PNNL-14015

Pacific Northwest
National Laboratory
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U.S. Department of Energy

Statewide Savings Projections from the Adoption of a Commercial Building Energy Code in Illinois

KA Cort
DB Belzer

September 2002

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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Completed for the Building Standards and Guidelines Program, U.S. Department of Energy.

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Executive Summary

ANSI/ASHRAE/IESNA Standard 90.1-1999 Energy Standard for Buildings except Low-Rise Residential Buildings (hereafter referred to as ASHRAE 90.1-1999 or 90.1-1999) was developed in an effort to set minimum requirements for the energy efficient design and construction of new commercial buildings. A number of jurisdictions in the state of Illinois are considering adopting ASHRAE 90.1-1999 as their commercial building energy code. This report builds on the results of a previous study, *Analysis of Potential Benefits and Costs of Adopting ASHRAE Standard 90.1-1999 as a Commercial Building Energy Code in Illinois Jurisdictions*, to estimate the total potential impact of adopting ASHRAE 90.1-1999 as a statewide commercial building code in terms of Life-Cycle Cost (LCC) savings, total primary energy savings, and pollution emissions reductions.

Illinois does not currently have a statewide building energy code. Therefore, in the absence of a code, the LCC savings of adopting ASHRAE 90.1-1999 are estimated using two separate baseline scenarios to reflect the variability in current building practices. Similarly, the total primary energy savings are estimated using two sets of baseline assumptions. Finally, the corresponding greenhouse gas emissions reductions (CO_2, SO_2, NO_x, CO, PM, VOC) are estimated using both average and marginal emissions coefficients. The results of this analysis suggest that adopting and enforcing a commercial building energy code throughout the state of Illinois could produce substantial energy and cost savings, while reducing emissions of greenhouse gases.

Contents

1. Background

Illinois does not currently have a statewide building energy code that could be used as a baseline. It is, therefore, not possible to clearly define energy-related baseline characteristics for commercial building construction. While some new buildings may already be meeting or exceeding some of the requirements of ASHRAE 90.1-1999, others may be well below this standard. In an effort to reflect varied practices in the baseline, two separate building envelope baseline scenarios are used to calculate a range of potential savings from energy code adoption.

This study includes the impacts of adopting only the building envelope and lighting requirements of ASHRAE 90.1-1999 and applying it only to new commercial construction. Mechanical requirements are excluded because of expected changes in efficiencies due to federal manufacturing standards as referenced under the Energy Policy and Conservation Act (EPCA) as amended by the 1992 Energy Policy Act (EPAct). Under this legislation, the energy efficiency of most of the heating ventilation, and air-conditioning (HVAC) and the service water heating (SWH) equipment regulated under ASHRAE 90.1-1999 is also regulated by federal manufacturing standards, which by law will soon be updated to levels at least as stringent as those in 90.1-1999. Hence, the savings from these equipment requirements will generally occur regardless of the adoption of a building standard in Illinois. Efficiency improvements in equipment that are not covered under EPCA are discussed in Section 5.3 along with other requirements in the HVAC and SWH section of the standard. The potential quantitative impact of the equipment standards has been evaluated in detail in the report, *Screening Analysis for EPACT-Covered Commercial HVAC and Water heating Equipment.*

This report builds on a previous study that uses prototypical office, retail, and education buildings to estimate Life-Cycle Cost (LCC) savings estimates per square foot. Office, retail, and education buildings made up over 60% of the total value of new commercial construction in Illinois in 1997 (Census 2000). A 40-year time horizon was chosen for the LCC estimates to capture changes in building energy costs that occur over the life of the building. Specific energy simulation and economic assumptions are discussed more extensively in the report, *Analysis of Potential Benefits and Costs of Adopting ASHRAE Standard 90.1-1999 as a Commercial Building Energy Code in Illinois Jurisdictions.* The savings results upon which the statewide estimates are based may be found in the appendix of this report. Appendixes A and B include results and assumptions for building prototypes built with ASHRAE 90A-1980 baseline envelope specifications, assuming steel frames and mass walls, respectively. The savings estimates for building prototypes built using 90.1-1989 as the baseline are found in Appendixes C and D for steel frames and mass walls, respectively.

2. Key Assumption

The following section discusses some of the key assumptions necessary to calculate the net present value of benefits and costs to building owners and users in Illinois from the adoption of an energy code.

2.1 Building Envelope Baseline

This study uses the requirements of ASHRAE Standard 90A-1980 and ASHRAE 90.1-1989 to develop separate sets of baseline assumptions for envelope requirements because both standards take different approaches with respect to envelope requirements. ASHRAE 90A-1980 contains a set of charts, graphs, and equations that must be solved to obtain envelope requirements, while Standard 90.1-1999 contains sets of prescriptive requirements for envelope components along with a performance-based tradeoff approach. Although these requirements are not always directly comparable, in almost all cases the building envelope that is required to meet the 90.1-1999 standard is more energy efficient than the building envelope required to meet 90A-1980.

The ASHRAE 90.1-1989 requirements are described in detail in a previous study.[1] In most all cases the envelope requirements of ASHRAE 90.1-1989 are significantly more stringent than those of 90A-1980. In many cases, the envelope requirements of 90.1-1989 are more stringent than those required by 90.1-1999. Although the envelope design criteria for either ASHRAE 90A-1980 or 90.1-1989 may not accurately reflect specific current building practices in Illinois, together they represent a wide range of building envelope characteristics. It is likely that most new buildings are built at least to the standards specified in 90A-1980 and, at most, to a level of 90.1-1989.

2.2 Lighting Baseline

Designers and builders in the state of Illinois are not required to adopt lighting practices that meet or exceed any mandated level. However, due to overall improvements in lighting technologies, it is likely that builders are installing lighting systems that would exceed the 90A-1980 requirements for building types included in the evaluation. In order to reflect this practice, this study uses the lighting requirements of 90.1-1989 to represent the baseline lighting levels for both baseline scenarios. It is worth noting, however, that despite technological improvements, it is possible for someone to build a commercial building below the level specified by the 90.1-1989 requirements. This would most likely be a result of excessive use of less efficient lighting technologies such as incandescent and older fluorescent (T12) or from illumination levels that exceed the common practice represented by the 90.1-1989 lighting power limits.

[1] *Analysis of Potential Benefits and Costs of Adopting ASHRAE Standard 90.1-1999 as a Commercial Building Energy Code in Illinois Jurisdictions*

2.3 Building Types

Approximately 60 million square feet of new commercial building space is constructed in Illinois each year[2]. It is estimated that office, retail, and education buildings make up more than 60% of the total square feet of new commercial space. As a result, this study focuses on the LCC and energy savings estimates for these building types and estimates average savings for the remaining building types. Buildings are weighted appropriately, as described in Table 1. In addition to the categories listed in Table 1, buildings were weighted by type of wall construction (e.g., steel frame with siding versus mass wall construction) and office buildings were further categorized by window-to-wall ratios, based on information from the 1992 Commercial Buildings Energy Consumption Survey (CBECS).

Table 1. Building Weights

BUIDING TYPE	ESTIMATED SQUARE FOOTAGE (In Millions)
Office	**15.9**
• *"Small" Office (1-2 floors)*	*9.1*
• *"Large" Office (3 or more floors)*	*6.8*
Retail	**15.9**
Education	**7.0**
• *Single-story (Elementary)*	*2.8*
• *More than one floor*	*4.2*
Other	**21.4**
TOTAL	**60.2**

It is assumed that these representative buildings are heated with a gas furnace and cooled with an electric air conditioner. It is assumed that all buildings are well operated (e.g., heating is set back when buildings are not occupied). When a building is operated in this manner, the energy losses that would occur from heat losses through relatively poorly insulated roofs, walls, and windows would be minimized. By assuming buildings are well-operated and heated with gas, the prototype buildings chosen in the study most likely represent the lower end of potential energy savings from envelope improvements.

2.4 Climate

The climate zone is defined by long-term weather conditions, which affect heating and cooling loads in buildings. The zones are based on an annual average number of degree-days, which are a measurement of how cold/hot a building location is relative to the base

[2] This estimate is based on 1997 Census study (Census 2000), which estimates total expenditures on new commercial construction by building type in Illinois. New commercial square footage estimates are derived by dividing the total dollars spent on new commercial construction by the average cost/s.f. (MEANS) by building category. These numbers are then adjusted to fit total U.S. square footage estimates listed in the Statistical Abstract of the United States (2000).

temperature[3]. Although Illinois has varying temperatures throughout the state, this analysis focuses on the northern region where much of the population growth and building construction is occurring. The climate in northern Illinois is generally defined as having fewer than 3000 average annual cooling degree-days (CDD) and 5500 to 7000 average annual heating degree-days (HDD) . Representative weather data is taken from the Typical Meteorological Year (TMY) weather data set.

2.5 Economic Variables

The economic benefits and costs of adopting 90.1-1999 are determined utilizing the LCC approach, which compares the monetary savings over a specified time horizon in comparison to the associated costs of complying with the code. For this study the LCC is a general measure of the cost of operating a building over its assumed 40-year lifetime and includes the initial incremental construction cost, replacement of key components, and annual energy expenditures. A key assumption in the valuation of future benefits and costs is the time-value of money or discount rate that reflects the opportunity cost of capital. This study uses a constant 7% (real) discount rate, which is consistent with the value used by U.S. Department of Energy in analyses of residential and commercial equipment efficiency standards.

Several factors influence the cost and savings from adopting an energy efficiency building code –first costs, replacement costs, maintenance costs, and energy savings. The primary costs associated with code adoption are the incremental costs of required materials and installation that will contribute to reduced annual energy consumption (e.g., higher levels of insulation, more efficient light fixtures) relative to the cost of building materials that would satisfy a less stringent set of requirements. These costs are often referred to as "first costs," as they are incurred when the building is first built. The collection and treatment of first costs for lighting and building envelope materials are discussed in the previous Pacific Northwest National Laboratory (PNNL) study[4].

The primary ongoing monetary benefit of an energy code is the energy that is saved over the life of a building by using relatively more energy-efficient designs, materials and equipment. The incremental energy savings are valued using forecasted average commercial gas and electricity rates over a specified time horizon. The resulting LCC savings and primary energy savings for all of Illinois are estimated in the following sections.

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[3] The daily heating degree days (HDD) is the numerical difference between a day's average temperature and 65°F (HDD is zero if the day's average temperature is less than 65°F and the annual HDD is the sum of the daily HDD for the year. The daily cooling degree days (CDD) is the numerical difference between a day's average temperature and 50°F (CDD is zero if the day's average temperature greater than 50°F) and annual CDD is the sum of the daily CDD for the year.

[4] *Analysis of Potential Benefits and Costs of Adopting ASHRAE Standard 90.1-1999 as a Commercial Building Energy Code in Illinois Jurisdictions*

3. Estimated Total State Impacts

All LCC savings and energy savings described in this section stem from a previous study that analyzed energy use and LCC savings for selected prototypical buildings simulated with Illinois climate characteristics, the results of which are included in the appendix. Quantitative measures of energy-use impacts were estimated using the Building Loads Analysis and System Thermodynamics (BLAST) simulations and combined with the energy and capital costs to derive LCC savings per square foot.

3.1 Life-Cycle Cost Savings

The LCC savings per square foot for each prototypical building included in the study are listed in Table 2. The total annual LCC savings for Illinois are estimated using the overall commercial floor space weights listed in Table 1, along with wall construction and window-to-wall ratio splits from CBECS (1992), and are shown in the bottom row of Table 2. These estimates assume the energy and cost savings estimated for the building prototypes modeled are representative of new building construction in Illinois.

Table 2. LCC Savings by Building Type and State Totals from 90.1-1999 adoption

BUIDING TYPE	90A-1980 Baseline		90.1-1989 Baseline	
	Steel frame	Mass wall	Steel frame	Mass wall
	LCC Savings ($/ S.F.)	**LCC Savings ($/ S.F.)**	**LCC Savings ($/ S.F.)**	**LCC Savings ($/ S.F.)**
Office				
"Small" Office (1-2 floors)				
• *With less than 38% window-to-wall ratio*	.97	.99	1.33	1.37
• *With more than 38% window-to-wall ratio*	.94	.98	1.71	1.79
"Large" Office (3 or more floors)				
• *With less than 38% window-to-wall ratio*	.90	.89	.99	1.04
• *With more than 38% window-to-wall ratio*	.84	.85	1.23	1.31
Retail	1.50	1.55	1.97	2.00
Education				
• *Single-story (Elementary)*	.54	.44	.63	.65
• *More than one floor*	.69	.50	.57	.60
Other (Average)	.91	.89	1.20	1.25
Total Annual LCC Savings in Illinois (Derived from per square foot savings)	**$61 Million**		**$83 Million**	

Because the first cost differences are more significant for building designs that are moving from a 90A-1980 baseline to 90.1-1999, the total LCC savings is less than the LCC savings using the 90.1-1989 baseline. Both scenarios, however, produce annual LCC savings in excess of $60 million to the state of Illinois.

The annual LCC savings is equivalent to the net present value of the changes in capital (first) and energy costs associated with code adoption for all new buildings built in a given year. Assuming approximately 60 million square feet of building space is added to the commercial building stock each year, the net present value for construction over a 20-year period would range from around $700,000 to nearly 1 billion dollars (See Figure 1). The net present value is calculated by discounting the LCC savings for each future year's construction (e.g., $61 million or $83 million, depending on the chosen baseline) back to 2002, using a discount rate of 7%[5].

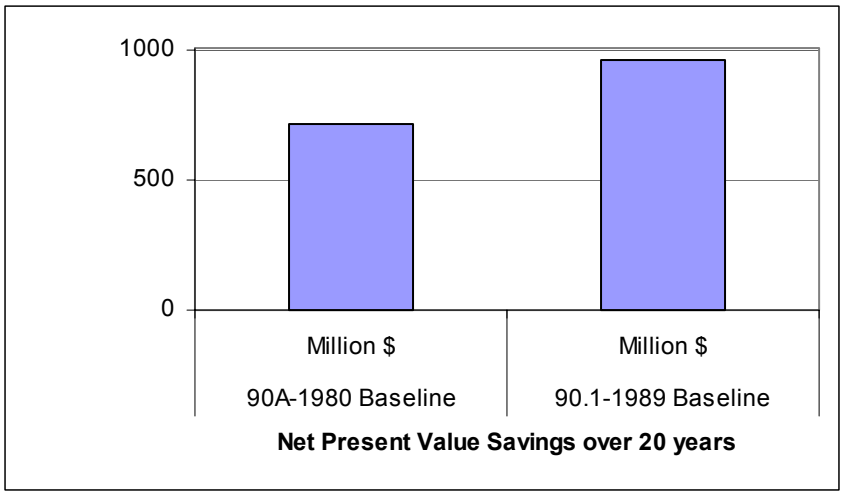

Figure 1. Net Present Value from 90.1-1999 Code Adoption over a 20-Year Period

3.2 Primary Energy Savings

Primary energy savings are reported in trillion Btu (TBtu) per year. These results are derived from the site electricity savings[6] per square foot (from fan systems, cooling, and lighting savings), added together with the natural gas savings (or losses) for each building type, multiplied by the total number of square feet in each building category. The differences in envelope requirements between the baseline ASHRAE 90A-1980 and 90.1-1999 are more significant than the differences in envelope requirements between 90.1-1989 and 90.1-1999. As a result, the annual energy savings using the 90A-1980 baseline are greater than the savings using the 90.1-1989 baseline, as illustrated in Table 3.

[5] Assuming a constant rate of annual LCC savings.
[6] Site electricity is converted to primary electricity to derive primary energy.

Table 3. Primary Energy Savings from 90.1-1999 adoption (in TBtu/Year)*

BASELINE	2002	2005	2010	2015	2020
90A-1980	**1.2**	**4.7**	**10.6**	**16.4**	**22.3**
90.1-1989	**0.9**	**3.8**	**8.5**	**13.3**	**18.0**

*Using Average Electricity Conversion Factors

The energy savings resulting from energy code adoption persist for the life of the building. Although the total amount saved in the first year of adoption may be relatively modest compared with the total amount of energy consumed by the entire commercial sector, these savings from new buildings adopting codes in any given year continue into the future as more new buildings are added to the existing building stock. The savings from code adoption relative to total energy consumption become more significant in future years. Figure 2 illustrates the potential impact through 2020 of code adoption (applied only to new construction) on total commercial energy consumption in Illinois. This does not include potential savings if the code is applied to commercial building renovations[7].

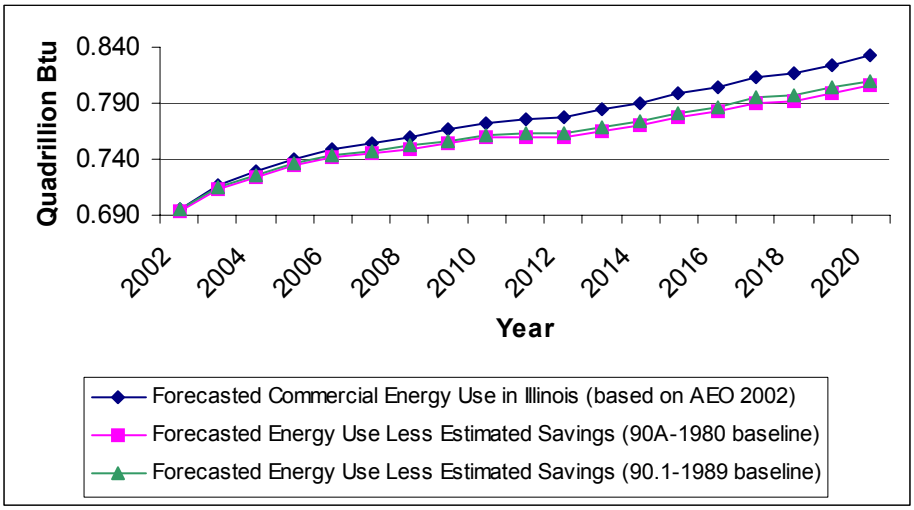

Figure 2. Forecasted Commercial Energy Use in Illinois With and Without Adoption of 90.1-1999

3.3 Pollution Emissions Reductions

Emissions reductions are based on the energy savings calculations described in Section 3.2. Emissions coefficients for all primary greenhouse gases (CO_2, SO_2, NO_x, VOC, CO, and PM) are based on U.S. Department of Energy estimates.[8] The coefficients are based on the content of the greenhouse gas in each fuel type. For example, the carbon emission factors are based on the carbon content of the fuel and the fraction of the fuel

[7] The value of annual investment in commercial alternations and renovations is approximately 50% of the value of new construction in a given year. Expanding the application of the code to commercial building alternations and renovations would potentially significantly increase the statewide energy savings.

[8] The GPRA 2002 Data Call, produced by DOE (which are the same as the AEO 2000 emission coefficient assumptions used by EIA)

consumed in combustion. Emissions factors can be in terms of *marginal* emissions rates, which focus on future displaced energy consumption, or the emissions factors can be *average* rates, which take an average of the fuel mixes being used today. The marginal and average rates yield significantly different emission displacement numbers.

The marginal rates are based on the forecasted displaced fuel mix for the next 20 years[9]. The average coefficients for electricity are based on the electricity generation mix in Illinois, which is approximately 45% from coal generating plants, 50% from nuclear plants, and 4% from natural gas plants (EIA 2000b). Note that there are no greenhouse gas emissions associated with the production of nuclear power.

The emissions coefficients are multiplied by the primary energy savings, as listed in Section 3.2, to yield the total emissions reductions listed in Tables 3, 4, and 5.

Table 3. Carbon Equivalent Emissions Reductions from 90.1-1999 adoption (in Metric Tons/Year)

BASELINE	**2002**	**2005**	**2010**	**2015**	**2020**
90A-1980 (Average*)	14,315	57,259	128,833	200,407	271,981
90.1-1989 (Average*)	11,370	45,479	102,327	159,175	216,023
90A-1980 (Marginal)**	21,752	89,860	187,610	258,624	326,818
90.1-1989 (Marginal)**	17,978	74,445	154,552	210,902	264,747

*Using Average Carbon Emissions Coefficients
**Using Marginal Carbon Emissions Coefficients

As illustrated in the Table 3 and Figure 3, the displaced emissions estimates vary significantly depending on which rate (marginal or average) is used. The average coefficients provide a snap shot of the present situation, representing current fuel mixes in Illinois. In the case of Illinois, this includes a relatively high percentage of nuclear power generation, which produces no greenhouse emissions. The marginal rates may be more appropriate to observe if the focus is on future displaced generation (focusing on the sources of potential marginal power generation). Because of the difficulty of locating nuclear and hydro plants, these zero emitting power sources are not considered in the development of the marginal emissions coefficients.

[9] In the absence of state-specific data, it was assumed that the Illinois marginal fuel mix would be same as the national estimates of displaced fuel.

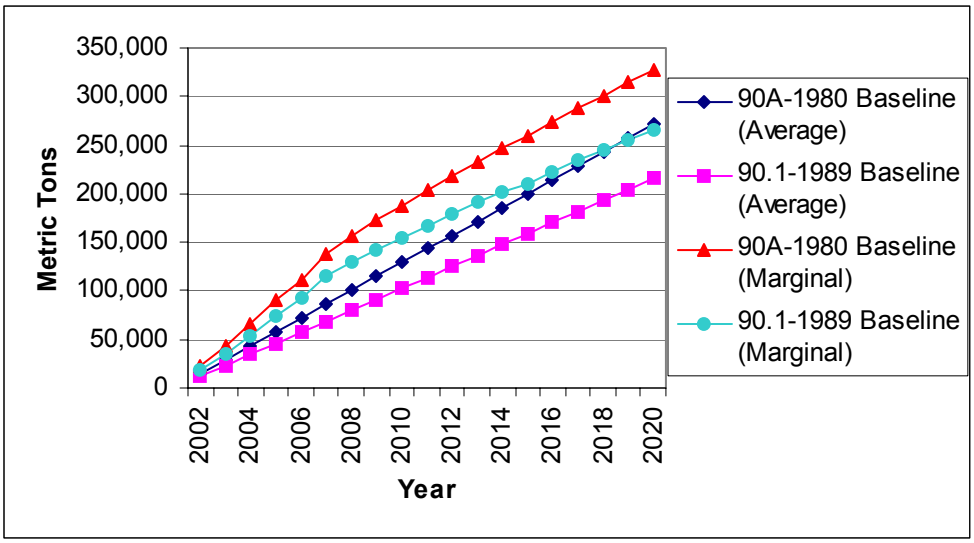

Figure 3. Carbon Emissions Reduction from 90.1-1999 adoption using Marginal and Average Emissions Coefficients

In either case (using marginal or average coefficients), the potential carbon emissions reductions stemming from building code energy savings are significant, ranging from 10,000-20,000 metric tons in the short term, increasing up to 330,000 metric tons in the longer term (2020).

Table 4. Other Greenhouse Gas Emissions from 90.1-1999 adoption Calculated Using Average Emission Coefficients

OTHER GREENHOUSE GASES	EMISSIONS REDUCTION (Metric Tons) 90A-1980 Baseline		EMISSIONS REDUCTION (Metric Tons) 90.1-1989 Baseline	
year	**2002**	**2020**	**2002**	**2020**
Sulfur Dioxide (SO_2)	317	6032	282	5359
Nitrous Oxides (NO_x)	141	2679	115	2191
Carbon Monoxide (MO)	6	118	3	53
Particulate Matter (PM_{10})	7	128	6	114
Volatile Organic Compound (VOC)	1	12	0	6

Tables 4 and 5 provide the potential emissions reductions for all other major green house gases. For the most part, the results from using marginal and average emissions coefficients follow the same pattern as the carbon equivalent emissions shown in Table 3. That is, the emissions reduction under the marginal rates produce greater emissions reductions due to the fact that nuclear power (a zero emitting source) would not be included in the future mixes of the power generation. The exception, however, is that sulfur dioxide emissions and particulate matter are greater when calculated with average coefficient because of the high percentage of coal power plants (which produces a high amount of SO_2 and PM) in the current mix of Illinois power generation.

Table 5. Other Greenhouse Gas Emissions from 90.1-1999 adoption Calculated Using Marginal Emission Coefficients

OTHER GREENHOUSE GASES	EMISSIONS REDUCTION (Metric Tons) 90A-1980 Baseline		EMISSIONS REDUCTION (Metric Tons) 90.1-1989 Baseline	
year	**2002**	**2020**	**2002**	**2020**
Sulfur Dioxide (SO_2)	246	4575	219	4065
Nitrous Oxides (NO_x)	179	2913	149	2399
Carbon Monoxide (MO)	28	345	22	255
Particulate Matter (PM_{10})	5	106	5	94
Volatile Organic Compound (VOC)	3	35	3	26

4. Conclusions

Assuming that the new building code impacts approximately 60 million square feet of new commercial building space each year and that the building prototypes modeled in this study are representative of new building stock in Illinois, the monetary impact of adopting a state-wide building energy code in Illinois could produce approximately $60-$80 million dollars of LCC savings for each year of construction. When evaluating the benefits of the code over a series of future years, the net present value represents an aggregate measure of the discounted total dollar savings to the state. Including future construction over the next 20 years, the estimated net present value is on the order of $1 billion. In addition, the energy savings from code adoption could significantly reduce the need to expand power generation and would produce significant environmental benefits. Carbon dioxide emissions could potentially be reduced by over 300,000 metric tons in the next 20 years.

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APPENDIX A

Metal Frame Results
90.1-1980 Envelope Baseline

Small Office (WWR=0.18)
Wall Type: **Steel Frame**
Bldg. Size **10,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	1,014	U-factor(std)	0.720	0.570		0.570
		sh. coef.(std)	0.840	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.72	0.571		0.571
		sh. coef.(cost)	0.836	0.453		0.453
		cost ($/sqft)	$4.66	$7.38		$7.38
Opaque Walls	4,619	U-factor	0.132	0.084		0.084
		cost ($/sqft)	$0.33	$0.70		$0.70
Roof	10,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$17,331	$22,029		$22,029
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$15,720		$17,554	$17,554
Construction Cost			$33,050	$37,749	$34,885	$39,584
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	119	100	107	88
Natural Gas		MMBtu	108	88	124	103
Total Annual Energy Cost			$9,234	$8,732	$8,335	$7,820
Economic Measures						
Life-Cycle Cost Savings				**$1,163**	**$8,372**	**$9,715**
Savings-to-Investment Ratio (SIR)				1.2	4.2	2.2
Adjusted IRR				7.5%	10.9%	9.2%

Notes:

1 **No economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Small Office (WWR=0.38)
Wall Type: **Steel Frame**
Bldg. Size **10,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	2,141	U-factor(std)	0.570	0.570		0.570
		sh. coef.(std)	0.570	0.453		0.453
(Window-Wall Ratio = 0.38)		U-factor(cost)	0.57	0.571		0.571
		sh. coef.(cost)	0.570	0.453		0.453
		cost ($/sqft)	$6.81	$7.38		$7.38
Opaque Walls	3,493	U-factor	0.087	0.084		0.084
		cost ($/sqft)	$0.67	$0.70		$0.70
Roof	10,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$27,999	$29,558		$29,558
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$15,720		$17,554	$17,554
Construction Cost			$43,719	$45,278	$45,553	$47,112
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	136	121	123	109
Natural Gas		MMBtu	116	121	132	138
Total Annual Energy Cost			$9,612	$9,368	$8,711	$8,476
Economic Measures						
Life-Cycle Cost Savings				**$1,104**	**$8,404**	**$9,387**
Savings-to-Investment Ratio (SIR)				1.6	4.2	3.1
Adjusted IRR				8.2%	10.9%	10.0%

Notes:

1 **No economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Large Office (WWR=0.18)
Wall Type: **Steel Frame**
Bldg. Size **60,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	4,302	U-factor(std)	0.720	0.570		0.570
		sh. coef.(std)	0.840	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.72	0.571		0.571
		sh. coef.(cost)	0.836	0.453		0.453
		cost ($/sqft)	$4.66	$7.38		$7.38
Opaque Walls	19,598	U-factor	0.132	0.084		0.084
		cost ($/sqft)	$0.33	$0.70		$0.70
Roof	20,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	613	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$48,153	$68,111		$68,111
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$94,319		$105,326	$105,326
Construction Cost			$142,472	$162,430	$153,480	$173,438
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,926	1,926	1,687	1,687
Electricity, HVAC		MMBtu	609	514	566	470
Natural Gas		MMBtu	369	299	433	355
Total Annual Energy Cost			$51,514	$49,202	$46,482	$44,110
Economic Measures						
Life-Cycle Cost Savings				**$7,408**	**$45,980**	**$54,200**
Savings-to-Investment Ratio (SIR)				1.3	3.9	2.4
Adjusted IRR				7.8%	10.7%	9.4%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Large Office (WWR=0.38)
Wall Type: **Steel Frame**
Bldg. Size **60,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	9,082	U-factor(std)	0.570	0.570		0.570
		sh. coef.(std)	0.570	0.453		0.453
(Window-Wall Ratio = 0.38)		U-factor(cost)	0.57	0.571		0.571
		sh. coef.(cost)	0.570	0.453		0.453
		cost ($/sqft)	$6.81	$7.38		$7.38
Opaque Walls	14,818	U-factor	0.087	0.084		0.084
		cost ($/sqft)	$0.67	$0.70		$0.70
Roof	20,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	613	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$93,414	$100,053		$100,053
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$94,319		$105,326	$105,326
Construction Cost			$187,733	$194,372	$198,740	$205,379
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,926	1,926	1,687	1,687
Electricity, HVAC		MMBtu	685	624	643	582
Natural Gas		MMBtu	396	416	459	483
Total Annual Energy Cost			$53,162	$52,127	$48,146	$47,126
Economic Measures						
Life-Cycle Cost Savings				**$4,968**	**$45,784**	**$50,537**
Savings-to-Investment Ratio (SIR)				1.6	3.9	3.1
Adjusted IRR				8.3%	10.7%	10.1%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Retail
Wall Type: **Steel Frame**
Bldg. Size **24,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	624	U-factor(std)	1.220	0.570		0.570
		sh. coef.(std)	0.950	0.570		0.570
(Window-Wall Ratio = 0.07)		U-factor(cost)	1.18	0.570		0.570
		sh. coef.(cost)	0.870	0.570		0.570
		cost ($/sqft)	$1.86	$6.81		$6.81
Opaque Walls	8,292	U-factor	0.132	0.084		0.084
		cost ($/sqft)	$0.33	$0.70		$0.70
Roof	24,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	686	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$29,762	$37,190		$37,190
Lighting						
Lighting Power Density		watts/sqft	2.36		1.90	1.90
Lighting Cost		$/sqft	$0.70		$0.84	$0.84
Total Lighting Cost			$16,848		$20,215	$20,215
Construction Cost			$46,610	$54,038	$49,977	$57,405
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	900	900	754	754
Electricity, HVAC		MMBtu	291	287	242	237
Natural Gas		MMBtu	121	74	158	98
Total Annual Energy Cost			$23,840	$23,437	$20,324	$19,821
Economic Measures						
Life-Cycle Cost Savings				**($2,730)**	**$37,397**	**$35,997**
Savings-to-Investment Ratio (SIR)				0.7	7.4	3.6
Adjusted IRR				5.9%	12.5%	10.5%

Notes:

1 **No economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Education (elementary)
Wall Type: **Steel Frame**
Bldg. Size **50,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	2,991	U-factor(std)	0.730	0.570		0.570
		sh. coef.(std)	0.840	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.73	0.571		0.571
		sh. coef.(cost)	0.840	0.453		0.453
		cost ($/sqft)	$4.55	$7.38		$7.38
Opaque Walls	13,624	U-factor	0.132	0.084		0.084
		cost ($/sqft)	$0.33	$0.70		$0.70
Roof	50,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	1,278	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$71,664	$88,151		$88,151
Lighting						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		$/sqft	$1.80		$1.96	$1.96
Total Lighting Cost			$89,774		$97,805	$97,805
Construction Cost			$161,438	$177,925	$169,469	$185,956
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,056	1,056	915	915
Electricity, HVAC		MMBtu	443	382	406	345
Natural Gas		MMBtu	1,161	1,080	1,240	1,160
Total Annual Energy Cost			$36,789	$35,072	$33,888	$32,170
Economic Measures						
Life-Cycle Cost Savings				**$3,675**	**$23,418**	**$27,087**
Savings-to-Investment Ratio (SIR)				1.2	3.0	1.9
Adjusted IRR				7.5%	9.9%	8.7%

Notes:

1 **No economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Education (two-story)
Wall Type: **Steel Frame**
Bldg. Size **80,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	5,023	U-factor(std)	0.730	0.570		0.570
		sh. coef.(std)	0.840	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.73	0.571		0.571
		sh. coef.(cost)	0.840	0.453		0.453
		cost ($/sqft)	$4.55	$7.38		$7.38
Opaque Walls	22,883	U-factor	0.132	0.084		0.084
		cost ($/sqft)	$0.33	$0.70		$0.70
Roof	40,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	1,073	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$73,373	$98,346		$98,346
Lighting						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		$/sqft	$1.80		$1.96	$1.96
Total Lighting Cost			$143,638		$156,487	$156,487
Construction Cost			$217,011	$241,984	$229,860	$254,833
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,690	1,690	1,464	1,464
Electricity, HVAC		MMBtu	849	716	783	650
Natural Gas		MMBtu	1,634	1,519	1,753	1,638
Total Annual Energy Cost			$60,076	$56,742	$55,245	$51,897
Economic Measures						
Life-Cycle Cost Savings				**$14,816**	**$39,851**	**$54,840**
Savings-to-Investment Ratio (SIR)				1.5	3.1	2.2
Adjusted IRR				8.2%	10.1%	9.1%

Notes:

1 **No economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Summary of Results by Building

Wall Type: Steel Frame			Standard Level			
			90.1-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Small Office (WWR=0.18)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sqft/yr)	44.0	1.9	5.2	7.1
No. of floors	1	Nat. Gas (kBtu/sqft/yr)	10.8	2.0	-1.6	0.5
Aspect ratio	2.25	Energy cost ($/sqft/yr)	$0.92	$0.05	$0.09	$0.14
Core ratio	0.44	Life-cycle cost ($/sqft)		$0.12	$0.84	$0.97
Window-wall ratio	0.18					
Economizer (?)	no	Savings-to-invest. Ratio		1.2	4.2	2.2
		Adjusted IRR		7.5%	10.9%	9.2%
Small Office (WWR=0.38)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sqft/yr)	45.7	1.4	5.2	6.6
No. of floors	1	Nat. Gas (kBtu/sqft/yr)	11.6	-0.5	-1.6	-2.2
Aspect ratio	2.25	Energy cost ($/sqft/yr)	$0.96	$0.02	$0.09	$0.11
Core ratio	0.44	Life-cycle cost ($/sqft)		$0.11	$0.84	$0.94
Window-wall ratio	0.38					
Economizer (?)	no	Savings-to-invest. Ratio		1.6	4.2	3.1
		Adjusted IRR		8.2%	10.9%	10.0%
Large Office (WWR=0.18)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sqft/yr)	42.2	1.6	4.7	6.3
No. of floors	3	Nat. Gas (kBtu/sqft/yr)	6.2	1.2	-1.1	0.2
Aspect ratio	2.25	Energy cost ($/sqft/yr)	$0.86	$0.04	$0.08	$0.12
Core ratio	0.59	Life-cycle cost ($/sqft)		$0.12	$0.77	$0.90
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		1.3	3.9	2.4
		Adjusted IRR		7.8%	10.7%	9.4%
Large Office (WWR=0.38)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sqft/yr)	43.5	1.0	4.7	5.7
No. of floors	3	Nat. Gas (kBtu/sqft/yr)	6.6	-0.3	-1.1	-1.5
Aspect ratio	2.25	Energy cost ($/sqft/yr)	$0.89	$0.02	$0.08	$0.10
Core ratio	0.59	Life-cycle cost ($/sqft)		$0.08	$0.76	$0.84
Window-wall ratio	0.38					
Economizer (?)	yes	Savings-to-invest. Ratio		1.6	3.9	3.1
		Adjusted IRR		8.3%	10.7%	10.1%

Summary of Results by Building

Wall Type: Steel Frame			Standard Level			
			90.1-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Retail		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	24,000	Electricity (kBtu/sqft/yr)	49.6	0.2	8.1	8.3
No. of floors	1	Nat. Gas (kBtu/sqft/yr)	5.1	2.0	-1.5	1.0
Aspect ratio	2.50	Energy cost ($/sqft/yr)	$0.99	$0.02	$0.15	$0.17
Core ratio	0.61	Life-cycle cost ($/sqft)		-$0.11	$1.56	$1.50
Window-wall ratio	0.07					
Economizer (?)	no	Savings-to-invest. Ratio		0.7	7.4	3.6
		Adjusted IRR		5.9%	12.5%	10.5%
Education (elementary)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	50,000	Electricity (kBtu/sqft/yr)	30.0	1.2	3.5	4.8
No. of floors	1	Nat. Gas (kBtu/sqft/yr)	23.2	1.6	-1.6	0.0
Aspect ratio	6.00	Energy cost ($/sqft/yr)	$0.74	$0.03	$0.06	$0.09
Core ratio	0.63	Life-cycle cost ($/sqft)		$0.07	$0.47	$0.54
Window-wall ratio	0.18					
Economizer (?)	no	Savings-to-invest. Ratio		1.2	3.0	1.9
		Adjusted IRR		7.5%	9.9%	8.7%
Education (two-story)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	80,000	Electricity (kBtu/sqft/yr)	31.7	1.7	3.6	5.3
No. of floors	2	Nat. Gas (kBtu/sqft/yr)	20.4	1.4	-1.5	-0.1
Aspect ratio	5.00	Energy cost ($/sqft/yr)	$0.75	$0.04	$0.06	$0.10
Core ratio	0.62	Life-cycle cost ($/sqft)		$0.19	$0.50	$0.69
Window-wall ratio	0.18					
Economizer (?)	no	Savings-to-invest. Ratio		1.5	3.1	2.2
		Adjusted IRR		8.2%	10.1%	9.1%

APPENDIX B

Mass Wall Results
90.1-1980 Envelope Baseline

Small Office (WWR=0.18)
Wall Type: **Mass**
Bldg. Size **10,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	1,014	U-factor(std)	0.720	0.570		0.570
		sh. coef.(std)	0.840	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.72	0.571		0.571
		sh. coef.(cost)	0.836	0.453		0.453
		cost ($/sqft)	$4.66	$7.38		$7.38
Opaque Walls	4,619	U-factor	0.132	0.123		0.123
		cost ($/sqft)	$2.16	$2.08		$2.08
Roof	10,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$25,759	$28,380		$28,380
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$15,720		$17,554	$17,554
Construction Cost			$41,478	$44,099	$43,313	$45,934
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	320	321	281	281
Electricity, HVAC		MMBtu	116	96	104	85
Natural Gas		MMBtu	112	108	129	126
Total Annual Energy Cost			$9,196	$8,802	$8,318	$7,918
Economic Measures						
Life-Cycle Cost Savings				**$1,699**	**$8,111**	**$9,876**
Savings-to-Investment Ratio (SIR)				1.5	4.1	2.7
Adjusted IRR				8.1%	10.8%	9.7%

Notes:

1 **No economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Small Office (WWR=0.38)
Wall Type: **Mass**
Bldg. Size **10,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	2,141	U-factor(std)	0.570	0.570		0.570
		sh. coef.(std)	0.570	0.453		0.453
(Window-Wall Ratio = 0.38)		U-factor(cost)	0.57	0.571		0.571
		sh. coef.(cost)	0.570	0.453		0.453
		cost ($/sqft)	$6.81	$7.38		$7.38
Opaque Walls	3,493	U-factor	0.087	0.123		0.123
		cost ($/sqft)	$2.55	$2.08		$2.08
Roof	10,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$34,543	$34,359		$34,359
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$15,720		$17,554	$17,554
Construction Cost			$50,263	$50,079	$52,098	$51,914
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	320	321	281	281
Electricity, HVAC		MMBtu	135	120	123	108
Natural Gas		MMBtu	119	136	135	153
Total Annual Energy Cost			$9,599	$9,440	$8,716	$8,558
Economic Measures						
Life-Cycle Cost Savings				**$1,619**	**$8,165**	**$9,768**
Savings-to-Investment Ratio (SIR)				8.7	4.1	4.4
Adjusted IRR				12.9%	10.8%	11.1%

Notes:

1 **No economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Large Office (WWR=0.18)
Wall Type: **Mass**
Bldg. Size **60,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	4,302	U-factor(std)	0.720	0.570		0.570
		sh. coef.(std)	0.840	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.72	0.571		0.571
		sh. coef.(cost)	0.836	0.453		0.453
		cost ($/sqft)	$4.66	$7.38		$7.38
Opaque Walls	19,598	U-factor	0.132	0.123		0.123
		cost ($/sqft)	$2.16	$2.08		$2.08
Roof	20,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	613	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$83,910	$95,054		$95,054
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$94,319		$105,326	$105,326
Construction Cost			$178,229	$189,373	$189,236	$200,381
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,922	1,926	1,687	1,687
Electricity, HVAC		MMBtu	580	494	538	450
Natural Gas		MMBtu	376	366	441	433
Total Annual Energy Cost			$50,940	$49,264	$45,990	$44,236
Economic Measures						
Life-Cycle Cost Savings				**$7,535**	**$44,951**	**$53,448**
Savings-to-Investment Ratio (SIR)				1.6	3.8	2.8
Adjusted IRR				8.2%	10.7%	9.8%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Large Office (WWR=0.38)
Wall Type: **Mass**
Bldg. Size **60,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	9,082	U-factor(std)	0.570	0.570		0.570
		sh. coef.(std)	0.570	0.453		0.453
(Window-Wall Ratio = 0.38)		U-factor(cost)	0.57	0.571		0.571
		sh. coef.(cost)	0.570	0.453		0.453
		cost ($/sqft)	$6.81	$7.38		$7.38
Opaque Walls	14,818	U-factor	0.087	0.123		0.123
		cost ($/sqft)	$2.55	$2.08		$2.08
Roof	20,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	613	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$121,179	$120,425		$120,425
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$94,319		$105,326	$105,326
Construction Cost			$215,498	$214,743	$226,506	$225,751
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,922	1,926	1,687	1,687
Electricity, HVAC		MMBtu	661	602	619	559
Natural Gas		MMBtu	396	469	461	541
Total Annual Energy Cost			$52,632	$52,044	$47,690	$47,083
Economic Measures						
Life-Cycle Cost Savings				**$6,143**	**$44,855**	**$51,174**
Savings-to-Investment Ratio (SIR)				11.3	3.8	4.1
Adjusted IRR				13.7%	10.7%	10.8%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Retail
Wall Type: **Mass**
Bldg. Size **24,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	624	U-factor(std)	1.220	0.570		0.570
		sh. coef.(std)	0.950	0.570		0.570
(Window-Wall Ratio = 0.07)		U-factor(cost)	1.18	0.570		0.570
		sh. coef.(cost)	0.870	0.570		0.570
		cost ($/sqft)	$1.86	$6.81		$6.81
Opaque Walls	8,292	U-factor	0.132	0.123		0.123
		cost ($/sqft)	$2.16	$2.08		$2.08
Roof	24,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	686	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$44,891	$48,590		$48,590
Lighting						
Lighting Power Density		watts/sqft	2.36		1.90	1.90
Lighting Cost		$/sqft	$0.70		$0.84	$0.84
Total Lighting Cost			$16,848		$20,215	$20,215
Construction Cost			$61,738	$65,438	$65,106	$68,805
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	899	900	754	754
Electricity, HVAC		MMBtu	285	279	238	230
Natural Gas		MMBtu	130	100	171	136
Total Annual Energy Cost			$23,788	$23,462	$20,333	$19,942
Economic Measures						
Life-Cycle Cost Savings				**($237)**	**$36,607**	**$37,215**
Savings-to-Investment Ratio (SIR)				0.9	7.2	4.6
Adjusted IRR				6.9%	12.4%	11.2%

Notes:

1 **No economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Education (elementary)
Wall Type: **Mass**
Bldg. Size **50,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	2,991	U-factor(std)	0.730	0.570		0.570
		sh. coef.(std)	0.840	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.73	0.571		0.571
		sh. coef.(cost)	0.840	0.453		0.453
		cost ($/sqft)	$4.55	$7.38		$7.38
Opaque Walls	13,624	U-factor	0.132	0.123		0.123
		cost ($/sqft)	$2.16	$2.08		$2.08
Roof	50,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	1,278	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$96,521	$106,880		$106,880
Lighting						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		$/sqft	$1.80		$1.96	$1.96
Total Lighting Cost			$89,774		$97,805	$97,805
Construction Cost			$186,294	$196,654	$194,325	$204,685
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,057	1,056	915	915
Electricity, HVAC		MMBtu	371	318	347	294
Natural Gas		MMBtu	1,161	1,144	1,242	1,230
Total Annual Energy Cost			$35,425	$34,275	$32,754	$31,656
Economic Measures						
Life-Cycle Cost Savings				**$2,026**	**$20,536**	**$21,900**
Savings-to-Investment Ratio (SIR)				1.2	2.7	1.9
Adjusted IRR				7.4%	9.7%	8.7%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Education (two-story)
Wall Type: **Mass**
Bldg. Size **80,000 sq. ft.**

			Standard Level			
			90A-1980 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	5,023	U-factor(std)	0.730	0.570		0.570
		sh. coef.(std)	0.840	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.73	0.571		0.571
		sh. coef.(cost)	0.840	0.453		0.453
		cost ($/sqft)	$4.55	$7.38		$7.38
Opaque Walls	22,883	U-factor	0.132	0.123		0.123
		cost ($/sqft)	$2.16	$2.08		$2.08
Roof	40,000	U-factor	0.074	0.063		0.063
		cost ($/sqft)	$1.02	$1.13		$1.13
	(feet)					
Slab perimeter	1,073	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$115,123	$129,805		$129,805
Lighting						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		$/sqft	$1.80		$1.96	$1.96
Total Lighting Cost			$143,638		$156,487	$156,487
Construction Cost			$258,761	$273,443	$271,610	$286,292
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,691	1,690	1,464	1,464
Electricity, HVAC		MMBtu	662	564	622	525
Natural Gas		MMBtu	1,633	1,624	1,756	1,751
Total Annual Energy Cost			$56,499	$54,514	$52,154	$50,228
Economic Measures						
Life-Cycle Cost Savings				**$7,177**	**$33,811**	**$40,233**
Savings-to-Investment Ratio (SIR)				1.4	2.8	2.1
Adjusted IRR				7.9%	9.8%	9.0%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Summary of Results by Building

Wall Type: MASS			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Small Office (WWR=0.18)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sqft/yr)	43.6	1.9	5.1	7.1
No. of floors	1	Nat. Gas (kBtu/sqft/yr)	11.2	0.4	-1.7	-1.4
Aspect ratio	2.25	Energy cost ($/sqft/yr)	$0.92	$0.04	$0.09	$0.13
Core ratio	0.44	Life-cycle cost ($/sqft)		$0.17	$0.81	$0.99
Window-wall ratio	0.18					
Economizer (?)	no	Savings-to-invest. Ratio		1.5	4.1	2.7
		Adjusted IRR		8.1%	10.8%	9.7%
Small Office (WWR=0.38)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sqft/yr)	45.5	1.4	5.1	6.6
No. of floors	1	Nat. Gas (kBtu/sqft/yr)	11.9	-1.7	-1.6	-3.5
Aspect ratio	2.25	Energy cost ($/sqft/yr)	$0.96	$0.02	$0.09	$0.10
Core ratio	0.44	Life-cycle cost ($/sqft)		$0.16	$0.82	$0.98
Window-wall ratio	0.38					
Economizer (?)	no	Savings-to-invest. Ratio		8.7	4.1	4.4
		Adjusted IRR		12.9%	10.8%	11.1%
Large Office (WWR=0.18)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sqft/yr)	41.7	1.4	4.6	6.1
No. of floors	3	Nat. Gas (kBtu/sqft/yr)	6.3	0.2	-1.1	-0.9
Aspect ratio	2.25	Energy cost ($/sqft/yr)	$0.85	$0.03	$0.08	$0.11
Core ratio	0.59	Life-cycle cost ($/sqft)		$0.13	$0.75	$0.89
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		1.6	3.8	2.8
		Adjusted IRR		8.2%	10.7%	9.8%
Large Office (WWR=0.38)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sqft/yr)	43.1	0.9	4.6	5.6
No. of floors	3	Nat. Gas (kBtu/sqft/yr)	6.6	-1.2	-1.1	-2.4
Aspect ratio	2.25	Energy cost ($/sqft/yr)	$0.88	$0.01	$0.08	$0.09
Core ratio	0.59	Life-cycle cost ($/sqft)		$0.10	$0.75	$0.85
Window-wall ratio	0.38					
Economizer (?)	yes	Savings-to-invest. Ratio		11.3	3.8	4.1
		Adjusted IRR		13.7%	10.7%	10.8%

Summary of Results by Building

Wall Type: MASS			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Retail		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	24,000	Electricity (kBtu/sqft/yr)	49.4	0.3	8.0	8.4
No. of floors	1	Nat. Gas (kBtu/sqft/yr)	5.4	1.2	-1.7	-0.2
Aspect ratio	2.50	Energy cost ($/sqft/yr)	$0.99	$0.01	$0.14	$0.16
Core ratio	0.61	Life-cycle cost ($/sqft)		-$0.01	$1.53	$1.55
Window-wall ratio	0.07					
Economizer (?)	no	Savings-to-invest. Ratio		0.9	7.2	4.6
		Adjusted IRR		6.9%	12.4%	11.2%
Education (elementary)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	50,000	Electricity (kBtu/sqft/yr)	28.6	1.1	3.3	4.4
No. of floors	1	Nat. Gas (kBtu/sqft/yr)	23.2	0.3	-1.6	-1.4
Aspect ratio	6.00	Energy cost ($/sqft/yr)	$0.71	$0.02	$0.05	$0.08
Core ratio	0.63	Life-cycle cost ($/sqft)		$0.04	$0.41	$0.44
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		1.2	2.7	1.9
		Adjusted IRR		7.4%	9.7%	8.7%
Education (two-story)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	80,000	Electricity (kBtu/sqft/yr)	29.4	1.2	3.3	4.6
No. of floors	2	Nat. Gas (kBtu/sqft/yr)	20.4	0.1	-1.5	-1.5
Aspect ratio	5.00	Energy cost ($/sqft/yr)	$0.71	$0.02	$0.05	$0.08
Core ratio	0.62	Life-cycle cost ($/sqft)		$0.09	$0.42	$0.50
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		1.4	2.8	2.1
		Adjusted IRR		7.9%	9.8%	9.0%

APPENDIX C

Metal Frame Results
90.1-1989 Baseline

Small Office (WWR=0.18)
Wall Type: Metal Frame
Bldg. Size: 10,000 sq. ft.

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	1,014	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.710	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.59	0.571		0.571
		sh. coef.(cost)	0.709	0.453		0.453
		cost ($/sqft)	$6.33	$7.38		$7.38
Opaque Walls	4,619	U-factor	0.077	0.084		0.084
		cost ($/sqft)	$0.78	$0.70		$0.70
Roof	10,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$24,131	$22,029		$22,029
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$15,720		$17,554	$17,554
Construction Cost			$39,851	$37,749	$41,685	$39,584
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	116	100	103	88
Natural Gas		MMBtu	74	88	86	103
Total Annual Energy Cost			$8,954	$8,732	$8,013	$7,819
Economic Measures						
Life-Cycle Cost Savings				**$4,695**	**$8,924**	**$13,254**
Savings-to-Investment Ratio (SIR)				Invest. < 0	4.4	23.2
Adjusted IRR				Invest. < 0	11.0%	15.8%

Notes:

1 **No economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Small Office (WWR=0.38)
Wall Type: Metal Frame
Bldg. Size: 10,000 sq. ft.

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	2,141	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.250	0.453		0.453
(Window-Wall Ratio = 0.38)		U-factor(cost)	0.55	0.571		0.571
		sh. coef.(cost)	0.262	0.453		0.453
		cost ($/sqft)	$11.33	$7.38		$7.38
Opaque Walls	3,493	U-factor	0.077	0.084		0.084
		cost ($/sqft)	$0.78	$0.70		$0.70
Roof	10,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$41,082	$29,558		$29,558
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$15,720		$17,554	$17,554
Construction Cost			$56,802	$45,278	$58,636	$47,112
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	97	121	86	109
Natural Gas		MMBtu	138	121	157	138
Total Annual Energy Cost			$9,018	$9,368	$8,151	$8,475
Economic Measures						
Life-Cycle Cost Savings				**$8,768**	**$7,955**	**$17,059**
Savings-to-Investment Ratio (SIR)				Invest. < 0	4.0	Invest. < 0
Adjusted IRR				Invest. < 0	10.8%	Invest. < 0

Notes:

1 **No economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Large Office (WWR=0.18)
Wall Type: Metal Frame
Bldg. Size: 60,000 sq. ft.

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	4,302	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.710	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.59	0.571		0.571
		sh. coef.(cost)	0.709	0.453		0.453
		cost ($/sqft)	$6.33	$7.38		$7.38
Opaque Walls	19,598	U-factor	0.077	0.084		0.084
		cost ($/sqft)	$0.78	$0.70		$0.70
Roof	20,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	613	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$70,219	$68,112		$68,112
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$94,319		$105,326	$105,326
Construction Cost			$164,538	$162,430	$175,546	$173,438
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,926	1,926	1,686	1,686
Electricity, HVAC		MMBtu	579	514	535	470
Natural Gas		MMBtu	250	299	299	355
Total Annual Energy Cost			$50,138	$49,202	$44,978	$44,106
Economic Measures						
Life-Cycle Cost Savings				**$12,829**	**$47,683**	**$59,669**
Savings-to-Investment Ratio (SIR)				Invest. < 0	4.0	5.2
Adjusted IRR				Invest. < 0	10.8%	11.5%

Notes:

1 **Economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Large Office (WWR=0.38)
Wall Type: Metal Frame
Bldg. Size: 60,000 sq. ft.

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	9,082	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.250	0.453		0.453
(Window-Wall Ratio = 0.38)		U-factor(cost)	0.55	0.571		0.571
		sh. coef.(cost)	0.262	0.453		0.453
		cost ($/sqft)	$11.33	$7.38		$7.38
Opaque Walls	14,818	U-factor	0.077	0.084		0.084
		cost ($/sqft)	$0.78	$0.70		$0.70
Roof	20,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	613	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$142,137	$100,053		$100,053
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$94,319		$105,326	$105,326
Construction Cost			$236,455	$194,372	$247,463	$205,380
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,926	1,926	1,686	1,686
Electricity, HVAC		MMBtu	517	624	475	582
Natural Gas		MMBtu	479	416	554	483
Total Annual Energy Cost			$50,478	$52,127	$45,524	$47,122
Economic Measures						
Life-Cycle Cost Savings				**$28,013**	**$44,924**	**$73,630**
Savings-to-Investment Ratio (SIR)				Invest. < 0	3.8	Invest. < 0
Adjusted IRR				Invest. < 0	10.7%	Invest. < 0

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Retail
Wall Type: Metal Frame
Bldg. Size: 24,000 sq. ft.

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	624	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.770	0.570		0.570
(Window-Wall Ratio = 0.07)		U-factor(cost)	0.60	0.570		0.570
		sh. coef.(cost)	0.763	0.570		0.570
		cost ($/sqft)	$6.15	$6.81		$6.81
Opaque Walls	8,292	U-factor	0.077	0.084		0.084
		cost ($/sqft)	$0.78	$0.70		$0.70
Roof	24,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	686	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$43,424	$37,190		$37,190
Lighting						
Lighting Power Density		watts/sqft	2.36		1.90	1.90
Lighting Cost		$/sqft	$0.70		$0.84	$0.84
Total Lighting Cost			$16,848		$20,215	$20,215
Construction Cost			$60,272	$54,038	$63,639	$57,405
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	899	899	754	754
Electricity, HVAC		MMBtu	300	287	249	237
Natural Gas		MMBtu	63	74	85	98
Total Annual Energy Cost			$23,621	$23,434	$19,965	$19,823
Economic Measures						
Life-Cycle Cost Savings				**$8,716**	**$39,238**	**$47,385**
Savings-to-Investment Ratio (SIR)				Invest. < 0	7.7	Invest. < 0
Adjusted IRR				Invest. < 0	12.6%	Invest. < 0

Notes:

1 **No economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Education (elementary)
Wall Type: Metal Frame
Bldg. Size: 50,000 sq. ft.

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	2,991	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.710	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.59	0.571		0.571
		sh. coef.(cost)	0.709	0.453		0.453
		cost ($/sqft)	$6.33	$7.38		$7.38
Opaque Walls	13,624	U-factor	0.077	0.084		0.084
		cost ($/sqft)	$0.78	$0.70		$0.70
Roof	50,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	1,278	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$98,245	$88,151		$88,151
Lighting						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		$/sqft	$1.80		$1.96	$1.96
Total Lighting Cost			$89,774		$97,805	$97,805
Construction Cost			$188,019	$177,925	$196,050	$185,956
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,056	1,056	915	915
Electricity, HVAC		MMBtu	362	328	338	303
Natural Gas		MMBtu	996	1,077	1,073	1,158
Total Annual Energy Cost			$34,131	$34,006	$31,445	$31,345
Economic Measures						
Life-Cycle Cost Savings				**$11,204**	**$20,758**	**$31,626**
Savings-to-Investment Ratio (SIR)				Invest. < 0	2.7	20.1
Adjusted IRR				Invest. < 0	9.7%	15.3%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Education (two-story)
Wall Type: Metal Frame
Bldg. Size: 80,000 sq. ft.

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	5,023	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.710	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.59	0.571		0.571
		sh. coef.(cost)	0.709	0.453		0.453
		cost ($/sqft)	$6.33	$7.38		$7.38
Opaque Walls	22,883	U-factor	0.077	0.084		0.084
		cost ($/sqft)	$0.78	$0.70		$0.70
Roof	40,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	1,073	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$104,714	$98,346		$98,346
Lighting						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		$/sqft	$1.80		$1.96	$1.96
Total Lighting Cost			$143,638		$156,487	$156,487
Construction Cost			$248,351	$241,984	$261,201	$254,833
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,690	1,690	1,464	1,464
Electricity, HVAC		MMBtu	657	588	617	548
Natural Gas		MMBtu	1,398	1,514	1,512	1,634
Total Annual Energy Cost			$54,794	$54,231	$50,415	$49,888
Economic Measures						
Life-Cycle Cost Savings				**$12,121**	**$34,294**	**$45,924**
Savings-to-Investment Ratio (SIR)				Invest. < 0	2.8	4.5
Adjusted IRR				Invest. < 0	9.8%	11.1%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Summary of Results by Building (Office Buildings)

Wall Type: Metal Frame			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Small Office (WWR=0.18)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sf/yr)	43.7	1.6	5.3	6.9
No. of floors	1	Nat. Gas (kBtu/sf/yr)	7.4	-1.4	-1.2	-2.8
Aspect ratio	2.25	Energy cost ($/sf/yr)	$0.90	$0.02	$0.09	$0.11
Core ratio	0.44	Life-cycle cost ($/sf)		$0.47	$0.89	$1.33
Window-wall ratio	0.18					
Economizer (?)	no	Savings-to-invest. Ratio		Invest. < 0	4.4	23.2
		Adjusted IRR		Invest. < 0	11.0%	15.8%
Small Office (WWR=0.38)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sf/yr)	41.8	-2.4	5.1	2.8
No. of floors	1	Nat. Gas (kBtu/sf/yr)	13.8	1.7	-1.9	0.0
Aspect ratio	2.25	Energy cost ($/sf/yr)	$0.90	-$0.03	$0.09	$0.05
Core ratio	0.44	Life-cycle cost ($/sf)		$0.88	$0.80	$1.71
Window-wall ratio	0.38					
Economizer (?)	no	Savings-to-invest. Ratio		Invest. < 0	4.0	Invest. < 0
		Adjusted IRR		Invest. < 0	10.8%	Invest. < 0
Large Office (WWR=0.18)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sf/yr)	41.7	1.1	4.7	5.8
No. of floors	3	Nat. Gas (kBtu/sf/yr)	4.2	-0.8	-0.8	-1.7
Aspect ratio	2.25	Energy cost ($/sf/yr)	$0.84	$0.02	$0.09	$0.10
Core ratio	0.59	Life-cycle cost ($/sf)		$0.21	$0.79	$0.99
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		Invest. < 0	4.0	5.2
		Adjusted IRR		Invest. < 0	10.8%	11.5%
Large Office (WWR=0.38)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sf/yr)	40.7	-1.8	4.7	2.9
No. of floors	3	Nat. Gas (kBtu/sf/yr)	8.0	1.0	-1.3	-0.1
Aspect ratio	2.25	Energy cost ($/sf)	$0.84	-$0.03	$0.08	$0.06
Core ratio	0.59	Life-cycle cost ($/sf)		$0.47	$0.75	$1.23
Window-wall ratio	0.38					
Economizer (?)	yes	Savings-to-invest. Ratio		Invest. < 0	3.8	Invest. < 0
		Adjusted IRR		Invest. < 0	10.7%	Invest. < 0

Summary of Results by Building (Retail and Education Buildings)

			Standard Level			
Wall Type:	Metal Frame		*90.1-1989 Base*	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Retail		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	24,000	Electricity (kBtu/sf/yr)	50.0	0.6	8.2	8.7
No. of floors	1	Nat. Gas (kBtu/sf/yr)	2.6	-0.4	-0.9	-1.4
Aspect ratio	2.50	Energy cost ($/sf/yr)	$0.98	$0.01	$0.15	$0.16
Core ratio	0.61	Life-cycle cost ($/sf)		$0.36	$1.63	$1.97
Window-wall ratio	0.07					
Economizer (?)	no	Savings-to-invest. Ratio		Invest. < 0	7.7	Invest. < 0
		Adjusted IRR		Invest. < 0	12.6%	Invest. < 0
Education (elementary)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	50,000	Electricity (kBtu/sf/yr)	28.4	0.7	3.3	4.0
No. of floors	1	Nat. Gas (kBtu/sf/yr)	19.9	-1.6	-1.5	-3.2
Aspect ratio	6.00	Energy cost ($/sf/yr)	$0.68	$0.00	$0.05	$0.06
Core ratio	0.63	Life-cycle cost ($/sf)		$0.22	$0.42	$0.63
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		Invest. < 0	2.7	20.1
		Adjusted IRR		Invest. < 0	9.7%	15.3%
Education (two-story)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	80,000	Electricity (kBtu/sf/yr)	29.3	0.9	3.3	4.2
No. of floors	2	Nat. Gas (kBtu/sf/yr)	17.5	-1.4	-1.4	-2.9
Aspect ratio	5.00	Energy cost ($/sf/yr)	$0.68	$0.01	$0.05	$0.06
Core ratio	0.62	Life-cycle cost ($/sf)		$0.15	$0.43	$0.57
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		Invest. < 0	2.8	4.5
		Adjusted IRR		Invest. < 0	9.8%	11.1%

APPENDIX C

Mass Wall Results
90.1-1989 Baseline

Small Office (WWR=0.18)
Wall Type: **Mass**
Bldg. Size **10,000 sq. ft.**

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	1,014	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.710	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.59	0.571		0.571
		sh. coef.(cost)	0.709	0.453		0.453
		cost ($/sqft)	$6.33	$7.38		$7.38
Opaque Walls	4,619	U-factor	0.097	0.123		0.123
		cost ($/sqft)	$2.54	$2.08		$2.08
Roof	10,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$32,241	$28,380		$28,380
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$15,720		$17,554	$17,554
Construction Cost			$47,961	$44,099	$49,796	$45,934
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	114	96	101	85
Natural Gas		MMBtu	83	108	97	126
Total Annual Energy Cost			$8,963	$8,802	$8,041	$7,917
Economic Measures						
Life-Cycle Cost Savings				**$5,537**	**$8,668**	**$13,721**
Savings-to-Investment Ratio (SIR)				Invest. < 0	4.3	Invest. < 0
Adjusted IRR				Invest. < 0	11.0%	Invest. < 0

Notes:

1 **No economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Small Office (WWR=0.38)
Wall Type: **Mass**
Bldg. Size: **10,000 sq. ft.**

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	2,141	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.250	0.453		0.453
(Window-Wall Ratio = 0.38)		U-factor(cost)	0.55	0.571		0.571
		sh. coef.(cost)	0.262	0.453		0.453
		cost ($/sqft)	$11.33	$7.38		$7.38
Opaque Walls	3,493	U-factor	0.097	0.123		0.123
		cost ($/sqft)	$2.54	$2.08		$2.08
Roof	10,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$47,214	$34,360		$34,360
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$15,720		$17,554	$17,554
Construction Cost			$62,934	$50,079	$64,769	$51,914
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	96	120	85	108
Natural Gas		MMBtu	148	136	168	153
Total Annual Energy Cost			$9,070	$9,440	$8,211	$8,558
Economic Measures						
Life-Cycle Cost Savings				**$9,754**	**$7,847**	**$17,911**
Savings-to-Investment Ratio (SIR)				Invest. < 0	4.0	Invest. < 0
Adjusted IRR				Invest. < 0	10.8%	Invest. < 0

Notes:

1 **No economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Large Office (WWR=0.18)
Wall Type: **Mass**
Bldg. Size: **60,000 sq. ft.**

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	4,302	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.710	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.59	0.571		0.571
		sh. coef.(cost)	0.709	0.453		0.453
		cost ($/sqft)	$6.33	$7.38		$7.38
Opaque Walls	19,598	U-factor	0.097	0.123		0.123
		cost ($/sqft)	$2.54	$2.08		$2.08
Roof	20,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	613	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$104,629	$95,055		$95,055
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$94,319		$105,326	$105,326
Construction Cost			$198,947	$189,373	$209,955	$200,381
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,926	1,926	1,686	1,686
Electricity, HVAC		MMBtu	559	494	515	450
Natural Gas		MMBtu	280	366	334	433
Total Annual Energy Cost			$49,946	$49,264	$44,820	$44,232
Economic Measures						
Life-Cycle Cost Savings				**$16,572**	**$47,225**	**$62,532**
Savings-to-Investment Ratio (SIR)				Invest. < 0	4.0	9.8
Adjusted IRR				Invest. < 0	10.8%	13.3%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Large Office (WWR=0.38)
Wall Type: **Mass**
Bldg. Size: **60,000 sq. ft.**

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	9,082	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.250	0.453		0.453
(Window-Wall Ratio = 0.38)		U-factor(cost)	0.55	0.571		0.571
		sh. coef.(cost)	0.262	0.453		0.453
		cost ($/sqft)	$11.33	$7.38		$7.38
Opaque Walls	14,818	U-factor	0.097	0.123		0.123
		cost ($/sqft)	$2.54	$2.08		$2.08
Roof	20,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	613	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$168,153	$120,425		$120,425
Lighting						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		$/sqft	$1.57		$1.76	$1.76
Total Lighting Cost			$94,319		$105,326	$105,326
Construction Cost			$262,472	$214,744	$273,480	$225,751
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,926	1,926	1,686	1,686
Electricity, HVAC		MMBtu	501	602	459	559
Natural Gas		MMBtu	517	469	597	541
Total Annual Energy Cost			$50,424	$52,044	$45,500	$47,079
Economic Measures						
Life-Cycle Cost Savings				**$33,685**	**$44,528**	**$78,765**
Savings-to-Investment Ratio (SIR)				Invest. < 0	3.8	Invest. < 0
Adjusted IRR				Invest. < 0	10.6%	Invest. < 0

Notes:

1 **Economizer used**
2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Retail
Wall Type: **Mass**
Bldg. Size: **24,000 sq. ft.**

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	624	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.770	0.570		0.570
(Window-Wall Ratio = 0.07)		U-factor(cost)	0.60	0.570		0.570
		sh. coef.(cost)	0.763	0.570		0.570
		cost ($/sqft)	$6.15	$6.81		$6.81
Opaque Walls	8,292	U-factor	0.097	0.123		0.123
		cost ($/sqft)	$2.54	$2.08		$2.08
Roof	24,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	686	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$57,983	$48,589		$48,589
Lighting						
Lighting Power Density		watts/sqft	2.36		1.90	1.90
Lighting Cost		$/sqft	$0.70		$0.84	$0.84
Total Lighting Cost			$16,848		$20,215	$20,215
Construction Cost			$74,830	$65,437	$78,198	$68,804
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	899	899	754	754
Electricity, HVAC		MMBtu	294	279	243	230
Natural Gas		MMBtu	73	100	101	136
Total Annual Energy Cost			$23,569	$23,459	$19,968	$19,944
Economic Measures						
Life-Cycle Cost Savings				**$10,668**	**$38,512**	**$48,063**
Savings-to-Investment Ratio (SIR)				Invest. < 0	7.5	Invest. < 0
Adjusted IRR				Invest. < 0	12.5%	Invest. < 0

Notes:

1 **No economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Education (elementary)
Wall Type: **Mass**
Bldg. Size: **50,000 sq. ft.**

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	2,991	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.710	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.59	0.571		0.571
		sh. coef.(cost)	0.709	0.453		0.453
		cost ($/sqft)	$6.33	$7.38		$7.38
Opaque Walls	13,624	U-factor	0.097	0.123		0.123
		cost ($/sqft)	$2.54	$2.08		$2.08
Roof	50,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	1,278	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$122,165	$106,881		$106,881
Lighting						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		$/sqft	$1.80		$1.96	$1.96
Total Lighting Cost			$89,774		$97,805	$97,805
Construction Cost			$211,938	$196,654	$219,969	$204,685
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,056	1,056	915	915
Electricity, HVAC		MMBtu	354	318	330	294
Natural Gas		MMBtu	1,025	1,144	1,106	1,230
Total Annual Energy Cost			$34,157	$34,275	$31,507	$31,656
Economic Measures						
Life-Cycle Cost Savings				**$12,873**	**$20,280**	**$32,746**
Savings-to-Investment Ratio (SIR)				Invest. < 0	2.7	Invest. < 0
Adjusted IRR				Invest. < 0	9.7%	Invest. < 0

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Education (two-story)
Wall Type: **Mass**
Bldg. Size: **80,000 sq. ft.**

			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Envelope	**Area (sq. ft.)**					
Windows	5,023	U-factor(std)	0.580	0.570		0.570
		sh. coef.(std)	0.710	0.453		0.453
(Window-Wall Ratio = 0.18)		U-factor(cost)	0.59	0.571		0.571
		sh. coef.(cost)	0.709	0.453		0.453
		cost ($/sqft)	$6.33	$7.38		$7.38
Opaque Walls	22,883	U-factor	0.097	0.123		0.123
		cost ($/sqft)	$2.54	$2.08		$2.08
Roof	40,000	U-factor	0.053	0.063		0.063
		cost ($/sqft)	$1.32	$1.13		$1.13
	(feet)					
Slab perimeter	1,073	U-factor	0.125	not req'd		not req'd
		cost ($/ft)*	$2.08	$2.08		$2.08
		*24-inch depth				
Envelope Cost (incremental)			$144,890	$129,805		$129,805
Lighting						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		$/sqft	$1.80		$1.96	$1.96
Total Lighting Cost			$143,638		$156,487	$156,487
Construction Cost			$288,528	$273,443	$301,378	$286,292
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,690	1,690	1,464	1,464
Electricity, HVAC		MMBtu	633	564	592	525
Natural Gas		MMBtu	1,452	1,624	1,570	1,751
Total Annual Energy Cost			$54,675	$54,514	$50,325	$50,228
Economic Measures						
Life-Cycle Cost Savings				**$15,078**	**$33,905**	**$48,134**
Savings-to-Investment Ratio (SIR)				Invest. < 0	2.8	11.3
Adjusted IRR				Invest. < 0	9.8%	13.7%

Notes:

1 **Economizer used**

2 **2001 electricity price = 6.6 cents/kWh** **2001 gas price = $6.71 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Summary of Results by Building

Wall Type: Mass			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Small Office (WWR=0.18)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sf/yr)	43.5	1.7	5.3	6.9
No. of floors	1	Nat. Gas (kBtu/sf/yr)	8.3	-2.5	-1.4	-4.3
Aspect ratio	2.25	Energy cost ($/sf/yr)	$0.90	$0.02	$0.09	$0.10
Core ratio	0.44	Life-cycle cost ($/sf)		$0.55	$0.87	$1.37
Window-wall ratio	0.18					
Economizer (?)	no	Savings-to-invest. Ratio		Invest. < 0	4.3	Invest. < 0
		Adjusted IRR		Invest. < 0	11.0%	Invest. < 0
Small Office (WWR=0.38)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sf/yr)	41.7	-2.4	5.1	2.8
No. of floors	1	Nat. Gas (kBtu/sf/yr)	14.8	1.3	-1.9	-0.5
Aspect ratio	2.25	Energy cost ($/sf/yr)	$0.91	-$0.04	$0.09	$0.05
Core ratio	0.44	Life-cycle cost ($/sf)		$0.98	$0.78	$1.79
Window-wall ratio	0.38					
Economizer (?)	no	Savings-to-invest. Ratio		Invest. < 0	4.0	Invest. < 0
		Adjusted IRR		Invest. < 0	10.8%	Invest. < 0
Large Office (WWR=0.18)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sf/yr)	41.4	1.1	4.7	5.8
No. of floors	3	Nat. Gas (kBtu/sf/yr)	4.7	-1.4	-0.9	-2.5
Aspect ratio	2.25	Energy cost ($/sf/yr)	$0.83	$0.01	$0.09	$0.10
Core ratio	0.59	Life-cycle cost ($/sf)		$0.28	$0.79	$1.04
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		Invest. < 0	4.0	9.8
		Adjusted IRR		Invest. < 0	10.8%	13.3%
Large Office (WWR=0.38)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sf/yr)	40.5	-1.7	4.7	3.0
No. of floors	3	Nat. Gas (kBtu/sf/yr)	8.6	0.8	-1.3	-0.4
Aspect ratio	2.25	Energy cost ($/sf/yr)	$0.84	-$0.03	$0.08	$0.06
Core ratio	0.59	Life-cycle cost ($/sf)		$0.56	$0.74	$1.31
Window-wall ratio	0.38					
Economizer (?)	yes	Savings-to-invest. Ratio		Invest. < 0	3.8	Invest. < 0
		Adjusted IRR		Invest. < 0	10.6%	Invest. < 0

Summary of Results by Building (continued)

Wall Type: Mass			Standard Level			
			90.1-1989 Base	*90.1-1999 Envelope Only*	*90.1-1999 Lighting Only*	*90.1-1999 Envelope & Lighting*
Retail		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	24,000	Electricity (kBtu/sf/yr)	49.7	0.6	8.1	8.7
No. of floors	1	Nat. Gas (kBtu/sf/yr)	3.1	-1.1	-1.1	-2.6
Aspect ratio	2.50	Energy cost ($/sf/yr)	$0.98	$0.00	$0.15	$0.15
Core ratio	0.61	Life-cycle cost ($/sf)		$0.44	$1.60	$2.00
Window-wall ratio	0.07					
Economizer (?)	no	Savings-to-invest. Ratio		Invest. < 0	7.5	Invest. < 0
		Adjusted IRR		Invest. < 0	12.5%	Invest. < 0
Education (elementary)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	50,000	Electricity (kBtu/sf/yr)	28.2	0.7	3.3	4.0
No. of floors	1	Nat. Gas (kBtu/sf/yr)	20.5	-2.4	-1.6	-4.1
Aspect ratio	6.00	Energy cost ($/sf/yr)	$0.68	$0.00	$0.05	$0.05
Core ratio	0.63	Life-cycle cost ($/sf)		$0.26	$0.41	$0.65
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		Invest. < 0	2.7	Invest. < 0
		Adjusted IRR		Invest. < 0	9.7%	Invest. < 0
Education (two-story)		Normalized Results	Base	Savings Relative to Base		
Key Characteristics		Energy Use:				
Floor space	80,000	Electricity (kBtu/sf/yr)	29.0	0.9	3.3	4.2
No. of floors	2	Nat. Gas (kBtu/sf/yr)	18.2	-2.2	-1.5	-3.7
Aspect ratio	5.00	Energy cost ($/sf/yr)	$0.68	$0.00	$0.05	$0.06
Core ratio	0.62	Life-cycle cost ($/sf)		$0.19	$0.42	$0.60
Window-wall ratio	0.18					
Economizer (?)	yes	Savings-to-invest. Ratio		Invest. < 0	2.8	11.3
		Adjusted IRR		Invest. < 0	9.8%	13.7%