, each site implemented the US EPA's IAQ Tools for Schools Program[262]).[263]
- A study of several Illinois schools found that 20% of teachers were averaging 4 days per year of sick leave due to IAQ problems.[264]

Green building improvements – especially for new buildings – appear to be very cost effective compared with other available measures to enhance student performance. Under the recently adopted Federal Education Bill, schools and states stand to lose billions of dollars in federal funding if students do not perform well on annual standardized tests. School and university systems should consider adopting whole building green design at the Gold level as a standard requirement in new school design and school retrofits.

Because the school market is relatively heterogeneous, it may be more difficult to quantify financial benefits to schools as compared to State office buildings. Additional research should address specific attributes of schools and university buildings to better refine estimates of financial benefits.

---

[260] To view a 30 page condensed version of the study, see: http://www.pge.com/003_save_energy/003c_edu_train/pec/daylight/di_pubs/SchoolsCondensed820.PDF.
[261] Mark Schneider, "Public School Facilities and Teaching: Washington, DC and Chicago," November 2002. A Report Prepared for the Neighborhood Capital Budget Group (NCBG). Available at: http://www.ncbg.org/press/press111302.htm.
[262] US Environmental Protection Agency. "IAQ Tools for Schools," December 2000 (Second Edition). Available at: http://www.epa.gov/iaq/schools/.
[263] Illinois Healthy Schools Campaign, "Apparently Size Doesn't Matter: Two Illinois School Districts Show Successful IAQ Management." *School Health Watch*, Summer 2003. Available at: http://www.healthyschoolscampaign.org/school%20health%20watch_summer-2003.pdf.
[264] NCBG, 2002. Op. Cit.

IX. Spotlighted Technologies and Methodologies

This section contains a brief review of the impact of three specific green building features or systems: commissioning, underfloor air distribution systems, and cool roofs. The energy, environmental and health benefits of these technologies and practices are included in the relevant sections above. However, one additional benefit of underfloor air – reduced cost of churn – is not accounted for elsewhere in this report, and is calculated below.

Similarly, commissioning benefits include reduced operations and maintenance (O&M) costs, a benefit not captured above and therefore calculated here. Commissioning is a process that ensures proper system design and installation, and reduces costs by eliminating errors. It is an important part of the integrated design approach and helps ensure that green building systems perform as expected. Since all LEED buildings include commissioning (it is a prerequisite) and are likely to include other measures that help address operations and maintenance issues, the O&M benefits of commissioning can be included in calculations of the full financial benefits of green buildings.

Commissioning, and Measurement and Verification

Commissioning – a methodology to ensure that building systems are installed and operated as planned – is an increasingly common practice.[265] It has been defined as the "process of ensuring that systems are designed, installed, functionally tested and capable of being operated and maintained according to the owner's operational needs." [266]

Commissioning is particularly important for green buildings, because they are expected to achieve better performance (e.g., low energy use, better air quality) than conventional buildings. LEED requires "Fundamental Building Systems Commissioning," which currently entails hiring a commissioning expert, developing a commissioning plan and completing a commissioning report. In addition, LEED provides credits for additional commissioning and for including a building performance measurement and verification program. The measurement protocol referenced in LEED, the International Performance Measurement and Verification Protocol [267] is also used internationally as a way to demonstrate CO2 reductions benefits, providing a potentially helpful way to secure financial value through sale of CO2 reductions associated with green buildings.[268]

---

[265] See for example, Karl Sturm, "The Importance of Commissioning Green Buildings," *HPAC Heating/Piping/Air Conditioning Engineering*, Feb. 2000. See also: Jay Enck, "Preserving Our Natural Resources through Design, Maintenance and Commissioning," *Engineered Systems*, May 2002.
[266] "Building Commissioning: The Key to Quality Assurance," *US DOE Rebuild America guide series*, p.9. Available at: http://www.rebuild.org/attachments/guidebooks/commissioningguide.pdf.
[267] See www.ipmvp.org. For purposes of disclosure, the principal author of the present report, Greg Kats, co-founded the IPMVP and served as its Chairman until 2001.
[268] Edward Vine, Gregory Kats, Jayant Sathaye, and Hemant Joshi, "International Greenhouse Gas Trading Programs: A Discussion of Measurement and Accounting Issues," *Energy Policy*, January 2003. Available at: http://www.ipmvp.org.

Commissioning and green buildings share: [269]

- Use of a systems approach.
- Use of life cycle perspective.
- Greater attention to design.

Estimated cost of commissioning as a percentage of construction costs varies with building size and is typically viewed as a higher percentage for smaller buildings. However, there is evidence that resulting savings more than pay for the cost of commissioning for both green and non-green buildings. A recent report found that costs of commissioning, including travel expenses, range from 2% to 4% for buildings costing less than $5 million, down to 0.5 % to 1% for buildings costing over $50 million. The study used nine case studies to illustrate why savings from commissioning exceeded the cost of commissioning even before the projects were complete. Commissioning: [270]

- Helped eliminate costly change orders.
- Reduced requests for cost information.
- Helped ensure proper system/component selection.
- Improved performance of building systems.
- Reduced call backs.

Basic commissioning required for LEED costs even less. In six recent LEED office buildings and schools the average cost of "Fundamental Building Systems Commissioning" required for the LEED prerequisite was equal to 0.3 to 0.6 % of construction costs.[271]

The Portland Energy Conservation study cites cases – including a California commercial property and a California university building – in which commissioning led to identifying substantial design and operating problems, and opportunities for substantial savings.[272] Commissioning can also provide potentially significant insurance related benefits (see Section X).

LEED includes an additional credit for system metering. Detailed analysis of several hundred million dollars of energy building upgrades demonstrate that rigorous measurement and verification of energy and water efficiency and system retrofits tend to: [273]

- Increase initial savings level.
- Increase persistence of savings.
- Reduce variability on energy and water savings.

---

[269] Carolyn Dasher, Amanda Potter and Karl Sturm, "Commissioning to Meet Green Expectations." 2000. Available at: http://www.peci.org/cx/CxGreen.pdf.
Dan York, "Commissioning Green Buildings: Two Wisconsin Case Studies," *Proceedings of the 6th National Conference on Building Commissioning*, PECI, 1998.
[270] Chad Dorgan, Robert Cox and Charles Dorgan, "The Value of the Commissioning Process: Costs and Benefits", Farnsworth Group, Madison WI, paper presented at the 2002 *US Green Building Council Conference*, Austin, Texas.
Available at: http://www.usgbc.org/expo2002/schedule/documents/DS506_Dorgan_P152.pdf.
[271] Data provided by Bill Reed, Natural Logic, December 2002. http://www.natlogic.com/.
[272] Carolyn Dasher et al. Op. Cit.
[273] Greg Kats, Art Rosenfeld, and Scott McGaraghan, "Energy Efficiency as a Commodity: The Emergence of a Secondary Market for Efficiency Savings in Commercial Buildings," *1997 ECEEE Conference Proceedings*. Available at: http://www.ipmvp.org/info/ece397.pdf.

Commissioning and metering help ensure that buildings meet and maintain performance targets – including green performance targets. They make it easier to document and claim benefits in such areas as indoor air quality, productivity and emissions reductions. Improved metering allows building mangers to better manage upgrades and maintenance, helping to anticipate and avoid equipment failure, leaks and other costly operations and maintenance (O&M) problems.

Thus, commissioning and metering contribute to lower O&M costs, such as extended equipment life, though how much lower is not known. O&M costs in state buildings – $3,039 per person per year[274] or $12.25/ft^2/yr – are nearly an order of magnitude larger than energy costs. Therefore any reduction in O&M costs has a significant impact on financial benefits. For example, a reduction in O&M costs of 10% is equal to a savings of $304 per person, or $1.35/ft^2 per year. There is not enough data to estimate with any precision the reduction in O&M costs that would occur in green buildings. Clearly the reduction is larger than zero but probably under 25%. To be conservative, this report assumes that green buildings experience an O&M cost decline of 5% per year. This equals a savings of $0.68/ft^2 per year, for a 20-year PV savings of $8.47/ft^2.

Additional research on the O&M impact of green buildings is strongly recommended. Note that the reported savings in areas other than O&M appear to entirely pay for the cost of commissioning, so commissioning costs do not need to be deducted from the O&M-related financial savings.

Underfloor Air

It is estimated that underfloor or raised floor HVAC systems are used in 58% of new commercial buildings in Japan and half of new commercial buildings in Europe, but in only 10% of new commercial buildings in North America.[275] Only 2 of 21 green buildings reviewed included underfloor air,[276] the same percentage as conventional buildings, although there are strong indications that the use of underfloor air is rising in all US construction, and rising more rapidly in new US green building construction. Advocates of underfloor air cite a range of benefits relative to conventional overhead air distribution systems, including:

- Reduced life cycle building costs
- Improved ventilation efficiency and indoor air quality
- Reduced energy use
- Lower cost of churn
- Quieter working spaces resulting in greater occupant satisfaction

Underfloor air is "an innovative technology that uses the underfloor plenum below a raised floor to deliver space conditioning in offices and other commercial buildings."[277] Typically this involves either a pressurized underfloor plenum with a central air handler delivering air through

---

[274] Data provided by the California Department of General Services, Real Estate Services Division, December 2002.
[275] Andy Karvonen, "The Revolution is Underfoot," *Environmental Design & Construction*, posted 01/15/2001. Available at: http://www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,18731,00.html.
[276] Data provided by the US Green Building Council. January 2003. (Brendan Owens)
[277] Fred Bauman and Tom Webster, "Outlook for Underfloor Air Distribution," *ASHRAE Journal*, June 2001.

passive grills or diffusers, or a zero pressure plenum with air delivered though local fans in combination with a central air handler.[278] The most significant cost savings from underfloor air is the lower cost of "churn" – the cost of moving employees within buildings. There are also significant HVAC energy savings as demonstrated at the Block 225 building in the Capitol Area East End Complex in Sacramento.[279]

Underfloor air has been adopted less rapidly in the United States than some experts had anticipated, due in part to its newness as a technology, limited applicability to retrofit construction and perceived higher costs. Published costs for specific projects range from negative first cost[280] to $3/ft^2 [281] and higher. The actual costs appear to be very dependent on when the underfloor air systems are integrated into building design and construction. In the case of the State of California's Department of Education building (Block 225 of the East End Complex), underfloor air was added late in the design process through a change order and ended up adding about $4 million to the total construction costs. Block 225 of the East End complex experienced construction costs of only 1.9% above conventional design due to green elements other than underfloor air.[282]

According to Oppenheim Lewis Inc., a well-respected construction cost estimating firm in the San Francisco Bay Area, underfloor air systems, when integrated from the start of design, cost *slightly less* than overhead systems. In these cases, the lowered costs of the architectural, mechanical, and electrical work more than offset the higher materials and installation costs. A more precise breakdown is presented in Figure IX-1 below:

Figure IX-1. Capital Cost Analysis of Overhead (conventional) Air Systems vs. Underfloor Air[283]

Cost Component	Overhead	Underfloor
Architectural Work	$17.00	$14.50
Raised Access Floor	$ N/A	$ 7.00
Mechanical Work	$16.50	$12.40
Electrical	$ 7.00	$ 6.00
Total Cost	**$40.50/ft^2**	**$39.90/ft^2**

Source: Vivian Loftness, "Energy Savings Potential," June 2002

Perhaps the most comprehensive and authoritative US study to date of underfloor air and its costs and benefits, *Energy Savings Potential of Flexible and Adaptive HVAC Distribution Systems for*

278 These descriptions are drawn from "Technology Overview" of underfloor air posted on the Berkeley Center for the Built Environment Home Page. Available at: http://www.cbe.berkeley.edu/underfloorair/techOverview.htm.

279 Data provided by 3D/I, Project consultant on Capitol Area East End Complex. March 2003. (Jim Ogden).

280 Michael Maybaum, "A Breath of Fresh Air," *Building Operating Management, HVAC*, January 1999, p.21.

281 Bauman and Webster. Op. Cit.

282 See also: Anthony Bernheim, "Saving Resources," *Urban Land*, June 2001. Also, See: http://www.ciwmb.ca.gov/GreenBuilding/CaseStudies/GovtOffice/EastEnd.htm; "Greening" of the East End website: http://www.eastend.dgs.ca.gov.

283 Oppenheim Lewis, Presentation by Kevin Hyde et al., "Life-cycle Cost Analysis & Green Buildings Completing the Picture." Data assembled from V. Loftness et al., "Energy Savings Potential," June 2002.

Office Buildings, was undertaken by a team of six experts from Carnegie Mellon's Center for Building Performance and Diagnostics and the Oak Ridge National Laboratory.[284] The report surveys over 300 relevant case studies worldwide and selects the most rigorous of these. In nine studies with detailed cost estimates, underfloor air came with a premium of \$0 to \$3/ft^2, with one study showing a cost of \$6/ft^2 and two studies showing a cost of \$1 to \$3/ft^2.[285] The churn savings in this study range from \$1 to \$5 per square foot per move, or an annual savings of \$0.40 to \$2.00/ft^2/yr.[286]

The report finds that underfloor air typically provides energy savings in the range of 5% to 30% below conventional overhead systems, and provides measurable benefits in air quality, ventilation effectiveness and productivity. These attributes are part of why underfloor air is promoted in green building design. This section will focus on determining a reasonable and conservative estimate of the benefits associated with reduced cost of churn – a benefit not usually included in building design decisions. Estimating the churn savings from underfloor air can help quantify the full value of green buildings.

Churn Costs

The most significant cost savings from underfloor air is lower cost of "churn" – the cost of moving employees within buildings. As a recent valuable review of churn by Herman Miller describes, with underfloor air "floor layouts can be changed quickly, because power and cabling can be quickly relocated: and simple, easy to use furniture can be used because it does not need to carry large amounts of power and cabling."[287]

In 1995, a study by the International Facility Management Association (IFMA) of its 2200 members found an average churn rate of 35%.[288] This rate rose above 40% in 1997, with a churn rate of 48% reported for service and manufacturing companies.[289] Churn is generally higher for high tech firms and is likely to be lower for government agencies. In California state agencies, the frequency of costly "mass relocation from one building to another" is approximately once every 8 years[290] or 12.5% per year. There appears to be little hard data about churn rate within state buildings or for smaller, less costly, and very probably more frequent moves. In the absence of harder data on churn rate in government agencies, this analysis assumes an average churn rate of 30% for state of California employees, well below the IFMA reported industry average.

In the early 1990s, T.R.York found an average cost premium of \$2.29/ft^2 for underfloor air, but a churn savings of \$257 per year per employee from the greater ease of employee relocation.[291] A

[284] Vivian Loftness et al., "Energy Savings Potential of Flexible and Adaptive HVAC Distribution Systems for Office Buildings," Center for Building Performance and Diagnostics and the Oak Ridge National Laboratory, prepared for the *Air-Conditioning and Refrigeration Technology Institute*, June 2002. Available at: http://www.arti-21cr.org/research/completed/finalreports/30030-final.pdf.

[285] *Ibid,* Figure 10, p. XIII.

[286] *Ibid*, p. 91. This assumes an industry average churn rate of 40%.

[287] "Churn in the Workplace Understanding and Managing Its Impact," Herman Miller, 2001. Available at: http://www.hmeurope.com/WhitePapers/wp_Churn_in_Workpl.pdf.

[288] See: http://www.ifma.org/profdev/research/report16.cfm?actionbig=7&actionlil=166.

[289] IFMA Research Report #18, Benchmakers III, p. 36 and other documents on http://www.ifma.org/. See also: http://www.datathing.com/amaze/Main.asp.

[290] Data provided by the California Department of General Services, Real Estate Services Division, December 2002.

[291] T.R. York, "Can You Afford An Intelligent Building?" *FM Journal*, September/October 1993, pp. 22-27. Summarized in the Carnegie Mellon BIDS database: http://nodem.pc.cc.cmu.edu/bids/index.asp.

1996 study by Flack & Kurtz of an Owens Corning building found a $2/ft^2 first cost savings from raised floor cooling,[292] as well as $1.50/ft^2 in annual savings from the lower cost of churn.[293] DowElanco Corporation (a partnership between Dow Chemical Company and Eli Lilly) found the cost of relocating a workstation in an office with underfloor air to be $2.35/ft^2 compared with $20/ft^2 for hard walled offices.[294]

A more recent detailed examination was made of the Soffer Tech Office Building, a 64,000 ft^2 speculative office building constructed in Pittsburg. A study of this building shows churn savings significantly outweighing the additional costs of installing underfloor air. The combination of high performance design elements – a raised plenum with relocatable diffusers and relocatable wiring – cost $29.03/ft^2, or an additional $0.27/ft^2 over a conventional system, which would cost $28.76.[295] This represents a cost difference of less than 1% between a conventional overhead system and an underfloor air system.[296] The cost savings in of each reconfiguration is estimated at $4.66/ft^2, or about 7 times the initial additional capital cost of the high performance design. Assuming an average churn rate of 0.3 times per year (30% of office workers move each year) an annual churn cost of $1.86/ft^2 is avoided. This indicates a payback ($0.27/$1.86)– assuming a $0.27 initial capital cost increment – of under two months.

Another example of reduced churn costs is provided by the Pennsylvania Department of Environmental Protection. In one conventional office building they measured a cost of about $2,500 per move. (This churn cost is high and reflects the varying costs of moving.) In a new building with raised access flooring, underfloor air, and quick-disconnect manufactured power and teledata cabling, this cost dropped to approximately $250 per workstation, or 90% less.[297]

Conclusions

According to the IFMA 1998 Experience Exchange Report, the average cost of a move is $1063 per employee.[298] Other reports indicate a somewhat lower average cost of moving, reflecting varieties in the definition of moving. According to IFMA, a simple move to and from existing workplaces costs $173, a move including relocation of furniture costs $712 per move, and a move requiring construction costs $2100. Actual yearly moving costs are therefore dependent on what types of moves occur. The reported cost for moving a California state employee is $350, including phone line. Installation of a data line costs $200, so a simple move involving data line installation would cost $550.[299] Larger moves, especially involving construction, cost significantly more. State employees have a 12.5% rate of mass moves to other buildings (cited above), which would typically involve much higher costs, probably on the order of $1000 to $2000 per move. This limited data suggests move costs may be consistent with or somewhat less

---

292 Flack & Kurtz, "Building Design and Construction," November 1996. Summarized in the Carnegie Mellon BIDS database: http://nodem.pc.cc.cmu.edu/bids/index.asp.

293 Communication with Bill Browning, RMI, March 10, 2003.

294 Herman Miller, p. 4.Op. Cit.

295 V. Loftness et al., "Sustainable Development Alternatives for Speculative Office Buildings: A Case Study of The Soffer Tech Office Building," undertaken collaboratively by Carnegie Mellon University, Gardner & Pope Architects, RAY Engineering and the Soffer Organizations, May 26, 1999. Available at: http://www.tate-cheapertobuild.com/pdf/sustainable_development_alternatives.pdf.

296 Ibid. Appendix B.

297 Andy Karvonen, 2001. Op. Cit.

298 "BOMA 1998 Experience Exchange Report." Available at: http://www.energy2001.ee.doe.gov/Technology/S5-Bohsali/tsld028.htm.

299 Data supplied by the California Department of General Services, Real Estate Services Division. December 2002.

than IFMA reported averages. Absent more specific data about California public employee move costs, estimated savings are $300 per move in a building with underfloor air compared with a conventional building. This estimate is very likely to be low.

Assuming a churn rate of 30% (discussed above), this implies an annual savings of $90 per year per employee, significantly below the estimated costs in other studies, such as those completed by Owens Corning and Ray Engineering.[300]

An average of 225ft^2 per employee implies an annual savings of \$0.40/ft^2/yr (\$90 per year for each employee's 225ft2, or \$0.40/ft2/ year). This is significantly below the annual churn savings identified in the York and Souffer studies, and substantially lower than the DowElanco and Pennsylvania DEP estimated savings. This is also at the bottom of the range of the meta-study conducted by Carnegie Mellon/Oak Ridge, which identified average churn cost savings in the range of \$0.40 to \$2/ft ^{2}/yr.[301] Based on a review of the range of case studies and existing data, this report therefore assumes a conservative value of \$0.40/ft ^{2}/yr per employee in reduced churn costs associated with underfloor air, with 20-year PV at 5% discount of \$4.98/ft^2. This indicates that it is cost effective to install underfloor air in state buildings where the cost per square foot is less than $5.

Note that there is little data on churn costs in schools, so the above estimate should not be directly applied for schools. It is probable that churn is less frequent and/or less costly in schools, so churn reduction benefits of green buildings would be proportionally less. In the absence of good data, a reasonable estimate for churn reduction benefits in green schools might be about half that for state buildings, or a 20-year PV of \$2.50/ft^2. For specific educational buildings such as laboratories and administrative offices, churn costs are likely to be higher. Lack of data indicates the need for additional research in this area.

Additional analysis is recommended to obtain more accurate estimates of frequency and cost of churn, with type of churn (employee-only/phone/rewiring/construction) indicated.

Urban Heat Island Reduction – Cool Roofs

Extensive studies conducted by Lawrence Berkeley National Laboratory (LBNL), the California Energy Commission and others have documented large energy and health benefits from lighter color roofs, lighter color paving and tree planting. Darker surfaces absorb more sunlight, increasing temperature within buildings, and creating "heat islands" and an associated need for air conditioning. More air conditioning requires greater consumption of energy, which in turn leads to the release of more pollutants. In addition to increasing their own temperatures, dark roofs and surfaces also raise the temperatures in surrounding areas, increasing their needs for air conditioning as well. Since 1950, increased absorption of sunlight by dark buildings, roads and loss of tree coverage have played a large role in increasing the average temperature of Los Angeles by about 1ºC every 15 years.[302]

[300] Conversation with Vivian Loftness, December 2002. Lead author of comprehensive meta study, complete citation above.
[301] V. Loftness et al., June 2002. Op. Cit.
[302] A.H. Rosenfeld et al., "Cool Communities: Strategies for heat island mitigation and smog reduction," *Energy and Buildings*, 28, 1998.

The medical cost of poor air quality in Los Angeles is about $10 billion per year, of which 70% is from particulates and 30%, or $3 billion, is from health costs due to ozone.[303] High temperatures are a primary condition for the creation of smog (ozone). By reducing ambient urban temperatures, heat island reduction directly contributes to reduced ozone creation, in turn reducing the large human health costs associated with smog. For the city of Los Angeles, there are numerous estimated benefits of a comprehensive cool communities program:

- Direct savings of $100 million in annual residential air conditioning costs (A/C needs reduced by 10% to 30% as estimated by various studies).[304]
- $70 million reduction in indirect cooling costs (reduced air conditioning for other buildings due to lowered ambient air temperature).[305]
- $360 million from reduction of smog (12% ozone reduction).[306]

Most of the impacts and benefits of heat island reduction measures have been very extensively modeled and documented by LBNL, utilities such as PG&E,[307] cities and other entities. For example, the Southern California Air Quality Management District undertook an independent evaluation of the benefits of urban heat island mitigation before accepting heat island reduction measures as a legitimate option to meet their strict regulations restricting smog. At the same time, not all the benefits have been fully modeled statewide. The values for direct avoided energy costs have been modeled most extensively, while the health benefit values are somewhat less precise since they have not been fully modeled for all of California.

Potential heat island savings (both air quality and energy) for Northern California have not been fully modeled, but LBNL Senior Scientist Hashem Akbari, a leading expert on heat island reduction, estimates that potential savings from cool roofs in Northern California are at least half that of Southern California. His conservative estimate is that total statewide savings from heat reduction measures are at least $750 million per year, with $500 million from health improvements and $250 million from reduced energy use.[308]

The installation of "cool roofs" on buildings provides both energy and health benefits by reducing heat islanding. The technology is presented here because:

1) The financial benefits for California are significant and well documented.
2) It is an important feature in green building design systems such as LEED (75% of 21 LEED green buildings reviewed achieved one heat island reduction credit and 50% achieved both).
3) Perhaps because it is so simple, it is sometimes overlooked when compared with higher tech solutions.

---

[303] J.V. Hall, "Valuing the health benefits of clean air," *Science* 255, 1992.
[304] "Inclusion of Cool Roofs in Nonresidential Title 24 Prescriptive Requirements, Revised August 2002," Pacific Gas and Electric (2005 Title 24 Building Energy Efficiency Standards Update). Provided by Hashem Akbari.
[305] Data provided by Lawrence Berkeley National Laboratory. November 2002. (Hashem Akbari).
[306] Rosenfeld et al., 1998. Op. Cit.
[307] PG&E. "High Albedo (Cool) Roofs: Codes and Standards Enhancement Study." 2000. Available at: http://www.newbuildings.org/downloads/codes/CoolRoof.pdf.
[308] Data provided by Lawrence Berkeley National Laboratory. October 2002. (Hashem Akbari). See also: http://www.coolroofs.org/.

Cool (high albedo) roofs – roofs that have high thermal emittance (high radiation of heat) and high solar reflectance (high reflection of sunlight) – stay cooler in sunlight. They are also easy to incorporate and have a number of direct and indirect benefits.

Cool roofs come in several forms, including:

- Roofs painted or otherwise covered in a highly reflective surface (of light or metallic color).
- Roofs shaded by neighboring trees, PV panels, etc.
- Green roofs, which are densely planted for high sunlight absorbance and insulation.

In a report issued in 2000, PG&E modeled the effect of cool roofs on the energy usage of 990 California commercial buildings. They found an average 20-year present value energy savings from use of cool roof materials of $0.37/ft^2 for the roof area (not the whole building), resulting from reduced air conditioning requirements.[309]

In addition to energy and heat island impacts, cool roofs also experience less expansion and contraction than dark roofs, which contributes to statistically significant extension of the roof life. Typically, cool roofs last 20% longer than conventional roofs. LBNL has calculated that financial benefits of longer roof life are roughly equal to the value of energy savings.[310] Combining the benefits of direct reduction in air conditioning with the value of a longer roof life provides an estimated 20-year PV of $0.75/ft^2.

As indicated above, the average statewide health value (principally from reduced smog creation) is twice that from direct reduced energy use, or about $0.70/ft^2 in direct health benefits. This report will count one half of the estimated direct health benefits from cool roofs, or $0.35/ft^2. Combined with benefits of direct reduction in air conditioning and longer roof life value (calculated above) of $0.75/ft^2, this provides an estimated 20-year PV savings from cool roofs of $1.10/ft^2 of roof surface. Additional benefits such as lower waste costs due to longer roof life and benefits of reduced temperature on surrounding buildings are not included in this analysis, tending to underestimate the financial benefits of cool roofs.

An additional benefit of cool roofs is that lower cooling demands can allow downsizing of air conditioning in buildings, providing an additional savings of about $0.10/ft^2 in capital costs. This is roughly offset by the additional cost of a cool roof, which is between $0.00 and $0.20/ft^2, though average marginal cost is below $0.10/ft^2.[311] This means that the $1.10/ft^2 value as calculated above can be considered a true 20-year NPV value, where additional cost is subtracted from overall benefits.

Because schools sometimes do not operate in summer months, some of the benefits, especially in reducing air conditioning load, are not achieved. This report conservatively assumes that schools see only 25% of the direct reduction in cooling costs, or $0.09/ft^2, and 50% of the health benefits ($0.35/ft^2). Because schools tend to be located in more wooded areas, roof-life extension benefits will be less, perhaps $0.28/ft^2, or 75% of the estimate for commercial buildings. This set of perhaps overly conservative assumptions indicates 20-year NPV benefits of $0.72/ft^2 for cool roofs on schools.

---

309 *Ibid*. Note that a 10 year life is assumed.
310 Data provided by Lawrence Berkeley National Laboratory. December 2002. (Hashem Akbari).
311 Data provided by Lawrence Berkeley National Laboratory. October 2002. (Hashem Akbari).

The large potential health and energy savings have resulted in the promotion of heat reduction measures by a number of organizations. This includes CEC incentives for application of cool roofs, incorporation of heat island reduction measures into the general air quality plans of the South Coast and Bay Area Air Quality Management Districts,[312] adoption of cool roofs in Title 24 as part of its non-residential perspective requirements, and inclusion of the following credits in LEED 2.1:

> Site credit 7.1 - 1 point for shade and/or reflectance and several other options.
>
> Site credit 7.2 - 1 point for energy star light colored/high reflectance roof with various restrictions added.

Despite the financial benefits and the inclusion of cool roofs in Tier 1 and CEC programs to support cool roof implementation, most new California state and school buildings are not built with them.[313] It seems clear that cool roofs and other urban heat island reduction measures are cost- effective and should be applied in new buildings.

To estimate benefits of urban heat island reduction measures for specific buildings, it is necessary to account for the number of floors. On a forty story building the average building-wide benefit of a cool roof is small. In contrast, the cool roof benefit of a one story building is relatively large. The average California state building has about 7 stories,[314] resulting in a cool roof NPV value of $0.15/ft^2 for the total building ($1.10/ft^2 of roof apportioned over seven stories, or about $0.15/ft^2 for the whole building). Note that school savings per square foot will be larger because schools typically have fewer floors. At an average of 2 floors per school,[315] the NPV benefits would be $0.36/ft^2 school-wide.

These estimates are almost certainly low. In addition urban heat island reduction measures other than cool roofs, including shading from tree planting and lighter surfaces surrounding buildings, such as parking lots, also reported to be very cost effective, but are not included in this study. A more thorough analysis should do so.

---

[312] Hashem Akbari and Malvin Pomerantz, "Implementation of Heat Island Reduction Measures: Where We Are and Where We Need to Go," *ACEEE Conference Proceedings*, Energy and Environment Policy - 9.1, 2002.
[313] Data provided by Lawrence Berkeley National Laboratory. October 2002. (Hashem Akbari).
[314] Data provided by the California Department of General Services, Real Estate Services Division, December 2002.
[315] Data provided by the California State Architect, Department of General Services, December 2002.

X. Insurance Benefits of Green Buildings[316]

Risk, and associated losses, is costly, with or without formal insurance. With conventional insurance, customer costs include deductibles, premiums and possible excess costs if the insured loss level is capped. If commercial insurance is not used, then the building owner is either formally or informally self-insured. Formal self-insurance implies that a distinct "premium" is paid from internal budgets and accumulated in the form of an earmarked loss reserve. If self-insurance is informal, then the risks are said to be "retained" and losses are paid from general operating budgets, without the creation of an anticipatory loss reserve.[317] Where formal or informal self-insurance is used, risk management is particularly important, since there is no hedge (upper limit) against loss costs.

Considerable untapped opportunities are suggested by the synergies between green-building technologies and risk management (Figure X-1).[318]

Figure X-1. Risk Management Benefits of Green Buildings

- **Worker Health & Safety.** Various benefits, including lower workmen's compensation costs, arise from improved indoor environmental quality, reduced likelihood of moisture damage, and other factors enhancing workplace safety.[319]
- **Property Loss Prevention.** A range of green building technologies reduce the likelihood of physical damages and losses in facilities.[320]
- **Liability Loss Prevention.** Business interruption risks can be reduced by facilities that derive their energy from on-site resources and/or have energy-efficiency features. This includes risks resulting from unplanned power outages.[321]
- **Natural Disaster Preparedness and Recovery.** A subset of energy efficient and renewable energy technologies make facilities less vulnerable to natural disasters, especially heat catastrophes.[322]

---

316 Adapted from a report written by Evan Mills, Senior Scientist, Lawrence Berkeley National Laboratory. "Green Buildings as a Risk Management Strategy," December 2002.

317 The basic difference between conventional insurance and self-insurance is that self-funded entities take responsibility for financing their own claims. The main advantages of self-insurance are: lower administrative costs, better claims control, meaningful claims statistics and potentially reduced losses through better loss control.

318 Extensive discussion and references on the subject can be found at http://eetd.lbl.gov/ea/mills/insurance/cifram.html.

319 Edward Vine et al., "Energy-Efficiency and Renewable Energy Options for Risk Management and Insurance Loss Reduction: An Inventory of Technologies, Research Capabilities, and Research Facilities at the U.S. Department of Energy's National Laboratories," LBNL Report No. 41432, 1998. Available at: http://eetd.lbl.gov/insurance/LBNL-41432.html.

320 Evan Mills, "The Insurance and Risk Management Industries: New Players in the Delivery of Energy-Efficient Products and Services," *Energy Policy* (in press), 2003. Available at: http://eetd.lbl.gov/emills/PUBS/Insurance_Case_Studies.html.

321 J. Eto et al., "Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy," prepared for the Electric Power Research Institute, 2001. Available at: http://eetd.lbl.gov/ea/EMS/reports/47911.pdf.

Lawrence Berkeley National Laboratory has mapped approximately 80 energy efficiency and renewable energy measures onto specific "lines" of insurance benefited by their use.[323] A number of forward-looking insurers have supported energy-efficient and renewable energy technologies, including 52 insurers and reinsurers, 5 brokers, 7 insurance organizations, and 13 non-insurance organizations in this arena.[324] The approaches can be grouped into eight categories:

- Information, education, and demonstration.
- Financial incentives.
- Specialized policies and products.
- Direct investment to promote energy efficiency and renewables.
- Value-added customer services and inspections.
- Efficient codes, standards, and policies.
- Research and development.
- In-house energy management in insurer-owned properties.

While the list is impressive, it should be stressed that it reflects a small fraction of insurance companies. Most insurers and risk managers have yet to make the connection between green buildings and reduced risk. There are instances where insurance companies have offered premium credits on the order of 10% for insured parties implementing selected energy savings strategies.[325] Little has been done, however, to quantify or monetize the benefits.

A more specific characterization of the potential insurance benefits of green buildings is included in Appendix K, where benefits are mapped onto the credits of the LEED system (Version 2.0). This provides an analysis of the precise insurance-related issues and benefits for the full range of green building attributes. Each LEED prerequisite and credit is evaluated against seven types of risk – property loss; general liability; business interruption; vehicular; health & workers comp; life; and environmental liability, along with related comments. Of the 64 LEED points possible in Design Areas 1-5 (excluding the Innovation and Design Process category, which is non-specific), 49 (77%) are associated with measures that have potential risk-management benefits. A few of these, however, are potentially associated with potential adverse consequences – an issue that merits more attention in the green buildings community.

Insurance and Risk Management in California[326]

Currently, most general government facilities and operations in the state of California do not purchase commercial insurance. The majority of State buildings are informally self-insured. The Capitol building itself is uninsured, as are other well-known properties such as Hearst Castle.

---

[322] Evan Mills, "Climate Change, Buildings, and the Insurance Sector: Technological Synergisms between Adaptation and Mitigation," *Building Research and Information* (in press), 2003. Available at: http://eetd.lbl.gov/emills/PUBS/Mitigation_Adaptation.html.

[323] Edward Vine, LBNL Report No. 41432, 1998. Available at: http://eetd.lbl.gov/insurance/LBNL-41432.html.

[324] Evan Mills, *Energy Policy* (in press), 2003. Available at: http://eetd.lbl.gov/emills/PUBS/Insurance_Case_Studies.html.

[325] *Ibid.*

[326] Unless otherwise noted, the observations in this section are taken from conversations between Evan Mills and the California's Office of Risk and Insurance Management (Gary Estrada).

Construction on the Capitol Area East End Complex, the largest state government project in California history and the first state buildings to pursue LEED silver and gold ratings, is now complete. As it is bond-funded, commercial insurance is required. The Office of Risk and Insurance Management (ORIM) is not aware of any insurance/risk-related problems with this project, but subscribes to the notion that green buildings will have happier and healthier occupants.

ORIM is located under the Department of General Services (DGS) and is responsible for all risk and insurance activities in state government. For buildings and other facilities constructed with bond-generated funds, the state purchases property insurance but not liability insurance. In this case, deductibles are generally set high (currently $500,000 - $2.5 million) to minimize the premium. Under California's "Master Policies," there is approximately $1.5 billion of property at 15-20 locations that is commercially insured for property and liability risks, plus roughly $3 billion of additional property currently under construction.[327] Total premiums paid for commercial insurance were $18 million in 2000, of which perhaps 15% were for buildings.[328] The state's primary provider is Affiliated FM, which has, in the past, shown interest in energy efficiency as a tool of risk management.[329]

One of ORIM's most important initiatives at present is their "Owner-Controlled Insurance Program," under which the state buys Workers Comp, General Liability, and Excess Liability coverage for construction projects. Of relevance to the discussion of green buildings, evidence from closed-claims studies suggests that the associated risks can be reduced through the use of building commissioning,[330] and potentially result in lower premiums for the state. Commissioning (see Section IX) is one of the procedures called for in the LEED green building rating system. It is worth noting that state initiatives to promote alternative transportation solutions (one of the criteria of the LEED system) would result in fewer person-miles driven and corresponding reductions in the likelihood of vehicle-related claims.

Lastly, ORIM sees mold as a "growing" issue, and as a potential driver for more proactive risk management and holistic thinking about buildings. According to the Chief Economist at the Insurance Information Institute, most insurers report a tripling of mold-related claims in the last year. More than 9000 claims related to mold are pending the nation's courts, though most involve family homes.[331] A special program provides California state property insurance of $4-5 million for the single family homes of military veterans. While the vast majority of this is for earthquake and flood risks, mold issues have become a real concern in this program. Improved ventilation in green buildings is likely to combat mold problems. Many insurance companies have dropped all coverage for mold and IAQ. Although there are a few policies that cover mold losses, these have become very costly and the state has yet to purchase one.

---

[327] Insurance is discontinued once the bond is paid off.

[328] "Annual Report," ORIM. 2001. Available at: http://www.orim.dgs.ca.gov/Publications/default.htm.

[329] D. Avery et al., "Campus Lighting — Lighting Efficiency Options for Student Residential Living Units: A Study at Northeastern University, Boston, Massachusetts," LBNL Report PUB-816, 1998. Available at: http://eetd.lbl.gov/EMills/PUBS/arkwright.html.

[330] R. Brady, "Commissioning Services Can Reduce Professional Liability Losses," Proceedings of the Third National Conference on Building Commissioning, Portland Energy Conservation, Inc., Portland, OR, 1995.

[331] Ray Smith, "Mold Problems Grow in Shops, Hotels, Offices," *Wall Street Journal*, December 4, 2002. Available at: http://www.iuoe.org/cm/iaq_bpconc.asp?Item=356.

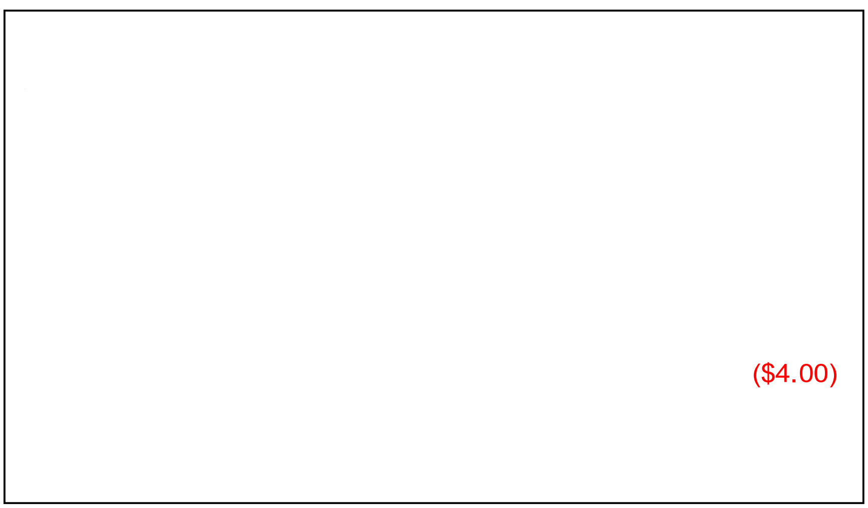
XI. Conclusions

This report has sought to define, document and analyze the costs and financial benefits of green buildings. It has attempted to identify gaps in current knowledge about green building costs and benefits and to identify recommended areas of future research and analysis.

The financial benefits estimated in this report are a measure of financial benefits to the state of California as a whole, rather than to specific building tenants or owners. While a government entity should care about the benefits their building may have for society, a private commercial entity may not. Private sector building owners, for example, may be less likely to care about health and environmental impacts, and hence might perceive lower financial benefits of building green. In addition, because of higher capital costs and hurdle rates, future financial benefits are discounted more heavily by private entities than by public ones, potentially further reducing the perceived value of future green building financial benefits for the private sector. These differences help explain the significant disparity between public and private sector adoption of green building design.

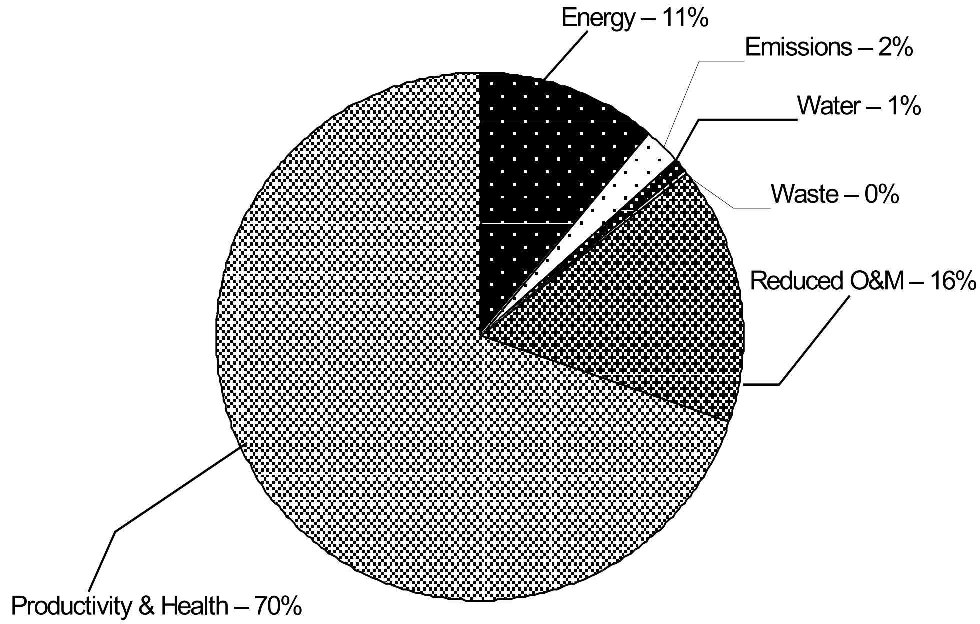
This report began with an aggregation of data on actual or modeled costs for 33 green buildings. Largely derived from several dozen conversations with architects, developers and others, the data indicates that the average construction cost premium for green buildings is almost 2%, or about $4/ft^2 in California, substantially less than is generally perceived.

The body of this report focused on determining the financial benefits of a range of green building attributes, with the findings summarized below.



The relative percentages of the different benefit categories are shown in Figure XI-2 below.

Figure XI-2. Percentage Breakdown of Green Building Financial Benefits (LEED Certified and Silver Buildings)



Source: Capital E Analysis

The above pie chart is for Certified and Silver buildings. For Gold and Platinum buildings, a larger portion of benefits are represented by productivity and health, and the percentages of benefits from the other categories reduce correspondingly. The relatively large impact of productivity and health gains reflects the fact that the direct and indirect costs of employees are far larger than the costs of buildings and energy, so even small increases in employee productivity translate into large benefits. Note that this estimate does not include the financial benefits of reduced moving costs (churn) associated with underfloor air distribution systems because most green buildings do not currently use them.

As summarized above, total financial benefits of green design are estimated to be almost $50/ft^2 for Certified and Silver level green buildings, and over $75/ft^2 for Gold and Platinum level buildings. This is over ten times larger than the average 2% cost premium – about $3-5/ft^2 in California – for the 33 green buildings analyzed.

The financial benefits of green buildings include lower energy, waste, and water costs, lower environmental and emissions costs, and lower operations and maintenance costs and savings from increased productivity and health. These benefits range from being fairly predictable (energy, waste, and water savings) to relatively uncertain (productivity/health benefits.) Energy and water savings can be predicted with reasonable precision, measured, and monitored over time, so much so that commercial firms contract to buy streams of future energy and water savings. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy. This is due in part to the complexity of human health and performance issues, the large range in human reactions to indoor environmental quality changes, and the large range of ways that improvements can show up, including lowered insured or uninsured health costs, lower employee turnover or increased productivity.

There is now a very large body of research, reviewed in this report, which demonstrates significant and causal correlation between improvements in building comfort and control measures, and worker health and productivity. However, these studies vary widely in specific measured correlations. Further, there has been relatively little work completed to evaluate specific, measurable benefits from green building design in California in such areas as sick days, health costs, turnover and respiratory impacts such as asthma and allergies. Clearly, the benefits are significant and not zero, but the data supports a broad range of calculated benefits – in contrast to the more precisely measurable energy and water savings.

The financial benefits conclusions in this report should therefore be understood in this context. Energy, waste, and water savings and emissions reductions can be viewed as fairly precise, reasonably conservative estimates of direct benefits that alone significantly exceed the marginal cost of building green. Health and productivity benefits may be viewed as reasonable, conservative estimates within a large range of uncertainty that therefore justify additional research to better quantify and capture the associated benefits. These studies might include such measures as evaluating green building effects on insured and uninsured health effects, employee turnover, worker well being and, where relevant (e.g. in schools), test scores.

Schools are also an ideal application for green building. One-fifth of California's population spends weekdays in schools. Productivity and health are critically important, not just for the well-being of students and teachers, but also in order to enhance the learning environment and student performance. Some green building benefits (e.g., reduced cost of churn) are less relevant for school buildings. However, as discussed in the above *Note on Education*, children's increased vulnerability to toxic chemicals, allergens and other pollutants is a particularly compelling argument for green schools. Green buildings – especially at the Gold level – provide a significant degree of protection against potentially toxic chemicals that can lead to a rising incidence of asthma and allergies. The strong correlation between children's test scores and daylighting illuminates the large benefits available from greener design. Despite uncertainties about benefits of green design in schools, due to limited data and the large range of school building designs, this report concludes that green design up to LEED Gold level is now very cost-effective for school buildings.

There are additional benefits not evaluated in this report. As one example, the recent book *Small is Profitable*, identifies 207 benefits associated with use of distributed generation and energy efficiency,[332] only a few of which are reflected in this report. A range of other potentially significant benefits from building green include reduced medical costs from a healthier work/study environment and avoided school revenue losses due to higher student attendance. Additional studies should evaluate these and other potential benefits. Similarly, there are a few areas of potential health-related costs associated with green buildings. In particular, there is the possibility of higher indoor concentrations of pollution from lower air exchange rates, which are sometimes associated with more efficient buildings. This is addressed in LEED through reducing introduction of pollutants and toxics and enhanced ventilation. These issues should be examined more fully in a future analysis.

Constructing green buildings cost-effectively requires integrated green building design and a careful commissioning process. The commonly higher initial cost of green design and construction can be expected to drop as designers and builders gain experience in building green. The benefits of green buildings are greatest for public entities that have explicit responsibility to be concerned about broader societal benefits such as health.

---

[332] See: http://www.smallisprofitable.org/. Op. Cit.

There are a number of areas that warrant additional research to refine our understanding of the costs and financial benefits of green buildings. The following section includes a list of over thirty specific areas for recommended additional research.

Faced with limitations in available data, this report has attempted to make consistently conservative assumptions, and found that the financial benefits of green buildings are approximately ten times larger than the average additional cost of building them. Further research and analysis of areas of potential additional benefits would refine costs and benefits estimates (and probably increase estimated financial benefits). Despite gaps in data and analysis, the findings of this report point to a clear conclusion: building green up to the LEED Gold level makes financial sense today.

XII. Recommended Next Steps

After the general section, recommendations are grouped by category, in alphabetical order, followed by recommendations for research on private sector buildings.

General

1) *Fund Optimized Design.* Green buildings may be more complicated and more expensive (especially when including energy modeling and commissioning) to design than conventional buildings. Ensuring adequate resources for integrated design, use of charettes, modeling, etc., is critical to the construction of cost-effective green buildings. Money spent in the early design phase ensures future financial benefits and optimized building performance. The state should try to understand how to optimize the design process and ensure adequate resources for the early design phase in California green buildings. In doing so, the state should build on work completed by Eley & Associates, Natural Logic and others on performance-based fees – providing a better understanding of the most effective allocation of fees to different phases of the design process. This would allow more cost-effective and fair compensation for all participants including clients and the design team.

2) Support and participate in a more refined evaluation of the cost-effectiveness of adopting a LEED Gold level target for state buildings and academic institutions. Consider whether green building benefits can offset budget limitations, such that operations and productivity savings prevent an increase in expenditures. This could include mapping LEED Gold level points onto financial benefits and other targets specific to the state of California.

3) Evaluate the cost-effectiveness of adopting California's *LEED Supplement for California State Facilities*. Research should address whether additional elements need to be added (e.g., higher minimum energy reduction or peak demand reduction targets).

4) *Baseline Data Collection.* The state does not maintain easily retrievable data about standard design practice for its building projects and generally does not evaluate and catalogue building performance over time. Both of these endeavors are important to gain an accurate understanding of the full value of green building strategies.

5) Identify information sources and tracking mechanisms for green building cost data that are closer to the actual projects, instead of potentially biased second and third-hand sources. This might include obtaining construction records and original estimates, developing a transparent method of interpreting the cost data, and including an explanation of that method with the findings.

6) Support analysis and development of recommendations for the most cost effective policies to promote adoption of green buildings in California.

7) Analysis of data on California and public buildings should be expanded and updated in late 2003 to reflect a growing body of LEED submissions and other data available since this report analysis was undertaken (October-December, 2002). This expanded analysis should identify trends and provide additional cost and financial benefit insights related to green building elements and additional areas of benefits.

Commissioning

8) Support ongoing commissioning efforts at DGS. Encourage evaluation of the cost-effectiveness of commissioning in new non-green buildings as well as advanced commissioning in green buildings in California.
9) Support work to develop a commissioning template, including a checklist of recommended/required commissioning steps that are most important and cost-effective. The checklist could focus on ensuring environmental and health benefits.
10) *Maintenance.* Green buildings provide greater health, productivity, and/or enhanced learning and other benefits than conventional buildings. Green buildings also emphasize the importance of maintenance and periodic planned preventative commissioning. Additional work should be done to develop an approach to improved building maintenance, especially for green buildings, that maintains building benefits and also meets California state budgeting requirements. The cost-effectiveness of periodic re-commissioning as well as improved durability and ease of maintenance of green products and systems should also be examined.

Emissions

11) This paper roughly assumes an "Average California Emissions Factor" (ACEF) approach to quantify cost of emissions from electricity generation. However, a more detailed analysis would look at variations across electricity generators, and assign greater benefit to reducing consumption from the dirtiest sources.
12) Emissions calculations generally cover only pollution at time of generation. However, considerable emissions are created during extraction/production, purification, and other steps in energy life cycle as well. A more thorough analysis would include these. See Appendix E.
13) *Financial Impact of Reduced Non-Fossil Fuel Electricity Generation*. Explore impact of emissions and/or other environmental costs associated with nuclear (16% of California generation) and large hydro (20% of CA generation).[333]
14) Reductions in volatile Organic Compounds (VOCs), mercury and other emissions from building materials, office machines, nearby traffic and other sources may have significant value but are not explicitly calculated in this preliminary report. A fuller report should quantify the benefits of these reduced emissions including operations and maintenance benefits and the incidence and costs of human productivity and health effects. Specifically, estimate reductions of indoor levels of carcinogens in green buildings and use cancer cost estimates (developed by US EPA) to calculate resultant economic benefit.
15) *Indirect effect of building siting on transportation:* Future work should explore this impact of inappropriate siting of buildings in light of the dominant influence of vehicle emissions on outdoor air quality in California, lost productivity due to gridlock, loss of agricultural land resources, and the growing importance of exposure to high levels of pollutants on or near roadways.

[333] California electricity generation profile: http://www.green-e.org/your_e_choices/ca.html, April 2003. Data compiled by US Environmental Protection Agency.

Energy

16) *Better Understanding of the Potential of Green Building to Cut Peak Electric Load.* This is an important and largely overlooked issue and it is recommended that additional work be undertaken to more accurately value green building peak demand reduction.

17) *Leased Properties.* The California state government leases one third of the commercial buildings it occupies and provides building performance guidelines to the renting firms.[334] It appears that there is no formal cost analysis for the incorporation of these "green lease" guidelines. Analysis should be done to determine the cost-effectiveness and plausibility of requiring that leased space be green.

    Rising energy costs have a significant impact on the profitability of leasing agencies and therefore on the availability and cost of properties for lease to the state. In 2001, nine of California's eleven real estate investment trusts (REITs) underperformed the market average. One reason for this is California's high energy costs. A survey of California REITs found that for office properties, energy costs amounted to 9.5% of their net operating income, the highest portion for any of the building classes reported. This reflects both high energy costs and lower operating margins for office buildings, underlining the potential value of greater energy efficiency in state-leased office properties.[335]

    Additional work should be undertaken to evaluate the impact of greening on leased properties, including: value of buildings, lease rate impacts, and net operating impacts for the state.

Insurance

18) *Better Quantification of the Insurance-related Benefits of Green Buildings.* The minimal use of commercial insurance in California means that data must be collected from less formal agency-level sources, which may or may not be available. Efforts could be focused on analyzing insurance loss data (often referred to as "data mining") for a broader market, and extrapolating the results to California state-owned buildings and to educational institutions. Specifically, the impact on insurance premiums of reduced mold liability through the construction of moisture resistant buildings, improved quality control of construction and improved maintenance, should be examined.

19) Develop a resource for state risk managers and other decision makers, catalog what is known about the risk and risk-management aspects of green building technologies (expanding on the list of 80 technologies prepared in 1998 for DOE).[336]

20) Use state's purchasing power to negotiate better insurance premiums for existing and future green buildings, e.g., lower premiums for liability insurance under the "Owner-Controlled Insurance Program."

---

[334] Exhibit B is now the standard for leased spaces. See: http://www.ciwmb.ca.gov/GreenBuilding/TaskForce/Blueprint/ExhibitB.pdf.
Exhibit C contains the building performance goals used by DGS. See: http://www.ciwmb.ca.gov/GreenBuilding/Design/ExhibitCLEED.doc.

[335] "Are California REITs Getting Zapped by the Electricity Mess?" Green Street Advisors, 2001. Available at: http://www.greenstreetadvisors.com.

[336] The DOE database is available at: http://eetd.lbl.gov/insurance/welcome.html.

21) Identify adverse interactions associated with green building technologies and create corresponding risk-management/reduction protocols to mitigate the risks. A common example is concern over adverse linkages between energy efficiency measures and indoor air quality or moisture problems. Whether real or perceived, these "downside" aspects are a significant barrier to the acceptance of innovative green building strategies. Relay the results to the CEC's Public Interest Energy Research (PIER) Program so that they are better addressed in the state's major energy-efficiency R&D efforts. Current research efforts in the PIER program are attempting to more precisely determine this relationship.

22) Participate in the next Risk Management Conference (sponsored periodically by the California Office of Insurance and Risk Management). Other relevant venues are the Public Agency Risk Mangers Association (PARMA) [337] meeting for state risk managers and the national public sector insurance meeting of Public Risk Management Association (PRIMA).[338]

Productivity and Health

23) Support a team in gathering more data about productivity issues. A study of green buildings might include the measurement of thermal comfort parameters and application of better monitoring – with quality control measures. Other data that could be gathered include: absenteeism, overall satisfaction, health symptoms, and school test scores.

24) Because productivity and health gains can be the dominant benefits of green buildings, more work should be done to assess and expand upon the findings of this report. A greater sensitivity should be paid to variances between specific cases, with error bars attached to benefits to show nominal and worst case conclusions. Consider supporting R&D to develop a set of predictor considerations for what factors specifically impact productivity.

25) California should consider participating in Seattle's "human factors commissioning" database project, which is measuring the impact of greening on worker comfort, health, productivity and related measures for all new or renovated municipal buildings that meet or exceed the LEED Silver level.[339]

26) Expand upon CBE analysis aggregating data from state buildings on:

    - Occupant satisfaction.
    - Absence rates.
    - Number of days actually sick.

    This might involve evaluation and measurement of ventilation rates, pollutants, human output, comfort, absence and sickness in green office buildings. A baseline could be selected (newer, nicer buildings) from the EPA database survey of 100 office buildings.[340]

[337] See: http://www.parma.com/.
[338] See: http://www.primacentral.org/default.php.
[339] See: http://www.edcmag.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,4118,19794,00.html.
[340] The "EPA Base Study" measured IAQ parameters and collected data on occupant health symptoms (via questionnaires). William Fisk, Senior Scientist, LBNL, December 2002.

Residential

27) There is no national consensus definition and guide for green residences. Participate in the development of a LEED residential application, including evaluation of cost-effectiveness of applying LEED for residences (including low income housing) with a focus on improving health.

Schools

28) Identify a senior-level state expert on schools to help lead an effort to evaluate the value that a LEED schools application guide might have for California. This would build upon and be coordinated with CHPS.

Water

29) *True Marginal Cost*. Currently available full cost estimates for new water supplies are inadequate. The state should commission a study that re-examines this issue and includes all of the considerations discussed in this document. Any new study examining marginal cost should also consider the marginal cost numbers used by water agencies in their grant applications for Proposition 13 funds. These were scheduled to be submitted to DWR in December 2002.

30) *Impact of Conservation*. The value of a conserved acre-foot varies depending on a range of factors, including: the alternative uses for the conserved water, the location of the conserved water, and timing of the conservation.[341] These factors ought to be examined more closely in any future investigation of value of conserved water.

31) *Cost of Conservation*. Analyze the cost of implementing conservation measures to determine their cost-effectiveness.

Waste

32) *California Environmental Data.* While the Massachusetts report[342] is quite comprehensive in its approach to environmental costs and benefits, its conclusions may or may not be appropriate for the state of California. A comparable California-specific study should be conducted.

33) *Economic Data*. While the UCB and NRC/REI reports provide significant insight into the economic impacts of diversion and disposal in California, they do not evaluate the following important areas: the actual retail price of C&D diversion vs. disposal in all regions of the state, the value to the state of recycled vs. virgin building materials, and cost to the building owner of implementing an office recycling program.

34) *Value of Enforcing Current Ordinances*. Determine the result of meeting current California waste reduction guidelines (Exhibit C – Tiers 1 & 2). Determine the cost to state agencies of implementing recycling and other waste reduction practices.

[341] Ray Hoagland, DWR, memo to the authors, January 13, 2003.
[342] Lisa Skumatz and Jeffrey Morris, "Massachusetts Recycle 2000: Baseline Report." See Section VII: Waste Reduction.

Research Opportunities for Private Sector Benefits of Green Buildings[343]

- *Increased Rent and Lower Vacancy*. Green buildings are more comfortable and healthier for building occupants, in addition to supporting increases in productivity. Therefore they should be in greater demand than conventional buildings: achievable rents should be higher and vacancies lower. A study that tracks green buildings in the marketplace could confirm or deny this.
- *IRR Case Studies*. Owners need more case studies on the internal rate of return (IRR) of green buildings. The San Diego Ridgehaven building is a good example – showing a 57% IRR on investment. [344]
- *Faster Tenant Lease-Up*. With higher press attention and greater tenant value, it is likely that green buildings will lease-up faster than non-green buildings. If proven, it could demonstrate substantial financial savings to the user.
- *Green Appraisals*. Very few appraisers understand green buildings and their benefits, including potentially increased income, lower expenses, and lower future liability. The state could meet with a few of the largest appraisal firms and discuss the impact of green buildings on their business.

[343] Excerpted from work completed by David Gottfried, Gottfried Technology Inc. Re: Future Green Building Research Needs. January 2003.
[344] See for example: http://www.ciwmb.ca.gov/GreenBuilding/CaseStudies/Commercial/Ridgehaven.htm.

Appendices

Appendix A: The LEED System[345]

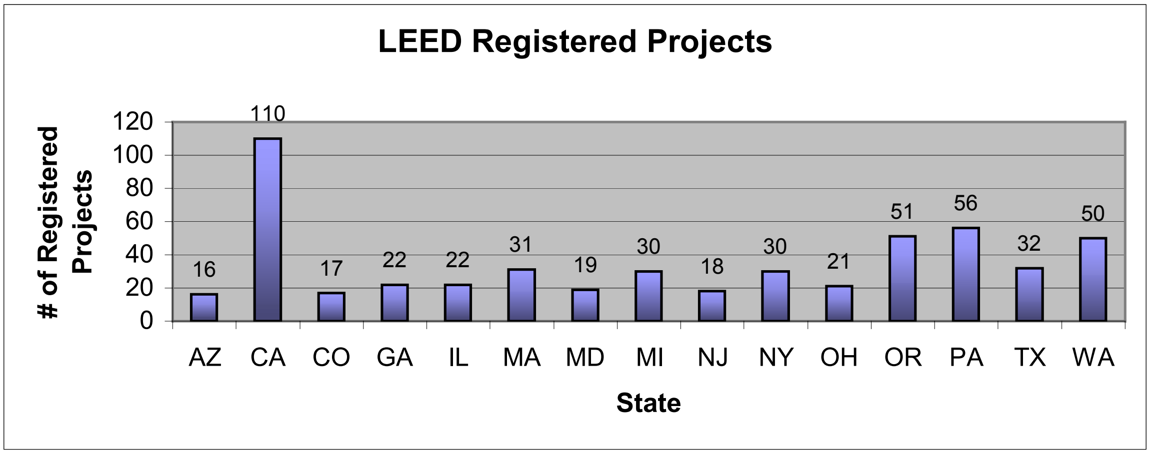
LEED provides four award levels based on the number of environmentally related points achieved by a new building project. The four levels include: Certified (26-32 points) Silver (33-38 points), Gold (39-51 points) and Platinum (52-69 points).

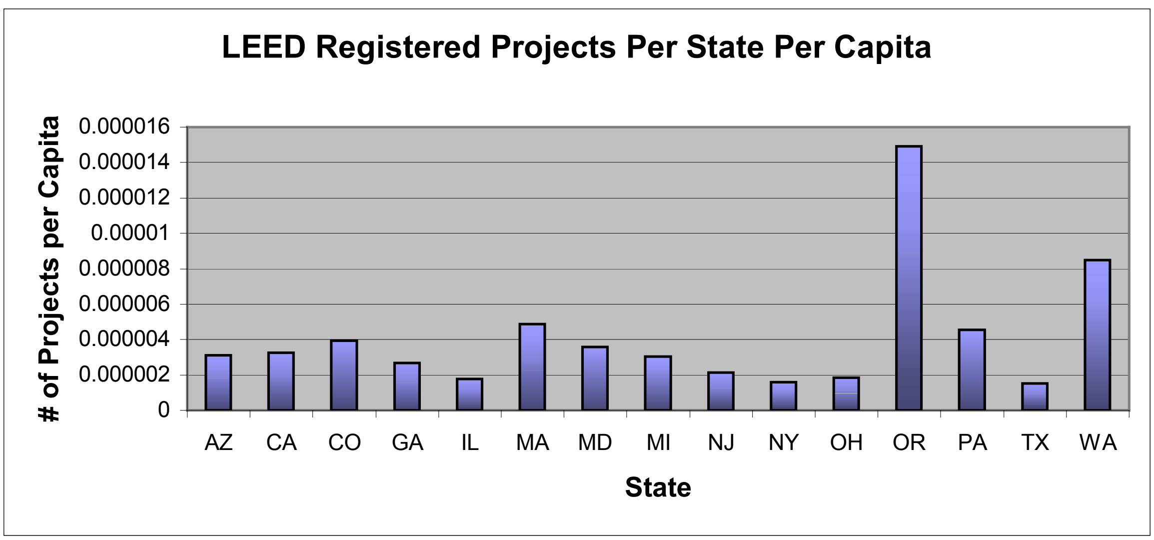
LEED Version 2.1			
Design Area 1	**Sustainable Sites (14 Points possible)**		
	Prereq 1	Erosion & Sedimentation Control (Required)	
	Credit 1	Site Selection (1 point)	
	Credit 2	Urban Redevelopment (1 point)	
	Credit 3	Brownfield Redevelopment (1 point)	
	Credit 4.1	Alternative Transportation, Public Transportation Access (1 point)	
	Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms (1 point)	
	Credit 4.3	Alternative Transportation, Alternative Fuel Vehicles (1 point)	
	Credit 4.4	Alternative Transportation, Parking Capacity (1 point)	
	Credit 5.1	Reduced Site Disturbance, Protect or Restore Open Space (1 point)	
	Credit 5.2	Reduced Site Disturbance, Development Footprint (1 point)	
	Credit 6.1	Stormwater Management, Rate and Quantity (1 point)	
	Credit 6.2	Stormwater Management, Treatment (1 point)	
	Credit 7.1	Landscape & Exterior Design to Reduce Heat Islands, Non-Roof (1 point)	
	Credit 7.2	Landscape & Exterior Design to Reduce Heat Islands, Roof (1 point)	
	Credit 8	Light Pollution Reduction (1 point)	
Design Area 2	**Water Efficiency (5 Points possible)**		
	Credit 1.1	Water Efficient Landscaping, Reduce by 50% (1 point)	
	Credit 1.2	Water Efficient Landscaping, No Potable Use or No Irrigation (1 point)	
	Credit 2	Innovative Wastewater Technologies (1 point)	
	Credit 3.1	Water Use Reduction, 20% Reduction (1 point)	
	Credit 3.2	Water Use Reduction, 30% Reduction (1 point)	
Design Area 3	**Energy & Atmosphere (17 Points possible)**		
	Prereq 1	Fundamental Building Systems Commissioning (Required)	
	Prereq 2	Minimum Energy Performance (Required)	
	Prereq 3	CFC Reduction in HVAC&R Equipment (Required)	
	Credit 1	Optimize Energy Performance (1 to 10 points)	
	Credit 2.1	Renewable Energy, 5% (1 point)	
	Credit 2.2	Renewable Energy, 10% (1 point)	
	Credit 2.3	Renewable Energy, 20% (1 point)	
	Credit 3	Additional Commissioning (1 point)	
	Credit 4	Ozone Depletion (1 point)	
	Credit 5	Measurement & Verification (1 point)	
	Credit 6	Green Power (1 point)	

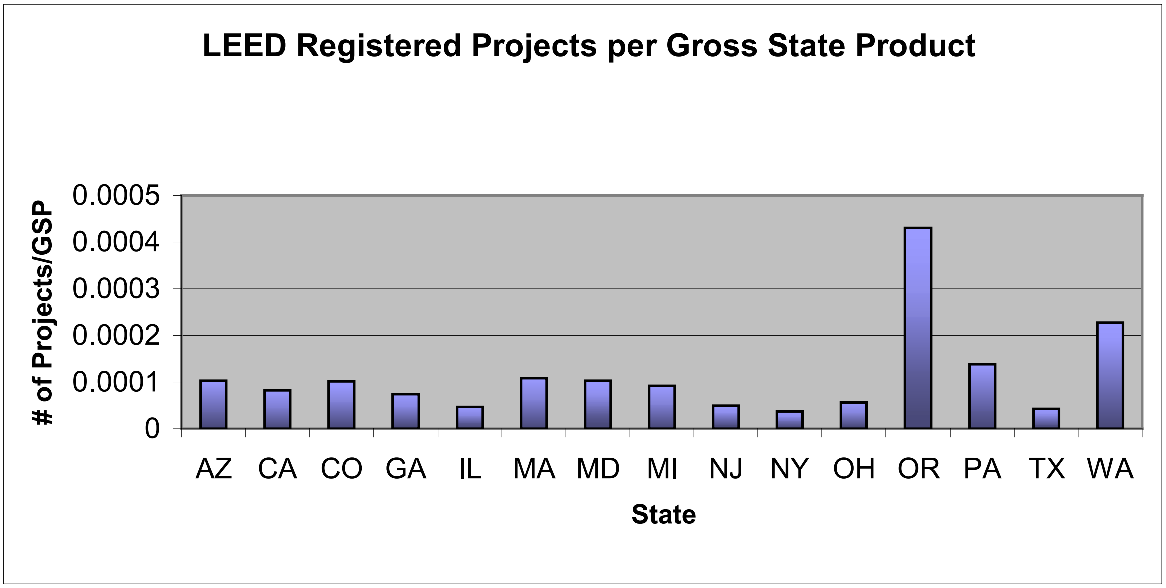
[345] See: www.usgbc.org.

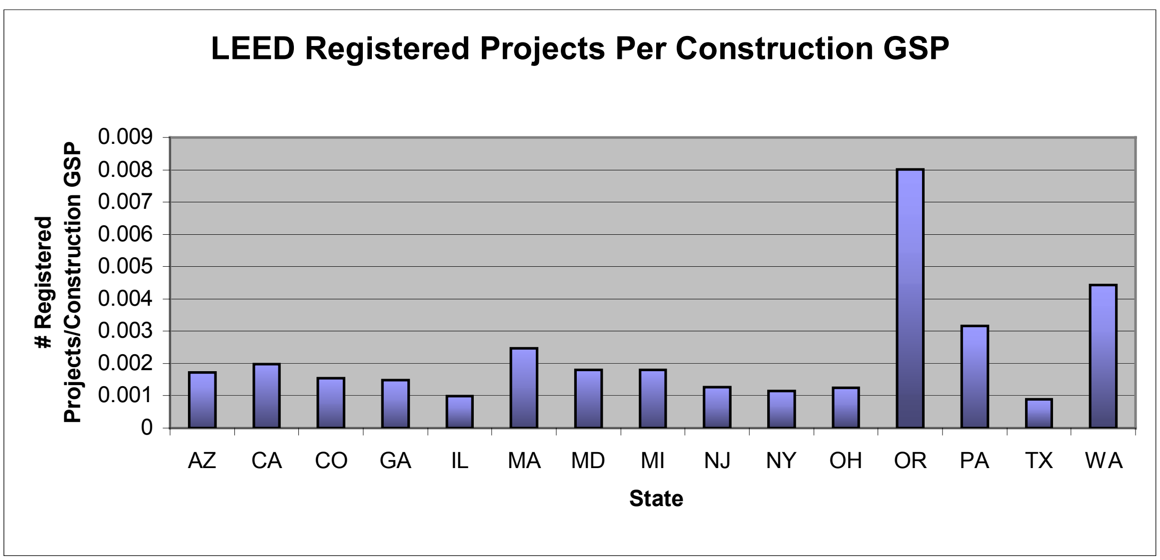
Design Area 4	**Materials & Resources (13 Points possible)**	
	Prereq 1	Storage & Collection of Recyclables (Required)
	Credit 1.1	Building Reuse, Maintain 75% of Existing Shell (1 point)
	Credit 1.2	Building Reuse, Maintain 100% of Shell (1 point)
	Credit 1.3	Building Reuse, Maintain 100% Shell & 50% Non-Shell (1 point)
	Credit 2.1	Construction Waste Management, Divert 50% (1 point)
	Credit 2.2	Construction Waste Management, Divert 75% (1 point)
	Credit 3.1	Resource Reuse, Specify 5% (1 point)
	Credit 3.2	Resource Reuse, Specify 10% (1 point)
	Credit 4.1	Recycled Content, Specify 5% p.c. or 10% p.c. + 1/2 p.i. (1 point)
	Credit 4.2	Recycled Content, Specify 10% p.c. or 20% p.c. + 1/2 p.i (1 point)
	Credit 5.1	Local/Regional Materials, 20% Manufactured Locally (1 point)
	Credit 5.2	Local/Regional Materials, of 20% Above, 50% Harvested Locally (1 point)
	Credit 6	Rapidly Renewable Materials (1 point)
	Credit 7	Certified Wood (1 point)
Design Area 5	**Indoor Environmental Quality (15 Points possible)**	
	Prereq 1	Minimum IAQ Performance (Required)
	Prereq 2	Environmental Tobacco Smoke (ETS) Control (Required)
	Credit 1	Carbon Dioxide (CO2) Monitoring (1 point)
	Credit 2	Ventilation Effectiveness (1 point)
	Credit 3.1	Construction IAQ Management Plan, During Construction (1 point)
	Credit 3.2	Construction IAQ Management Plan, Before Occupancy (1 point)
	Credit 4.1	Low-Emitting Materials, Adhesives & Sealants (1 point)
	Credit 4.2	Low-Emitting Materials, Paints (1 point)
	Credit 4.3	Low-Emitting Materials, Carpet (1 point)
	Credit 4.4	Low-Emitting Materials, Composite Wood
	Credit 5	Indoor Chemical & Pollutant Source Control (1 point)
	Credit 6.1	Controllability of Systems, Perimeter (1 point)
	Credit 6.2	Controllability of Systems, Non-Perimeter (1 point)
	Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992 (1 point)
	Credit 7.2	Thermal Comfort, Permanent Monitoring System (1 point)
	Credit 8.1	Daylight & Views, Daylight 75% of Spaces (1 point)
	Credit 8.2	Daylight & Views, Views for 90% of Spaces (1 point)
Design Area 6	**Innovation & Design Process (5 Points possible)**	
	Credit 1.1	Innovation in Design: Specific Title (1 point)
	Credit 1.2	Innovation in Design: Specific Title (1 point)
	Credit 1.3	Innovation in Design: Specific Title (1 point)
	Credit 1.4	Innovation in Design: Specific Title (1 point)
	Credit 2	LEED™ Accredited Professional (1 point)

Appendix B: Analysis of LEED Registered Projects






LEED Registered Projects per Gross State Product
# of Projects/GSP
0.0005
0.0004
0.0003
0.0002
0.0001
0
AZ CA CO GA IL MA MD MI NJ NY OH OR PA TX WA
State


LEED Registered Projects Per Construction GSP
Registered Projects/Construction GSP
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
AZ CA CO GA IL MA MD MI NJ NY OH OR PA TX WA
State

Appendix C: List of 33 Green Buildings, Green Cost Premiums, and Level of Green Standard

Project	Location	Type	Date Completed	Green Cost Premium	Green Standard
Energy Resource Center[1]	Downey, CA	Office	1995	0.00%	Level 1-Certified
KSBA Architects[1]	Pittsburgh, PA	Office	1998	0.00%	Level 1-Certified
Brengel Tech Center[1]	Milwaukee, WI	Office	2000	0.00%	Level 1-Certified
Stewart's Building[2]	Baltimore, MD	Office	2003	0.50%	Level 1-Certified
Pier One[3]	San Francisco, CA	Office	2001	0.70%	Level 1-Certified
PA EPA S. Central Regional[1]	Harrisburg, PA	Office	1998	1.00%	Level 1-Certified
Continental Towers[11]	Chicago, IL	Office	1998	1.50%	Level 1-Certified
Cal EPA Headquarters[3]	Sacramento, CA	Office	2000	1.60%	Level 1-Certified
EPA Regional[4]	Kansas City, KS	Office	1999	0.00%	Level 2-Silver
Ash Creek Intermed. School[10]	Independence, OR	School	2002	0.00%	Level 2-Silver
PNC Firstside Center[1]	Pittsburgh, PA	Office	2000	0.25%	Level 2-Silver
Clackamas High School[10]	Clackamas, OR	School	2002	0.30%	Level 2-Silver
Southern Alleghenies Museum[2]	Loretto, PA	Office	2003	0.50%	Level 2-Silver
DPR-ABD Office Building[5]	Sacramento, CA	Office	2003	0.85%	Level 2-Silver
Luhrs Univ. Elementary[2]	Shippensburg, PA	School	2000	1.20%	Level 2-Silver
Clearview Elementary[2]	Hanover, PA	School	2002	1.30%	Level 2-Silver
West Whiteland Township[2]	Exton, PA	Office	2004	1.50%	Level 2-Silver
Twin Valley Elementary[2]	Elverson, PA	School	2004	1.50%	Level 2-Silver
Licking County Vocational[2]	Newark, OH	School	2003	1.80%	Level 2-Silver
3 Portland Public Buildings[1*]	Portland, OR	Office	since 1994	2.20%	Level 2-Silver
Nidus Center of Science[1]	Creve Coeur, MO	Office	1999	3.50%	Level 2-Silver
Municipal Courts[1]	Seattle, WA	Office	2002	4.00%	Level 2-Silver
St. Stephens Cathedral[12]	Harrisburg, PA	School	2003	7.10%	Level 2-Silver
4 Times Square[6]	New York City	Office	1999	7.50%	Level 2-Silver
PA DEP Southeast[2]	Norristown, PA	Office	2003	0.10%	Level 3-Gold
The Dalles Middle School[10]	The Dalles, OR	School	2002	0.50%	Level 3-Gold
Dev. Resource Center[8]	Chattanooga, TN	Office	2001	1.00%	Level 3-Gold
PA DEP Cambria[2]	Ebensburg, PA	Office	2000	1.20%	Level 3-Gold
PA DEP California[2]	California, PA	Office	2003	1.70%	Level 3-Gold
East End Complex-Blk 225[7]	Sacramento, CA	Office	2003	6.41%	Level 3-Gold
Botanical Garden Admin[9]	Queens, NY	Office	2003	6.50%	Level 4-Platinum

1 Cost data from "Resource Guide for Sustainable Development in an Urban Environment: A Case Study in South Lake Union, Seattle, WA," prepared by UEI, Oct 22, 2002, p.42. http://www.usgbc.org/Resources/research.asp. Note that many of these 33 data points typically came from more than one source and/or were checked with more than one source.
2 Cost data from presentation and discussions with John Boecker, Vice President, L. Robert Kimball & Associates, November 20 and December 20, 2002, and May 2003.
3 Cost data from Anthony Bernheim, "Saving Resources," Urban Land, June 2001 and Anthony Bernheim and Scott Lewis, "Measure and Cost of Green Building," presented at the AIA National Convention, May 2000.
4 C. C. Sullivan, "Off-the-Shelf Ecology," Building Design & Construction, May 2001, pp 57-60.
5 Communication with David Gottfried, WorldBuild, December 27, 2002, forwarded information from Craig Greenough, DPR Inc.
6 Communication with Pam Lippe, Environmental Consultant to the Durst Organization, Dec 19, 2002.
7 Cost data from Jim Ogden, 3D/I, "Summary of Green Building Costs - Block 225," 2003.
8 Communication with Randy Croxton, Croxton Collaborative, November 20, 2002.
9 David Kozlowski, "Urban Green," Building Operating Management, December 2001. Indicated cost increase 5-8%.
10 Communication with Heinz Rudolf, Principal, BOORA Architects, November 2002, June 2003. Bill Harper, Assoc. Principal, BOORA Architects, May, 2003. For more info, see: http://www.energy.state.or.us/school/highperform.htm
11 Communication with Kevork Derderian, Continental Offices Ltd., Nov 21, 2002.
12 Communication with Vern McKissick, Architect, McKissick Asssociates. May become gold, but silver for now.
* Without more complete information than that the buildings were completed between 1994-2001, the three were attributed to 1997 in this analysis.

Appendix D: Non-energy Value of Peak Demand Reduction

Below are updated numbers for 11 utility studies on the value of peak demand reduction in lowering T&D and related costs. The result is an average current value of $600/kW for peak power demand reduction. These savings can be realized with peak-shaving energy efficiency improvements and/or the installation of on-site distributed generation, such as solar photovoltaics.

A first set of studies from six utilities (Georgia Power, Florida Power & Light, Green Mountain Energy, New Mexico, and two from Southern California Edison), analyzed by Zaininger Engineering and presented in Figure D-1, indicate an average T&D-related benefit of $549/kW (2002 dollars).

Figure D-1. Non-energy Benefits of Peak Reduction/KW[346]

	Georgia	FPL	Green Mount.	New Mexico	So Cal Ed 1*	So Cal Ed 2*	CA Avg. (*)	Average of all 6
Environmental Externalities					$414	$634	$524	
Distribution facility deferral	$0	$0	$0	$1,033	$227	$0	$113	$210
Distribution Losses	$76	$55	$73	$18	$65	$265	$165	$92
Voltage Regulation	-$5	-$4	-$2	-$4	-$5	-$5	-$5	-$4
Transmission Capacity	$105	$0	$244	$0	$344	$107	$226	$133
Transmission losses	$39	$0	$0	$0	$46	$54	$50	$23
TOTAL NON-ENERGY BENEFITS	$215	$51	$315	$1,048	$677	$421	$549	$454
As % of generation capital cost ($600/KW)	36%	9%	52%	175%	113%	70%	92%	76%

The second set of data are from studies undertaken at five utilities (including two at Southern California Edison in California) and indicate average T&D and line loss benefits of $673/KW (2002 $), or about 110% of the current cost of marginal generation peaking plants.

Figure D-2. Non-energy Value of Peak Reduction[347]

	APS	COA	SRP	PG&E*	SMUD*	CA Avg. (*)	Average of all 5
Losses	$218	$95	$85	$89	$0	$45	$98
Distribution	$780	$18	$637	$62	$172	$117	$334
Transmission	$445	$0	$153	$548	$65	$306	$242
TOTAL NON-ENERGY VALUE	$1,443	$113	$875	$699	$237	$468	$673
% of generation capital cost ($600/KW)	241%	19%	146%	117%	39%	78%	112%

[346] Henry W. Zaininger, Zaininger Engineering Co., Inc., 9959 Granite Crest Ct., Granite Bay, CA 95746, taken from *CEC Energy Innovations '99*, October 25 - 27, 1999. Personal communication with Hank Zaininger, November 2002, CPI inflation adjusted.

[347] Howard Wenger, Tom Hoff & Dale Furseth, Pacific Energy Group; Christy Herig, National Renewable Energy Laboratory; John Stevens, Sandia National Laboratory. Data assembled by US DOE. Personal communications with study co-author Tom Hoff, November, 2002, CPI inflation adjusted.

Appendix E: Emissions

Some Assumptions

a) This report focuses on four pollutants: NOx, SO2, PM10 and CO2. While other pollutants impose significant costs and should be evaluated in a more thorough study, these four pollutants probably represent most of the damage from burning fossil fuels. Further research should analyze the value of reducing all emissions, including the waste products of nuclear reactors, which supply 16% of California's power.[348] This report also focuses on electricity and leaves out the cost of using gas in state buildings, both because gas represents a small percentage (<5%) of energy use in commercial buildings and because pollution from gas is well within the range of pollution intensity for the statewide mix of electricity sources.

b) California imports between 20% and 35% of its power (at peak) from out-of-state and this is roughly twice as dirty as in-state generation.[349] Of 50,000 MW total in-state generating capacity, only 500 MW, or 1% is generated from coal. However some 2000 MW of LADWP power that is sold in California is from coal burning power plants located out-of-state.[350] Emissions factors developed by Tellus were used in this analysis because these include out-of-state emissions. (See Section V.)

c) Emissions calculations generally cover only pollution at time of generation. However, considerable emissions are created during the extraction/production, purification and other steps in energy life cycle as well. For example, a recent PhD thesis at the Harvard School of Public Health estimated that a substantial portion of the damaging emissions from natural gas actually occur during extraction and production phases (that is, prior to combustion), but that these emissions are generally not included in calculation of emissions costs associated with energy production. See Figure D-1 below.

Figure E-1. Air Pollutant Emissions from Natural Gas Fuel Cycle (ton/ft^3)[351]

Stage	NOx	SOx	Total PM	CO_2
Extraction/ Production[a]	8.5×10^{-8}	1.4×10^{-6}	1.9×10^{-9}	3.3×10^{-6}
Purification[b]	4.1×10^{-8}	5.4×10^{-12}	1.6×10^{-10}	-
Power plant combustion	1.2×10^{-7}	1.7×10^{-9}	3.5×10^{-9}	6.2×10^{-5}
TOTAL	2.5×10^{-7}	1.4×10^{-6}	5.6×10^{-9}	6.6×10^{-5}
End-use fraction of total	0.49	0.0013	0.63	0.95

[348] Source: http://www.green-e.org/your_e_choices/ca.html, April 2003. Data compiled by the US Environmental Protection Agency.
[349] Communication with Joe Loyer, Environmental Unit of the State Energy Siting Division, on October 23, 2002. jmloyer@energy.state.ca..us. See also Tellus Study. Op. Cit.
[350] Data provided by the California Energy Commission, Systems Assessment and Facilities Siting Division. December 2002.
[351] Jonathan Levy, "Environmental Health Effects of Energy Use: A Damage Function Approach." Thesis submitted to the Faculty of The Harvard School of Public Health in Partial Fulfillment of the Requirements for the Degree of Doctor of Science in the Departments of Environmental Health and Health Policy and Management Boston, Massachusetts, May, 1999, Table 15. This report kindly provided by Bob Berkebile of BNIM.

These and similar studies indicate the need to evaluate the life cycle emissions impact of fossil fuel consumption in order to achieve a more accurate environmental accounting of emissions and costs. It is not within the scope of this study to do so, tending to underestimate the financial benefits associated with lower emissions from reduced issue of purchased electricity in green buildings.

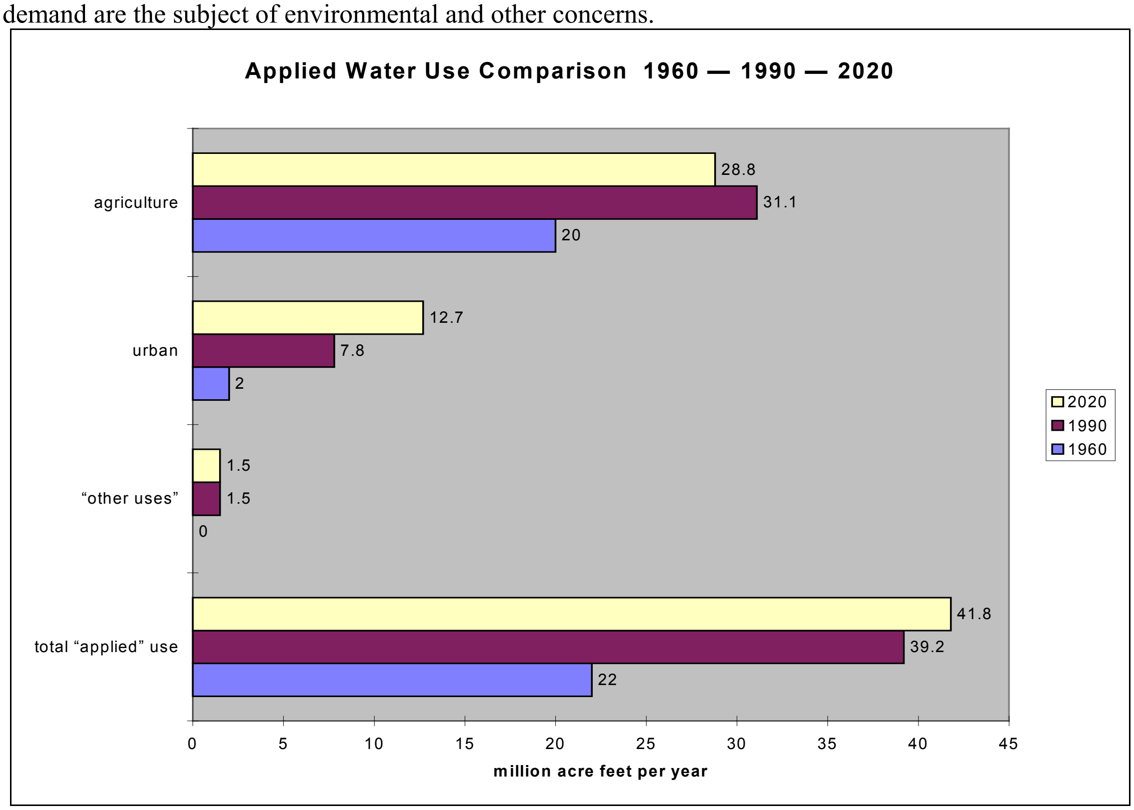
Appendix F: Water Use in California

The following is excerpted and adapted from the work of Bob Wilkinson, UC Santa Barbara.[352]

Water in California is extracted from natural systems primarily for use in the urban and agricultural sectors. The urban water use sector includes residential, commercial, industrial, and institutional uses, as well as municipal uses such landscaping and fire-fighting. As the state's population continues to grow, urban uses of water are steadily increasing. The state now projects a continued decline in water use for agriculture. Land retirement, crop shifting, water transfers, and improved efficiencies in irrigation as well as conveyance and management will all contribute to a reduction in water used for irrigation. Despite this decline, however, total extractions from the state's water systems have increased through the years, with flows for the environment decreasing as a result.

With very real limits to the state's water system, and every major supply source being reduced, the state's water systems may be fairly said to be stressed. Every major water supply source in California is currently beyond the physical or legal capacity to be sustained. California's entitlement to Colorado River water is 4.4 mafy, but it has been taking 5.2 mafy. An average of 1.3 mafy of groundwater extraction is overdraft (extractions exceed recharge by more than 18 percent). In severe drought years, this overdraft may be as high as four to 10 mafy, which drastically depletes economically recoverable groundwater resources.

The municipal and industrial (M&I) sector accounts for approximately 20% of the state's developed water use. The costs of water supply options have increased significantly, and water supplies to meet urban demand are the subject of environmental and other concerns.



* Total of "other outflow" and "environmental," a category which is not disaggregated for 1960. Assumes total water resources of 85 mafy for 2020, consistent with 1960 and 1990 data.

Source: California Department of Water Resources. California Water Plan Update, Bulletin 160-93, 1994.

[352] Robert Wilkinson, "Methodology for Analysis of the Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures," January 2000, p. 16-17. (mafy = million acre-feet per year).

Appendix G: Water Calculations

Weighted Average Value (WAV) Calculation

Population data is based on projections from 1995-2020.[353]

	Total 20-year PV ($/af)	% of CA population	Component of WAV
Bay Area	$9,546	8.1%	$769.36
Central Coast	$5,576	3.9%	$216.24
Sacramento	$1,783	9.3%	$166.35
San Joaquin	$3,098	9.3%	$287.39
South Coast	$9,074	45.5%	$4,128.23
S. Lahontan	$4,837	8.5%	$408.93
Tulare	$3,200	10.1%	$322.71
	Weighted Average Value:		**$6,299.21**

For the following calculations, doubling this WAV number seems to make sense because of the numerous unaccounted for costs in the studies on which these numbers are based, as outlined in Section VI.

Value of Potential Water Savings – An Example

Determining the value of potential water savings in a typical new building project requires making multiple assumptions about the size of the structure, its intended use, and its location within the state and baseline design elements. For the purposes of this example, assume the following:

Building Size:	100,000 ft^2
Building Type:	Standard Commercial Office w/ Cooling Tower
Number of Employees:	400 (250 ft^2/employee)
Baseline Building Practice:	Code
Baseline Indoor Water Usage:	25 gallons per employee per day[354]
Use Reduction through Green Design:	30%[355]
Baseline Landscape Water Usage:	1.46 million gallons per acre per year[356]
Average size of landscaped area:	0.75 acres per building[357]

[353] Source: "Bulletin 160-98: California Water Plan," California Department of Water Resources, Table 4.1.

[354] The amount of water used in California's commercial buildings varies widely by building type and use. Cooling towers and restaurants have the greatest impact on consumption. Average daily per capita consumption ranges from 15 to 40+ gallons. From conversation with Dale Lessick, Irvine Ranch Water District, October 2, 2002.

[355] Indoor savings of 30% are considered typical when incorporating relatively simple green design features. Source: USGBC, http://www.usgbc.org.

[356] Landscape water usage is even more difficult to generalize than indoor use. Planted landscapes range in size from a few potted plants (mostly in urban centers) to several acres (mostly in the suburbs). In addition, plant types require vastly different amounts of water. From http://www.cimis.water.ca.gov/, the average ETo in California across all 18 zones is 51.6 inches per year. According to the CUWCC, typical turf grass requires roughly 70% of ETo – 36 inches per year. Assuming that water delivery systems, are on average 50% inefficient, this hypothetical turf grass would require 54 inches of water applied per year. Calculations: 4.5 ft^3 x 43,460 ft^2/acre x 7.48 gallons/ft^3 = 1.46 million gallons per year (mgpy). We assume that through more efficient irrigation systems and better plant selection, conservation can achieve a 50% water use reduction, resulting in a required application of 730 mgpy.

Use Reduction through Green Design:	50%[358]
Marginal 20-yr PV cost of water:	$12,598/af

Calculations:
(1 af = 325,851 gallons)

Indoor Water Conserved:
25 gallons x 30% = 7.5 gpd savings
400 people x 7.5 gpd savings x 260 work days/yr = 780,000 gpy (2.39 af)
2.39 af x $12,598/af = $30,109

Irrigation Water Conserved:
(1,460,000 gallons per acre x .75 acres) x 50% = 547,500 gpy (1.68 af)
1.68 af x $12,598/af = $21,164

Figure G-1. 20-Year NPV of Water Savings

Total Value Per 100,000 ft^2 Building		
Indoor	**Irrigation**	**Total**
$30,109	$21, 164	$51,271
Total Value Per ft^2 of Building		
Indoor	**Irrigation**	**Total**
$0.30	$0.21	$0.51

The PV values were calculated by multiplying the PV value of one acre-foot of water, as derived in Section VI, with the amount of savings (in acre-feet) that are achieved in this hypothetical example. The total 20-year PV for both Indoor and Outdoor water savings is calculated as follows:

PV of 1 af = $12,598	(from Section VI)
($12,598 x 2.39 af)	(savings from indoor water reduction)
+ ($12,598 x 1.68 af)	(savings from outdoor water reduction)
= $51,271	
$51,271 / 100,000 ft^2 = **$0.51/ft^2**	(20-year PV)

[357] Conversation with Dale Lessick. This is the average landscaped acreage of over 800 commercial buildings in the Irvine Ranch Water District.

[358] Outdoor landscaping savings of 50% are considered typical when incorporating relatively simple green design features. Source: USGBC, http://www.usgbc.org.

Appendix H: Value of Waste Reduction – A State Building Example

The following example shows the economic impact of C&D diversion in a hypothetical new state green building project. The calculated value is in downstream product manufacture and sales, real tax revenues, and environmental impacts. It is important to note that some of the assumptions in this calculation are based on values for curbside recycling. Due to the relatively higher quality of most C&D materials, C&D recycling is generally more financially beneficial than curbside residential or commercial recycling service. Ultimately, this is a calculation of the benefits of waste diversion, of which recycling is one part.

The Impact of Construction and Demolition Waste Diversion

Assumptions

Building Size:	100,000 ft^2
Construction Waste Generated:	200 tons (400,000 lbs) [359]
Demolition Waste Generated:	775 tons (1,550,000 lbs)
Baseline Case:	50% Diversion Rate[360]
Green Case:	75% Diversion Rate
Value of Ton of Diverted Waste:	
Output Impact:	\$325/ton[361]
Income Impact:	\$70/ton
Value Added Impact (taxable):	\$111/ton
Environmental Impact:	\$47/ton[362]
State Income Tax:	3%
State Sales Tax:	8.25%

Calculations

Full Value of Ton Diverted (Output + Environmental): \$325 + \$47 = \$372
Tax Value of Ton Diverted: \$2.10 (e.g.\$70 x 3%) + \$9.16 (e.g.\$111 x 8.25%) = \$11.25

Conclusions for the whole building, assuming additional 25% diversion over baseline

Construction Diversion		
Full Value:	\$18,600	(200 tons x 25% x \$372)
Environmental Value:	\$2,350	(200 tons x 25% x \$47)
Tax Value:	\$563	(200 tons x 25% x \$11.25)
Demolition Diversion		
Full Value:	\$72,075	(775 tons x 25% x \$372)
Environmental Value:	\$9,106	(775 tons x 25% x \$47)
Tax Value:	\$2,180	(775 tons x 25% x \$11.25)

---

[359] For nonresidential buildings: 155 lbs/ft^2 demolition waste, about 4 lbs/ft^2 construction waste. US Environmental Protection Agency Municipal and Industrial Solid Waste Division, Office of Solid Waste. *Characterization of Building-related Construction and Demolition Debris in the United States*. June 1998.
[360] Note: Statewide estimated overall diversion rate in 2002 was 48% (CIWMB) – and green buildings can often reach the 75% diversion threshold.
[361] Average Output Impact average from UCB and NRC study.
[362] The environmental cost number for California is probably similar to the environmental cost number from the Massachusetts study plus or minus 25%. A conservative estimate of 75% of the Massachusetts number is used here. This number is similar to the curbside recycling environmental value.

The savings of C&D waste diversion are presented in Figure G-1 below.

Figure H-1. Value of C&D Waste Diversion in 100,000 ft^2 Office Building

		Building	Per ft^2
Construction	**Full Value**	$18,600	$0.19
	Eco Value	$2,350	$0.02
	Tax Value	$563	$0.01
Demolition	**Full Value**	$72,075	$0.72
	Eco Value	$9,106	$0.09
	Tax Value	$2,180	$0.02

For construction on barren land, use only the construction values. For construction on already developed land where an existing structure must first be demolished, use the demolition values plus the construction values.

Which metric is the right one to use?

The most accurate number for the state to use when evaluating the value of waste diversion is the Tax Value[363] plus the Eco-Value, according to the following rationale. The Tax Value is the most precise and conservative metric. It represents actual revenue earned by the state as a result of diversion. The Eco-Value also represents real avoided cost to the state even if it is, in part, speculative (e.g., reduced green house gas emissions). The Full Value includes all the multiplier effects of diversion (e.g., income effects, product value effects, taxes, etc.) – many of which accrue to individual actors within the state, but not to the state itself.

Using this approach, then, the potential values for reaching a 50% C&D diversion rate (25% over baseline) are:

> **\$0.03/ft^2** or \$3,000 per 100,000 ft^2 building for construction only.
>
> **\$0.11/ft^2** or \$11,000 per 100,000 ft^2 building for demolition only.
>
> **\$0.14/ft^2** or \$14,000 per 100,000 ft^2 building for construction preceded by demolition.

All numbers reflect the value that occurs in the year of the construction. This is not an NPV calculation. While there undoubtedly are effects from landfill reduction that reverberate through the future years, they are not included in this analysis and assumed to be small. A more thorough study should analyze this further.

Note on Office Recycling

In this example, office recycling has been removed from calculations of green building waste reduction benefits. It is not clear that the tenants of green buildings would reduce disposed waste beyond California's already relatively aggressive statewide recycling goals.

---

[363] The tax value refers to the additional taxes the state is likely to collect as a result of the economic activity generation through diversion activities.

Appendix I: Total User Costs for California State Buildings
Calculations follow the chart.

Figure I-1. DGS Data for California State Buildings
2002 data for 9.25 million square feet of California state office space with 27,428 employees.

Total User Costs	Annual $/Employee					
BLDG.#	Electricity	O&M	Other Energy	Rent	Employee	Total
001	$555	$22,132	$0	$175	$65,141	$88,003
002	$432	$2,589	$0	$2,477	$65,141	$70,340
003	$557	$3,060	$16	$7,239	$65,141	$75,595
004	$619	$3,585	$0	$0	$65,141	$68,958
006/056	$771	$2,958	$0	$5,747	$65,141	$73,975
008	$406	$2,373	$0	$8,367	$65,141	$75,991
009	$117	$1,812	$0	$932	$65,141	$67,929
010	$189	$1,609	$0	$4,603	$65,141	$71,436
011	$202	$6,476	$0	$4,445	$65,141	$76,247
013	$183	$979	$0	$3,349	$65,141	$69,651
018	$223	$806	$0	$2,962	$65,141	$69,595
019	$351	$1,612	$147	$0	$65,141	$67,018
021	$387	$2,442	$0	$4,959	$65,141	$72,625
025	$725	$5,997	$5	$13,893	$65,141	$85,354
028	$335	$167	$14	$0	$65,141	$66,020
030	$335	$1,166	$24	$5,705	$65,141	$72,371
036	$1,570	$4,563	$5	$0	$65,141	$70,232
039/045	$231	$1,024	$1	$3,061	$65,141	$69,804
075	$516	$1,862	$19	$3,320	$65,141	$71,117
091	$325	$17,112	$0	$0	$65,141	$82,270
330	$376	$6,308	$18	$6,346	$65,141	$77,946
402	$602	$2,631	$0	$15,044	$65,141	$83,869
460	$633	$7,164	$52	$6,275	$65,141	$78,663
461	$290	$1,424	$19	$2,540	$65,141	$69,163
470	$628	$5,486	$0	$5,695	$65,141	$76,479
480	$313	$4,921	$47	$3,226	$65,141	$73,439
512	$397	$2,356	$21	$8,296	$65,141	$76,145
530	$540	$5,177	$31	$6,489	$65,141	$76,972
602	$634	$1,959	$19	$9,063	$65,141	$77,133
701	$515	$3,237	$53	$5,258	$65,141	$73,861
753	$1,039	$3,392	$88	$9,915	$65,141	$78,587
801	$701	$4,999	$96	$6,994	$65,141	$77,391
901	$615	$3,780	$41	$3,995	$65,141	$73,048
Averages	**$408**	**$3,039**	**$12**	**$4,755**	**$65,141**	**$73,355**

Assembled for this report by the California Department of General Services and the Real Estate Services Division.

Energy Use Calculations
For purposes of calculating emissions from energy for Section V, it was necessary to determine a conservative value for electricity used per square foot. This can be derived by first determining electricity consumption per employee, then multiplying electricity consumption per employee by number of employees and dividing by the number of total square feet, as follows:

$408/0.12kWh/ft2	=	3400 kWh/employee/year
3,400 x 27,428	=	93,255,200 kWh/year (for all building area)
93,255,200/9,250,000	=	**10 kWh/ft^2/yr**

Office energy costs for California state employees in 2002 were about:[364]
$1.60/ft^2 or $360/employee/year

This paper assumes an expected drop in electricity prices from $0.12/kWh to $0.11/kWh.[365] Therefore these figures are discounted to:
$1.47/ft^2/yr or $330/employee/year

Figure H-1 shows total energy costs per employee of $420.
Electricity + Other Energy = Total Energy: $408+$12=$420

Additionally, according to the Real Estate Services Division, average office space per worker is:
225 ft^2/employee

However, the information in Figure H-1 seems to imply more space than this:
9,250,000/27,428 = 337 ft^2/employee

These discrepancies can be explained as follows:

The total energy costs from Figure H-1 are understood to be the total energy consumed by the buildings divided by the number of employees. Therefore, energy costs for all buildings are:

27,428 x $420 = $11,519,760

This doesn't account for two factors:

1. The influence of "transients" or non-employees in the building, thereby increasing the effective number of employees.
2. Non-office space such as stairwells, elevator shafts and hallways, which are communal and generally unconditioned.

State buildings, in providing services, often have many non-employees inside them. Assuming a "transient factor" of 5% (on average there is space for 5% more people in the building than reported employees) results in a higher number of "effective employees":

[364] Data provided by the California Department of General Services, Real Estate Services Division, Building Property Management Brach, December 2002.
[365] California Energy Commission. Office of the Supervisor of Rates. December 2002. $0.11/kWh is a conservative estimate. Higher rates would increase green building benefits.

27,428 x 1.05 = 28,799 effective employees

All office buildings have a significant amount of non-office space. This space is generally both shared by all and less heavily conditioned (requiring less energy in heat and electricity) than office space. Assuming 30% of these state office buildings are non-office space delivers:

9.25 million ft^2 x 70% = 6.475 million ft^2 office space

Assuming non-office space requires 1/3 the energy of office space, this means that, while office space only makes up 70% of the building, it consumes 90% of the energy, thus:

$11,519,760 x 90% = $10,367,784 (energy cost of conditioning office space)

It is only this energy cost that should be attributed to employees, as energy costs of non-office space can't be assumed to scale evenly with number of employees.
Thus, energy costs per effective employee are:

$10,367,784/28,799 = $360/employee/year

Furthermore, office space per employee is:

6,475,000/28,799 = **225 ft^2/employee/year**

And energy costs per square foot are:

$10,367,784/6,475,000 = $1.60/$ft^2$/yr

These numbers are for 2002, when electricity cost (and therefore most of the cost of energy) was $0.12/kWh. However, estimates for future electricity cost are $0.11/kWh. Scaling the above figure down delivers:

$1.60 x (11/12) = **$1.47/ft^2/yr**

This is the number used throughout this report.

Appendix J: Health and Productivity Gains from Better Indoor Environments[366]

This is a direct excerpt from the work of William J. Fisk and Satish Kumar.

Acute Respiratory Illness (ARI)

No high quality studies identified had investigated but failed to find a link between building characteristics and acute respiratory illnesses (ARIs) such as influenza and common colds. Eight studies reported statistically significant 23% to 76% reductions in ARIs among occupants of buildings with higher ventilation rates, reduced space sharing, reduced occupant density, or irradiation of air with ultraviolet light. These changes to buildings or building use were considered technically feasible and practical, given sufficient benefits. One study found a 35% reduction in short-term absence, a surrogate for ARI, in buildings with higher ventilation rates. Because some of these studies took place in unusual building types, such as barracks and a jail, reductions in ARIs were adjusted downwards, and ranged from 9% to 20%. Multiplying this range by the annual cases of common colds and influenza resulted in an estimated 16 million to 37 million potentially avoided cases of common cold and influenza. Given the $70 billion annual cost of ARIs, the associated potential productivity gains were $6 billion to $14 billion.

Allergies and Asthma

The scientific literature reports statistically significant links between prevalence of allergy and asthma symptoms and a variety of changeable building characteristics or practices, including indoor allergen concentrations, moisture and mold problems, pets, and tobacco smoking. The reported links between these risk factors and symptoms were often quite strong. For example, parental smoking was typically associated with 20% to 40% increases in asthma symptoms. In numerous studies, mold or moisture problems in residences were associated with 100% increases in lower respiratory symptoms indicative of asthma. These moisture and mold problems are common; for example, about 20% of U.S. houses have water leaks. Based on these data, the estimated potential reduction in allergy and asthma symptoms from improved IEQ was 8% to 25%, among a large population -- 53 million with allergies and 16 million asthmatics. Given the $15 billion annual cost of allergies and asthma, the potential economic gains are $1 billion to $4 billion.

Sick Building Syndrome (SBS) Symptoms

SBS symptoms are acute symptoms, such as eye and nose irritation and headache, associated with occupancy in a specific building, but not indicating a specific disease. Risk factors for SBS symptoms identified in many studies include lower ventilation rates, presence of air conditioning, and higher indoor air temperatures. Increased chemical and microbiological pollutants in the air or on indoor surfaces, debris or moisture problems in HVAC systems, more carpets and fabrics, and less frequent vacuuming were risk factors in a smaller number of studies. One large study suggests that a 10 cfm per person increase in ventilation rates would decrease prevalences of the most common SBS symptoms on average by one third. Practical measures could diminish all these risk factors. Based on these data, the estimated potential reduction in SBS symptoms was 20% to 50%. The affected population is very large – in a survey of 100 U.S. offices, 23% of office workers (64 million workers) frequently experienced two or more SBS symptoms at work. The estimated productivity decrement caused by SBS symptoms in the office worker population was 2%, with an annual cost of $60 billion. A 20-50% reduction in these symptoms, considered feasible and practical, would bring annual economic benefits of $10 billion to $30 billion.

---

[366] Excerpted directly from: Satish Kumar and William J. Fisk, "The Role of Emerging Energy Efficient Technology in Promoting Workplace Productivity and Health: Final Report," LBNL, February 13, 2002, pp. 20-21. Available at: http://www-library.lbl.gov/docs/LBNL/497/06/PDF/LBNL-49706.pdf.

Direct Productivity Gains

Published literature documents direct linkages of worker performance with air temperatures and lighting conditions, without apparent effects on worker health. Many but not all studies indicate that small (few ^{o}C) differences in temperatures can influence workers' speed or accuracy by 2% to 20% in tasks such as typewriting, learning performance, reading speed, multiplication speed, and word memory. Surveys have documented that indoor air temperature is often poorly controlled, implying an opportunity to increase productivity.[367] It is estimated that providing ± 3^{o}C of individual temperature control would increase work performance by 3% to 7%. A smaller number of studies have documented improvements in work performance with better lighting, with benefits most apparent for visually demanding work. Increased daylighting was also linked in one study to improved student learning. Based on these studies and recognizing that performance of only some work tasks is likely to be sensitive to temperature and lighting, the estimated potential direct productivity gain is 0.5% to 5%, with the factor of ten range reflecting the large uncertainty. Considering only U.S. office workers, the corresponding annual productivity gain is $20 billion to $200 billion.

---

[367] Wyon. 1996. Op. Cit.

Appendix K: Insurance and Risk Management Benefits of Green Building Attributes

From: Evan Mills, "Green Buildings as a Risk-Management Strategy," *Energy Associates*, Prepared for Capital-E, December 2002.

			Category of Green Buildings Insurance/Risk-Management Benefits							
			Property Loss	**General Liability**	**Business Interruption**	**Vehicle (Prop or Liab)**	**Health & Workers Comp.**	**Life**	**Environmental Liability**	**Notes**
Design Area 1	Sustainable Sites (14 Points possible)		1			4	3	2	3	
	Prereq 1	**Erosion & Sedimentation Control** (Required)	+						+	Reduced likelihood of property damage due to mudslides and soil subsidence.
	Credit 1	**Site Selection** (1 point)								
	Credit 2	**Urban Redevelopment** (1 point)								
	Credit 3	**Brownfield Redevelopment** (1 point)		-	-		-		-	
	Credit 4.1	**Alternative Transportation**, Public Transportation Access (1 point)				+				Reduced number of personnel using insured transportation infrastructure.
	Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms (1 point)				+				Reduced number of personnel using insured transportation infrastructure.
	Credit 4.3	**Alternative Transportation**, Alternative Fuel Refueling Stations (1 point)				+/-				Reduced number of personnel using insured transportation infrastructure. Potential new risks associated with alternate fuels and vehicles.
	Credit 4.4	**Alternative Transportation**, Parking Capacity (1 point)				+				Reduced number of personnel using insured transportation infrastructure.
	Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space (1 point)								
	Credit 5.2	**Reduced Site Disturbance**, Development Footprint (1 point)								
	Credit 6.1	**Stormwater Management**, Rate or Quantity (1 point)							+	Reduced likelihood of environmental risks associated with runoff.
	Credit 6.2	**Stormwater Management**, Treatment (1 point)							+	Reduced likelihood of environmental risks associated with runoff.
	Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof (1 point)	-				+	+		Reduced stormwater runoff due to water retention by vegetation. Reduced risk of heat-catastrophe mortality. Elevated fire risk due to added vegetation near building.
	Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof (1 point)					+	+		Reduced interior temperatures; increased roof lifetime. Reduced risk of heat-catastrophe mortality.
	Credit 8	**Light Pollution Reduction** (1 point)					+			Reduced labor for lamp replacements and maintenance (workers compensation exposure).
Design Area 2	ater Efficiency (5 Points possible)								1	
	Credit 1.1	**Water Efficient Landscaping**, Reduce by 50% (1 point)								
	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation (1 point)								
	Credit 2	**Innovative Wastewater Technologies** (1 point)							+/-	Potential beneficial or adverse

Category of Green Buildings Insurance/Risk-Management Benefits										
			Property Loss	General Liability	Business Interruption	Vehicle (Prop or Liab)	Health & Workers Comp.	Life	Environmental Liability	Notes
										consequences of alternative technologies.
	Credit 3.1	**Water Use Reduction**, 20% Reduction (1 point)								
	Credit 3.2	**Water Use Reduction**, 30% Reduction (1 point)								
Design Area 3	**nergy & Atmosphere (17 Points ossible)**		**6**	**6**	**9**		**6**	**3**	**6**	
	Prereq 1	**Fundamental Building Systems Commissioning** (Required)	**+**	**+**	**+**		**+**			Facilitates detection of property and/or health risks associated with project that could lead to service interruptions or physical damages. Reduces liability of architects and engineers.
	Prereq 2	**Minimum Energy Performance** (Required)	**+/-**	**+**	**+**		**+/-**	**+**		Diverse set of benefits ranging from reduced fire risk due to multi-pane windows or non-halogen light sources, or reduced business interruption. Isolated potential adverse consequences.
	Prereq 3	**CFC Reduction in HVAC&R Equipment** (Required)							**+**	
	Credit 1.1	**Optimize Energy Performance**, 20% New / 10% Existing (2 points)	**+/-**	**+**	**+**		**+/-**	**+**	**+**	(See above).
	Credit 1.2	**Optimize Energy Performance**, 30% New / 20% Existing (2 points)	**+/-**	**+**	**+**		**+/-**	**+**	**+**	(See above).
	Credit 1.3	**Optimize Energy Performance**, 40% New / 30% Existing (2 points)	**+/-**	**+**	**+**		**+/-**	**+**	**+**	(See above).
	Credit 1.4	**Optimize Energy Performance**, 50% New / 40% Existing (2 points)	**+/-**	**+**	**+**		**+/-**	**+**	**+**	(See above).
	Credit 1.5	**Optimize Energy Performance**, 60% New / 50% Existing (2 points)	**+/-**	**+**	**+**		**+/-**	**+**	**+**	(See above).
	Credit 2.1	**Renewable Energy**, 5% (1 point)	**-**		**+**				**+**	Increased reliability for on-site generation. Possible reduced environmental liability associated with on-site fossil-fuel (e.g., diesel) systems. New insurance costs and risks associated with added on-site technologies.
	Credit 2.2	**Renewable Energy**, 10% (1 point)	**-**		**+**				**+**	(See above).
	Credit 2.3	**Renewable Energy**, 20% (1 point)	**-**		**+**				**+**	(See above).
	Credit 3	**Additional Commissioning** (1 point)	**+**	**+**	**+**		**+**			(See notes on commissioning under Prereq 1).
	Credit 4	**Ozone Depletion** (1 point)								
	Credit 5	**Measurement & Verification** (1 point)	**+**	**+/-**	**+**		**+**		**+**	Reduced risk of underattainment of savings (see notes on commissioning - possible adverse effects on liability of service providers, ESCOs, etc.).
	Credit 6	**Green Power** (1 point)								
Design Area 4	**aterials & Resources (13 Points ossible)**					**2**	**3**		**8**	
	Prereq 1	**Storage & Collection of Recyclables** (Required)	**-**						**+/-**	Fire risks from stored flammables. Pollution risks or benefits.
	Credit 1.1	**Building Reuse**, Maintain 75% of	**-**				**+**		**+**	Reduced exposure to environmental risks

Category of Green Buildings Insurance/Risk-Management Benefits										
			Property Loss	**General Liability**	**Business Interruption**	**Vehicle (Prop or Liab)**	**Health & Workers Comp.**	**Life**	**Environmental Liability**	**Notes**
		Existing Shell (1 point)								associated with waste handling and disposal, as well as occupational risks to construction workers (assuming reduced new construction). Buildings may not meet current codes for earthquake, etc.
	Credit 1.2	**Building Reuse**, Maintain 100% of Shell (1 point)	-				+		+	Reduced exposure to environmental risks associated with waste handling and disposal, as well as occupational risks to construction workers (assuming reduced new construction). Buildings may not meet current codes for earthquake, etc.
	Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell (1 point)	-				+		+	Reduced exposure to environmental risks associated with waste handling and disposal, as well as occupational risks to construction workers (assuming reduced new construction). Buildings may not meet current codes for earthquake, etc.
	Credit 2.1	**Construction Waste Management**, Divert 50% (1 point)							+	Reduced exposure to environmental liability issues from waste disposal.
	Credit 2.2	**Construction Waste Management**, Divert 75% (1 point)							+	Reduced exposure to environmental liability issues from waste disposal.
	Credit 3.1	**Resource Reuse**, Specify 5% (1 point)							+	Reduced exposure to environmental liability issues from waste disposal.
	Credit 3.2	**Resource Reuse**, Specify 10% (1 point)							+	Reduced exposure to environmental liability issues from waste disposal.
	Credit 4.1	**Recycled Content**, Specify 25% (1 point)								
	Credit 4.2	**Recycled Content**, Specify 50% (1 point)								
	Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally (1 point)				+				Reduced freight-mileage. Of benefit if state-owned vehicles used.
	Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally (1 point)				+				Reduced freight-mileage. Of benefit if state-owned vehicles used.
	Credit 6	**Rapidly Renewable Materials** (1 point)								
	Credit 7	**Certified Wood** (1 point)								
Design Area 5	**door Environmental Quality (15 oints possible)**		**6**	**11**	**10**		**17**	**2**	**13**	
	Prereq 1	**Minimum IAQ Performance** (Required)	+	+	+		+	+	+	Diverse health benefits, formerly excluded by many insurance policies but increasingly being successfully litigated. Reduced risk of moisture damage (e.g., toxic mold). Reduced risk of liability to designer/builder/operator. Can avert absenteeism, shutdowns, or forced relocation due to IAQ problems.
	Prereq 2	**Environmental Tobacco Smoke** (ETS)		+			+	+	+	(See above).

Category of Green Buildings Insurance/Risk-Management Benefits										
			Property Loss	General Liability	Business Interruption	Vehicle (Prop or Liab)	Health & Workers Comp.	Life	Environmental Liability	Notes
		Control (Required)								
	Credit 1	**Carbon Dioxide** (CO_2) **Monitoring** (1 point)		+			+		+	(See above).
	Credit 2	**Increase Ventilation Effectiveness** (1 point)	+	+			+		+	(See above).
	Credit 3.1	**Construction IAQ Management Plan**, During Construction (1 point)	+	+	+		+		+	(See above).
	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy (1 point)	+	+	+		+		+	(See above).
	Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants (1 point)		+	+		+		+	(See above).
	Credit 4.2	**Low-Emitting Materials**, Paints (1 point)		+	+		+		+	(See above).
	Credit 4.3	**Low-Emitting Materials**, Carpet (1 point)		+	+		+		+	(See above).
	Credit 4.4	**Low-Emitting Materials**, Composite Wood		+	+		+		+	(See above).
	Credit 5	**Indoor Chemical & Pollutant Source Control** (1 point)		+	+		+		+	(See above).
	Credit 6.1	**Controllability of Systems**, Perimeter (1 point)					+		+	(See above).
	Credit 6.2	**Controllability of Systems**, Non-Perimeter (1 point)	+				+		+	(See above).
	Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992 (1 point)					+			(See above).
	Credit 7.2	**Thermal Comfort**, Permanent Monitoring System (1 point)					+			(See above).
	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces (1 point)			+		+			(See above).
	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces (1 point)			+		+			(See above).
Design Area 6	**ssible)**									
	Credit 1.1	**Innovation in Design**: Specific Title (1 point)								Amplifies benefits noted above.
	Credit 1.2	**Innovation in Design**: Specific Title (1 point)								Amplifies benefits noted above.
	Credit 1.3	**Innovation in Design**: Specific Title (1 point)								Amplifies benefits noted above.
	Credit 1.4	**Innovation in Design**: Specific Title (1 point)								Amplifies benefits noted above.
	Credit 2	**LEED™ Accredited Professional** (1 point)								Amplifies benefits noted above.

Appendix L: Annotated Bibliography

The following is a guide to primary sources in areas for which there are no comprehensive internet resources: Water Conservation and Waste Reduction.

Water Conservation

Water Use in Buildings

Pike, Charles. *Study of Potential Water Efficiency Improvement in Commercial Business*. US EPA/DWR, April 1997.
Sweeten, Jon and Ben Chaput. *Identifying the Conservation Opportunities in the Commercial, Industrial, and Institutional Sector*. Paper delivered to the AWWA, 1997.

These studies conclude that there is considerable opportunity for cost effective water conservation technology adoption in most commercial building types.

Sustainable Use of Water: California Success Stories. Publication of the Pacific Institute, January 1999. Available online at: http://www.pacinst.org/water.html

This document identifies, describes, and analyzes examples of sustainable water policies and practices throughout the state. Many of the 28 "stories" highlighted offer specific examples of water utilities that have adopted innovative water conservation policies. Others present an overview of a particular water conservation issue area. The most useful "story" for our purposes is Chapter 6: *An Overview of Water – Efficiency Potential in the CII Sector*. It finds that significant cost-effective water conservation potential currently exists in the CII building sector.

Externalities of Water Use and Public Policy

Renzetti, Steven. "Municipal Water Supply and Sewage Treatment: Costs, Prices, and Distortions." *Canadian Journal of Economics*, May 1999. Available online at: http://economics.ca/cje/

This empirical study in Canada estimated that the price charged for fresh water was only one-third to one-half the long-run marginal supply cost, and the prices charged for sewage were approximately one-fifth the long run cost of sewage treatment

---

CUWCC. *Guidelines for Preparing Cost-Effectiveness of Urban Water Conservation Best Management Practices*. September 1996. Available online, with many other resources related to urban water conservation, at: http://www.cuwcc.org/home.html.

This document contains the Total Society Cost Model of water conservation. It is designed to capture all avoided future economic, environmental, and social costs of urban water conservation in order to determine its true avoided cost. The CUWCC is currently conducting workshops to assist water utilities in using this model.

Economic Evaluation of Water Management Alternatives. Prepared for the CALFED Bay-Delta Program, October 1999. See: http://calwater.ca.gov/Archives/WaterManagement/WaterManagementArchive.shtml.

Available online at: http://calfed.ca.gov/Programs/WaterManagement/adobe_pdf/Calfed.pdf.

This document evaluates the cost-effectiveness of different water management options that would meet the state's anticipated water needs in 2020. The perspective taken is that of the end user of water in each region where SWP or CVP water is expected to be needed in 2020. The study analyses seven scenarios, each one assuming different policy decisions leading up to year 2020.

Fiske, Gary and Associates. *California Urban Water Agencies Urban Water Conservation Potential - Final Report,* August 2001. Available online at: http://www.cuwa.org/publications.html.

This study determines marginal cost numbers for new water supplies for every region of the state for each year from 2000 – 2040, from the perspective of the regional utility. It includes wastewater facility expansion and O&M expenses in these estimates. Many water experts in the state believe that the marginal cost numbers presented in this study are too low.

Bulletin 160-98: California Water Plan. California Department of Water Resources, 1998.
Available online at: http://rubicon.water.ca.gov/b160index.html.

This document, which is updated every five years, evaluates water supplies and assesses agricultural, urban, and environmental water uses to quantify the gap between water supplies and uses. It also evaluates options for meeting the State's future water needs. The next update will be released in 2003.

The Clean Water and Drinking Water Infrastructure Gap Analysis. Published by the EPA, August 2002.
Available online at: http://www.epa.gov/safewater/gapreport.pdf.

This document evaluates our country's current water delivery and treatment systems, and the financial health of the agencies that operate them. It concludes that the expected gap between future revenues (based on historical price increases) and infrastructure needs for potable water and wastewater treatment will be approximately $148 billion over the next twenty years.

Field, Christopher. *Confronting Climate Change in California: Ecological Impacts on the Golden State.* Publication of the Union of Concerned Scientists, 1999. Available online at http://www.ucsusa.org/.

This document summarizes the likely impacts of climate change in California. It indicates that changes in precipitation patterns will have a dramatic affect on the state's ecology and economy. Specifically, more precipitation will fall as rain, rather than snow, causing massive flooding in the spring and droughts by late summer. Reduced summer runoff of fresh water would also increase summer salinity in San Francisco Bay.

Gleick, Peter. *Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States*. Publication of the Pacific Institute, September 2000.
Available online at: http://www.pacinst.org/.

This document summarizes the results of nearly 1,000 peer-reviewed studies on climate change. Consensus conclusions are similar to those presented in the UCS study above.

Bulletin 132: Management of the California State Water Project. Publication of DWR, 1999.
Available online at: http://wwwdwr.water.ca.gov/.

This is part of a series of annual reports that describe the status of State Water Project (SWP) operations. Each annual report updates information regarding project costs and financing, water supply planning,

power operations, and significant events that affect the management of the State Water Project. The publication aggregates SWP energy costs associated with pumping water throughout the state.

Preparing for California's Next Drought. Publication of DWR, July 2000.
Available online at: http://wwwdwr.water.ca.gov/.

Between 1987-1992, California experienced its longest drought in more than a century. Over 85% of the counties in the state declared local emergencies. This document presents the lessons learned from this experience and offers policy recommendations to better prepare for future drought years.

Notably, the document states the following:
Article X, Section 2 of the California Constitution prohibits waste or unreasonable use or unreasonable method of use of water. ... Water Code Section 275 directs the Department [of Water Resources] and the SWRCB to take appropriate actions before courts, administrative agencies, and legislative bodies to prevent waste or misuse of water.

Multi-Agency Benchmarking Project. Published by the King County Department of Natural Resources, publication 1282, September 1999.

This document presents the findings from a collaborative effort among seven large West Coast wastewater utilities to collect, compare and analyze cost and operational data. The investigation examines all aspects of sewage treatment facility operation. For example, in 1997, the average direct operating cost among these utilities was $729 per million gallons of treated water. Operations and Maintenance (O&M) accounted for roughly half of this amount. O&M includes direct operational labor, as well as energy and chemicals. Notably, power purchases were the second largest cost factor within O&M.

Waste Reduction

Skumatz, Lisa, SERA Inc, and Jeff Morris, SRMG. *Massachusetts Recycle 2000: Baseline Report* (Excerpts). Prepared for the Executive Office of Environmental Affairs, State of Massachusetts, December 1998.

This document compares the economic and environmental costs of waste disposal and curbside recycling in Massachusetts. This is the only analysis that we have seen that attempts to quantify the "hard to quantify" environmental costs from a state's perspective. It concludes that the total benefits of recycling, net of disposal benefits, are worth $270 - $379 per ton to the state.

Goldman, George and Aya Ogishi. *The Economic Impact of Waste Disposal and Diversion in California.* Department of Agricultural and Resource Economic, UC Berkeley, April 2001.
Available online at: http://are.berkeley.edu/coopext/EconImpWaste.pdf.

This study quantifies and compares the economic impacts of disposal and diversion in six regions within the state. The results show both that on average, diversion has twice the economic impact of disposal and that the benefits of diversion vary greatly among regions in the state. In general, recycling has a greater impact in regions with well-developed recycling infrastructure and mature recycling industries.

California Recycling Economic Information Study (REI), prepared for CIWMB by the National Recycling Coalition in association with R.W. Beck, Inc, July 2001.
Available online at: http://www.ciwmb.ca.gov/agendas/mtgdocs/2002/01/00007124.pdf.

This study uses a broader definition of diversion than the UCB study to quantify the size and makeup of the diversion industry in California and its economic impacts. It also compares diversion to other sectors of the economy and shows how the economic impacts from diversion in California fit within the nationwide economy. It reaches similar conclusions about the economic impact of diversion as the UCB study.

Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste, Final Report. Prepared by the US EPA, September 1998.

This document summarizes and assesses air emission data from different forms of waste management including incineration, landfilling and recycling.

Disposal Cost Fee Study, Final Report. Prepared by the Tellus Institute for the California Integrated Waste Management Board, February 1991.

Before the UCB and REI studies were released, this study provided the most comprehensive data on California's waste disposal system. It categorizes and analyzes the types of waste found in California's waste stream, and identifies environmental threats associated with waste diversion and disposal of various products/types of waste.

Construction Waste Management Section of the California Sustainable Design Training Manual, 2001.

This document provides an overview of waste management and all of the relevant green issues associated with it. It also provides an extensive list of internet sites with additional resources on the topic.

Glossary of Acronyms

A number of acronyms are referred to or used in this report. They are spelled out below, and when they first appear in the text.

ACEEE – American Council for an Energy Efficient Economy
ADL – Arthur D. Little Consultants
af – acre-foot (of water)
ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ARB – Air Resources Board (CA)
ASTM – American Society for Testing and Materials
BEPAC – Building Environmental Performance Criteria (Canada)
BEES – Building for Environmental and Economic Sustainability
BIDS – Building Investment Decision Support
BOMA – Building Owners & Managers Association
BREEAM – British Research Establishment Environment Assessment Method
C&D – construction & demolition
CalTrans – Department of Transportation (CA)
CBA – cost benefit analysis
CEC – California Energy Commission
CIWMB – California Integrated Waste Management Board
CO2 – carbon dioxide
CUWA – California Urban Water Agencies
CUWCC – California Urban Water Conservation Council
DGS – Department of General Services (CA)
DOE – Department of Energy (US)
DOF – Department of Finance (CA)
DSA – Division of the State Architect (CA)
DWR – Department of Water Resources (CA)
EIA – Energy Information Administration (US)
EPA – Environmental Protection Agency
FEMP – Federal Energy Management Program
GHG – greenhouse gases
GW(h) – gigawatt (hour) = 1 billion watts
HVAC – heating, ventilation and air conditioning
IAQ – indoor air quality
IEQ – indoor environmental quality
IFMA – International Facilities Management Association
IPCC – Intergovernmental Panel on Climate Change
IPMVP – International Performance Measurement & Verification Protocol
IRR – internal rate of return
ISO – International Organization for Standardization
kW(h) – kilowatt (hour) = 1000 watts
LADWP – Los Angeles Department of Water and Power
LBNL – Lawrence Berkeley National Labs
LCA – life cycle assessment
LEED – Leadership in Energy & Environmental Design (USGBC)
MW(h) – megawatt (hour) = 1 million watts
MWD – Metropolitan Water District
NIST – National Institute of Standards and Technology
NOx – oxides of nitrogen
NPV – net present value
NREL – National Renewable Energy Labs
O&M – operations & maintenance
PG&E – Pacific Gas & Electric Company
PIER – Public Interest Energy Research (CA)
PM10 – particulate matter
PUC – Public Utilities Commission
PV – solar photovoltaics
PV – present value
SBTF – Sustainable Building Task Force (CA)
SCE – Southern California Edison
SDG&E – San Diego Gas & Electric Co.
SMUD – Sacramento Municipal Utility District
SOx – oxides of sulfur
T&D – transmission & distribution
USGBC – US Green Building Council
VOC – volatile organic compound