National Review of Green Schools: Costs, Benefits, and Implications for Massachusetts

A Report for the Massachusetts Technology Collaborative

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A Capital E Report

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Front cover photos:

Left: Danvers – Holten-Richmond Middle School
Middle: Dedham Middle School – rainwater collection tanks
Right: Blackstone Valley Regional Vocational Technical High School

About the Authors

Gregory H. Kats is cofounder and Principal of Capital E (www.cap-e.com) a national energy technology and green building consulting firm for Fortune 500 and public sector clients. He is the Principal Advisor in developing $550 million of green low-income housing, involving, among others, the Enterprise Foundation, JPMorgan Chase, Fannie Mae, and the American Institute of Architects (www.greencommunitiesonline.org/about-partners.asp). Mr. Kats served as the Director of Financing for Energy Efficiency and Renewable Energy at the U.S. Department of Energy (1996-2001). With a billion dollar budget, it is the country's largest clean energy and advanced building technology development and deployment program. He initiated and led DOE's successful effort to persuade the Securities and Exchange Commission to lift key restrictions on domestic and international expansion of US energy service companies, and developed a national renewable energy insurance program described by the Financial Times as "remarkably high leverage." He co-founded and, from 1995 to 2001, chaired the International Performance Measurement & Verification Protocol (www.ipmvp.org), now the de facto US standard that has served as a technical basis for over $8 billion in building upgrades, and has been translated into 10 languages.

Mr. Kats serves as Chair of the Energy and Atmosphere Technical Advisory Group for LEED (the national green building standard) and serves on the LEED Steering Committee. He is the principal author in the most widely referenced study on costs and benefits of green buildings, The Costs and Financial Benefits of Green Buildings, developed for 40 California state agencies. He is also a principal author of the Urban Land Institute's 2005 book, Green Office Buildings: a Practical Guide to Development. Mr. Kats recently led the energy design charette for a new town of 60,000 near London, intended to be the greenest town in Europe. Mr. Kats earned an MBA from Stanford University and, concurrently, an MPA from Princeton University on a Woodrow Wilson Fellowship. He graduated with highest honors from UNC Chapel Hill as a Morehead Scholar, and is a LEED Accredited Professional and a Certified Energy Manager. He advises corporations, finance firms, Congressional House members, federal legislative staff, pension fund managers, and cities and states (e.g. California, New Jersey and New York) on green buildings, clean technology, financing, and legislation. He serves on various corporate and not for profit boards and regularly testifies and serves as a conference keynote speaker on green buildings, clean energy technology, and finance issues.

Jeff Perlman – In addition to his work for Capital E, Jeff is President of Bright Power (www.brightpower.biz) where he helps design, install, and obtain financing for solar and energy efficiency projects on commercial and residential buildings, as well as providing market analysis and other consulting services to individuals, universities and large corporations. He was a contributing author to the seminal 2003 Capital E report The Costs and Financial Benefits of Green Buildings. Based in New York City, he is a trained installer of solar electric systems on rooftops, as well as a builder of solar powered cars. Jeff has a degree in Applied Physics from Yale.

Sachin Jamadagni holds a Bachelors in Mechanical Engineering from the University of Mumbai, India and is about to complete his masters in Energy Engineering from the University of Massachusetts, Lowell. As a graduate student he was President of the Solar Energy Club. In the summer of 2005 he worked as an Intern at the Massachusetts Technology Collaborative where he researched the costs and benefits of green schools for Massachusetts.

1. Executive Summary

This report documents the financial costs and benefits of green schools compared to conventional schools, specifically with reference to Massachusetts. Making schools green is very cost-effective. A national review of 30 green schools and analysis of available research demonstrate that green schools cost 1.5% to 2.5% more than conventional schools, but provide financial benefits that are 10 to 20 times as large.

These financial benefits include: energy and water savings, reduction in costs associated with waste and emissions, increased student learning and future earning, reduced incidence of student asthma and other illnesses, reduced costs of teacher turnover, and net employment gains for the state. The largest benefits are related to energy cost savings and the impacts of improved student learning on their future earnings. The recent surge in energy prices puts pressure on school budgets, both increasing short-term costs and increasing interest in energy efficiency as a way to hold down future costs. Average green schools cut energy use by one-third compared with conventional school design, providing financial savings three times as large as the cost of greening. Even more important is the impact of green school design and operation on the health and quality of learning environments for students.

Some 50 million students spend their days in schools that are too often unhealthy and that restrict their ability to learn. A recent and rapidly growing trend is to design schools with the specific intent of providing healthy, comfortable and productive learning environments. These green, high performance schools generally cost more to build, which has often been considered a major obstacle at a time of limited school budgets and an expanding student population.

Conventional schools are typically designed to just meet the building codes that are often incomplete. Design of schools to meet minimum code performance tends to minimize initial capital costs but delivers schools that are not designed specifically to provide comfortable, productive, and healthy work environments for students and faculty.

Few states regulate indoor air quality in schools or provide for minimum ventilation standards. A chronic shortage of funds in schools means that schools typically suffer from inadequate maintenance, resulting in degradation of basic services such as ventilation and lighting systems. Not surprisingly, a large number of studies have found that nationally, and in Massachusetts in particular, schools are unhealthy - increasing illness and absenteeism and bringing down test scores. Greening school design provides an extraordinarily cost-effective way to enhance student learning, reduce health costs and, ultimately, increase school quality and competitiveness at both the student and state level.

The main reason for cities and states to adopt green building requirements is to cut costs, improve services, and address a broad array of challenges such as:

- The high and rising cost of energy.
- Worsening power grid constraints and power quality problems.
- Increasing cost of waste, water, and waste disposal and associated costs of water pollution.
- Continuing state and federal pressure to cut air pollution.
- Rising concern about global warming.
- Reversing the alarming rise of asthma and allergies in children.
- Increasing state competitiveness in quality of life indicators such as air and water quality, quality of schools, and the skills of its work force.

This analysis finds that greening schools provides an extremely cost-effective way to help address all these challenges. The financial benefits of greening schools are 10 to 20 times as large as the cost. Green school construction costs 1.5% to 2.5% more than conventional school construction, almost \$4 more per ft^2 for a typical \$25 million, 125,000 ft^2 school built for 900 students. The financial savings are about \$70 per ft^2, more than 10 times as high as the cost of going green. Only a portion of these savings accrue directly to the school. Lower energy and water costs, improved teacher retention, and lowered health costs save green schools directly about \$15/ft^2, about four times the additional cost of going green. Financial savings state-wide are significantly larger, and include lower energy costs, reduced cost of public infrastructure, lower air and water pollution, and a more skilled and better compensated workforce.

Table 1-1. The Financial Benefits of Green School Design (\$/ft2)

Energy	\$14
Emissions	\$1
Water and wastewater	\$1
Increased Earnings	\$37
Asthma Reduction	\$4
Cold and Flu Reduction	\$4
Teacher Retention	\$4
Employment impact	\$3
TOTAL	**\$68**
COSTS OF GREEN DESIGN	\$4
NET FINANCIAL BENEFITS	**\$60- \$70**

Massachusetts state law currently requires the provision of an additional 2% in funding for public schools that achieve "industry energy efficiency standards." To date, this incentive has only been offered to schools participating in the Massachusetts Green Schools Initiative, a pilot program managed and funded jointly by the Massachusetts Technology

Collaborative (MTC) and the Massachusetts Department of Education. Based on the findings of this report, extension of the 2% incentive for all high performance schools would be a prudent and cost-effective policy. The large net financial benefits from greening also indicate that a state-wide requirement to build only healthy and efficient green schools is also fiscally prudent.

Green schools provide a range of additional benefits that were not quantified in this report, including reduced teacher sick days, reduced operations and maintenance costs, reduced insured and uninsured risks, improved power quality and reliability, increased state competitiveness, reduced social inequity, and educational enrichment. There is insufficient data to quantify these additional benefits, but they are significant and, if calculated, would substantially increase the recognized financial benefits of greening schools.

Despite limits in data and need for additional research, there is now very substantial experience with high performance schools in Massachusetts and nationally. A large body of documented studies and experience allows quantification of costs and benefits of greening schools. For example, there are several thousand studies that examine the impact of high performance design features such as better lighting, temperature control, and improved indoor air quality on health and/or productivity. Analysis of the costs and benefits of 30 green schools nationally, including 12 in Massachusetts, and use of conservative and prudent financial assumptions in analyzing available data provides a clear and compelling case that greening schools today is extremely cost-effective from a financial standpoint. Building Green schools is today significantly more fiscally prudent and lower risk than continuing to build unhealthy, inefficient schools.

1.1. Context

This study was commissioned by the Massachusetts Technology Collaborative to provide a brief review of the costs and benefits of green schools in order to help determine whether greening schools is cost-effective and whether Massachusetts should mandate or provide financial incentives for all its public schools to be high performance schools. At the same time, Boston is considering joining cities such as Atlanta, Chicago, Dallas, Houston, Los Angeles, New York, Phoenix, Portland, Sacramento, Salt Lake City, San Diego, San Francisco and Seattle that already require that all future publicly funded construction (generally including publicly funded schools) be green.[1]

Green or high performance building is a very rapidly growing industry, already representing 5% of non-residential construction and growing about 50% per year. The 6,000 member US Green Building Council, through a consensus process, has developed the national green building standard called Leadership in Energy and Environmental Design (LEED). An application of LEED for schools, called the Collaborative for High Performance Schools (CHPS), was developed for California schools initially and has been adapted for Massachusetts schools (MA-CHPS).

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[1] See: http://www.usgbc.org/Docs/Member_Resource_Docs/toolkit_statelocal.pdf

This analysis draws heavily on the 2003 Capital E report "The Costs and Financial Benefits of Green Buildings, A Report to California's Sustainable Building Task Force," developed for 40 state agencies.[2] The report was the first to attempt to develop a rigorous analysis of the costs and benefits of green buildings. This report found that the average cost premium for green buildings was 2%. Draft findings of the report helped persuade the University of California Board of Regents to adopt the "Green Building Policy and Clean Energy Standard," a university-wide policy expected to affect billions of dollars of future higher education construction in California.[3] The findings informed a 2004 California Executive Order requiring that future publicly funded construction and retrofits be green.[4] In September 2005, New York City adopted legislation requiring that all NYC public buildings meet the US Green Building Council's standard for LEED silver or certified, depending on building type. This legislation references the 2003 Capital E report as its cost-effectiveness rationale. These initiatives will directly drive over $25 billion in green construction over the next decade. Based in part on the 2003 report, Boston Mayor Menino's Green Building Task Force developed a set of recommendations for accelerating adoption of green schools, which are now being implemented.[5]

A 2004 review of over 100 green buildings by the firm Davis Langdon mapped green and conventional building costs and found that there was no apparent difference in price.[6] The report does not analyze green building costs in any detail, but does provide another strong argument that there is little difference in cost between green and conventional buildings.

Until recently, there has been a widespread belief that green buildings are significantly more costly than conventional design. The building industry publication *Consulting – Specifying Engineer* in October 2002 noted that: "the perception that green design is more expensive is pervasive among developers and will take time to overcome."[7] This view is changing with the recent reports cited above and the very rapidly growing body of experience in building high performance buildings at little cost premium.

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[2] Kats, Greg et al. "The Costs and Financial Benefits of Green Buildings, A Report to California's Sustainable Building Task Force", California Sustainable Building Task Force, October 2003, available at www.cap-e.com. Principal Author: Greg Kats, Capital E, Contributing Authors: Leon Alevantis, Department of Health Services, Adam Berman, Capital E, Evan Mills, Lawrence Berkeley National Laboratory ,and Jeff Perlman, Capital E. The report was developed for the Sustainable Building 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.

[3] "UC Adopts Landmark Green Building Policy and Clean Energy Standard", Press release from the Office of the President of the University of California, July 17, 2003.

[4] http://www.dot.ca.gov/hq/energy/ExecOrderS-20-04.htm

[5] www.cityofboston.gov/bra/gbtf/documents/GBTF%20Executive%20Summary.pdf

[6] See: http://www.dladamson.com/Attachment%20Files/Research/costinggreen.pdf

[7] Siddens, Scott, Senior Editor, "Verdant Horizon," *Consulting –Specifying Engineer*, October 2002, pp. 30-34. Available at: http://www.syska.com/Sustainable/news/index.asp.

In 2005 The *Wall Street Journal* reported: "People will always need buildings, and the next generation wants them green. By far, the most talked about topic in the architecture universe is how to reduce the environmental impact of everything from summer cottages to skyscrapers."[8] A leading construction industry publication described sustainable development as "the most vibrant and powerful force to impact the building and construction field in a decade." Despite the rapid growth in green building adoption, the issue of cost-effectiveness remains the largest issue affecting adoption of green design requirements for schools and other buildings.

[8] Frangos, "Greener and Higher," *Wall Street Journal*, Jan. 31, 2005, R4.

2. Methodology and Assumptions

Data were taken from 30 green schools nation-wide, and then mapped onto Massachusetts-specific costs and characteristics, e.g., energy costs, teacher earnings, etc. The findings are therefore Massachusetts-specific though are nationally applicable.

2.1. Net Present Value Calculations

Conventional schools usually have lower design and construction costs and higher operational costs, whereas green schools usually have higher design and construction costs and lower operational costs. To evaluate the current value of a future stream of financial benefits and costs, we use net present value (NPV) analysis, with 2006 as our base year. NPV represents the present value of an investment's discounted future financial benefits minus any initial investment. A positive number indicates a good investment.

Typically, financial benefits for individual elements are calculated on a present value basis and then combined with net costs to arrive at a net present value estimate.

2.2. Term

This report assumes a 20 year term for benefits in new buildings. We assume a lower 15 year term for energy efficiency savings in existing buildings. A longer term is assumed for a new building because green design affects more permanent features – such as orientation, wall construction, and amount of insulation – which tend to last for the life of building, typically at least 50 years.[9] These long-life design characteristics are complemented by shorter-term design features such as lighting fixtures, typically replaced every 15 years or so. A conservative estimated lifetime for the combination of these two sets of elements is about 20 years.[10]

When a building undergoes a green retrofit, the long-term design features are usually not affected. Greening an existing building typically involves upgrading lighting and light controls, interior furnishings, and sometimes elements such as motors and windows. The average life of building energy efficiency retrofit measures in Massachusetts energy efficiency programs is about 14 years.[11] Consistent with Massachusetts and conventional

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[9] July 2004 legislation governing the Massachusetts School Building Authority in managing public school construction funding anticipates a useful school life of at least 50 years.
See 603 CMR 38.00, Education laws and regulations, School Construction, available at http://www.doe.mass.edu/lawsregs/603cmr38.html?section=03

[10] A 25 year term is used in other studies, such as "Washington High Performance School buildings: Report to the Legislature", Washington State Board of Education and Office of the Superintendent of Public Instruction, prepared by Paladino & Company, Jan 2005.

[11] Division of Energy Resources, Summer 2004, "An Annual Report to the Great and General Court on the Status of Energy Efficiency activities in Massachusetts for the year 2002" can be accessed at http://www.mass.gov/doer/pub_info/ee02-long.pdf. Green building upgrades appear to be slightly more comprehensive than Massachusetts energy efficiency programs and therefore have a slightly longer average upgrade lifetime.

practice, we will assume that the average period of benefits for greening of an existing building is 15 years.

2.3. Inflation

This analysis assumes an inflation rate of 2% per year, in line with most conventional inflation projections.[12] Unless otherwise indicated, this report makes a conventional assumption that most costs as well as benefits rise at the rate of inflation. The things that are not assumed to rise at the rate of inflation are energy, emissions value, water, waste water and health costs - these all rise faster than inflation. The rate increases for these are discussed in the relevant sections.

2.4. Discount Rate

To arrive at present value and net present value estimates, projected future costs and benefits must be discounted to provide a fair value in today's dollars. Present value calculations are made on the basis of a relatively conservative 7% discount rate (i.e., 5% real inflation rate plus an assumed 2% inflation).[13] This is higher than the rate at which states, the federal government, and many corporations borrow money.[14]

2.5. Schools Data

Our data on costs as well as savings compared to a conventional building were generally supplied by the schools' architects. Some schools have actual performance data while some are not yet complete. Thus some of the costs analyzed in the report are based on actual building performance, while some are based on architectural modeling and engineering estimates. For more information on the schools reviewed in this report, see Appendix A.

2.6. Green Building Terminology

Green building design guidelines are characterized by a soup of acronyms. All are based on the US Green Building Council's Leadership in Energy and Environmental Design (LEED), which is the national consensus green building standard. An application of LEED for schools was developed for California schools, and is called Collaborative for High Performance Schools (CHPS).[15] This standard was then adapted for Massachusetts schools, It is now known as the Massachusetts High Performance Green Schools

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[12] See, for example: http://oregonstate.edu/Dept/pol_sci/fac/sahr/cf166503.pdf and http://www.jsc.nasa.gov/bu2/inflateGDP.html.

[13] 7% (e.g., 5% real plus inflation) is consistent with the Kats/California Report and is higher (more conservative) than the Washington State high performance school study, which used 5% discount rate., op cit, Washington State Board of Education

[14] 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. See also: http://oregonstate.edu/Dept/pol_sci/fac/sahr/cf166503.pdf and http://www.jsc.nasa.gov/bu2/inflateGDP.html.

[15] Collaborative for High Performance Schools, http://www.chps.net

Guidelines, or MA CHPS.[16] In December 2003, Washington State released its own Washington Sustainable School (WSS) Protocol for High Performance Facilities,[17] also based on a variant of CHPS. Each is slightly different, generally learning from the standard before. All school specific applications are based on LEED.

The green schools we analyzed were based on either LEED, MA CHPS, or WSS. The schools in our analysis that supplied us with scorecards for these different standards had achieved the following average distributions of points (note that some schools provided data for multiple standards).

Table 2-1. A Comparison of Point Achievements for Green Schools Under Different Green Building Standards

	Possible MA-CHPS Points	MA-CHPS Avg. (16 schools)	Possible LEED Points	LEED Avg. (10 schools)	Possible WSS Points	WSS Avg. (2 schools)
SITE	14	7.8	14	6.5	16	10.7
WATER	7	2.6	5	3.4	6	3.0
ENERGY	27	8.6	17	7.2	20	9.3
MATERIALS	11	2.3	13	6.3	17	6.3
IEQ	24	10.6	15	10.1	21	14.0
EXTRA CREDIT	13	3.4	5	4.1	8	3.7
TOTAL	**96**	**35.3**	**69**	**37.6**	**88**	**47.0**

These green schools achieved the prerequisites and on average about one-half the available credits/points.

[16] http://www.mtpc.org/RenewableEnergy/green_schools/chps_standards.htm Also see: http://www.mphaweb.org/pol_schools_green.html for valuable set of resources

[17] O'Brien & Company, Inc. and Olympic Associates, Inc. "Washington Sustainable Schools Program – Phase 2. Pilot Project – Final Report." P.1

3. The Cost of Building Green Schools

The "green premium" is the initial extra cost to build a green building as opposed to a conventional building. Typically this cost premium is a result of more expensive (and sustainably-sourced) materials, more efficient mechanical systems, and better design modeling and integration and other high performance features. However, some architects report no cost premium or even "negative" cost premium. Many schools architects use a state or school district's pre-determined budget as their metric for appropriate school cost. Green schools are frequently built on the same budget as conventional schools.

However, typically green does cost more. For this report, we relied on the costs reported by architects based on their actual and modeled green and conventional versions of the same building. For a full breakout of all schools analyzed, see Appendix A.

For schools, there is a range of construction costs depending on location and school type. Massachusetts School Building Assistance approved funding for school construction for fiscal year 2005 at the following levels per square foot:[18]

- Vocational School $225
- High School $211
- Middle School $198
- Elementary School $187

An average cost of construction for Massachusetts schools in 2006 is assumed to be $\$200/ft^2$, or \$25 million, for an average 125,000 ft^2 school, designed for 900 students.[19]

Overall, we find a less than 2.5% cost premium for green schools. The recently released report by HMFH, a Massachusetts based architectural firm, shows incremental costs of eight Massachusetts green schools at a 3.19% premium before incentives and a 0.77% premium after all incentives.[20] (Note that the national data set in this study includes data from the HMFH study. However, buildings in the HMFH Study that received a special 2% incentive from the state – 7 out of 8 schools – had their post-incentive green premiums recalculated to remove this 2% incentive, since it is not readily available to all schools. (See Table 3-1.) Achieving MA CHPS costs, on average, 1.5% to 2.5% more than conventional school design. Achieving MA CHPS prerequisites cost no more or between 0% and 0.5% and provides a slightly higher minimum performance level than conventional school design.

[18] HMFH Architects, Inc. and Vermont Energy Investment Corp. "The Incremental Costs and Benefits of Green Schools in Massachusetts," MTC, 2005. Note that the Massachusetts School Building Assistance program, formerly operated by the Massachusetts Department of Education, has been suspended. Its function was assumed by the newly established Massachusetts School Building Authority (MSBA).
[19] Based on average school size and attendance available from Massachusetts Department of Education and discussions with DOE personnel including Christine Lynch and Andrea Ranger, November 2005.
[20] HMFH Architects, Inc. and Vermont Energy Investment Corp. "The Incremental Costs and Benefits of Green Schools in Massachusetts," MTC, 2005.

Table 3-1. MTC Green Schools Incremental Costs, Without Renewable Energy Elements (e.g., Solar Photovoltaics)

Project	Green Premium without incentives	Green Premium with incentives	Green Premium with incentives, without state 2% incentive
Ashland	3.21%	-0.09%	1.91%
Berkshire	5.06%	1.99%	3.99%
Blackstone*	1.90%	0.91%	0.91%
Danvers	3.78%	1.79%	3.79%
Dedham	3.53%	0.89%	2.89%
Melrose	1.83%	0.02%	2.02%
Whitman-Hanson	2.83%	-0.50%	1.50%
Woburn	3.41%	1.07%	3.07%
AVERAGE	**3.19%**	**0.77%**	**2.51%**

*Source: HMFH Study, * - did not receive 2% incentive*

Overall, we find that those schools that achieve the LEED gold level cost more than those that achieve only lower levels of LEED. Schools exhibit increasing energy and water savings at higher LEED levels, as shown in Figure 3-1.

Figure 3-1. Green School Cost Premium and Performance vs. LEED Level

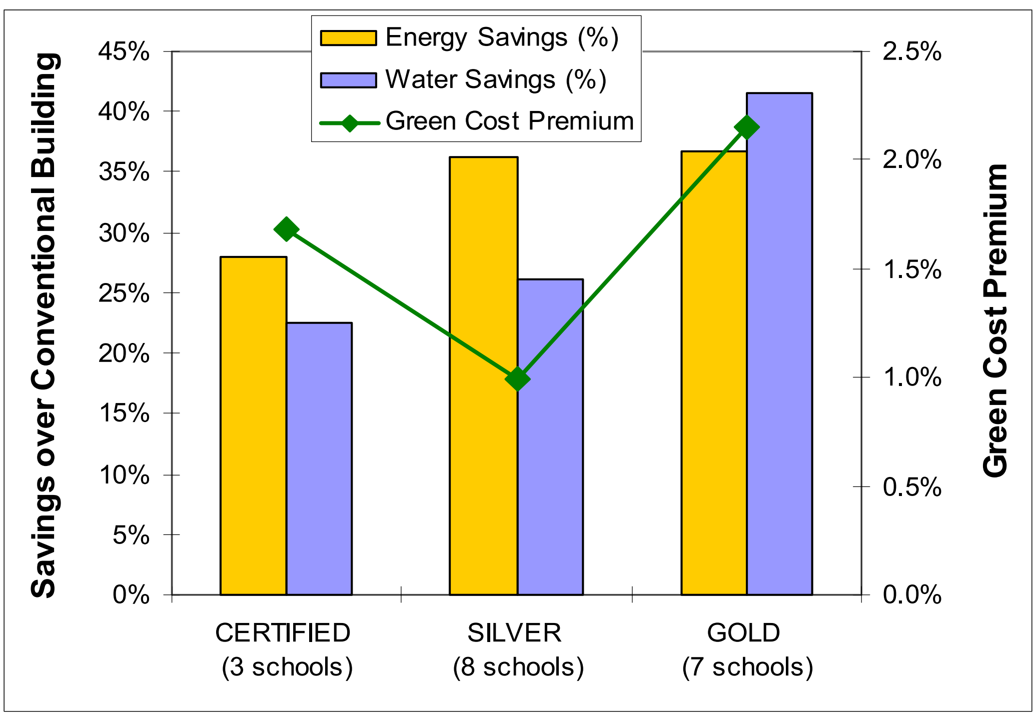

Table 3-2. The 12 Massachusetts Schools Analyzed in This Report

Name	Year Completed	2005 MA-CHPS	LEED Score	Cost Premium	Energy Savings	Water Savings
Ashland High School*	2005	19		1.91%	29%	
Berkshire Hills Regional Middle School*	2004	27		3.99%	34%	0%
Blackstone Valley Regional Vocational Technical High School*	2005	27		0.91%	32%	12%
Michael E. Capuano Early Childhood Center	2003		26	3.60%	41%	
Crocker Farm School	2001	37		1.07%	32%	62%
Danvers—Holten-Richmond Middle School*	2005	25		3.79%	23%	7%
Dedham Middle School*	2006	32		2.89%	29%	78%
Newton South High School			32	1.36%	20%	20%
Melrose Middle School*		36		2.02%	29%	35%
Whitman-Hanson Regional High School*	2005	35		1.50%	35%	38%
Williamstown Elementary School	2002	37		0.00%	31%	
Woburn High School*	2006	32		3.07%	30%	50%
AVERAGE				**2.18%**	**30.4%**	**33.6%**

*Data Supplied by the Architects except for * - from Doug Sacra, HMFH Architects, November 2005. See Appendix A for more on sources.*

Table 3-3. All 30 National School Buildings Analyzed in This Report

Name	State	Year Completed	2005 MA-CHPS	LEED Score	LEED Level	Cost Premium	Energy Savings	Water Savings
Ash Creek Intermediate School	OR	2002				0.00%	30%	20%
Ashland High School*	MA	2005	19			1.91%	29%	
Berkshire Hills*	MA	2004	27			3.99%	34%	0%
Blackstone Valley Tech*	MA	2005	27			0.91%	32%	12%
Capuano	MA	2003		26	1-CERTIFIED	3.60%	41%	
Canby Middle School	OR	2006		40	3-GOLD	0.00%	47%	30%
Clackamas	OR	2002		33		0.30%	38%	20%
Clearview Elementary	PA	2002	49	42	3-GOLD	1.30%	59%	39%
Crocker Farm School	MA	2001	37			1.07%	32%	62%
C-TEC	OH	2006	35	38	2-SILVER	0.53%	23%	45%
The Dalles Middle School	OR	2002			2-SILVER	0.50%	50%	20%
Danvers*	MA	2005	25			3.79%	23%	7%
Dedham*	MA	2006	32			2.89%	29%	78%
Lincoln Heights Elementary School	WA	2006			2-SILVER		30%	20%
Newton South High School	MA			32	1-CERTIFIED	1.36%	20%	20%
Melrose*	MA		36			2.02%	29%	35%
Model Green School	IL	2004		34	2-SILVER	0.99%	30%	20%
Prairie Crossing Charter School	IL	2004		34	2-SILVER	3.00%	48%	16%
Punahou School	HI	2004		43	3-GOLD	6.27%	43%	50%
Third Creek Elementary	NC	2002		39	3-GOLD	1.52%	26%	63%
Twin Valley Elementary	PA	2004	41	35	2-SILVER	1.50%	49%	42%
Summerfield Elementary School	NJ	2006	42	44	3-GOLD	0.78%	32%	35%
Washington Middle School	WA	2006		40	3-GOLD	3.03%	25%	40%
Whitman-Hanson*	MA	2005	35			1.50%	35%	38%
Williamstown Elementary School	MA	2002	37			0.00%	31%	
Willow School Phase 1	NJ	2003		39	3-GOLD		25%	34%
Woburn High School*	MA	2006	32			3.07%	30%	50%
Woodword Academy Classroom	GA	2002		34	2-SILVER	0.00%	31%	23%
Woodword Academy Dining	GA	2003		27	1-CERTIFIED	0.10%	23%	25%
Wrightsville Elementary School	PA	2003		38	2-SILVER	0.40%	30%	23%
AVERAGE						**1.65%**	**33.4%**	**32.1%**

*Data Supplied by the Architects except for * - from Doug Sacra, HMFH Architects, November 2005. See Appendix A for more on sources.*

Increased cost of green design is typically at least partially offset by savings elsewhere, for example in reduced cost of HVAC systems or in reduced code compliance costs. Increased water retention through the use of a green roof can avoid the capital cost of a water retention system normally required to comply with water codes. An example of reduced capital costs from integrated design is the model green school developed by the architectural firm OWP/P for the Chicago market. The school includes a green roof that allows the building to avoid the water retention system, providing savings sufficient to reduce the school cost premium to 1%.[21]

[21] Personal communication with architect Kevin Hall, OWP/P.

4. Energy Cost Savings in Green Schools

Reduced energy use is perhaps the most widely recognized benefit of green design. Energy costs are volatile and rose steeply in 2005.

Green, energy efficient schools use less energy than conventionally designed energy inefficient schools. Typical energy performance enhancements include more efficient lighting, greater use of daylighting and sensors, more efficient heating and cooling systems and better insulated walls and roofs.

Massachusetts schools use electricity, heating oil and gas. Recent trends include increased use of air conditioning and a shift from oil to natural gas for heating purposes. A review of eight Massachusetts schools showed that they spend about 70% of their energy budget on electricity and 30% natural gas.[22] New schools generally do not use heating oil except in the western part of the state, where there is limited natural gas infrastructure.[23]

Note on Energy Efficiency in Schools

Optimizing the use of energy in schools requires an integrated approach which begins with a focus on reducing the energy loads. Energy modeling in the early stages and throughout the design phases can be used as a design tool to guide decision-making.

Orientation of the building to minimize east/west exposures and maximize south/north exposures can significantly reduce energy consumption. Many schools tend to be external load dominated, so particular attention should be paid to optimizing the thermal envelope performance through higher levels of insulation and high performance windows (triple-pane can be justified in some cases). A critical, lynch-pin load is lighting design. Effective daylighting strategies, occupancy sensor controls and lighting designed at under 1.0 watts/square foot can reduce the internal heat gains from lighting by 40% to 50%, saving energy, reducing loads and lowering the first cost of the lighting system in many cases.

Overall load reductions of 40% or more are possible with a combination of energy efficiency strategies. This reduction in loads translates into a first cost savings since the selected HVAC system can be smaller. Quite often this reduced first cost will pay for all of the energy efficiency strategies, resulting in a building which significantly reduces operating costs without increasing the building's first cost.

Whichever HVAC system is selected (the appropriate system will vary considerably depending upon numerous factors such as climate, utility rates, etc.), its performance

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[22] Analysis of base case energy data for 8 green schools data supplied by Doug Sacra, HMFH Architects, Inc., November 2005.
[23] Personal Communication with Kim Cullinane, MTC, referencing MSBA. (11/17/05)

should be optimized to include high efficiency equipment, variable speed drives, high efficiency motors, and appropriate control strategies like demand controlled ventilation.

The green Neptune Township Community School in New Jersey was able to reduce its heating/cooling loads by over 40% through a combination of energy efficiency measures such as good lighting design, daylight dimming, additional insulation and triple pane windows. The extra cost of these measures amounted to $125,000. However, the load reduction strategies reduced the cost of the groundsource heat pump system by $400,000, resulting in a net first cost reduction of $275,000. The project is projected to reduce energy cost by over 50% compared to a code compliant facility, saving more than $80,000 per year.

-- Marcus Sheffer, 7group, November 2005

Reduced energy consumption in green schools has two distinct financial energy benefits: (1) direct reduction in school energy costs, and (2) indirect secondary impact from reduced overall market demand and resulting lower energy prices market-wide. Direct savings are in the form of lower bills to the school. Indirect savings result from the impact that reduced demand has in lowering the market price of energy. This indirect impact shows up in minute changes in price across entire markets. For an individual school, the price impact is miniscule, but state-wide the cost impact of reduced energy consumption can be substantial.

4.1. Direct Energy Cost Savings

Energy costs typically represent only 2-4% of school districts budgets. However, many elements of the budgets are fixed costs that cannot be reduced without reducing programs. As a percentage of manageable costs, energy is about 16%.[24] Thus, cutting energy use by a third has a very real positive impact on school budgets.

4.1.1. Energy Prices

Energy prices have surged in the last year. In October 2005, the Energy Information Administration and the National Energy Assistance Director's Association projected heating costs jumping by 35% to 50% in the winter of 2005.[25] For this report, we use the following energy price estimates for 2006:

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[24] HMFH Architects, Inc. and Vermont Energy Investment Corp. "The Incremental Costs and Benefits of Green Schools in Massachusetts", MTC, 2005.

[25] Energy Information Administration, October 12th, 2005, "Short-Term Energy Outlook", See: http://www.eia.doe.gov/emeu/steo/pub/contents.html, and http://www.neada.org/comm/press/pr041025.pdf Note that natural gas and oil prices have risen sharply while electricity prices rises have been more modest both because fuel cost is only a portion of electricity prices and because electricity prices increases are typically phased in gradually through a regulatory review process.

Table 4-1. Energy Price Estimates Used in this Report

Electricity	$0.15 kWh
Heating oil	$2.50/gallon
Natural gas	$1.50/therm
Annual Increase	4% per year (2% above inflation)

Source: Mike Sherman, Energy Efficiency Group Manager at the Massachusetts Division of Energy Resources (DOER).[26]

4.1.2. Direct Energy Savings

For the 30 green schools reviewed in this report, the average energy reduction compared with conventional design is 33%. This reduction is slightly higher than the eight green schools evaluated by the HMFH report, which found energy savings of 30%.

Table 4-2. Annual Energy Costs for Conventional vs. Green Schools

	Conventional School	Green School	Difference/ Savings
Electric	$1.24	$0.92	$0.33
Natural Gas	$0.57	$0.35	$0.22
Total	**$1.81**	**$1.26**	**$0.55**

Source: Capital E Analysis

Energy prices are projected to rise 4% per year.[27] Over a 20 year period, and assuming 7% discount of future benefits of lower energy prices, the result is a present value of $\$10/\text{ft}^2$ for new schools. In green building upgrades of existing schools, the present value benefit of reduced energy use over a 15 year period at a 7% discount rate is $\$8/\text{ft}^2$. Note that the cost and benefits numbers in this report have all been rounded to the nearest whole dollar amount. Uncertainties about the data, including future price escalation, make greater precision misleading.

4.2. Indirect Energy Cost Savings

Market-wide energy cost savings represent an important additional benefit often not included in energy efficiency financial analyses. From a state or societal perspective, the financial benefit of lowered energy prices is substantial and provides an additional reason for public entities such as states to promote or require energy efficiency programs.

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26 Personal communication with Mike Sherman, October and November, 2005. As of November 5, 2005 the most recent planning numbers for 2005 winter peak natural gas are $1.92/Therm. Also: Andrea Ranger, Green Schools Specialist, Massachusetts School Building Authority.

27 In some schools percentage gas savings may be greater than electricity savings, but savings vary from school to school and this is a reasonable simplifying assumption.

The price impact from efficiency-driven reductions in demand can be significant. Some recent research indicates that a 1% reduction in national natural gas demand could lead to long-term average wellhead price reductions of 0.8% to 2%.[28]

A 2004 report by David O'Connor, Commissioner of the Division of Energy Resources and Beth Lindstrom, Director of the Consumer Affairs and Business Regulation Agencies on 2002 Massachusetts State Energy Efficiency Activities found that the indirect savings from lower overall energy prices due to lower energy demand amounted to $19.4 million.[29] This report found that these indirect energy cost savings are almost as large as the direct savings of $21.5 million at the facilities where the efficiency upgrades occurred. Thus, the indirect secondary financial benefits garnered from the lowered energy demand of Massachusetts energy efficiency programs are almost as large as the direct energy efficiency savings.

To be conservative, we assume the indirect price impact is 50% rather than 90% of the direct energy price reduction as found in the above Massachusetts 2004 study. Thus the impact of indirect energy cost reduction benefits for Massachusetts as a whole for new and retrofitted schools has a present value of $5/ft^2 over 20 years.

The total direct and indirect energy cost savings from a new green school compared with a conventional school is $14/ft^2. Total direct and indirect energy cost savings from a green upgrade of an existing school compared with a conventional school is $12/ft^2. Note that these numbers have all been rounded to the nearest whole dollar amount, as noted above.

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[28] Wiser, Ryan, Mark Bolinger and Matt St. Clair. "Easing the Natural Gas Crisis: Reducing Natural Gas Prices through Increased Deployment of Renewable Energy and Energy Efficiency." January 2005. p. 40. http://eetd.lbl.gov/EA/EMP

[29] O'Connor, David Commissioner of the Division of Energy Resources and Beth Lindstrom, Director of the Consumer Affairs and Business Regulation Agencies, "2002 Energy Efficiency Activities Report by the Division of Energy Resources", summer 2004, Office of Consumer and Business Affairs, Commonwealth of Massachusetts.

5. Emissions Reduction Benefits of Green Schools [30]

Residential, commercial and industrial buildings use about 45% of the nation's energy, including about 75% of the nation's electricity. Air pollution, from burning fossil fuels to heat buildings (natural gas and oil) and to generate electricity (coal, natural gas and oil) for these buildings, imposes considerable health, environmental, and property damage costs. Demonstrated health costs nationally include tens of thousands of additional deaths per year and tens of millions of respiratory incidents and ailments.[31]

Reduction in electricity and gas use in buildings means lower emissions of pollutants (due to avoided burning of fossil fuels) that are damaging to human health, to the environment, and to property. The health, environmental, and property damages associated with pollution from burning fossil fuels are only slightly reflected in the price of energy.[32] Estimating the costs of externalities is technically difficult.

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

- Oxides of Nitrogen (NO_x) – a principal cause of smog.
- Particulate matter (including particulate matter under 10 microns in diameter, known as PM_{10}) – a principal cause of respiratory illness and an important contributor to smog.
- Sulfur Dioxide (SO_2 or SO_x) – a principal cause of acid rain. (SO_x and SO_2 are functionally the same for the purposes of this report.)
- Carbon Dioxide (CO_2) – the principal greenhouse gas and the principal product of combustion.

Important pollutants, such as mercury and smaller particulates (e.g. $PM_{2.5}$), have large adverse health effects that are not addressed in this report. A more comprehensive analysis should evaluate the costs of a fuller set of these additional pollutants, especially small particulates and mercury. Additional fossil fuel related pollutants include reactive organic compounds (ROC,) carbon monoxide (CO), and Volatile Organic Compounds (VOCs).

5.1. Estimating Costs of Emissions for Massachusetts Schools

Since the energy crisis of the 1970's, energy efficiency has gained favor as a means of saving money. Meanwhile, health and environmental organizations have advocated reducing energy consumption to reduce emissions. Numerous efforts have been made to quantify these emission reductions. The quantification is complicated by the complex

[30] Pete O'Connor of GETF drafted a substantial portion of this section

[31] 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.

[32] For a valuable introduction and overview of past 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 .

nature of the electricity grid, the impact of pollution control regulations, and innate problems of projecting future energy consumption patterns.

Green, or high performance schools, that use 34% less energy due to more efficient equipment and better design, offer significant potential for emission reductions. Our calculations are based on electricity consumption of 8.57 kWh per square foot per year, gas consumption of 0.38 therms per square foot per year, and a total school space of 125,000 square feet.

As a rough estimate, this could lead to the following emission reductions *per school*:

- 1,200 pounds of nitrogen oxides (NO_x)
- 1,300 pounds of sulfur dioxide (SO_2)
- 585,000 pounds of carbon dioxide (CO_2)
- 150 pounds of coarse particulate matter (PM_{10})
- 2.6 grams of mercury (Hg)

The avoided emissions would have an economic value of approximately $4,000 per year, or about half a dollar per square foot over a 20 year period.

Determining avoided emissions is not trivial. The impact of government-mandated emissions trading programs may, in some cases, limit the emission reduction benefits of energy efficiency. The state's Public Benefit Set-Aside can prevent this from occurring if credits are obtained and retired, but only applies during the summer months. On the other hand, uncapped emissions, such as CO_2 and mercury, are generally assumed to be avoided whenever electricity generation is reduced.

5.2. The Value of Avoided Emissions

For some pollutants, including NO_x and SO_x, there is a well-established, liquid market and these market prices are the most available measure of the marginal price of emissions reductions. Because the current market for emissions is driven by caps set by regulations, and not by calculations of actual costs such as the health effects of emissions, these market prices underestimate the full health, property, and other costs associated with these air pollutants. This underestimate of actual costs by the market is particularly true for CO_2, the primary gas causing anthropogenic (human-induced) climate change.

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.[33] The United States is responsible for about one quarter of global greenhouse gas (GHG) emissions. Of this, the US building sector is responsible for about 45% of US CO_2 emissions. This includes residential, commercial and industrial buildings.

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

US buildings alone are responsible for more CO_2 emissions than those of any other entire economy in the world except China.[34]

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 significant financial 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."[35] 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.[36] A 2005 study by Harvard Medical School, Swiss Re and the United Nations Development Program summarizes a broad range of large economic costs that continued climate change and global warming, driven primarily by burning fossil fuels, will impose.[37]

A study funded by the EPA and conducted by researchers at Tufts University, Boston University, and the University of Maryland, estimated that by the end of this century, global warming threatens to send flood waters into Boston's downtown waterfront, the Financial District, and much of the Back Bay, and that coastal flooding would extend from Rockport to Duxbury. The study estimated that the financial costs of global warming to the Boston metropolitan area will range from $20 billion to as much as $94 billion over this century.[38] As Massachusetts Attorney General Tom Reilly observes "Global warming is no longer some abstract idea far off in the future — it's a serious threat of growing concern to the public."[39]

Costs for CO_2 are uncertain, although there is some consensus that early actions to reduce CO_2 emissions (such as the Regional Greenhouse Gas Initiative) will see a cost of control of approximately $5 per ton of CO_2 (not per ton of carbon). At the recommendation of the Executive Office of Environmental Affairs, we have employed CO_2 values of $2 per ton and $6 per ton.[40] By comparison, in April 2005, the California Public Utility Commission adopted a net present value of $8 per ton CO2, escalating at 5%/year, based on a cost

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

[35] 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/.

[36] 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.

[37] Climate Change Futures Health, Ecological and Economic Dimensions, Harvard medical Schools, Nov 2005. See: http://www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf

[38] http://www.commondreams.org/headlines05/0215-01.htm

Civil and Environmental Engineering Department, Tufts University, School of Public Policy, University of Maryland Center for Transportation Studies, Boston University Metropolitan Area Planning Council, August 2004, "Climate's Long-term Impacts on Metro Boston (CLIMB), Final report" available at http://www.tufts.edu/tie/climb/CLIMBFV1-8_10pdf.pdf

[39] http://www.ago.state.ma.us/sp.cfm?pageid=986&id=1110

[40] Personal communication with Sonia Hamel, Massachusetts Executive Office of Environmental Affairs.

stream of $5 per ton CO2 in the near term, $12.50 per ton CO2 by 2008, and $17.50 per ton CO2 by 2013 (CPUC Decision 05-04-024, Conclusion of Law 7).[41]

Emissions have an economic impact because of their effect on public health. The precise value of this effect is difficult to determine, but some efforts have been made in areas where allowance trading does not exist. In other cases, estimates of the cost of control can be used. For our analysis, we use the values in the following table.

Table 5-1. Estimated Emissions Values for Massachusetts

Pollutant	Value ($/lb)	Source
NO_x	$1.34	Average of NO_x allowance prices for October 2004-September 2005 (NO_x SIP Call region).
SO_2	$0.585	Average of SO_2 allowance prices for October 2004-September 2005 (national Acid Rain Program trading).
CO_2	$0.001 or $0.006	Rough estimate of trading value during initial period of Regional Greenhouse Gas Initiative trading
PM_{10}	$1.00	"Damage function" – economic impact of PM_{10} pollution – identified in a range of studies by researchers from LBNL[42]
Hg	$55,000	January 28, 2004 memorandum from EPA Clean Air Markets division regarding cost of control; cost of $1.6 billion to reduce 2010 emissions by 14.6 tons[43]

For more about the derivation of these values, see Appendix B.

5.3. Emissions Conclusion

We project the following avoided emissions for 2006:

Table 5-2. Electricity Emissions

Pollutant	2006 Marginal Rate (lbs/MWh)	Value of Avoided Emissions ($/lb)	Avoided Emissions (lbs/year)	Value of Avoided Emissions ($/year)
NO_x	1.34	$1.40	488	$681.26
SO_2	3.57	$0.33	1,300	$426.41
CO_2 at $2/ton	1088	$0.001	396,117	$396.12
CO_2 at $6/ton		*$0.006*		*$1188.35*
PM_{10}	0.19	$1.00	69	$69.20
Mercury	0.000016	$55,000	0.006	$320.52

Most avoided rates are based on the *MTC Avoided Emissions Calculator* for electricity. Appendix B details the methodology used in the *Calculator*. Mercury rates are based on projections from the Ozone Transport Commission's *Emission Reduction Workbook*.

[41] Personal communication with Will Clift at Rocky Mountain Institute.
[42] *Introduction to Environmental Externality Costs*, J. Koomey and F. Krause, Lawrence Berkeley National Laboratory, 1997. See http://enduse.lbl.gov/INFO/Externalities.pdf.
[43] http://www.epa.gov/mercury/pdfs/OAR-2002-0056-0048.pdf. This is a conservative (low) estimate.

Table 5-3. Natural Gas Emissions

Pollutant	Marginal Rate (lbs/MMBTU)	Value of Avoided Emissions ($/lb)	Avoided Emissions (lbs/year)	Value of Avoided Emissions ($/year)
NO_x	0.44	$1.40	711	$991.88
SO_2	0.001	$0.33	1.6	$0.53
CO_2 at $2/ton	117	$0.001	188,955	$188.96
CO_2 at $6/ton		*$0.006*		*$566.87*
PM_{10}	0.05	$1.00	81	$80.75

Table 5-4. Total Emissions Reductions

Pollutant	Avoided Emissions (lbs/year)	Value of Avoided Emissions ($/year)
NO_x	1,199	$1,673.14
SO_2	1,302	$426.94
CO_2 at $2/ton	585,072	$585.07
CO_2 at $6/ton		*$1,755.21*
PM_{10}	150	$149.95
Hg	0.006	$320.52
Total (CO_2 $2/ton)		***$3,155.63***
Total (CO_2 $6/ton)		***$4,325.77***

Over 20 years, emissions value at the low CO2 price of $2/ton is equal to $0.38/ft^2 for a green school. At the higher $6/ton price the present value of emissions reductions per square foot is $0.53/ft^2 from a green school, and this is the cost provided in this report.[44] As noted above, this value greatly understates the true cost of emissions. The large health, environmental and property damages associated with pollution from burning fossil fuels are only very partially reflected in the price of emissions.

[44] Emission value assumed to rise at 4% per year, discount at 7% per years for future benefits.

6. Water & Wastewater Impacts of Green Schools

Green design typically lowers water and wastewater costs by 20% to 40%. The 30 green schools evaluated here achieved an average water use reduction of 32%. This reduction has direct savings for the building as well as substantial societal benefits from lower pollution and reduced infrastructure costs to deliver water and to transport and treat wastewater. The nature and value of these benefits varies within and between states, depending on annual rainfall, population trends and other factors.

Massachusetts is a relatively water-rich state, with rainfall averaging a consistent 3-4 inches per month.[45] Most domestic water is delivered from municipal water systems (84%), and the majority of wastewater (58%) is flushed into public sewer systems.[46]

6.1. Green Schools Water and Wastewater Reduction Strategies

The Massachusetts Executive Office of Environmental Affairs finds that most communities can "save 15-30% of their water through water conservation efforts."[47]

6.1.1. Restroom Water Conservation Strategies

Toilets make up a substantial portion of the water used in school restrooms. In a 1989 revision to the plumbing code, Massachusetts became the first state to require "ultra low flush" toilets and water efficient plumbing in all new construction, remodeling and replacement projects.[48] The cost of water efficient appliances has decreased significantly recently. For example, the Melrose school in Massachusetts used costly dual-flush Caroma toilets at a premium of $950 each. However, the Sloan Valve Company has recently released an equivalent model for only $20 cost premium per unit, reducing the simple payback from 15.9 years to less than 1 year.[49]

6.1.2. Landscaping/Irrigation Water Efficiency

There is a range of landscaping water efficiency strategies. Rainwater, gray-water, and other non-potable water can be used for irrigation, while xeriscaping (use of native drought resistant species) can sharply reduce or even eliminate external use of water for irrigation. Advanced controls can minimize wasteful irrigation practices. Four of the eight schools studied in the recent HMFH report use cisterns to catch rainwater for irrigation. An early

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[45] Personal communication with Stephen Estes-Smargiassi, Director of Planning, MWRA, 9/30/05.
[46] Tighe and Bond *2004 Massachusetts Water Rate Survey*; *2004 Massachusetts Sewer Rate Survey*, 2004.
[47] Executive Office of Environmental Affairs, The Commonwealth of Massachusetts, "Securing our Water Future: Ensuring a Water Rich Massachusetts," presented to the Community Preservation Institute Alumni Class, September 30, 2002, p.1
[48] Massachusetts Water Resources Authority, "Facts About Ultra Low Flush Toilets," 2002, p1.
[49] HMFH Architects, Inc. and Vermont Energy Investment Corp. "The Incremental Costs and Benefits of Green Schools in Massachusetts", MTC, 2005.

MTC Green School Project, Capuano Early Childhood Education Center, utilizes drip irrigation.[50]

The Third Creek Elementary School in North Carolina combines waterless urinals, metering of faucets, low flow toilets and showerheads, and xeriscaping to cut overall water use by two-thirds compared with a conventional school.[51]

6.1.3. Wastewater Reductions

Buildings that use less water send less water into the sewer system. Stormwater runoff can overflow many older sewer systems. This problem can be mitigated by rainwater catchment systems and the installation of green roofs on buildings. Furthermore, some green buildings implement on-site waste water treatment systems, or reuse gray-water for toilets or irrigation.

6.2. Financial Benefits of Water and Wastewater Efficiency in Massachusetts

Prices typically reflect average rather than marginal costs. Because water and wastewater costs are generally rising, prices tend to substantially understate actual marginal cost of additional water and wastewater capacity borne by utilities and society at large.
There are two ways of assessing the value of water:

- The cost of purchasing a unit of water (price).
- The marginal cost, or cost of developing a new source to supply that water.

For an individual school, the first method is most useful. However, for a society or for a government (of which public schools are a part), it is prudent to consider marginal cost as well. Increased need for marginal additional water or wastewater treatment capacity impacts the retail cost of water for all consumers as higher marginal cost infrastructure costs get amortized through higher prices for all consumers.

6.2.1. Price of Water and Wastewater

From the Tighe and Bond Massachusetts Water and Sewer Rate Surveys, we estimate the following costs:

- Water: $0.0039/gallon[52]
- Sewer: $0.0052/gallon[53]

[50] HMFH Architects, Inc. and Vermont Energy Investment Corp. "The Incremental Costs and Benefits of Green Schools in Massachusetts", MTC, 2005.
[51] From Moseley Architects summary sheet, available from Chris Venable: cvenable@moseleyarchitects.com. The school achieved a LEED gold rating
[52] Tighe and Bond, *2004 Massachusetts Water Rate Survey*, p.2. Based on 90,000 gallons per household, annual water bills $45-$1,215, avg. $321, price normalized from 2004 to 2006.
[53] Tighe and Bond, *2004 Massachusetts Sewer Rate Survey*, p.2. Assuming consumption of 120 hundred cubic feet (90,000 gallons) of water per year, $120-$1329 per household per year, $408 average, price normalized from 2004 to 2006.

Based on the Tighe and Bond reports from 2002 and 2004, average Massachusetts water rates are increasing at about 4.5% annually and sewer costs are rising at about 7% annually.[54] The Boston Water & Sewer Commission projects an 8.6% increase each year from 2006 to 2010 for water and sewer services.[55] There will be rising capital needs for wastewater systems due to: the expiration of sewage treatment plants that will need replacement, higher drinking and wastewater standards, increased expense and controversy surrounding new sources of water, and greater abatement needed for non-point source pollution.[56] This report assumes a conservative (low) rate of cost increase of 4.5% per year for water and 7% for wastewater.

This report also makes a simplifying assumption that wastewater reductions are equivalent to water use reductions. In fact, wastewater reductions are dependent upon the types of water efficiency strategies implemented. Interior plumbing efficiencies effect both water and sewer use equally. Landscaping water efficiencies reduce water use but not sewer use. Rainwater catchment strategies can reduce sewer use during times of rain, but can also increase sewer demand beyond water demand if the rainwater is then used for toilets.

We calculate the following benefits:

Table 6-1. Average MA Green School Water Savings Based on National Average Green School Water Savings Percentage (Annual)

	Water	Wastewater
Base Case (gals/ft^2)	9.2	9.2
32% Savings (gals/ft^2)	3.0	3.0
Water Cost ($/gallon)	$0.00393	$0.00515
Cost Savings ($/ft^2)	$0.0116	$0.0152
20 Year PV ($/ft^2)	$0.18	$0.28

Note that rate structures vary and some (flat fee, descending rates that give a volume discount for increased water consumption) may diminish the financial benefits of water efficiency. The savings calculated above are based on state averages, assuming a flat rate structure.

6.2.2. Marginal Costs of Water and Wastewater

Marginal cost is harder to estimate than water and sewer prices. A recent EPA study found that nationally there is a gross under-investment in water delivery and treatment systems, indicating that current water utility rates will have to rise more steeply to secure the funds needed for required infrastructure upgrades. The EPA report 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. [57]

[54] Communication with Mary Beth Morris, author of the Tighe and Bond report, 8/10/05.
[55] Personal communication with William J. O'Brien, 9/8/05.
[56] Personal communication with Holly Stallworth, p.6
[57] *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.

The marginal cost of supplying more water to a municipality depends on available capacity. A low estimate of the cost of 1 million gallons a day (mgd) of new supply is about $5 million.[58] An 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.[59]

Currently, Massachusetts Water Resource Authority (MWRA), which supplies water to about one-third of Massachusetts, primarily to larger cites, has a substantial amount (over 20%) of excess capacity. This is largely attributable to a comprehensive water conservation program that reduced average daily demand from 336 mgd in 1987 to 256 mgd in 1997.[60] The result is that the marginal cost of additional supply in MWRA territory is currently quite low. In fact, because there are high fixed costs involved in maintaining the water collection, treatment and distribution infrastructure, increasing water consumption across the MWRA service territory could actually temporarily reduce prices for all customers. This, of course, is only true up to the point at which the system can no longer supply additional capacity and new water sources must be sought.[61]

Rapidly-growing suburban regions of Massachusetts are seeing far greater need for new supply. The Massachusetts Executive Office of Environmental Affairs developed buildouts (models assuming maximum development allowed under zoning) of all the communities in the Commonwealth. The model shows that the state will have 312,000 additional residents at buildout, will double the total developed land to 353,000 acres (70% of region), and will need a lot more water, 320 mgd, as shown below.

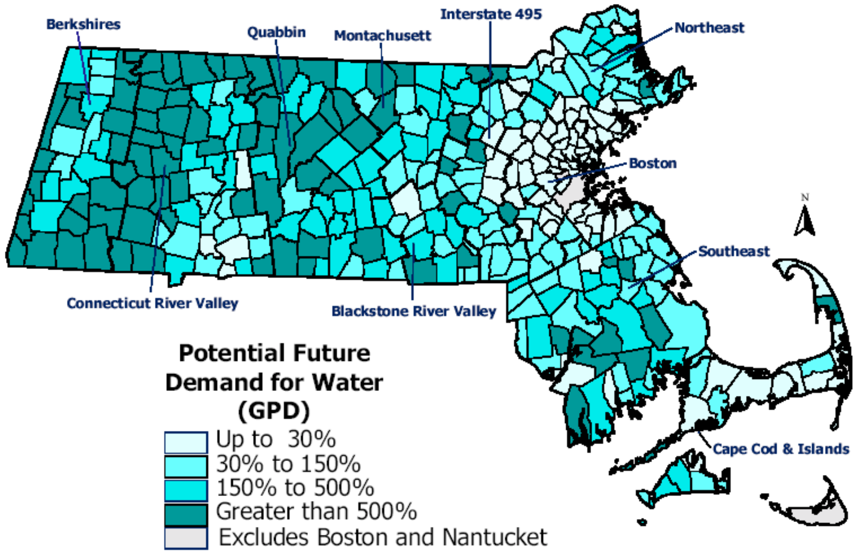
Table 6-2. MA Regions, Water Use Profile (in mgd)

MA Region	Current Water Use (Avg.)	Additional Water Demand at Buildout	Remaining Capacity in Region	Water Needed to Support Buildout
Interstate 495	63	47	-15	32
Northeast	103	35	-17	18
Southeast	114	115	-34	91
Central MA/Quabbin	64	98	-7	91
Western MA	108	118	-17	101
Boston	250	19	-36	-13
TOTAL	**702**	**432**	**-126**	**320**

Source: Massachusetts Executive Office of Environmental Affairs, 2002

58 Personal communication with Stephen Estes-Smargiassi, Director of Planning, MWRA, 9/30/05.
59 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/
60 United States Environmental Protection Agency, p.27-28
61 Personal communication with Stephen Estes-Smargiassi, Director of Planning, MWRA, 9/30/05.

Figure 6-1. Additional MA Water Demand at Buildout



Source: Massachusetts Executive Office of Environmental Affairs, 2002

Supply capacities must be sized to meet peak demand. Peak demand for water in Massachusetts typically occurs in June, with high usage in July and August as well.[62] The marginal cost of one gallon of new supply is about $5. If we assume school operation of 200 days, then water efficiency is worth about $\$0.05/ft^2$ in reduced capacity needs.[63]

6.2.3. Marginal Capacity of Wastewater Systems

When there is heavy and extended rainfall, wastewater systems commonly overflow. The benefits of some green building water strategies such rainwater catchment and green roofs are recognized by some municipalities. For example, in Dedham MA, the school design team, through providing rainwater storage capacity on site, saved the town the cost of enlarging an off-site stormwater detention facility. The city valued this infrastructure improvement at $400,000.[64]

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[62] Conversation with Stephen Estes-Smargiassi, Director of Planning, MWRA, 9/30/05.

[63] The cost of 1 mgd new capacity is about $5 – reference Stephen Estes-Smargiassi. 2.2 gal/ft2/yr / 200 days x $5/gallon = $0.05/ ft2. We assume comparable waste water savings This is almost certainly a underestimate.

[64] Sacra et al. "HMFH report, "water vignette"

6.3. Total Financial Benefits of Water and Wastewater Efficiency

The water and sewer benefits of green schools in Massachusetts are summarized below.

Table 6-3. Water and Wastewater Benefits of Green Schools in Massachusetts

	20 year present value ($\$/ft^2$)
Water Cost Savings	$0.18
Wastewater Cost Savings	$0.28
Water Marginal Capacity Savings	$0.05
Wastewater Marginal Capacity Savings	$0.05
TOTAL	**$0.56**

The total impact is about $0.50 per square foot over 20 years. This savings is almost certainly a large underestimate of the financial benefits of reduced water and sewer cost associated with green design. Nor does it reflect the large savings from reduced water runoff from green schools and the cost savings from reduced water pollution and increased groundwater recharging.

7. Construction & Demolition Waste Benefits of Green Schools

Waste reduction is an objective in both the construction and operation of green buildings. While there are financial benefits for operational waste reduction strategies such as recycling, this report focuses only on the financial benefits of waste reduction created during construction and demolition – what is commonly referred to as C&D waste.

About 25% of the solid waste discarded nationally is C&D waste, adding up to 130 million tons of waste per year.[65] About 5 million tons is generated annually in Massachusetts.[66]

Fifty-seven percent of national C&D waste comes from non-residential building projects,[67] deriving from three sources: [68,69]

- *demolition*, which creates about 155 pounds of waste per square foot, and makes up 58% of national non-residential C&D waste;
- *construction*, which creates about 3.9 pounds of waste per square foot, and makes up 6% of national non-residential C&D waste;
- *renovation*, which makes up 36% of national non-residential C&D waste.

C&D diversion rates are typically at least 50-75% in green buildings and have reached as high as 99% on some projects.[70] In a study of 21 green buildings submitted to USGBC for certification, 81% reduced construction waste by at lease 50%, while 38% reduced construction waste by 75% or more.[71] Green renovation 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.).[72]

The Green Schools studied in this report have an average C&D diversion rate of 74%, or about 0.005 tons/ft^2.

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[65] Lennon, Mark et al. *Recycling Construction and Demolition Wastes: A Guide for Architects and Contractors, April 2005*. The Institution Recycling Network. Page 3. http://www.wastemiser.com/CDRecyclingGuide.pdf

[66] Massachusetts Department of Environmental Protection, *3rd Annual Progress Report on the Beyond 2000 Solid Waste Master Plan,* September 2004, http://www.mass.gov/dep/bwp/dswm/files/swpr3.doc, page 9, Table 8.

[67] Kats, Greg et al. "The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainability Task Force." October 2003. www.cap-e.com

[68] Freyman, Vance. "Making plans: a New England Contractor conducts careful planning for its construction materials recycling program – Construction Recycling Trends," *Construction & Demolition Recycling*, Jan-Feb 2004. Downloaded 1/14/05 from www.findarticles.com

[69] 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

[70] California State and Consumer Services Agency and Sustainable Building Task Force. "Building Better Buildings: A Blueprint for Sustainable State Facilities." December 2001. p16.

[71] Data provided by USGBC

[72] LEED Reference Package. Version 2.0. US Green Building Council. June 2001. pages 170-180.

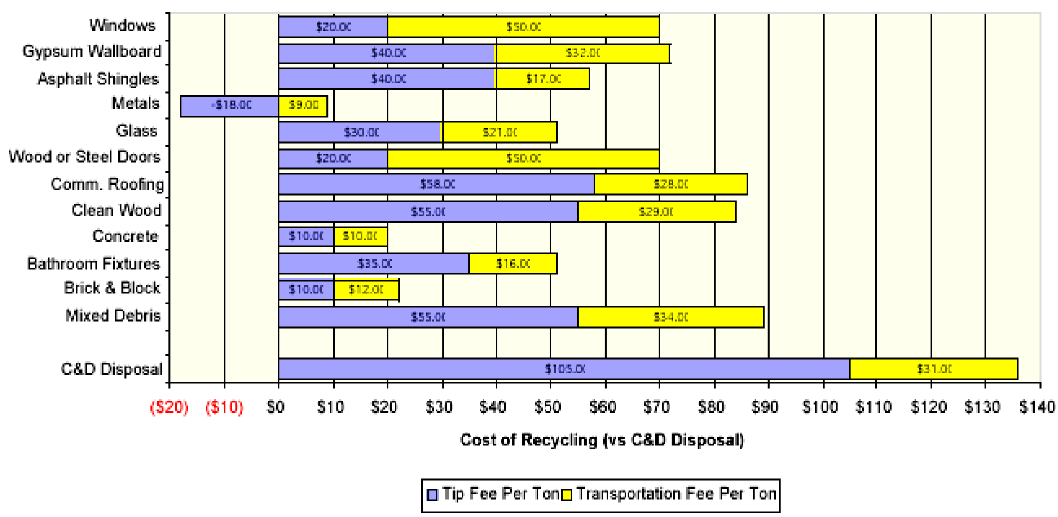
Table 7-1. Massachusetts C&D Waste Generation and Diversion (in tons, 2000)

Material Type	(a) Actual Generation	(b) Calculated Recycling Rate	(c) Recycled	(d)Disposed (and/or Exported)
Asphalt, Brick, Concrete (ABC)	3,635,998	90%	3,290,000	345,998
Wood	366,927	16%	60,000	306,927
Metal	99,400	70%	70,000	29,400

Source: Tellus Institute, 2002

Many building materials recovered from job sites are of a relative high quality. As markets for them become better established and collection costs drop, C&D recycling has become less expensive per ton than curbside or commercial recycling services.[73] The following chart shows that in the Boston area, costs of C&D diversion for all materials are cheaper than the cost of disposal (the last line).

Figure 7-1. The Cost of Recycling vs Disposal of C&D Wastes (Boston area)



Source: The Institution Recycling Network, 2005

All Costs in $/ton. Tip fee = cost to market the material to a recycler or dispose of waste in a landfill, Transportation fee = cost to reach the market (dependent on location and size of the containers used for transportation). Depicted costs are for Boston area projects. Pricing will vary depending on specific job locations.[74] For mixed debris recycled, usually 75%-90% is actually sorted, recovered, and reused.[75]

Appendix D of this report includes a review of six waste reduction projects in Massachusetts conducted since 2001.

[73] Kats, Greg, et al.,
[74] The Institution Recycling Network, May 15, 2005. downloaded 10/15/05 from http://www.wastemiser.com/costcomparisonchart.pdf
[75] Lennon, page 5.

7.1. Trends in C&D Waste Diversion in Massachusetts

The table below shows the trends of Massachusetts C&D waste management over the years 1998-2002.

Table 7-2. Massachusetts Solid Waste Management: C&D, 1998-2002 (in tons per year) [76]

	1998	1999	2000	2001	2002
Total Generation	4,270,000	4,700,000	4,480,000	4,540,000	4,820,000
Diversion	3,120,000	3,520,000	3,500,000	3,150,000	3,590,000
Other C&D Diversion*	-	-	300,000	510,000	590,000
% Diverted	73%	75%	85%	81%	87%
Landfill Disposal	1,070,000	920,000	660,000	620,000	520,000
% Disposed	25%	20%	15%	14%	11%

* For 2000, 2001 and 2002 total generation includes "other C&D Diversion" tonnage that was not included in previous years.
Source: MA DEP, Capital E analysis

As the table shows, C&D generation has been steadily increasing in Massachusetts, but so has diversion.

The issues of C&D Waste Reduction Strategies and Costs and Benefits of C&D Waste Diversion are dealt with at more length in Appendix D.

On July 1, 2006, the MA Department of Environmental Protection will impose a ban on the disposal of asphalt, pavement, brick, concrete, metal and wood.[77] These materials comprise over 91% of the Massachusetts C&D waste stream.[78] While green schools can reduce C&D waste a bit further than 91%, the capacity to do so is limited, leaving relatively little room for green schools to create benefits beyond a conventional building. As a result, we assign no additional financial benefit to Massachusetts green schools for C&D waste diversion.

[76] Massachusetts Department of Environmental Protection, *3rd Annual Progress Report on the Beyond 2000 Solid Waste Master Plan,* September 2004, http://www.mass.gov/dep/bwp/dswm/files/swpr3.doc, page 4, Table 4.
[77] Solid Waste Regulations, Department of Environmental Protection, Commonwealth of Massachusetts, 310 CMR 19.017 (effective date: 10/7/05)
[78] Analysis of data from *Waste Reduction Program Assessment and Analysis for Massachusetts*, Tellus Institute, December 2002. Based on: 4,480,000 tons of C&D waste total and 4,102,325 tons of ABC, Wood and Metal

8. Health and Learning Benefits of Green Schools

According the US General Accounting Office, 14 million students (over a quarter) attend schools considered below standard or dangerous and almost two-thirds of schools have building features such as air conditioning that are in need of extensive repair or replacement. This statistic does not include schools with less obvious but important health related problems such as inadequate ventilation. A recently published document by the American Federation of Teachers notes that the General Accounting Office found that the air is unfit to breathe in nearly fifteen thousand schools.[79]

A recent major review of 500 studies relating indoor air pollutants and thermal conditions in schools to student performance finds that American schools commonly feature unhealthy indoor air quality and related problems that adversely affect the learning environment of students and hurt student health and test scores. The study concludes:

> …much evidence links poor IEQ [indoor environmental quality] (e.g. low ventilation rates, excess moisture, or formaldehyde) with adverse health effects in children and adults and documents dampness problems and inadequate ventilation as common in schools. Overall, evidence suggests that poor IEQ in schools is common and adversely influences the performance and attendance of students.[80]

Poor health and study conditions in schools are of particular concern for a number of reasons, including:

1) There are some 55 million students, faculty and staff in schools.
2) The large majority of schools are built not to optimize design, but rather to achieve a minimum required level of design performance at lowest cost.
3) Few states regulate indoor air quality in schools or provide for minimum ventilation standards.
4) Almost no schools are designed with the specific objective of creating healthy, productive study and learning environments.
5) Chronic shortage of funds in schools means that schools typically suffer from inadequate maintenance and experience degradation of basic systems such as ventilation, air quality and lighting quality, as well as poor control over pollutants (e.g., from cleaning materials).

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[79] "An Environment for Learning," American Federation of Teachers, "The Hill", April 21, 2004. GAO, 1005, "School Facilities: America's Schools not Designed or Equipped for the 21st Century", GAO Report # HEHS-95-95. See also: Environmental Protection Agency, revised August 2003 "IAQ and student performance", available at http://www.epa.gov/iaq/schools/images/iaq_and_student_performance.pdf

[80] Mendell and Heath, "Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature" Indoor Air, 2004. Mendel is at Lawrence Berkeley National Laboratory and Heath is at Berkeley.

6) Students and faculty typically spend 85% to 90% of their time indoors (at home and at school), and the concentration of pollutants indoors is typically higher than outdoors, sometimes by as much as 10 or even 100 times.[81]
7) Children are growing and their organs are developing. They breathe more air relative to their body size than adults, and as a result sustain greater health problems and risks than adults from toxics and pollutants common in schools.[82]

There is growing recognition of the large health and productivity costs imposed by poor indoor environmental quality (IEQ). Business Week's cover for its June 5, 2000 issue, for example, featured a picture of a large menacing office building to accompany the feature story: "Is Your Office Killing You? The Dangers of Sick Buildings."[83] The article cites potential benefits of up to $250 billion per year from improved indoor air quality in US office buildings.

Active unions, desire to improve worker productivity, and concern about lawsuits have prompted corporate efforts to improve and maintain indoor air quality and work environments. Yet, despite the greater vulnerability of children to poor air and related adverse health conditions, schools have largely failed to ensure healthy and productive learning environments for our children. The costs of poor indoor environmental and air quality in schools, including higher absenteeism and increased respiratory ailments, have generally been "hidden" in sick days, lower teacher and staff productivity, lower student motivation, slower learning, lower tests scores, increased medical costs, and lowered lifelong achievement and earnings.

These problems appear to be particularly severe in Massachusetts schools. A report based on a 1999 federal study by the TEAM Education Fund (now the Massachusetts Budget and Policy Center) found that *Massachusetts has among the worst school buildings in the nation*. Another study, conducted jointly by the Department of Public Health and Department of Environmental Protection in 1999, found that *all 16 schools examined had indoor air quality problems and all violated at least one DEP environmental rule*.[84] (Italics added)

Because of poor indoor air quality and conditions in conventional schools, high performance schools would appear to present large opportunities to improve students'

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

[82] General Accounting Office, 1995, Mendell and Heath, "Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature" Indoor Air, 2004. Also see: "Do School Facilities Affect Academic Outcome", National Clearinghouse for Educational Facilities, Mark Schneider, Nov, 2002. See www.edfacilites.org

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

[84] Referenced in December 2002 report to the Senate Committee on Post Audit and Oversight of the Massachusetts Senate " Attacking Asthma, Combating an epidemic among our children." See www.state.ma.us/dph/beha/iaq/overview.htm Nov, 2002. The Senate Report notes that "The Department of Public Health (DPH) can conduct inspections of schools upon request, but cannot impose or enforce corrective actions."

health, quality of learning environment, test scores, and related measures of student well-being and performance. In this section we seek to quantify these benefits.

8.1. Impact of Poor School Conditions on Student Health and Learning

There is a large body of research linking health and productivity with specific building design operation attributes (e.g., indoor air quality and control over work environment, including lighting levels, air flow, humidity, and temperature). A National Science and Technology Council project entitled *Indoor Health & Productivity* provides a valuable database of 900 papers on the subject.[85] Most of these and other related studies and reports focus on occupants in commercial or public buildings and only a minority focus on schools.

Many reviews of the effects of classroom healthiness on students look only at school-specific studies. This limited scope unnecessarily limits the relevant data available to understand and quantify benefits of high performance, healthy design in schools. The tasks done by "knowledge workers" (including most non-factory white collar workers) – such as reading comprehension, synthesis of information, writing, calculations, and communications – are very similar to the work students do. Large-scale studies correlating green or high performance features to increased productivity and performance in many non-academic institutions are therefore relevant to schools.[86]

One of the leading national centers of expertise on the topic is the Center for Building Performance at Carnegie Mellon University. The Center's Building Investment Decision Support (BIDS) program has reviewed over 1,500 studies that relate technical characteristics of buildings, such as lighting, ventilation and thermal control, to tenant responses, such as productivity or health.[87] Collectively, these studies demonstrate that better building design correlates 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, such as typing, addition, proof reading, paragraph completion, reading comprehension, and creative thinking, were found to improve in high performance building ventilation, thermal control, and lighting control environments.[88]

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[85] 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.

[86] Vivian Loftness, former head of the School of Architecture at Carnegie Mellon makes this point eloquently. Personal communication 2003 and October 2005.

[87] Loftness, Vivian 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.

[88] Data extracted from BIDS™. Carnegie Mellon University Department of Architecture. Communication with Vivian Loftness, CMU, February 2003, October 2005.

Two studies of over 11,000 workers in 107 European buildings analyzed the health effect of worker-controlled temperature and ventilation. These studies found significantly reduced illness symptoms, reduced absenteeism and increased productivity relative to workers in a group whose workspace lacked these features.[89]

MA CHPS, LEED and other green building certifications are designed to specifically address the materials, designs, and operations affecting learning environment, productivity, and health issues discussed above. LEED, CHPS and MA CHPS all include prerequisites related to indoor air quality, commissioning, and related measures that are required for design. Credits directly relating to health and productivity are included in the Indoor Environmental Quality section of these rating systems. A review of green buildings scorecards, for both MA-CHPS and LEED confirms that these buildings include a range of material, design and operation measures that directly improve human health and productivity. In addition to achieving the prerequisites, the 30 green schools reviewed achieved about half the available IEQ points.

Table 8-1. IEQ Points Earned by Green Schools Under Different Rating Systems

Average IEQ Points for Schools		Max Possible
MA-CHPS (12 schools)	9.4	24
LEED (9 schools)	10.3	15
WSS (5 schools)	16	21

8.2. Health, Learning and Attendance Benefits in Green Schools

A recent major review of the impact of indoor pollutants and thermal conditions on student performance found that:

> A large body of evidence, much of it from studies of children, links microbiological and chemical exposures from indoor sources, building characteristics such as excessive dampness and (possibly indoor) exposures to pollutants from outdoors to respiratory infections, asthma, lower respiratory symptoms, and allergies, all documented to reduce school attendance... Indoor microbiological and chemical pollutants (including emissions from plastics) from indoor sources, and possibly from outdoor sources, as well as a variety of HVAC and building characteristics, have related to a broad range of additional [adverse] health outcomes… [90]

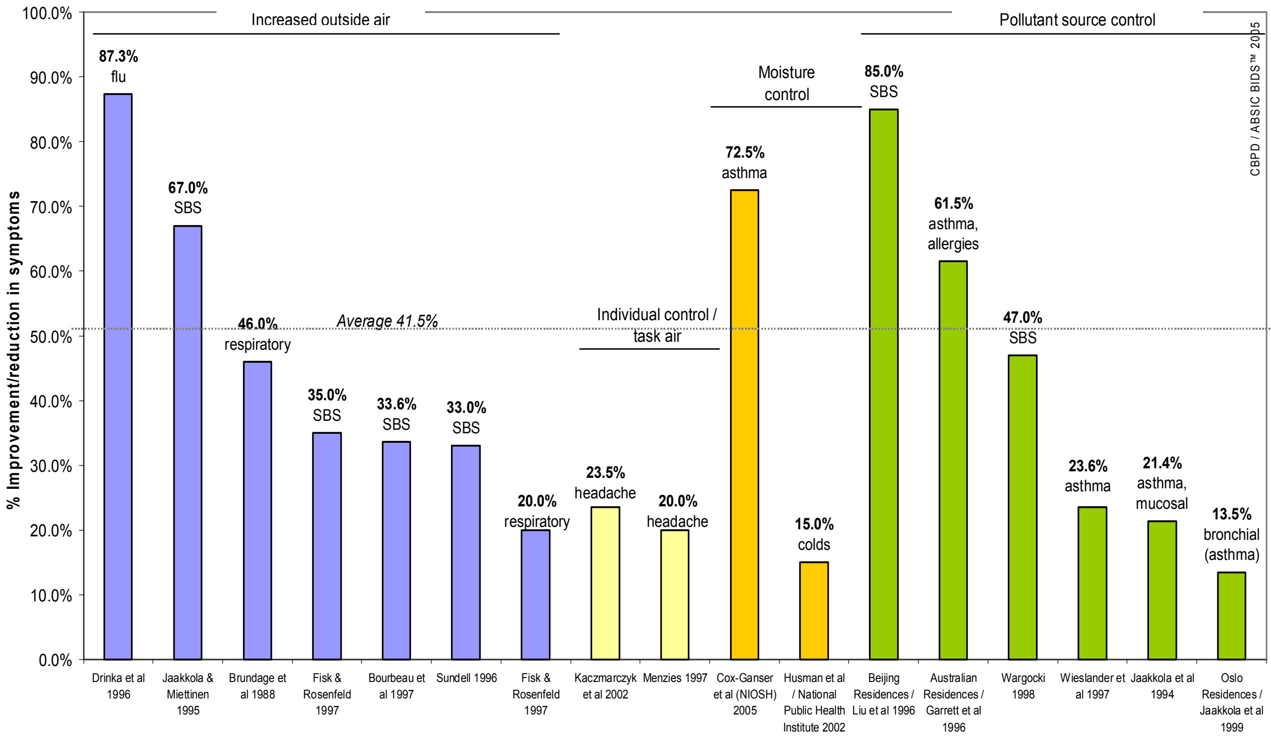
[89] Heerwagen, Judith. "Sustainable Design Can Be an Asset to the Bottom Line - expanded internet edition," *Environmental Design & Construction*, Posted 07/15/02. Available at: http://www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,80724,00.html.

[90] Mendell and Heath, "Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature" Indoor Air, 2004.

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. Consequently we should expect to see a range of impacts found in studies on the health or productivity impacts from improvements in air quality or related building comfort conditions.

The Carnegie Mellon building performance program, BIDS, identified 17 substantial studies that document the relationship between improved air quality and health. The health impacts include asthma, flu, sick building syndrome, respiratory problems, and headaches. These 17 separate studies all found positive health impacts (e.g. reduction in reported prevalence of symptoms) ranging from 13.5% up to 87% improvement, with average improvement of 41% (Figure 8-1).

Figure 8-1. Health Gains from Improved Indoor Air Quality



Source: Carnegie Mellon University Center for Building Performance, 2005

8.2.1. Temperature Control

Teachers believe that temperature comfort affects both teaching quality and student achievement.[91] Another study found that the best teachers emphasized that their ability to control temperature in classrooms was very important to student performance.[92]

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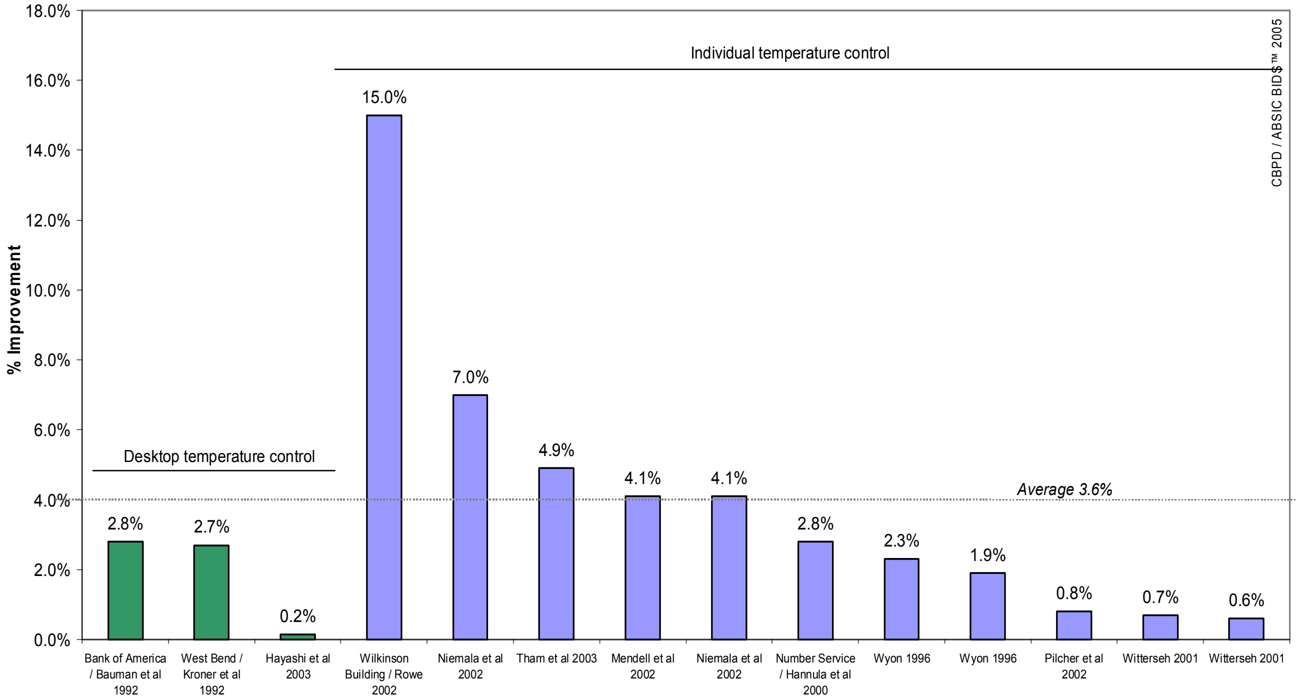
[91] Schneider, Mark. "Do School Facilities Affect Academic Outcomes?" National Clearinghouse for Education Facilities, November 2002. See www.edfacilites.org

[92] Lowe, JM. "The Interface between educational facilities and learning climate." Texas A&M dissertation , cited in Schneider.

A review of 14 studies by Carnegie Mellon on the impact in improved temperature control on productivity found a positive correlation for all studies, with productivity improvements ranging from 0.2% up to 15%, and with an average (mean) of 3.6%.

Figure 8-2. Productivity Gains from Improved Temperature Control



Source: Carnegie Mellon University Center for Building Performance, 2005

8.2.2. High Performance Lighting

Green school design typically emphasizes providing views and managing daylight – specifically increasing daylight while eliminating glare. These two design features have both been correlated with improvements in performance on tests of office workers. In a study of 200 utility workers, workers with the best views performed 10% -25% better on tests. Workers in offices without glare outperformed workers with glare by 15% or more.[93]

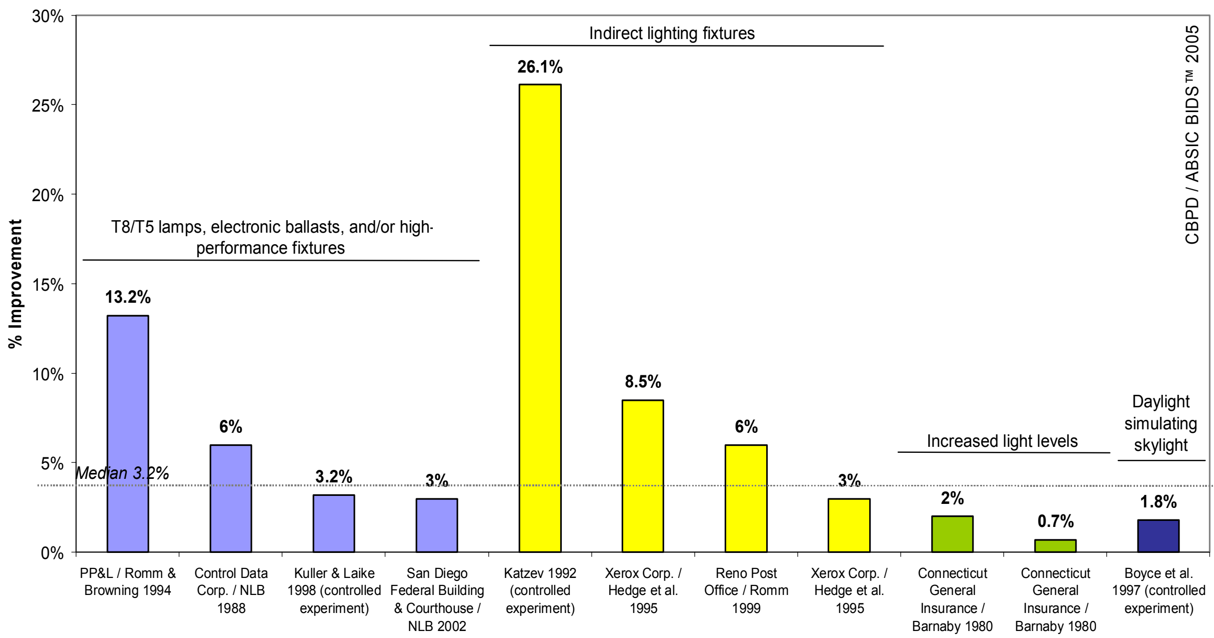
The consensus findings in a review of 17 studies from the mid 1930s to 1997 found that good lighting "improves test scores, reduces off-task behavior, and plays a significant role

[93] Study described in valuable review of green building productivity issues in: Alex Wilson, "Productivity in Green Buildings", Environmental Building News, October 2004.

in the achievement of students."[94] Another synthesis of 53 generally more recent studies also found that more daylighting fosters higher student achievement.[95]

Carnegie Mellon summarized findings from 11 studies documenting the productivity impact from high performance lighting fixtures on productivity. Their analysis, (see fig 8-3) found that productivity gains ranged between 0.7% and 26.1% with an average (median) of 3.2%. The high performance lighting attributes include efficient lighting and use of indirect lighting fixtures, features that are normal in high performance green buildings.

Figure 8-3. Productivity Gains from High Performance Lighting Systems



Source: Carnegie Mellon University Center for Building Performance, 2005

8.2.3. Improved Learning and Test Scores

An analysis of two school districts in Illinois, one small and one large, found that student attendance rose by 5% after incorporating cost-effective indoor air quality improvements.[96] Students moving into the Ash Creek Intermediate School, a LEED silver school in Oregon,

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[94] Buckley, Jack et al. "Fix it and they will stay: the effects of schools facility quality on teacher retention in urban school districts", Boston College, supported in Part by the Ford Foundation and the 21st Century schools fund. See: http://www2.bc.edu/~bucklesj/retention04.pdf

[95] Lemasters, LK, "A synthesis of studies pertaining to facilities, student achievement and student behavior", VA Polytechnic, 1997. Cited in Schneider

[96] 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. Also see: US Environmental Protection Agency. "IAQ Tools for Schools," December 2000 (Second Edition). Available at: http://www.epa.gov/iaq/schools/.

experienced a 15% reduction in absenteeism.[97] Increased absenteeism has been strongly correlated with lowered test scores.

A study of Chicago and Washington, DC schools found that better school facilities can add 3 to 4 percentage points to a school's standardized test scores, even after controlling for demographic factors.[98] A recent study of the cost and benefits of green schools for Washington State estimated a 15% reduction in absenteeism and a 5% increase in student test scores.[99]

In fall 2005 Turner Construction released a survey of 665 executives at organizations involved with green K-12 facilities. Three-quarters of executives believe that green schools better attract and retain teachers, reduce student absenteeism, and increase student performance. A quarter said student performance is "much better" in green schools.[100]

The Third Creek Elementary School in Statesville North Carolina is the country's first LEED gold K-12 school. Completed in 2002, the 800 student school replaced two older schools. Documented student test scores before and after the move provide compelling evidence that learning and test scores improve in greener, healthier buildings. According to Terry Holliday, the Superintendent of the Iredell-Statesville Schools (which includes Third Creek Elementary School),

> "Third Creek Elementary School replaced ADR and Wayside Elementary schools, schools that were two of the district's lowest performing school in regards to test scores and teacher retention/absence. This same group of students and teachers improved from less than 60% of students on grade level in reading and math to 80% of students on grade level in reading and math since moving into the new Third Creek Elementary School. Third Creek had the most gains in academic performance of any of the 32 schools in the school system. We feel that the sustainable approach to this project has had very positive results."[101]

As discussed above, the average productivity impacts found by Carnegie Mellon in the 25 studies reviewed for lighting impact was 3.2% and, separately, temperature control impact on productivity is 3.6%. Another area of productivity impact evaluated by Carnegie Mellon found an average productivity gain from improved daylighting and control of 11%

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[97] Personal communication with architect Heinz Rudolph, November 2005.

[98] Schneider, Mark. "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.

[99] "Washington High Performance School Buildings: Report to Legislature", prepared by Paladino & Company, January 31, 2005

[100] See: http://www.turnerconstruction.com/corporate/content.asp?d=4919

[101] From Moseley Architects summary sheet, available from Chris Venable: cvenable@moseleyarchitects.com

in 5 studies reviewed.[102] Improvements in acoustics and reduced noise in schools also have been found to improve the quality of learning environments.[103]

Students moving from a conventional school to the new green Clearview Elementary School, a 2002 LEED silver building in Pennsylvania, experienced substantial improvements in health and test scores. A PhD thesis on the school found a 19% increase in average Student Oral Reading Fluency Scores (DIBELS) when compared to the prior, conventional school.[104]

There is a significant health and productivity impact from high performance attributes such as improved daylighting, lighting, and temperature and ventilation control, reduced indoor pollutants, and improved air quality. A 3-5% improvement in learning ability and test scores in green schools appears reasonable and conservative based on very substantial data (some of which is addressed above) about productivity and test performance of healthier, more comfortable study and learning environments. Intuitively, a school specifically designed to be healthy, and characterized by more daylighting, improved ventilation and acoustics, better light quality and improved air quality would provide a better study and learning environment.

8.3. Financial Impact of Improved Health and Learning in Green Schools

8.3.1. Future Earnings

Faster learning and higher test scores are significantly and positively associated with higher lifetime earnings.[105] A June 2005 review of the financial benefits of education in an International Monetary Fund publication concluded that:

> Research also links test scores directly to individual earnings and productivity: the better an individual performs on standardized tests, the more likely he or she is to earn a good salary… [Recent] studies, which are based on different, nationally representative data sets that follow students after they leave the education system and enter the labor force, provide remarkably similar estimates: one standard deviation increase (moving from the average of the distribution to the 84th percentile) in mathematics performance at the end of high school translates into 12 percent higher annual earnings — an earnings gain that can be expected across the entire

[102] Source: Carnegie Mellon University Center for Building Performance 2005

[103] For a useful review of impact of acoustics on school performance, See: Mark Schneider, "Do School Facilities Affect Academic Outcomes?" National Clearinghouse for Education Facilities, Nov, 2002 See www.edfacilites.org

[104] Personal communication with architect John Boecker, 7Group, Nov, 2005. Also, case study on schools in "Wesley Doll, "Green Design Experiences: A Case Study", PHD Dissertation for University of Pennsylvania, 2005. The thesis evaluated the impacts on students of the Clearview green school compared to the prior, conventional school.

[105] See for example http://www.ed.gov/pubs/VoEd/Chapter4/Part6.html, and http://portal.unesco.org/education/en/ev.php-URL_ID=35945&URL_DO=DO_TOPIC&URL_SECTION=201.html

> working life of the individual. And there are reasons to believe that these estimates provide a lower bound on the effect of higher educational achievement.[106]

An increase in test scores from 50% to 84% is associated with a 12% increase in annual earnings. As discussed earlier, a smaller improvement in test scores can be conservatively expected from high performance schools compared with conventional schools – in the range of 3% to 5%. Based on the IMF analysis cited above, a 3-5% improvement in learning and test scores is equivalent to a 1.4% lifetime annual earnings increase.

With average annual salary in Massachusetts about $50,000 per year, this improvement in learning and test scores implies an earnings increase of $600 per year for each graduate from Massachusetts schools that provide greener, healthier, more successful learning environments. We are assuming, conservatively, that the earnings benefits last only 20 years, even though studies show they last for the employment lifetime of about 40 years. Assuming, conservatively that earnings only rise at the rate of inflation, the present value is about $7,500 per student, or about $55 per ft^2. We assume that one-third of Massachusetts students move to other states, so we discount the benefits to Massachusetts by one-third, for an estimated 20 year financial benefit of about $35/ft^2. This calculation is an approximate and somewhat conservative estimate of the large impact that improving school learning environments can have on long-term earnings and on the state's economic performance. Indeed, this increase in earnings is the single largest area of benefits of higher performance schools. Green building design appears to be extraordinarily cost-effective compared with other available measures to enhance student performance.

8.3.2. Financial Benefits of Reduction of Asthma

Asthma is a widespread and worsening disease among school children.[107] The American Lung Association has found that American school children miss more than 14 million school days a year because of asthma exacerbated by poor indoor air quality (IAQ).[108] In Massachusetts, 9% to 10% of all school children suffer from asthma.[109]

An American Lung Association, 2005 Fact Sheet on Asthma and Children notes that:

- Asthma is the most common chronic disorder in childhood, currently affecting an estimated 6.2 million children under 18 years; of which 4 million suffered from an asthma attack or episode in 2003.[110].

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[106] Hanushek, Erick. "Why Quality Matters in education", Finance And Development, International Monetary Fund, June 2005. See: http://www.imf.org/external/pubs/ft/fandd/2005/06/hanushek.htm

[107] "Pediatric Asthma in Massachusetts 2003-2004, Mass Department of Public Health, Center for Environmental Health, August 2005. And American Lung Association, Epidemiology and Statistics Unit, Trends in Asthma Morbidity and Mortality, May 2005

[108] American Lung Association, 2002, "Asthma in Children fact sheet. See: www.lungusa.org/asthma/ascpedface99.html And: EPA" Indoor Air Quality and Student Performance", at: http://www.epa.gov/iaq/schools/images/iaq_and_student_performance.pdf

[109] "Pediatric Asthma in Massachusetts", 2005

[110] National Center for Health Statistics. Raw Data from the National Health Interview Survey, U.S., 2003. (Analysis by the American Lung Association). See: American Lung Association, Asthma and Children Fact Sheet, July 2005 at: http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=44352

- Asthma is the third leading cause of hospitalization among children under the age of 15, and it disproportionately affects children.
- The annual direct health care cost of asthma is approximately $11.5 billion, with additional indirect costs (e.g. lost productivity) of another $4.6 billion.[111]

It costs nearly three times more to provide health care for a child with asthma than a child without asthma. [112] In 2006 dollars this amount is equal to $1650 per child.[113] Note that most of these health costs are not borne by the schools but rather by the students and their families. Since we are concerned about state-wide impact, these costs are relevant to this study.

A 1999 study by the Bureau of Environmental Health Assessment of the Massachusetts Department of Public Health evaluated indoor air quality issues among the state's elementary schools.[114] Schools with reported IAQ problems experienced a one-third higher incidence of asthma than schools without reported IAQ problems. According to Suzanne Condon, an author of the 1999 study and now Assistant Commissioner of Health for Massachusetts (and an advisor to this report) the schools selected were representative of schools statewide.[115] A recent review by Carnegie Mellon of five separate studies evaluating the impact of improved indoor air quality on asthma found an average reduction of 38.5% in asthma in buildings with improved air quality.[116]

We will assume the impact of a shift from an unhealthy, conventional school to a healthy school results in a reduction in asthma incidence of 25%. In an average sized new school of 900 students, a 25% reduction in asthma incidence in a healthy school translates into 20 fewer children a year with asthma, with an associated annual cost of $33,000.[117] Over 20 years, and assuming (conservatively) costs of illness only rise at the rate of inflation, at a 7% discount rate this translates into a benefit of over $3/ft^2. This calculation underestimates the asthma reduction benefits since it does not reflect health improvements in school faculty and staff, which are only partially captured in the analysis on faculty retention impact below.

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[111] National Heart, Lung and Blood Institute Chartbook, U.S. Department of Health and Human Services, National Institute of Health, 2004. See: American Lung Association, Asthma and Children Fact Sheet, July 2005 at: http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=44352

[112] "Attacking Asthma, Combating an epidemic among our children." Report to the Senate Committee on Post Audit and Oversight of the Massachusetts Senate, December 2002. Referencing *The Economic Burden of Asthma in US Children: Estimates from the National Medical Expenditure Survey." Journal of Allergy, Clinical Immunology 1999; 104:957-63* See: http://www.mass.gov/legis/senate/asthma.htm

[113] In 1987 dollars average yearly health costs $468 for a child without asthma, and $1129 with asthma, for a difference of $661. From 1987 to 2006 average health experienced a 150% price increase, based on the yearly average CPI for medical care in 2003 recently issued by the U.S. Department of Labor, Bureau of Labor Statistics.) See: http://www.hrsa.gov/osp/dfcr/provide/ppn0401.htm

[114] "A Report on Issues Related to Indoor Air Quality among Massachusetts Elementary Schools", Bureau of Environmental Health Assessment of the Massachusetts Department of Public Health, January 1999

[115] Personal communication, Suzanne Condon, Assistant Commissioner of Health for Massachusetts, October, 2005

[116] Carnegie Mellon University Center for Building Performance 2005

[117] 25% reduction from the current Mass student asthma incidence rate of 9.5%.

8.3.3. Colds and Flu Reduction

Improved ventilation and air quality reduces a range of respiratory illnesses, including common colds and influenza. A review by Carnegie Mellon of two studies evaluating the impact of improved indoor air quality on colds and flu found an average reduction of 51% in buildings with improved air quality.[118] A major review of the literature estimates that better ventilation and indoor air quality would reduce these illnesses by 9-20% in the general population, result in 16-37 million fewer cases of the cold and influenza and provide annual savings of $6-14 billion.[119] The average impact of $10 billion, adjusted to 2006 dollars is $13 billion,[120] or about $45 per person per year.

We are also assuming that the impact on children is the same as on adults – this may be a conservative assumption (i.e., it underestimates benefits of green schools for students) because children are more susceptible to the transmission of flu and colds. Adults typically earn much more than children, so the direct cost of a child's illness is far less than for an adult. However, a child sick from school commonly either obligates a parent to stay home from work or pay for childcare to attend the sick child, and is economically disruptive. These secondary costs of children's illness are large. Better ventilation and indoor air quality in green schools can therefore be estimated to cut costs per pupil from reduced cold and influenza by approximately $45 per student per year. Over 20 years, and assuming (conservatively) costs of illness only rise at the projected growth rate of inflation, this savings translates into $4/ft^2$. (If we assumed the costs rise at the rate of projected health cost of 5% per year, the present value of reduced incidence of influenza and colds in green schools would be $5/ft^2$.)

8.3.4. Teacher Retention

A recent review by professors at Boston College and Stony Brook University found that school facility quality has a significant impact on teacher retention.[121] As discussed above, teachers commonly express concern about school facilities and highlight the issues that green design addresses – lighting quality, temperature control, indoor air quality, etc. Cost of turnover is variously estimated to be 25% up to 200% of annual salary plus benefits (this includes costs of termination, hiring, loss of learning, etc).[122]

Average salary and benefits for Massachusetts public school teachers can be estimated at $70,000.[123] The Boston College analysis, cited above, finds that improved facility quality increases teacher retention by 3%.[124] A recent report on impact of green schools in

[118] Carnegie Mellon University Center for Building Performance 2005

[119] Fisk, Bill. Lawrence Berkeley National Laboratory, Indoor Air Quality Handbook, McGraw Hill, 1999.

[120] Health CPI inflator: See: www.hrsa.gov/osp/dfcr/provide/ppn0401.htm

[121] Buckley, Jack et al. "Fix it and they will stay: the effects of schools facility quality on teacher retention in urban school districts", Boston College, supported in Part by the Ford Foundation and the 21st Century schools fund, undated (2003?) See: http://www2.bc.edu/~bucklesj/retention04.pdf

[122] "The Cost of Teacher Turnover", Texas Center for Educational Research, 2000 See: http://www.sbec.state.tx.us/SBECOnline/txbess/turnoverrpt.pdf

[123] See: http://boston.k12.ma.us/textonly/jobs/teaching.asp#salary

[124] Buckley et al.

Washington State estimated a 5% improvement in teacher retention.[125] If we assume a 3% reduction in teacher turnover and the relatively conservative estimate that the cost of teacher loss is 50% of salary (about one-third salary plus benefits or $25,000) then a 3% increase in teacher retention is worth $750 per teacher per year. At an average of 2,300 ft^2 of school space per teacher, this benefit translates into a financial savings of about $4/$ft^2$ over a 20 year period from increased teacher retention.

[125] "Washington High Performance School Buildings: Report to Legislature", prepared by Paladino & Company, January 31, 2005

9. Employment Impacts of Green Schools

One of the reasons for the adoption of green construction requirements by cities and states is to increase employment. For example, employment benefits are one of the reasons that the New York City Council passed legislation in September 2005 requiring that significant new construction be built green.[126] This trend will drive about $12 billion in green construction and renovation over the next decade, including about $5 billion in green schools.

A coalition of labor movements, public entities, NGOs and businesses, called the Apollo Alliance, is advocating an ambitious national clean investment program. An Apollo Alliance analysis models a $300 billion national investment over a decade in high performance green buildings, rebuilding public infrastructure, increasing energy efficiency diversity and investing in industries of the future (such as clean technologies), and concludes that this would create 460,000 jobs.[127]

Green buildings typically involve greater initial costs to achieve important green objectives such as improved energy efficiency, increased use of renewable energy (on site and offsite), and diversion of waste from landfill into recycling. Each of these aspects of green design involves increased employment compared with conventional non-green buildings.

9.1. Energy Efficiency

The typical green school uses about one-third less energy than conventional schools. This reduction is a result of a combination of better design, more energy efficiency equipment, and installation of energy efficiency measures such as increased insulation.

A 2004 Massachusetts report by David O'Connor, Commissioner of the Division of Energy Resources and Beth Lindstrom, Director of the Consumer Affairs and Business Regulation Agencies, addresses the labor impact of energy efficiency activities in some detail. The report found that energy efficiency investment of about $113 million in the state in 2002 resulted in direct energy savings of about $21.5 million annually. This work also created 1780 new short-term jobs in the Massachusetts economy in 2002, mostly in the service sector (44%) and manufacturing (16%).[128] These jobs endured for the period required to produce and install energy efficiency measures. (The Report notes that these employment benefits reflect similar analysis in Iowa and Illinois as well as a combined study of the employment impacts of increased energy efficiency in New York, New Jersey and Pennsylvania). In addition to these shorter term impacts, lowered energy bills for participants and for Massachusetts result in additional spending, creating 315 new long-

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[126] See: http://webdocs.nyccouncil.info/textfiles/Int%200324-004.htm?CFID=4253&CFTOKEN=13543578

[127] "The Apollo Jobs Report: For Good Jobs & Energy Independence New Energy for America." See: http://www.apolloalliance.org/docUploads/ApolloReport.pdf

[128] David O'Connor, Commissioner of the Division of Energy Resources and Beth Lindstrom, Director of the Consumer Affairs and business Regulation 2002 "Energy Efficiency Activities A report by the Division of Energy Resources", Summer 2004. See www.mass.gov/doer.

term jobs. Thus every $10 million in additional energy efficiency investments contributes about 160 short-term jobs and 30 long-term or permanent jobs. Every $200,000 in additional energy efficiency investments contributes about 3 short-term jobs and one-half a permanent job.

According to the 2004 report by the Massachusetts Division of Energy Resources and the Consumer Affairs and Business Regulation Agencies, energy efficiency jobs added $139 million to the gross state product, including $64 million in disposable income. [129] The energy efficiency investments created from improved energy efficiency are typically offset by smaller heating cooling and ventilation systems, much of which are manufactured out of state and which are less labor intensive.

Average net additional investment in energy efficiency into green low income housing is 0.5% to 2%.[130] Net increased energy efficiency costs in multi unit green low income housing is equal to 1% to 2% of the construction costs. [131] Assuming an average school cost of $25 million (125,000 ft^2 at a cost of $200/ft^2), this suggests about $200,000 in additional energy efficiency related investments in a green school relative to a conventional school. As noted above, in Massachusetts, this creates three short- term jobs through additional work and half of a long-term job.[132]

The average income for a permanent job created can be conservatively estimated as $50,000,[133] indicating a long-term annual increase in salary in-state for each green school of $25,000 (half of one fulltime job created from increased energy efficiency). On a 20 year discounted basis, this is $320,000 of direct in-state salary created, equal to $3/ft^2 for a typical 125,000 ft^2 school. This calculation does not include the positive net employment impact of short-term jobs created.

9.2. Increased Use of Renewable Energy

Green buildings generally use more renewable energy, both on site and off site, than conventional buildings, primarily from purchase of green power and renewable energy

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[129] In the case of this state funded program, determining net economic impact would require comparing the impact to the programmatic employment impact of alternate use of funds. Doing so would show a lower short-term employment impact since the funds, derived from state surcharges on utility bills, would otherwise have been used by rate payers and spent largely in state. The net economic impact of increased energy efficiency through mandating improved school energy efficiency would therefore by somewhat larger on a net basis for short-term jobs created from improved energy performance requirement for green schools compared with Massachusetts efficiency investments. The long-term job creation impact from these two approaches would be roughly the same.

[130] Personal communications with John Boecker and Marcus Sheffer of the 7 Group, November 2005.

[131] Personal communication with Peter Werwath of The Enterprise Foundation, November 2005. See www.greecommunitesonline.org.

[132] Based on the analysis by the Massachusetts Division of Energy Resources and the Consumer Affairs and Business Regulation Agencies.

[133] Massachusetts Technology Renewable Energy Trust, " Energy Efficiency, Renewable Energy, and Jobs in Massachusetts", 2005

credits. Use of renewable energy generally displaces less labor intensive and more polluting energy sources such as imported heating oil, gas, and coal burned in power plants to make electricity.

A shift to more renewable energy would increase employment. Compared with a business as usual energy growth mix through 2020, expanding renewable energy use up to 20% nationally by 2020 would create roughly 100,000 net new jobs nationally.[134] The majority of these jobs would be in manufacturing and construction, and would be relatively well distributed (all states would experience positive employment growth).

It is beyond the scope of this report to estimate the positive employment benefit from increased use of renewable energy. This increase in employment is expected to be significant, so not calculating it underestimates the financial benefits to Massachusetts of requiring that schools be green.

9.3. Waste Diversion

A third way that green schools increase employment is by diverting waste from landfills to more labor intensive activities such as separation and recycling.

A recent Berkeley study found that total economic impacts from diversion are nearly twice as large as the impacts from disposal. One ton of waste diverted as recyclables generates about twice the impact of a ton of waste disposed in a landfill. Only 2.5 jobs are created for every 1,000 tons of waste disposed, while 4.7 jobs are created for waste diverted as recyclables.[135]

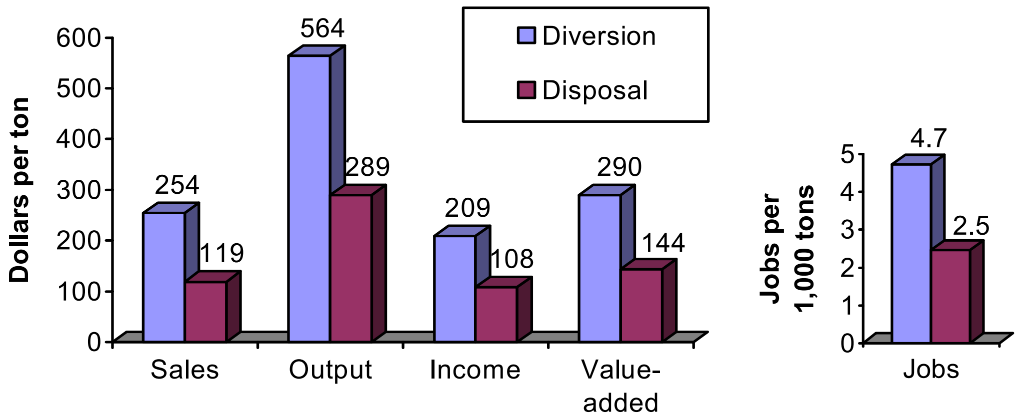
A comprehensive study on the environmental benefits of recycling was conducted in Massachusetts in the late 1990s. The study calculated that the total benefits per ton were \$151-\$331.[136] The benefits that Massachusetts gains from the recycling economy, as reported by the MA Department of Environmental Protection, include the direct benefits of 19,500 recycling jobs + 11,452 indirect jobs.

[134] Kammen et al, Berkeley, ERG Full cite

[135] Goldman, George 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.

[136] Skumatz, Lisa, Jeffrey Morris et al. "Recycle 2000: Recommendations for Increasing Recycling in the Commonwealth of Massachusetts" prepared for the Commonwealth of Massachusetts Executive Office of Environmental Affairs (EOEA) by the Recycling 2000 Task Force, February 1999. p. 6-7

Figure 9-1. Job Impacts of Waste Diversion vs. Disposal



Source: Goldman and Ogishi, April 2001

Recently enacted Massachusetts waste diversion standards for four common types of construction and demolition waste means that all new and retrofitted schools – green or not – will have to reuse or recycle much of their C&D waste. Additional C&D waste diversion impacts in green building will be relatively small compared with conventional schools (assuming these adhere to new waste diversion requirements), and are not calculated here.

9.4. Conclusion on Job Impacts

Clearly green schools create more jobs than conventional schools. Most energy used in schools comes from burning fossil fuels, much of which are imported. Thus, the shift to more energy efficiency, which includes in-state manufacturing, system design and installation labor for insulation, renewable energy systems, better windows, etc., would have substantial employment and economic impacts for Massachusetts. This report calculates only one of these – long-term employment impact of increased energy efficiency – and it is found to provide $\$3/ft^2$ of benefits.

10. Additional Non-Quantified Benefits

Green schools provide a range of additional benefits compared with conventional schools. Some of these are discussed below.

10.1. Reduced Teacher Sick Days

Improved air, comfort and health in green buildings positively affect teachers. There is insufficient data to estimate the impact of green design on teacher sick days. However, an analysis of the Clearview Elementary School, a 2002 LEED silver building in Pennsylvania, is suggestive. A PhD thesis on the school found that teachers experience 1.41 fewer missed working days, a 12% decrease from previous traditional school.[137] If teachers miss a day a year less because of healthy air and a better work environment, the reduced cost of substitute teachers indicates a present value of about $2/ft^2.

Improved Acoustics.
Green Schools, and particularly CHPS and MA CHPS Schools, encourage better acoustical quality. Reduced noise has been correlated with increased learning. [138]

Paula Vaughan, Project Architect for the green Woodward School in Georgia drew on both LEED and MA CHPS in their school design. She notes that:

> From the beginning, the health, safety and well-being of the students and faculty was central to our design decisions, including the decision to seek LEED certification. In order to reduce noise transmission between classrooms, we utilized design practices including extending partitions to the underside of structure, using carpet floor covering, acoustical tile ceilings, and pairing classrooms so that there are never more than two adjacent classrooms. Sound baffles in the corridors further reduces noise and reverberation during class changes. [139]

Reduction in noise level in green schools improves concentration and makes classrooms better learning environments. This report has not calculated the benefits associated with improved acoustical performance in green schools. MA CHPS is better than LEED in addressing building noise issues.

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[137] Personal communication with architect John Boeker, 7 Group, Nov, 2005. Also, case study in "Wesley Doll, "Green Design Experiences: A Case Study", PHD Dissertation for University of Pennsylvania, 2005. The thesis evaluated the impacts on students of the Clearview green school compared to the prior, conventional school.

[138] Schneider, Mark. "Do School Facilities Affect Academic Outcomes?" National Clearinghouse for Education Facilities, Nov, 2002. See www.edfacilites.org

[139] Personal communication with Paula Vaughan, Associate, Perkins + Will, November 2005. She notes that these steps would meet the MA CHPS P3.1 and earn C5.1 as well.

10.2. Heat Island Reduction Measures

Darker building surfaces absorb more sunlight, increasing temperature within buildings, as well as on exterior surfaces. In cities this effect creates urban "heat islands" and an associated need for increased air conditioning. Dark roofs can be substituted with lightly colored roofs, reflective roofs or green (planted roofs) – collectively known as "cool roofs." 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. In addition to energy and heat island impacts, cool roofs also experience less expansion and contraction than dark roofs, which contributes to a significant extension of the roof life. Typically, highly reflective roofs last 20% longer than conventional roofs[140] Green roofs (with plants in soil on an impermeable membrane) are expected to typically last 30-50 years or longer.

10.3. Lower Operations and Maintenance (O&M) Costs

A major recent study of costs and benefits of green buildings for 40 state agencies found that the operations and maintenance (O&M) benefits of greening California public building provides savings worth $8/ft^2 over a 20 year period.[141] Green schools, like other green buildings, incorporate design elements such as commissioning and more durable materials that reduce O&M costs. For example, the LEED gold Canby School, designed by Boora Architects, features exterior surfaces of brick and metal with a baked finish that require virtually no maintenance/painting, as well as a linoleum floor with lower maintenance than conventional flooring.[142] Similarly, the Blackstone Valley Vocational Technical High School in Upton, MA installed recycled rubber flooring in high traffic areas. Rubber floors last longer than the typical common vinyl composition tile and require less maintenance. [143] Estimating O&M benefits from green schools is beyond the scope of this study but benefits are probably significant.

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[140] Data provided by Lawrence Berkeley National Laboratory. December 2002. (Hashem Akbari). From Kats et al. See also: PG&E. "High Albedo (Cool) Roofs: Codes and Standards Enhancement Study." 2000. Available at: http://www.newbuildings.org/downloads/codes/CoolRoof.pdf
[141] Kats et al
[142] Personal communication with architect Heinz Rudolph, October 2005.
[143] For VCT Maintenance needs see: http://www.wolfeflooring.com/maintanence_vct.asp

10.4. Enhancement of Generating System Reliability and Improved Power Quality

The Massachusetts Division of Energy Resources 2004 Annual Report on Energy Efficiency activities notes that:

> By reducing demand, the energy efficiency programs contribute to system reliability in terms of supply adequacy within a particular area or region… all energy efficiency measures… help maintain adequate margins of generation supply, and can help deter brownouts and blackouts….By reducing load and demand on the power distribution network, the [efficiency] programs decrease the costly likelihood of failures.[144]

The benefits for state businesses and state competitiveness of improved power quality resulting from greater energy efficiency could be quite large. Power quality concerns are a significant issue for many businesses.

10.5. Insurance and Risk Related Benefits

Green building design has multiple, potentially significant impacts on insured and uninsured costs, and these costs – and potential benefits of green buildings – are rising.

Health related benefits from green schools have significant risk and insurance impacts. For example, according to the Chief Economist at the Insurance Information Institute, most insurers reported a tripling of mold-related claims in 2002. At of the end of 2002, more than 9000 claims related to mold are pending the nation's courts, though most involve family homes.[145] Improved ventilation and greater commissioning in green buildings reduces the likelihood of mold and associated liability problems.

The Kats/California report characterized the potential insurance benefits of green buildings, by mapping risk and insurance related benefits onto the credits of the LEED system. Each LEED prerequisite and credit was evaluated against seven types of risk: property loss; general liability, business interruption, vehicular, health & workers comp, life, and environmental liability. Of the 64 LEED points available (not including innovation credits) 49 (77%) are associated with measures that have potential risk-management benefits.

[144] Division of Energy Resources, Summer 2004, "An Annual Report to the Great and General Court on the Status of Energy Efficiency activities in Massachusetts for the year 2002" can be accessed at http://www.mass.gov/doer/pub_info/ee02-long.pdf

[145] Smith, Ray. "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.

Insurance-related benefits of green, high performance design are summarized below (and reproduced from the Kats/California study).

- **Worker Health & Safety.** Various benefits, including lower worker's compensation costs, arise from improved indoor environmental quality, reduced likelihood of moisture damage, and other factors enhancing workplace safety.[146]
- **Property Loss Prevention.** A range of green building technologies reduce the likelihood of physical damages and losses in facilities.[147]
- **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. These risks include those resulting from unplanned power outages.[148]
- **Natural Disaster Preparedness and Recovery.** A subset of energy efficient and renewable energy technologies make facilities less vulnerable to natural disasters, especially heat catastrophes.[149]

This report does not estimate the value of the risk and liability reduction benefits of green buildings.

10.6. Improving Equity, and Addressing Spiritual Values

Lower income and minorities disproportionately suffer from poor indoor air quality and related problems in conventional schools. Children in low income families are 30% to 50% more likely to have respiratory problems such as asthma and allergies that in turn increase absenteeism, and diminished learning and test scores. This increase in respiratory problems results in large part from exposure to polluted and unhealthy air and study conditions in schools and at home. Wealthy families can move their children into better designed and healthier private schools. Less wealthy families are less likely to have that luxury.

Concern about poor health among economically disadvantaged children is a primary reason for the creation of a national green low income housing initiative involving the Enterprise Foundation, American Institute of Architects, NRDC, American Planning Association, the US Green Building Council, Fannie Mae, Freddie Mac, JPMorgan Chase,

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[146] Vine, Edward 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.

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

[148] 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.

[149] Mills, Evan. "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.

Bank of America and other private and public partners.[150] The intent of this effort is to make all future low income housing green, in large part to improve the health of economically disadvantaged children. This national initiative includes a $209 million Massachusetts green low income commitment by the Massachusetts Housing Finance Authority, MTC and Enterprise and its partners.[151] The enormous success of this initiative nationally in greening and funding low income housing, a building sector with even more limited financing than schools, suggests that greening schools at a state-wide level in Massachusetts is feasible. Healthy schools and homes, where children spend the majority of their time, would have a large positive impact on the health of economically disadvantaged children. The financial and moral benefits of a less inequitable educational system are difficult to calculate.

Many people are spiritual and religious, and value environmental richness and environmental protection as an important spiritual issue. For example, a recent Le Moyne College/Zogby International Contemporary Catholic Trends Poll found that 87% of those polled said that protecting the environment is an important issue, with 21% placing it as "the most important issue" facing America today. A majority of Catholics also believe they can make a difference for the environment with 81% agreeing that making changes in lifestyle would have an impact. [152]

10.7. Educational Enrichment as an Aspect of Greener, Healthier Facilities

High performance schools provide hands-on educational opportunities that conventional schools do not. For example, the Massachusetts Blackstone Valley Vocational Technical High School incorporates its green building design into vocational courses. A student acts as the "help desk" for HVAC systems problems during the day, and students and staff apply their vocational skills to outfit some of the school's green building features. [153]

The Ashland High School, one of 18 green schools built or being built in Massachusetts, will have a kiosk that allows the public to monitor its energy use and students to learn about energy efficiency technologies and impacts. [154]

Sidwell Friends, a highly regarded Quaker affiliated school in Washington DC, is making greening a principal objective in its campus renovation and expansion. The ongoing effort

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[150] See: www.greencommunitiesonline.org
[151] Nichols, Russell. "Building Support for 'Green Housing'", Boston Globe, July 8, 2005.
[152] See: http://www.lemoyne.edu/academics/zogby_fall05.htm. See also Kats, Greg " The costs and benefits of green buildings" in Green Office Buildings A Practical Guide to Development, Urban Land Institute, 2005.
[153] However, there is some evidence that the current generation of Massachusetts green schools may not be taking full advantage of educational benefits. A recent review of eight MTC-funded green schools expressed surprise to find no hands-on opportunities for students to access installed on site solar energy systems. HMFH Architects, Inc. and Vermont Energy Investment Corp. "The Incremental Costs and Benefits of Green Schools in Massachusetts", MTC, 2005.
[154] Brodkin, John. "New school in Ashland will be energy efficient" Daily News Tribune, http://www.dailynewstribune.com/localRegional/view.bg?articleid=58897

to make the school's building more environmentally-friendly and healthy provides a rich source of hands-on educational material for both full time and summer students. Mike Saxenian, Assistant Head of the School and Chief Financial Officer says that "students have responded with enthusiasm to the school's decision to build green, and faculty are eager to use the new facilities as a laboratory to demonstrate solutions to environmental problems discussed in class. Trustees, faculty and administrators see the green building program as an affirmation of the school's core values." [155]

[155] Personal communication, Mike Saxenian, November 2005.

11. Conclusions and Recommendations

Green school design is very cost-effective. Green schools cost 1.5% to 2.5% more than conventional schools. Achieving MA CHPS costs up to 2.5% more than conventional schools. Achieving MA CHPS prerequisites cost no more or between 0% and 0.5% and provides a slightly higher minimum performance level than conventional school design.

The financial benefits of greening schools, summarized below, are 10 to 20 times as large as the cost. Green school construction costs 1.5% to 2.5% more than conventional school construction, almost \$4 more per ft^2 for a typical \$25 million, 125,000 ft^2 school built for 900 students. The financial savings are \$60 to \$70 per ft^2, more than 10 times as high as the cost of going green. Only a portion of these savings accrue directly to the school. Lower energy and water costs, improved teacher retention, and lowered health costs save green schools directly about \$15/ft^2, about four times the additional cost of going green.

Table 11-1. The Financial Benefits of Green School Design (\$/ft^2)

Energy	\$14
Emissions	\$1
Water and wastewater	\$1
Increased Earnings	\$37
Asthma Reduction	\$4
Cold and Flu Reduction	\$4
Teacher Retention	\$4
Employment impact	\$3
TOTAL	**\$68**
COSTS OF GREEN DESIGN	\$4
NET FINANCIAL BENEFITS	**\$60-\$70**

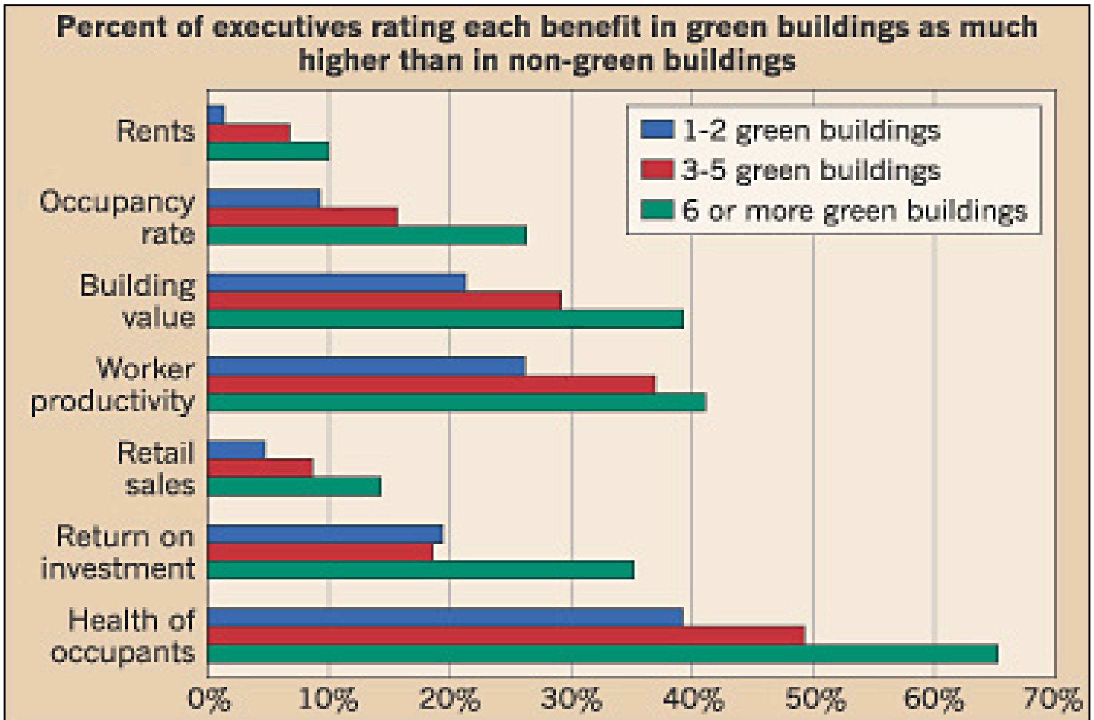
It is important to note that there is a learning curve associated with designing and building green schools. For both public and private owners and developers of green schools, subsequent green schools generally cost less than the first green school. The trend of declining costs associated with increased experience in green building construction has been experienced in Pennsylvania,[156] as well as in Portland and Seattle. Portland's three reported completed LEED Silver buildings were finished in 1995, 1997, and 2000. They incurred cost premiums of 2%, 1% and 0% respectively.[157] Seattle has seen the cost of

[156] 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.
[157] Data provided by Heinz Rudolf, BOORA Architects. See Portfolio/Schools at: http://www.boora.com/

LEED Silver buildings drop from 3-4% to 1-2% recently.[158] With increased green school construction, Massachusetts can expect to see a declining cost of achieving LEED or MA CHPS and its prerequisites.

Similarly, there is strong evidence that the perceived value of building green increases as owners and developers build more green schools. A recent survey by the national construction firm, Turner Construction, found that the recognized benefits of green building in a range of areas, (including health benefits and productivity) increase relatively steeply as owners and developers build more green buildings (see figure 11-1).

Figure 11-1. Executives' Views of Green Building Benefits by Number of Buildings



Source: Turner Construction Survey, 09/04 [159]

The full benefits of greening schools in Massachusetts can be expected to become more apparent and important as the state builds more green buildings, in turn increasing support for the required marginal additional investment to go green.

. Also see Kats/California report.

[158] 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.

[159] See: http://www.turnerconstruction.com/corporate/content.asp?d=4919

There are a number of different strategies available for state-wide greening of schools. For example:

- In July 2005, the Pennsylvania legislature passed House Bill 628, amending the Public School Code to provide a financial incentive to public school districts that achieve LEED Silver certification. [160]
- On April 8, 2005, Washington Governor Christine Gregoire signed into law ESSB 5509 requiring state-funded projects over 5,000 sq ft, including school district buildings, to achieve LEED Silver certification. (Washington was also the first state in the country to adopt LEED legislation state-wide).[161]
- In 2002, then Governor James McGreevey signed an Executive Order requiring all new New Jersey schools to incorporate LEED guidelines, stating in part that:

> it is in the best interests of the people of New Jersey that school facilities developed under the Act shall be modern facilities of the 21st century, combining all of these features: the best possible learning environment, the most energy-efficient design, the most environmentally sustainable systems, and the highest community-relevance.[162]

The 2% incentive for energy efficiency currently available from the Massachusetts School Building Authority (MSBA), if applied to high performance schools, would constitute a prudent and effective incentive for greening Massachusetts schools. Some additional suggestions to consider:

- Give MA school districts a financial incentive to document student performance, especially in green schools versus non green schools.
- Give school districts a financial incentive to document, measure and verify schools performance data (e.g. in energy and water use).[163]

The central recommendation of this report is that Massachusetts should ensure that all future school construction be green. Analysis of the costs and benefits of 30 schools and use of conservative and prudent financial assumptions provides a clear and compelling case that greening schools today is financially extremely cost-effective. Building green schools is significantly more fiscally prudent and lower risk than continuing to build unhealthy, inefficient schools.

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[160] See: http://www2.legis.state.pa.us/WU01/LI/BI/BT/2005/0/HB0628P2564.pdf
[161] ESSB 5509: http://www.leg.wa.gov/pub/billinfo/2005-06/Htm/Bills/Senate%20Passed%20Legislature/5509-S.PL.htm
These state write up are taken from the valuable review of state, city and local initiatives adopting LEED. It is available on the USGBC website at:: https://www.usgbc.org/FileHandling/show_general_file.asp?DocumentID=691
[162] See: http://www.state.nj.us/infobank/circular/eom24.htm
[163] Suggested by architect John Boecker, personal communication, November 2005.

Appendices

Appendix A: All 30 Schools Used in the Analysis

Name	State	Year Completed	Architect	Firm	Cost Premium	Energy Savings	Water Savings
Ash Creek Intermediate School	OR	2002	Heinz Rudolph	Boora Architects	0.00%	30%	20%
Ashland High School*	MA	2005			1.91%	29%	
Berkshire Hills Regional Middle School*	MA	2004			3.99%	34%	0%
Blackstone Valley Regional Voc. Tech High School*	MA	2005			0.91%	32%	12%
Michael E. Capuano Early Childhood Center	MA	2003	Doug Sacra	HMFH Architects	3.60%	41%	
Canby Middle School	OR	2006	Heinz Rudolph	Boora Architects	0.00%	47%	30%
Clackamas	OR	2002	Heinz Rudolph	Boora Architects	0.30%	38%	20%
Clearview Elementary	PA	2002	John Boecker	7group	1.30%	59%	39%
Crocker Farm School	MA	2001	Margo Jones	Margo Jones Architects	1.07%	32%	62%
C-TEC	OH	2006	John Boecker	7group	0.53%	23%	45%
The Dalles Middle School	OR	2002	Heinz Rudolph	Boora Architects	0.50%	50%	20%
Danvers – Holten-Richmond Middle School*	MA	2005			3.79%	23%	7%
Dedham Middle School*	MA	2006			2.89%	29%	78%
Lincoln Heights Elementary School	WA	2006	Rebecca L. Baibak	Integrus Architects		30%	20%
Newton South High School	MA		Paul Brown	DR&I Architects	1.36%	20%	20%
Melrose Middle School*	MA				2.02%	29%	35%
Model Green School	IL	2004	Kevin Hall	OWP/P	0.99%	30%	20%
Prairie Crossing Charter School	IL	2004	Bill Sturm	Serena Sturm Architects	3.00%	48%	16%
Punahou School	HI	2004	Randy Overton	John O'Hara Associates	6.27%	43%	50%
Third Creek Elementary	NC	2002	Chris Venable	Moseley Architects	1.52%	26%	63%
Twin Valley Elementary	PA	2004	John Boecker	7group	1.50%	49%	42%
Summerfield Elementary School	NJ	2006	Marcus Sheffer	7group	0.78%	32%	35%
Washington Middle School	WA	2006	Katrina Morgan	MAHALUM Architects	3.03%	25%	40%
Whitman-Hanson Regional High School*	MA	2005			1.50%	35%	38%
Williamstown Elementary School	MA	2002	Margo Jones	Margo Jones Architects	0.00%	31%	
Willow School Phase 1	NJ	2003	Marcus Sheffer	7group		25%	34%
Woburn High School*	MA	2006			3.07%	30%	50%
Woodword Academy Classroom	GA	2002	Paula Vaughan	Perkins + Will	0.00%	31%	23%
Woodword Academy Dining	GA	2003	Paula Vaughan	Perkins + Will	0.10%	23%	25%
Wrightsville Elementary School	PA	2003	Marcus Sheffer	7group	0.40%	30%	23%
AVERAGE					**1.65%**	**33.4%**	**32.1%**

*Sources: All data supplied by the architects except * - from Sacra et al, November 2005.*

Appendix B: Estimating the Value of Avoided Emissions

Massachusetts Technology Collaborative Methodology for Estimating Avoided Emissions (Version 2 - June, 2004)

Due to the complex nature of our New England electric system, and its operational interconnection with neighboring systems in New York, Quebec and the Canadian Maritimes, it is not practical to estimate emissions reductions that would result from the operation of a specific new renewable generating facility operating at a specific location in New England. Rather, MTC relies upon an analysis of emissions reductions that would occur, in aggregate, as a result of operation of a mix of new renewable generators located throughout New England. Thus, the stated emissions reduction for a specific facility (e.g. a wind project in western Massachusetts) is calculated for an equivalent capacity (MW) of a mix of generating technologies disbursed throughout New England.
Our estimates of avoided emissions are derived from an analysis performed for MTC by La Capra Associates and MSB Energy Associates in February 2003.[164] That analysis incorporates the following key characteristics and assumptions:

1. The La Capra / MSB analysis used an electricity market dispatch model (PROSYM®) to simulate electricity market operation under specific input assumptions. La Capra adapted the model to estimate power generator emissions under a Benchmark - No Renewables case and six renewables development scenarios. The Benchmark - No Renewables case takes into account the approximately 10,000 MW of natural gas generation that has recently come on-line in the region.

   Avoided emissions are calculated for two snapshot years - 2006 and 2009 - as follows: "annual energy production of the facility" (MWh) multiplied by "New England Marginal Emission Rate" (pounds/MWh). Avoided emissions are expressed in pounds of SO2, NOx, CO2 or particulates over the course of a full year. See Table 1 for the New England Marginal Emission Rates.

2. MTC bases its avoided emissions estimates on the Renewables Scenario - Base Case. Among other things, this scenario assumes that:

   Massachusetts and Connecticut both have renewable portfolio standards that apply to all electricity sales, resulting in development of approximately 400 MW of "new"[165] renewables by 2006 and 720 MW by 2009; and a specific mix of renewable resources developed (e.g. biomass, landfill gas, wind) and locations of facilities throughout New England (see Table 2).

3. The operation of new renewable facilities in New England tends to free up some fossil-based New England generation for export. These exports, primarily to New York, result in a corresponding backing off of generation in the importing region resulting in emissions reductions in that region. The New England Marginal Emission Rate, and therefore, our emissions reduction estimates, includes emission reductions occurring in neighboring regions.

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[164] Electric System Emissions Displaced due to Renewable Energy Projects in New England, La Capra Associates and MSB Energy Associates, February 2003.

[165] "New" renewables refer to generating facilities that receive a Statement of Qualification as eligible for the Massachusetts Renewable Portfolio Standard. Along with technology and resource requirements, this means that the facility began commercial operation January 1, 1998 or later. See http://www.mass.gov/doer/rps/index.htm.

Table B-1. New England Marginal Emission Rates by Pollutant and Scenario
(Note, MTC uses the "Renewables - Base" values. Values in parenthesis indicate they are negative and represent emissions reductions per MWh.)

Scenario	2006 Marginal Emission Rates				2009 Marginal Emission Rates			
	SO2 (lbs/MWh)	NOx (lbs/MWh)	CO2 (lbs/MWh)	PM (lbs/MWh)	SO2 (lbs/MWh)	NOx (lbs/MWh)	CO2 (lbs/MWh)	PM (lbs/MWh)
Renewables - Base	(3.57)	(1.34)	(1,087.56)	(0.19)	(1.66)	(0.70)	(981.83)	(0.15)
No CT RPS	(2.52)	(0.98)	(952.27)	(0.17)	(1.78)	(0.77)	(1,003.46)	(0.16)
More Wind	(2.59)	(1.12)	(1,047.59)	(0.17)	(1.61)	(0.91)	(955.31)	(0.14)
More Biomass	(3.23)	(1.13)	(1,043.46)	(0.18)	(1.84)	(0.60)	(1,006.17)	(0.15)
Fuel Price*	(3.20)	(1.60)	(1,018.47)	(0.16)	(2.47)	(1.17)	(1,017.91)	(0.12)
Transmission**	(3.39)	(1.27)	(1,067.70)	(0.18)	(1.87)	(0.76)	(1,001.88)	(0.15)

* The shift in fuel prices would last no more than a few months; fuel price scenario was compared to a Benchmark - Fuel Price Case. See report for details.
** Transmission Congestion Scenario was compared to the Benchmark - Transmission Case. See report for details.

Source: La Capra Associates, February 2003

Table B-2. New England New Renewables Energy Output, Capacity, and Location Assumptions, Renewables Scenario-Base Case

Technology	Location	2006				2009			
		% of tech at location	GWh	Assumed CF	MW	% of tech at location	GWh	Assumed CF	MW
Offshore wind	SEMA/RI	50%	309.72	35%	101.02	50%	496.53	35%	161.95
Onshore wind	SEMA/RI	5%	30.97	30%	11.79	5%	49.65	30%	18.89
	NH/westMA	10%	61.94	30%	23.57	10%	99.31	30%	37.79
	ME	20%	123.89	30%	47.14	20%	198.61	30%	75.58
	VT	15%	92.92	30%	35.36	15%	148.96	30%	56.68
Biomass	ME	35%	171.90	65%	30.19	35%	472.21	65%	82.93
	VT	20%	98.23	65%	17.25	20%	269.83	65%	47.39
	CT	10%	49.11	65%	8.63	10%	134.92	65%	23.69
	NH/westMA	35%	171.90	65%	30.19	35%	472.21	65%	82.93
Digester	NEMA	100%	37.23	80%	5.31	100%	37.23	80%	5.31
Behind the meter	NEMA	25%	2.19	30%	0.83	25%	4.38	30%	1.67
	CT	25%	2.19	30%	0.83	25%	4.38	30%	1.67
	SEMA/RI	15%	1.31	30%	0.50	15%	2.63	30%	1.00
	NH/westMA	35%	3.07	30%	1.17	35%	6.13	30%	2.33
Fuel cells	CT	30%	1.96	95%	0.24	30%	19.99	95%	2.40
	NEMA	30%	1.96	95%	0.24	30%	19.99	95%	2.40
	SEMA/RI	20%	1.31	95%	0.16	20%	13.33	95%	1.60
	NH/westMA	20%	1.31	95%	0.16	20%	13.33	95%	1.60
LFG	SEMA/RI	50%	345.59	90%	43.83	50%	446.49	90%	56.63
	CT	15%	103.68	90%	13.15	15%	133.95	90%	16.99
	NH/westMA	35%	241.91	90%	30.68	35%	312.54	90%	39.64
TOTAL			1,854.27		402.22		3,356.60		721.08

Source: La Capra Associates, February 2003

Estimating Mercury Emissions Reductions

In October 2003, the Massachusetts Department of Environmental Protection (DEP) released proposed amendments to regulation 310 CMR 7.29 regarding mercury emission standards for four power plants in the state. These amendments occurring in two phases give the facilities the option of either meeting mercury removal efficiencies or regulating the emissions rates.
Phase I, by Oct 2006 achieve either:

- 85 percent removal of mercury from the combusted coal or
- An output based emissions rate of 0.0075 lbs/Gwh
- Phase II, by Oct 2012 achieve either:
- 95 percent removal of mercury from the combusted coal or
- An output based emissions rate of 0.0025 lbs/Gwh

For compliance, averaging across units is permitted, but emissions trading or averaging across different power plants is not permitted. The cost to comply varies for different power plants. The Mt Tom station, for example will require spending around $300,000 per pound per year of mercury removal to meet the phase I requirements, while for a larger station like the Brayton Point Station costs would be around $80,000 per pound per year.

Source: "Mercury emissions from Coal power plants: The case for Regulatory Action." NESCAUM, October 2003,
http://bronze.nescaum.org/airtopics/mercury/rpt031104mercury.pdf

See also: Bureau of Waste Prevention, Division of Planning and Evaluation, May 2004, "response to comments for proposed amendments to 310 CMR 7.00 et seq, 310 CMR 7.29 – Emission Standards for Power Plants" responses from the Owners/Operators of Electric Generating Facilities.

Estimating Natural Gas Emissions Reductions

Natural gas NO_x emissions rate is based on the Massachusetts Public Benefit Set-Aside rate for allowance allocation. Measures that reduce thermal energy demand are credited at the rate of 0.44 pounds of NO_x per million BTU. The American Gas Association cites a typical SO_2 rate from natural gas consumption of 0.6 pounds per billion BTU, although a survey of operating licenses for natural gas boilers shows higher permitted limits. Some natural gas is "sour" with a higher sulfur content, but natural gas is generally a very minor source of SO_2.

The CO_2 emissions rate for natural gas is typically 117 pounds per million BTU. This varies slightly with the composition of natural gas (relative fractions of methane and heavier hydrocarbons).

PM_{10} rates are estimated based on surveys of air emissions licenses for natural gas boilers. Typical rates range from 0.01 to 0.1 pounds per million BTU, with significant regional variation. Natural gas combustion is not a significant source of mercury.

Appendix C: Estimating Water and Wastewater Costs

The most comprehensive information available on Massachusetts water costs is from the Tighe and Bond 2004 Massachusetts Water Survey, which presents data on residential water costs. In this survey, typical water costs range from $0.0005/gallon to $0.0135/gallon, with an average of $0.0036/gallon.[166] Only 18% of the municipalities surveyed have a different rate structure for businesses and in a recent analysis of water consumption in five green schools, the average water rate was $0.0052/gallon.[167] Thus, we feel comfortable estimating that $0.0036/gallon is a conservative average water rate for Massachusetts schools.

Typical annual sewer rates in Massachusetts range from $0.0013/gallon to $0.0148/gallon, with an average of $0.0045/gallon.[168] This cost is about half of the average sewer rates for five schools analyzed in the HMFH report ($0.0086).

Based on the Tighe and Bond reports from 2002 and 2004, average Massachusetts water rates are increasing at about 4.5% annually.[169] The Boston Water & Sewer Commission projects an 8.6% increase each year from 2006 to 2010 for water and sewer services.[170] This report assumes a conservative (low) rate of cost increase of 4.5% per year.

We normalized the 2004 water costs for 2006 using rate increases of 4.5% per year for water and 7% per year for wastewater.

Table C-1. Calculation of Water Reduction Benefits of Green Schools

Four Massachusetts Green Schools with Detailed Water Reduction Data (Annual)						
School	**Size (ft^2)**	**BaseCase Water Consumption (gals)**	**Irrigation Water Savings (gals)**	**Toilet Water Savings (gals)**	**Total Water Savings (gals)**	**% Savings Over Base Case**
Danvers	148,000	1,508,972	110,372		110,372	7%
Dedham	130,100	1,188,360	291,600	634,680	926,280	78%
Whitman Hanson	234,500	1,575,900		603,540	603,540	38%
Woburn	340,000	3,606,632	683,792	1,134,000	1,817,792	50%
AVERAGE	**213,150**	**1,969,966**	**361,921**	**790,740**	**864,496**	**43%**

Source: Data from HMFH Architects, Capital E Analysis

Our Gallons per square foot numbers were taken using the data in Table C-1.

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[166] Tighe and Bond, *2004 Massachusetts Water Survey*, p.2. Based on 90,000 gallons per household, annual water bills $45-$1,215, avg. $321.
[167] Data supplied by Doug Sacra, HMFH, 11/04/05.
[168] Tighe and Bond, p.2, Assuming consumption of 120 hundred cubic feet (90,000 gallons) of water per year, $120-$1329 per household per year, $408 average.
[169] Communication with Mary Beth Morris, author of the Tighe and Bond report, 8/10/05.
[170] Information provided by William J. O'Brien, 9/8/05 to Greg Kats

Appendix D: Economic Benefits of Waste Reduction in MA

C&D Waste Reduction Strategies

Construction waste reduction options include:

Reuse and minimization of C&D debris and *diversion* of C&D waste from landfills to recycling facilities (from any job site, 90%-100% of waste materials can be recycled.[171])

Source reduction, e.g.

- use of building materials that are more durable and easier to repair and maintain,
- design to generate less scrap metal through good planning, increased recycled content,
- use of reclaimed building materials, and
- 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.[172]

Reuse and recycling are typically referred to as "diversion," in contrast to landfill "disposal." Diversion strategies save money by avoiding disposal costs, reducing transportation costs and reducing societal costs of landfill creation and maintenance. Diversion strategies also catalyze economic growth in relatively labor intensive industries that reprocess diverted waste and use recycled raw materials.

Costs and Benefits of C&D Waste Diversion

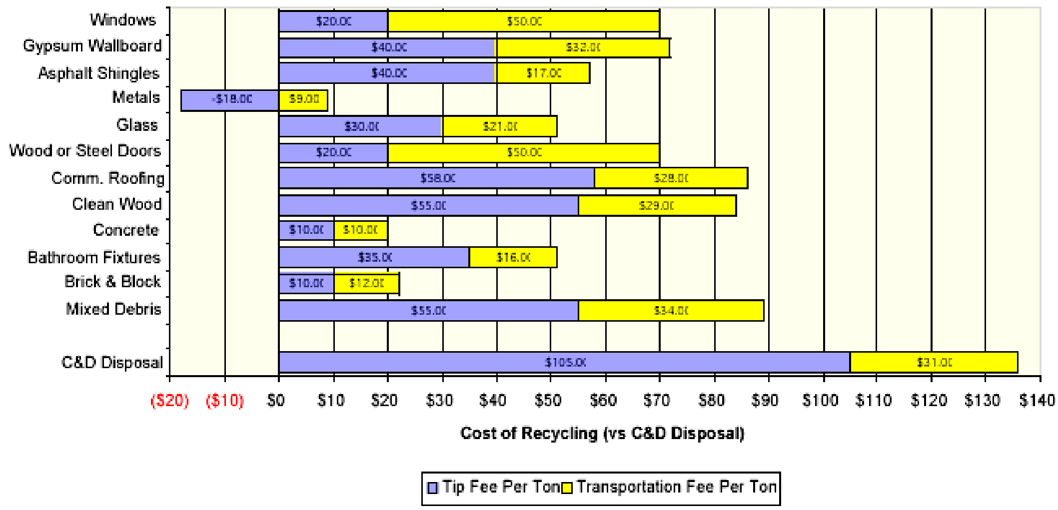
Research has shown that it actually costs less to recycle most C&D waste than to dispose of it. The chart below shows the relative cost of recycling a variety of C&D waste materials as compared to the cost of disposing of these materials as mixed waste (the bar labeled "C&D Disposal") in the Boston area. The chart shows that for *all* construction and demolition wastes (including mixed debris), the cost of recycling is less than the cost of disposal by at least 35%.

[171] Lennon, p3 "The remaining materials may be hazardous or special waste, requiring special management, materials whose markets are not yet developed enough, or materials that are contaminated through use and cannot be easily recycled."

[172] LEED Reference Guide: For New Construction & Major Renovations (LEED-NC) Version 2.1. Second Edition, May 2003. p185.

> *One of the most effective strategies for minimizing the environmental impacts of material use is to reuse existing building. Rehabilitation of existing building shells and non-shell components reduces solid waste volumes and diverts these waste volumes from landfills. It also reduces environmental impacts associated with the production and delivery of new building products. Reuse of an existing building minimizes habitat disturbance and typically requires less infrastructure such as utilities and roads.*

Figure D-1. The Cost of Recycling vs Disposal of C&D Wastes in Boston area



Source: The Institution Recycling Network, 2005

All Costs in $/ton. Tip fee = cost to market the material to a recycler or dispose of waste in a landfill, Transportation fee = cost to reach the market (dependent on location and size of the containers used for transportation). Depicted costs are for Boston area projects. Pricing will vary somewhat depending on specific job locations.[173] For mixed debris recycled, usually 75%-90% is actually sorted, recovered, and reused.[174]

The comparison of this data to the breakdown of Massachusetts C&D waste generation and recycling rates highlights that the cheapest materials to recycle, metals and ABC, are also the ones that are most often diverted from landfills.

Consigli Construction Waste Reduction, MA Pilot

Since 2001, Consigli Construction has been involved in a voluntary pilot study of C&D source separation. Consigli's overall waste reduction rate is 72.7 % on projects with source-separation operations, and is 91.4% of C&D materials have been diverted from landfills for five DEP case study projects.[175]

[173] The Institution Recycling Network, May 15, 2005. downloaded 10/15/05 from http://www.wastemiser.com/costcomparisonchart.pdf
[174] Lennon, page 5.
[175] Freymann, Vance.

Table D-1. Summary of Consigli Massachusetts Waste Reduction Projects

	Type	Bldg Size (ft2)	Tons reused & recycled	Tons disposed	% waste reduction (recycled/ reused)	Recycling cost	Avoided disposal cost	Savings
Douglas School	NC 137000 & renovation 6800	143800	443.67	338	57%	$16,652	$48,464	**$31,812**
City Hall Annex	Commercial Renovation	32000	688.2	173	80%	$37,035	$92,192	**$55,157**
Milford Fire Station	NC 10500 & renovation 6300	16800	569.1	118	83%	$2,979	$24,617	**$21,638**
St. Paul's Cathedral	Renovation	10200	145	39	79%	$936	$18,620	**$23,759**
Clarke Corporation	Commercial Renovation	60000	9488	233	98%	$7,974	$267,017	**$259,043**
MIT Media Lab	Commercial Demolition	47000	4519	193	96%	--	--	**$17,684**
Averages		**51633**	**2642**	**182**	**82%**	**$13,115**	**$90,182**	**$68,182**
Totals		309800	15853	1094	--	$65,576	$450,910	**$409,093**

Source: MA DEP Website[176]

Total Economic Benefits of C&D Diversion

Calculation of the full value of diverting material from landfills should include all quantifiable benefits, including direct economic benefits and avoided environmental costs. The most comprehensive study on the environmental benefits of recycling was conducted in Massachusetts in the late 1990s. The study calculated that the total benefits per ton were $151-$331:

Table D-2. Estimated Environmental and Economic Benefits per Ton Recycled[177]

Source/Type of Benefit	**Average Dollar Value of Benefit per Ton Recycled**	**Benefits Accrue Mostly to This Entity**
1996 Material Sales Revenue minus processing costs (Range depending on processing facility/costs)	$-(55)-$16	Municipality/ MRF
Avoided Trash Costs (statewide average)	$88	Municipality/Hauler
Additional Employment from Recycling (net of disposal employment losses, if any)	$55-$164	State
Public Health and Environmental Benefits	$63	State
Total Benefits per Ton (combined)	**$151-$331**	**Combined**
Benefits per Ton for Municipalities	$33-$104	Municipality
Benefits per Ton for State	$118-$227 (69%-78%)	State

[176] http://www.mass.gov/dep/recycle/priorities/dswmpu01.htm#recycling, November 2005.
[177] Skumatz, Lisa, Jeffrey Morris et al. "Recycle 2000: Recommendations for Increasing Recycling in the Commonwealth of Massachusetts" prepared for the Commonwealth of Massachusetts Executive Office of Environmental Affairs (EOEA) by the Recycling 2000 Task Force, February 1999. p. 6-7

Diversion provides significant economic, environmental and social benefits including:

- Revenue generated when recycled materials are sold to commodity markets.
- Reduced garbage collection, transfer, hauling and disposal costs.
- Additional jobs and revenues in manufacturing industries.
- Reduced use of virgin raw materials and fuels.
- Reduced demand for additional landfills and incinerators.

The industries that manufacture products using recycled materials use fewer virgin natural resources and fuels than manufacturers that do not use recycled content, which has the following benefits:

- Reduced emissions of greenhouse gases, ozone depleting chemicals, and air and water pollutants that impair public health.
- Less damage to productivity in natural resource industries.
- Reduced impacts on species habitat and ecosystems.
- Less intrusion of industrial activity into previously pristine, wild places.

The benefits that Massachusetts gains from the recycling economy, as reported by the MA Department of Environmental Protection, include the direct benefits of:

- 1,437 recycling businesses and organizations
- 19,500 recycling jobs + 11,452 indirect jobs
- $557 million annual payroll + $470 million indirect annual payroll
- $3.5 billion receipts + $1.6 billion indirect receipts
- $6.4 million in state tax revenues

The indirect benefits of the recycling economy include: interaction between recycling businesses and a wide variety of service-based businesses (e.g. equipment manufacturers, consultants, brokers, transporters, accounting firms, office supply companies).[178]

In 2002, source reduction and recycling in Massachusetts prevented disposal of 8 million tons of waste, or 22 new 1,200 ton per day disposal facilities. This achievement also:

- reduced greenhouse gas emissions by more than 1 million tons of carbon equivalent per year,
- saved nearly 12 trillion BTUs of energy (equivalent to 2.1 million barrels of oil),
- saved nearly 570,000 tons of iron ore, coal and limestone, and more than 16 million trees.[179]

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[178] *Fact Sheet: The Massachusetts Recycling Economy*, produced by the Bureau of Waste Prevention, July 2004.

[179] *Fact Sheet: 3rd Annual Progress Report on the Beyond 2000 Solid Waste Master Plan*, September 2004, p. 1. http://www.mass.gov/dep/bwp/dswm/files/swprfs3.doc