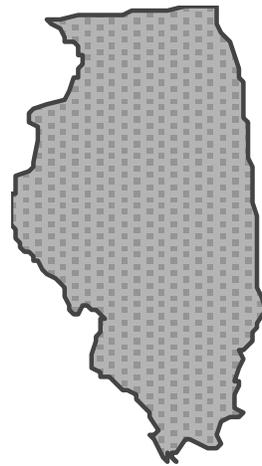


**Statewide Savings Projections from the  
Adoption of a Commercial Building  
Energy Code in Illinois: Updated to Reflect  
Current Utility Rates**



K.A. Cort  
D.B. Belzer

April 2004



Completed for the Building Standards and Guidelines Program,  
U.S. Department of Energy under Contract DE-AC06-76RLO 1830

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*under Contract DE-AC06-76RL01830*

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Completed by Pacific Northwest National Laboratory, Operated for the  
U.S. Department of Energy by Battelle

## Executive Summary

This report is an update of a previous report, *Statewide Savings Projections from the Adoption of a Commercial Building Energy Code in Illinois*, completed in September, 2002. This updated version is provided to incorporate the most recent gas and electric rates into the analysis.

*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<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, 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

<b>1. BACKGROUND .....</b>	<b>1</b>
<b>2. KEY ASSUMPTION .....</b>	<b>2</b>
2.1 BUILDING ENVELOPE BASELINE .....	2
2.2 LIGHTING BASELINE .....	2
2.3 BUILDING TYPES.....	3
2.4 CLIMATE.....	3
2.5 ECONOMIC VARIABLES .....	4
<b>3. ESTIMATED TOTAL STATE IMPACTS .....</b>	<b>5</b>
3.1 LIFE-CYCLE COST SAVINGS.....	5
3.2 PRIMARY ENERGY SAVINGS .....	6
3.3 POLLUTION EMISSIONS REDUCTIONS .....	7
<b>4. CONCLUSIONS .....</b>	<b>11</b>
<b>5. REFERENCES.....</b>	<b>12</b>
APPENDIX A.....	13
APPENDIX B .....	23
APPENDIX C .....	33
APPENDIX C .....	43

# 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). 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.<sup>1</sup> 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.

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<sup>1</sup> *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<sup>2</sup>. 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**

BUILDING TYPE	ESTIMATED SQUARE FOOTAGE (In Millions)
<b>Office</b>	<b>15.9</b>
• “Small” Office (1-2 floors)	9.1
• “Large” Office (3 or more floors)	6.8
<b>Retail</b>	<b>15.9</b>
<b>Education</b>	<b>7.0</b>
• Single-story (Elementary)	2.8
• More than one floor	4.2
<b>Other</b>	<b>21.4</b>
<b>TOTAL</b>	<b>60.2</b>

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 temperature<sup>3</sup>. Although Illinois has varying temperatures throughout the state, this

<sup>2</sup> 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).

<sup>3</sup> 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

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<sup>4</sup>.

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 base year of the study is 2004 and the most recently available annual electric and gas rates and escalation rates are used to forecast economic energy savings<sup>5</sup>. All prices are reported in 2001 dollars to be consistent with the study on which this report is based. The resulting statewide LCC savings and primary energy savings for Illinois are estimated in the following sections.

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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.

<sup>4</sup> *Analysis of Potential Benefits and Costs of Adopting ASHRAE Standard 90.1-1999 as a Commercial Building Energy Code in Illinois Jurisdictions*

<sup>5</sup> The base year utility rates are calculated using the Energy Information Administration’s (EIA) latest monthly and annual utility rates by state. Electric rates are based on, “Average Retail Price of Electricity to Ultimate Customers by Sector, by State, Year-to-Date,” Table 5.6.b, located on the web at [http://www.eia.doe.gov/cneaf/electricity/epm/table5\\_6\\_b.html](http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html) (accessed April, 2004). Gas rates are based on the Table, “Average Price of Natural Gas Sold to Commercial Customers,” located on the web at [http://www.eia.doe.gov/oil\\_gas/natural\\_gas/data\\_publications/natural\\_gas\\_monthly/ngm.html](http://www.eia.doe.gov/oil_gas/natural_gas/data_publications/natural_gas_monthly/ngm.html) (accessed in April, 2004).

### 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

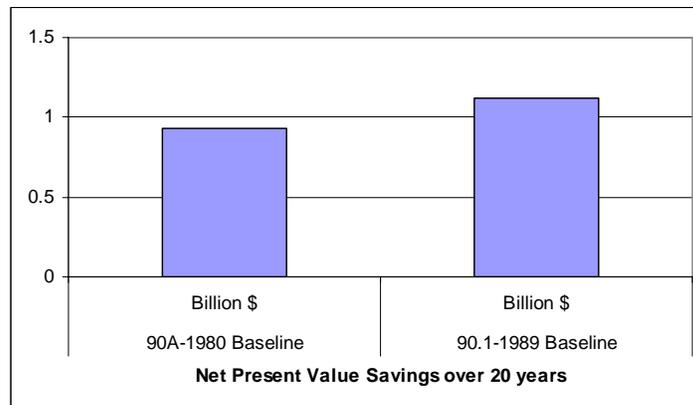
The LCC savings per square foot for each prototypical building included in the study are listed in Table 2. The total annual LCC savings for Illinois are estimated using the overall commercial floor space weights listed in Table 1, along with wall construction and window-to-wall ratio splits from CBECS (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**

BUILDING TYPE	90A-1980 Envelope 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.)
<b>Office</b>				
“Small” Office (1-2 floors)				
• With less than 38% window-to-wall ratio	1.44	1.41	1.70	1.72
• With more than 38% window-to-wall ratio	1.32	1.32	1.89	1.96
“Large” Office (3 or more floors)				
• With less than 38% window-to-wall ratio	1.31	1.26	1.33	1.36
• With more than 38% window-to-wall ratio	1.18	1.16	1.41	1.50
<b>Retail</b>	1.87	1.90	2.32	2.32
<b>Education</b>				
• Single-story (Elementary)	.85	.69	.82	.82
• More than one floor	1.02	.76	.78	.79
<b>Other (Average)</b>	1.28	1.21	1.46	1.50
<b>Total Annual LCC Savings in Illinois</b> (Derived from per square foot savings)	<b>\$82 Million</b>		<b>\$99 Million</b>	

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 \$80 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 \$930 million to just over 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., \$82 million or \$99 million, depending on the chosen baseline) back to 2004, using a discount rate of 7%<sup>6</sup>.



*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<sup>7</sup> 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.

<sup>6</sup> Assuming a constant rate of annual LCC savings.

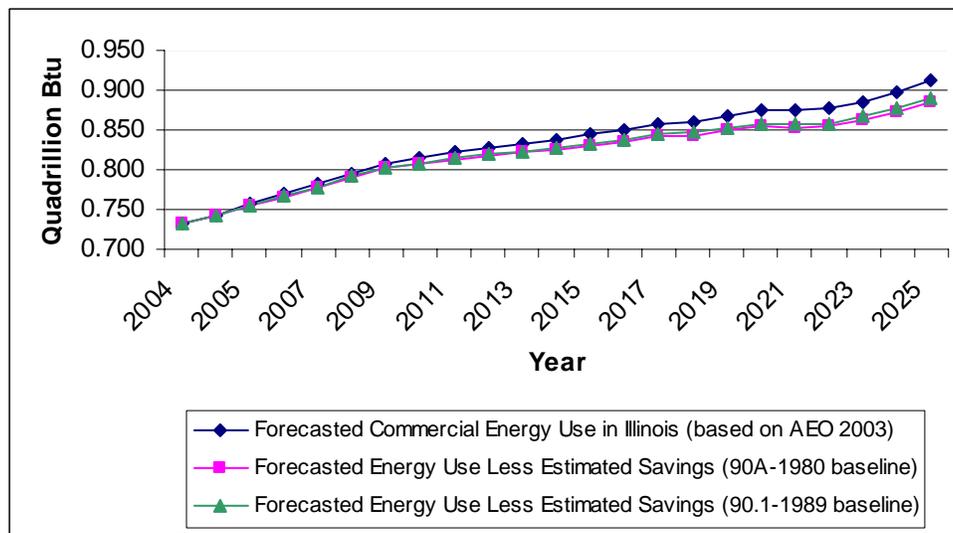
<sup>7</sup> Site electricity is converted to primary electricity to derive primary energy.

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

BASELINE	2004	2010	2015	2020	2030
<b>90A-1980</b>	<b>1.2</b>	<b>8.2</b>	<b>14.1</b>	<b>20.0</b>	<b>31.7</b>
<b>90.1-1989</b>	<b>0.9</b>	<b>6.6</b>	<b>11.4</b>	<b>16.1</b>	<b>25.6</b>

\*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, reducing energy use by 2-3% assuming either the 90A-1980 envelope baseline or the 90.1-1989 baseline. 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<sup>8</sup>.



**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<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, VOC, CO, and PM) are based on U.S. Department of Energy estimates.<sup>9</sup> The coefficients are based on the content of the greenhouse gas in each fuel type. For example, the carbon

<sup>8</sup> 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.

<sup>9</sup> The GPRA 2002 Data Call, produced by DOE (which are the same as the AEO 2000 emission coefficient assumptions used by EIA)

emission factors are based on the carbon content of the fuel and the fraction of the fuel 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<sup>10</sup>. 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 2001). 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)**

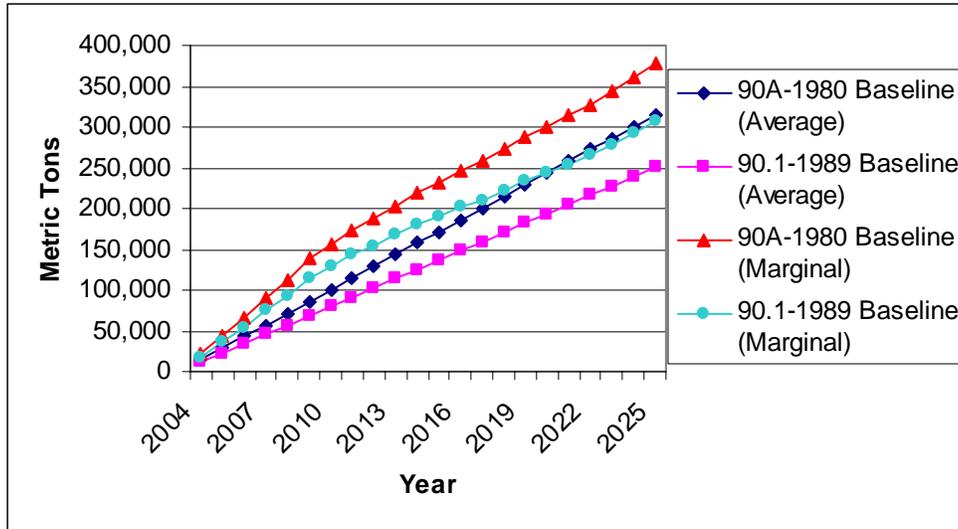
BASELINE	2004	2010	2015	2020	2025
<b>90A-1980 (Average*)</b>	14,315	100,204	171,778	243,352	314,926
<b>90.1-1989 (Average*)</b>	11,370	79,588	136,436	193,284	250,132
<b>90A-1980 (Marginal**)</b>	21,752	156,752	232,915	300,987	378,420
<b>90.1-1989 (Marginal**)</b>	17,978	129,832	190,759	244,495	306,549

\*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.

<sup>10</sup> 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 380,000 metric tons in the longer term (2025).

**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	
	2004	2020	2004	2020
year	<b>2004</b>	<b>2020</b>	<b>2004</b>	<b>2020</b>
<b>Sulfur Dioxide (SO<sub>2</sub>)</b>	317	5397	282	4795
<b>Nitrous Oxides (NO<sub>x</sub>)</b>	141	2397	115	1961
<b>Carbon Monoxide (MO)</b>	6	106	3	48
<b>Particulate Matter (PM<sub>10</sub>)</b>	7	115	6	102
<b>Volatile Organic Compound (VOC)</b>	1	11	0	5

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 the average coefficient because of the high percentage of electricity that is currently generated in Illinois by coal-fired power plants (coal plants produce a high amount of SO<sub>2</sub> and PM per kilowatt-hour produced).

**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	<b>2004</b>	<b>2020</b>	<b>2004</b>	<b>2020</b>
<b>Sulfur Dioxide (SO<sub>2</sub>)</b>		246	4303	219	3823
<b>Nitrous Oxides (NO<sub>x</sub>)</b>		179	2694	149	2225
<b>Carbon Monoxide (MO)</b>		28	308	22	228
<b>Particulate Matter (PM<sub>10</sub>)</b>		5	95	5	84
<b>Volatile Organic Compound (VOC)</b>		3	31	3	23

## **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 over \$80 million dollars of LCC savings for each year. 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. Assuming future construction remains near present levels 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.

## 5. References

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and Illuminating Engineering Society of North America (IESNA) 1999. *ASHRAE Standard Energy Standard for Buildings Except Low-Rise Residential Buildings*. 1999.

Belzer, DB with KA Cort, M Friedrich, EE Richman, and DW Winiarski. 2002. *Analysis of Potential Benefits and Costs of Adopting ASHRAE Standard 90.1-1999 as a Commercial Building Energy Code in Illinois Jurisdictions*. Pacific Northwest National Laboratory. April 2002.

Energy Information Administration (EIA) 2003. *Annual Energy Outlook 2003 with Projections to 2025*. U.S. Department of Energy. December 2003. Washington D.C.

Energy Information Administration (EIA). 1992. *Commercial Building Energy Consumption and Expenditures Survey 1992 (CBECS 92)*, Public Use Data, Micro-data files on EIA website: <ftp://ftp.eia.doe.gov/pub/consumption/commercial/micro.data/> U.S. Department of Energy. Washington D.C.

Energy Information Administration (EIA). 2001. "State Energy Profiles," U.S. Department of Energy. August 2001. Washington D.C.

R.S. MEANS Company. "MEANS Cost Works 2001." Kingston, MA. 2001.

Somasundaram, S. PR Armstrong, DB Belzer, SC Gaines, DL Hadley, S Katipumula, DL Smith, and DW Winiarski. 2000. *Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment*. Pacific Northwest National Laboratory, PNNL-13232. April 2000.

U.S. Census Bureau (Census). 2000. "1997 Economic Census Construction Geographic Area Series." U.S. Department of Commerce, March 2000. Washington D.C.

U.S. Department of Commerce. 2000. *Statistical Abstract of the United States 2000*. September 2000. Washington D.C.

**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.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$15,670		\$17,504	\$17,504
<b>Construction Cost</b>			\$33,000	\$37,699	\$34,835	\$39,533
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	119	100	107	88
Natural Gas		MMBtu	108	88	124	103
<b>Total Annual Energy Cost</b>			\$10,973	\$10,374	\$9,909	\$9,294
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$2,819</b>	<b>\$11,364</b>	<b>\$14,407</b>
Savings-to-Investment Ratio (SIR)				1.5	5.3	2.8
Adjusted IRR				8.2%	11.6%	9.8%

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh      2003 gas price = \$8.13 /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.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$15,670		\$17,504	\$17,504
<b>Construction Cost</b>			\$43,668	\$45,228	\$45,503	\$47,062
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	136	121	123	109
Natural Gas		MMBtu	116	121	132	138
<b>Total Annual Energy Cost</b>			\$11,423	\$11,134	\$10,356	\$10,078
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$1,918</b>	<b>\$11,406</b>	<b>\$13,171</b>
Savings-to-Investment Ratio (SIR)				2.0	5.3	3.9
Adjusted IRR				8.9%	11.6%	10.7%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

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.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$94,018		\$105,026	\$105,026
<b>Construction Cost</b>			\$142,171	\$162,130	\$153,179	\$173,137
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$61,177	\$58,422	\$55,218	\$52,390
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$15,049</b>	<b>\$62,715</b>	<b>\$78,775</b>
Savings-to-Investment Ratio (SIR)				1.7	5.0	3.1
Adjusted IRR				8.4%	11.4%	10.1%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

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.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$94,018		\$105,026	\$105,026
<b>Construction Cost</b>			\$187,432	\$194,071	\$198,440	\$205,079
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$63,136	\$61,912	\$57,197	\$55,991
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$8,415</b>	<b>\$62,466</b>	<b>\$70,617</b>
Savings-to-Investment Ratio (SIR)				2.1	4.9	4.0
Adjusted IRR				9.0%	11.4%	10.8%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

Discount Rate = 7.0%

Life-cycle cost savings includes replacement costs and residual values

<b>Retail</b> Wall Type: <b>Steel Frame</b> Bldg. Size: <b>24,000 sq. ft.</b>			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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	
Slab perimeter	(feet) 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	
<b>Lighting</b>						
Lighting Power Density		watts/sqft	2.36	1.90	1.90	
Lighting Cost		\$/sqft	\$1.57	\$1.80	\$1.80	
Total Lighting Cost			\$37,722	\$43,159	\$43,159	
<b>Construction Cost</b>			\$67,483	\$74,912	\$72,921	
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	900	900	754	
Electricity, HVAC		MMBtu	291	287	237	
Natural Gas		MMBtu	121	74	158	
<b>Total Annual Energy Cost</b>			\$28,304	\$27,818	\$24,138	
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>(\$1,416)</b>	<b>\$44,715</b>	
Savings-to-Investment Ratio (SIR)				0.8	5.4	
Adjusted IRR				6.5%	11.6%	
					10.4%	

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

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.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		\$/sqft	\$1.79		\$1.95	\$1.95
Total Lighting Cost			\$89,599		\$97,629	\$97,629
<b>Construction Cost</b>			\$161,263	\$177,749	\$169,294	\$185,780
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$43,843	\$41,791	\$40,414	\$38,362
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$9,337</b>	<b>\$33,089</b>	<b>\$42,422</b>
Savings-to-Investment Ratio (SIR)				1.5	3.8	2.4
Adjusted IRR				8.1%	10.6%	9.4%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

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.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	1,073 (feet)	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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		\$/sqft	\$1.79		\$1.95	\$1.95
Total Lighting Cost			\$143,358		\$156,207	\$156,207
<b>Construction Cost</b>			\$216,731	\$241,703	\$229,580	\$254,553
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$71,548	\$67,574	\$65,838	\$61,847
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$25,826</b>	<b>\$55,946</b>	<b>\$81,992</b>
Savings-to-Investment Ratio (SIR)				1.9	3.9	2.8
Adjusted IRR				8.8%	10.7%	9.8%

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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				
		90A-1980 Envelope Base	90.1-1999 Envelope Only	90.1- 1999 Lighting Only	90.1-1999 Envelope & Lighting	
<b>Small Office (WWR=0.18)</b>		Normalized Results		Base	Savings Relative to Base	
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sqft)	44.0	1.9	5.2	7.1
No. of floors	1	Nat. Gas (kBtu/sqft)	10.8	2.0	-1.6	0.5
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.10	\$0.06	\$0.11	\$0.17
Core ratio	0.44	Life-cycle cost (\$/sqft)		\$0.28	\$1.14	\$1.44
Window-wall ratio	0.18	Savings-to-invest. Ratio		1.5	5.3	2.8
Economizer (?)	no	Adjusted IRR		8.2%	11.6%	9.8%
<b>Small Office (WWR=0.38)</b>		Normalized Results		Base	Savings Relative to Base	
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sqft)	45.7	1.4	5.2	6.6
No. of floors	1	Nat. Gas (kBtu/sqft)	11.6	-0.5	-1.6	-2.2
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.14	\$0.03	\$0.11	\$0.13
Core ratio	0.44	Life-cycle cost (\$/sqft)		\$0.19	\$1.14	\$1.32
Window-wall ratio	0.38	Savings-to-invest. Ratio		2.0	5.3	3.9
Economizer (?)	no	Adjusted IRR		8.9%	11.6%	10.7%
<b>Large Office (WWR=0.18)</b>		Normalized Results		Base	Savings Relative to Base	
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sqft)	42.2	1.6	4.7	6.3
No. of floors	3	Nat. Gas (kBtu/sqft)	6.2	1.2	-1.1	0.2
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.02	\$0.05	\$0.10	\$0.15
Core ratio	0.59	Life-cycle cost (\$/sqft)		\$0.25	\$1.05	\$1.31
Window-wall ratio	0.18	Savings-to-invest. Ratio		1.7	5.0	3.1
Economizer (?)	yes	Adjusted IRR		8.4%	11.4%	10.1%
<b>Large Office (WWR=0.38)</b>		Normalized Results		Base	Savings Relative to Base	
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sqft)	43.5	1.0	4.7	5.7
No. of floors	3	Nat. Gas (kBtu/sqft)	6.6	-0.3	-1.1	-1.5
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.05	\$0.02	\$0.10	\$0.12
Core ratio	0.59	Life-cycle cost (\$/sqft)		\$0.14	\$1.04	\$1.18
Window-wall ratio	0.38	Savings-to-invest. Ratio		2.1	4.9	4.0
Economizer (?)	yes	Adjusted IRR		9.0%	11.4%	10.8%

### Summary of Results by Building (continued)

Wall Type: Steel Frame		Standard Level			
		90A-1980 Envelope Base	90.1-1999 Envelope Only	90.1- 1999 Lighting Only	90.1-1999 Envelope & Lighting
<b>Retail</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	24,000	Electricity (kBtu/sqft)	49.6	0.2	8.1
No. of floors	1	Nat. Gas (kBtu/sqft)	5.1	2.0	-1.5
Aspect ratio	2.50	Energy cost (\$/sqft)	\$1.18	\$0.02	\$0.17
Core ratio	0.61	Life-cycle cost (\$/sqft)		-\$0.06	\$1.86
Window-wall ratio	0.07	Savings-to-invest. Ratio		0.8	5.4
Economizer (?)	no	Adjusted IRR		6.5%	11.6%
				10.4%	
<b>Education (elementary)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	50,000	Electricity (kBtu/sqft)	30.0	1.2	3.5
No. of floors	1	Nat. Gas (kBtu/sqft)	23.2	1.6	-1.6
Aspect ratio	6.00	Energy cost (\$/sqft)	\$0.88	\$0.04	\$0.07
Core ratio	0.63	Life-cycle cost (\$/sqft)		\$0.19	\$0.66
Window-wall ratio	0.18	Savings-to-invest. Ratio		1.5	3.8
Economizer (?)	no	Adjusted IRR		8.1%	10.6%
				9.4%	
<b>Education (two-story)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	80,000	Electricity (kBtu/sqft)	31.7	1.7	3.6
No. of floors	2	Nat. Gas (kBtu/sqft)	20.4	1.4	-1.5
Aspect ratio	5.00	Energy cost (\$/sqft)	\$0.89	\$0.05	\$0.07
Core ratio	0.62	Life-cycle cost (\$/sqft)		\$0.32	\$0.70
Window-wall ratio	0.18	Savings-to-invest. Ratio		1.9	3.9
Economizer (?)	no	Adjusted IRR		8.8%	10.7%
				9.8%	

**APPENDIX B**  
**Mass Wall Results**  
**90.1-1980 Envelope Baseline**

**Small Office (WWR=0.18)**

Wall Type: **Mass Wall**  
 Bldg. Size: **10,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$15,670		\$17,504	\$17,504
<b>Construction Cost</b>			\$41,428	\$44,049	\$43,263	\$45,884
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	320	321	281	281
Electricity, HVAC		MMBtu	116	96	104	85
Natural Gas		MMBtu	112	108	129	126
<b>Total Annual Energy Cost</b>			\$10,929	\$10,461	\$9,889	\$9,415
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$3,004</b>	<b>\$11,035</b>	<b>\$14,125</b>
Savings-to-Investment Ratio (SIR)				1.9	5.2	3.4
Adjusted IRR				8.8%	11.5%	10.3%

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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 Wall**

Bldg. Size: **10,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
	(feet)	cost (\$/ft)*	\$2.08	\$2.08		\$2.08
		*24-inch depth				
Envelope Cost (incremental)			\$34,543	\$34,359		\$34,359
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$15,670		\$17,504	\$17,504
<b>Construction Cost</b>			\$50,213	\$50,029	\$52,047	\$51,864
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	320	321	281	281
Electricity, HVAC		MMBtu	135	120	123	108
Natural Gas		MMBtu	119	136	135	153
<b>Total Annual Energy Cost</b>			\$11,408	\$11,223	\$10,363	\$10,179
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$2,153</b>	<b>\$11,103</b>	<b>\$13,239</b>
Savings-to-Investment Ratio (SIR)				11.2	5.2	5.6
Adjusted IRR				13.7%	11.5%	11.7%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

Discount Rate = 7.0%

Life-cycle cost savings includes replacement costs and residual values

**Large Office (WWR=0.18)**

Wall Type: **Mass Wall**

Bldg. Size: **60,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$94,018		\$105,026	\$105,026
<b>Construction Cost</b>			\$177,928	\$189,073	\$188,936	\$200,080
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$60,497	\$58,507	\$54,636	\$52,553
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$13,094</b>	<b>\$61,414</b>	<b>\$75,732</b>
Savings-to-Investment Ratio (SIR)				2.0	4.9	3.6
Adjusted IRR				8.8%	11.3%	10.5%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

Discount Rate = 7.0%

Life-cycle cost savings includes replacement costs and residual values

**Large Office (WWR=0.38)**

Wall Type: **Mass Wall**

Bldg. Size: **60,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$94,018		\$105,026	\$105,026
<b>Construction Cost</b>			\$215,198	\$214,443	\$226,205	\$225,451
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$62,508	\$61,822	\$56,656	\$55,949
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$8,132</b>	<b>\$61,292</b>	<b>\$69,669</b>
Savings-to-Investment Ratio (SIR)				14.6	4.9	5.2
Adjusted IRR				14.4%	11.3%	11.5%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

Discount Rate = 7.0%

Life-cycle cost savings includes replacement costs and residual values

**Retail**

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

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	2.36		1.90	1.90
Lighting Cost		\$/sqft	\$1.57		\$1.80	\$1.80
Total Lighting Cost			\$37,722		\$43,159	\$43,159
<b>Construction Cost</b>			\$82,612	\$86,312	\$88,049	\$91,749
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	899	900	754	754
Electricity, HVAC		MMBtu	285	279	238	230
Natural Gas		MMBtu	130	100	171	136
<b>Total Annual Energy Cost</b>			\$28,244	\$27,852	\$24,152	\$23,681
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$831</b>	<b>\$43,723</b>	<b>\$45,613</b>
Savings-to-Investment Ratio (SIR)				1.2	5.3	4.1
Adjusted IRR				7.5%	11.5%	10.8%

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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 Wall**  
 Bldg. Size: **50,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		\$/sqft	\$1.79		\$1.95	\$1.95
Total Lighting Cost			\$89,599		\$97,629	\$97,629
<b>Construction Cost</b>			\$186,119	\$196,479	\$194,150	\$204,510
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$42,223	\$40,857	\$39,069	\$37,764
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$5,834</b>	<b>\$29,442</b>	<b>\$34,445</b>
Savings-to-Investment Ratio (SIR)				1.5	3.5	2.4
Adjusted IRR				8.0%	10.4%	9.4%

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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 Wall**  
 Bldg. Size: **80,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90A-1980 Envelope Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		\$/sqft	\$1.79		\$1.95	\$1.95
Total Lighting Cost			\$143,358		\$156,207	\$156,207
<b>Construction Cost</b>			\$258,481	\$273,162	\$271,330	\$286,012
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$67,306	\$64,949	\$62,172	\$59,886
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$13,762</b>	<b>\$48,296</b>	<b>\$61,110</b>
Savings-to-Investment Ratio (SIR)				1.8	3.5	2.7
Adjusted IRR				8.6%	10.4%	9.7%

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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				
		90A-1980 Envelope Base	90.1-1999 Envelope Only	90.1- 1999 Lighting Only	90.1-1999 Envelope & Lighting	
<b>Small Office (WWR=0.18)</b>		Normalized Results		Base	Savings Relative to Base	
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sqft)	43.6	1.9	5.1	7.1
No. of floors	1	Nat. Gas (kBtu/sqft)	11.2	0.4	-1.7	-1.4
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.09	\$0.05	\$0.10	\$0.15
Core ratio	0.44	Life-cycle cost (\$/sqft)		\$0.30	\$1.10	\$1.41
Window-wall ratio	0.18	Savings-to-invest. Ratio		1.9	5.2	3.4
Economizer (?)	no	Adjusted IRR		8.8%	11.5%	10.3%
<b>Small Office (WWR=0.38)</b>		Normalized Results		Base	Savings Relative to Base	
Key Characteristics		Energy Use:				
Floor space	10,000	Electricity (kBtu/sqft)	45.5	1.4	5.1	6.6
No. of floors	1	Nat. Gas (kBtu/sqft)	11.9	-1.7	-1.6	-3.5
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.14	\$0.02	\$0.10	\$0.12
Core ratio	0.44	Life-cycle cost (\$/sqft)		\$0.22	\$1.11	\$1.32
Window-wall ratio	0.38	Savings-to-invest. Ratio		11.2	5.2	5.6
Economizer (?)	no	Adjusted IRR		13.7%	11.5%	11.7%
<b>Large Office (WWR=0.18)</b>		Normalized Results		Base	Savings Relative to Base	
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sqft)	41.7	1.4	4.6	6.1
No. of floors	3	Nat. Gas (kBtu/sqft)	6.3	0.2	-1.1	-0.9
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.01	\$0.03	\$0.10	\$0.13
Core ratio	0.59	Life-cycle cost (\$/sqft)		\$0.22	\$1.02	\$1.26
Window-wall ratio	0.18	Savings-to-invest. Ratio		2.0	4.9	3.6
Economizer (?)	yes	Adjusted IRR		8.8%	11.3%	10.5%
<b>Large Office (WWR=0.38)</b>		Normalized Results		Base	Savings Relative to Base	
Key Characteristics		Energy Use:				
Floor space	60,000	Electricity (kBtu/sqft)	43.1	0.9	4.6	5.6
No. of floors	3	Nat. Gas (kBtu/sqft)	6.6	-1.2	-1.1	-2.4
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.04	\$0.01	\$0.10	\$0.11
Core ratio	0.59	Life-cycle cost (\$/sqft)		\$0.14	\$1.02	\$1.16
Window-wall ratio	0.38	Savings-to-invest. Ratio		14.6	4.9	5.2
Economizer (?)	yes	Adjusted IRR		14.4%	11.3%	11.5%

### Summary of Results by Building (continued)

Wall Type: Mass		Standard Level			
		90A-1980 Envelope Base	90.1-1999 Envelope Only	90.1- 1999 Lighting Only	90.1-1999 Envelope & Lighting
<b>Retail</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	24,000	Electricity (kBtu/sqft)	49.4	0.3	8.0
No. of floors	1	Nat. Gas (kBtu/sqft)	5.4	1.2	-1.7
Aspect ratio	2.50	Energy cost (\$/sqft)	\$1.18	\$0.02	\$0.17
Core ratio	0.61	Life-cycle cost (\$/sqft)		\$0.03	\$1.82
Window-wall ratio	0.07	Savings-to-invest. Ratio		1.2	5.3
Economizer (?)	no	Adjusted IRR		7.5%	11.5%
				10.8%	
<b>Education (elementary)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	50,000	Electricity (kBtu/sqft)	28.6	1.1	3.3
No. of floors	1	Nat. Gas (kBtu/sqft)	23.2	0.3	-1.6
Aspect ratio	6.00	Energy cost (\$/sqft)	\$0.84	\$0.03	\$0.06
Core ratio	0.63	Life-cycle cost (\$/sqft)		\$0.12	\$0.59
Window-wall ratio	0.18	Savings-to-invest. Ratio		1.5	3.5
Economizer (?)	yes	Adjusted IRR		8.0%	10.4%
				9.4%	
<b>Education (two-story)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	80,000	Electricity (kBtu/sqft)	29.4	1.2	3.3
No. of floors	2	Nat. Gas (kBtu/sqft)	20.4	0.1	-1.5
Aspect ratio	5.00	Energy cost (\$/sqft)	\$0.84	\$0.03	\$0.06
Core ratio	0.62	Life-cycle cost (\$/sqft)		\$0.17	\$0.60
Window-wall ratio	0.18	Savings-to-invest. Ratio		1.8	3.5
Economizer (?)	yes	Adjusted IRR		8.6%	10.4%
				9.7%	

**APPENDIX C**  
**Metal Frame Results**  
**90.1-1989 Baseline**

**Small Office (WWR=0.18)**

Wall Type: **Steel Frame**

Bldg. Size: **10,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$15,670		\$17,504	\$17,504
<b>Construction Cost</b>			\$39,801	\$37,699	\$41,635	\$39,533
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	116	100	103	88
Natural Gas		MMBtu	74	88	86	103
<b>Total Annual Energy Cost</b>			\$10,636	\$10,374	\$9,521	\$9,293
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$5,440</b>	<b>\$12,055</b>	<b>\$17,038</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	5.6	29.6
Adjusted IRR				Invest. < 0	11.7%	16.5%

**Notes:**

1 **Economizer used**

2 **2003 electricity price = 7.8 cents/kWh**

3 **Years for Analysis = 40**

**2003 gas price = \$8.13 /MMBtu**

**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.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$15,670		\$17,504	\$17,504
<b>Construction Cost</b>			\$56,752	\$45,228	\$58,586	\$47,062
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	97	121	86	109
Natural Gas		MMBtu	138	121	157	138
<b>Total Annual Energy Cost</b>			\$10,722	\$11,134	\$9,697	\$10,078
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$7,599</b>	<b>\$10,843</b>	<b>\$18,862</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	5.1	Invest. < 0
Adjusted IRR				Invest. < 0	11.4%	Invest. < 0

**Notes:**

- 1 No economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$94,018		\$105,026	\$105,026
<b>Construction Cost</b>			\$164,238	\$162,130	\$175,245	\$173,137
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$59,524	\$58,422	\$53,411	\$52,386
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$15,959</b>	<b>\$64,837</b>	<b>\$79,746</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	5.1	6.6
Adjusted IRR				Invest. < 0	11.4%	12.2%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

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.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$94,018		\$105,026	\$105,026
<b>Construction Cost</b>			\$236,155	\$194,072	\$247,163	\$205,079
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$59,966	\$61,912	\$54,102	\$55,986
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$22,509</b>	<b>\$61,406</b>	<b>\$84,772</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	4.9	Invest. < 0
Adjusted IRR				Invest. < 0	11.3%	Invest. < 0

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

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.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	2.36		1.90	1.90
Lighting Cost		\$/sqft	\$1.57		\$1.80	\$1.80
Total Lighting Cost			\$37,722		\$43,159	\$43,159
<b>Construction Cost</b>			\$81,146	\$74,911	\$86,583	\$80,349
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	899	899	754	754
Electricity, HVAC		MMBtu	300	287	249	237
Natural Gas		MMBtu	63	74	85	98
<b>Total Annual Energy Cost</b>			\$28,034	\$27,814	\$23,701	\$23,534
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$9,341</b>	<b>\$47,010</b>	<b>\$55,637</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	5.6	15.7
Adjusted IRR				Invest. < 0	11.7%	14.6%

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh      2003 gas price = \$8.13 /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.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		\$/sqft	\$1.79		\$1.95	\$1.95
Total Lighting Cost			\$89,599		\$97,629	\$97,629
<b>Construction Cost</b>			\$187,844	\$177,750	\$195,875	\$185,781
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$40,661	\$40,526	\$37,488	\$37,383
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$11,658</b>	<b>\$29,712</b>	<b>\$40,954</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	3.5	25.8
Adjusted IRR				Invest. < 0	10.4%	16.1%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

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.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		\$/sqft	\$1.79		\$1.95	\$1.95
Total Lighting Cost			\$143,358		\$156,207	\$156,207
<b>Construction Cost</b>			\$248,071	\$241,704	\$260,921	\$254,553
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$65,242	\$64,594	\$60,067	\$59,462
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$14,045</b>	<b>\$48,887</b>	<b>\$62,325</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	3.6	5.8
Adjusted IRR				Invest. < 0	10.5%	11.8%

**Notes:**

- 1 **Economizer used**
  - 2 **2003 electricity price = 7.8 cents/kWh**                      **2003 gas price = \$8.13 /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				
			90.1-1989 Base	90.1-1999 Envelope Only	90.1- 1999 Lighting Only	90.1-1999 Envelope & Lighting	
<b>Small Office (WWR=0.18)</b>			Normalized Results	Base	Savings Relative to Base		
Key Characteristics			Energy Use:				
Floor space	10,000		Electricity (kBtu/sqft)	43.7	1.6	5.3	6.9
No. of floors	1		Nat. Gas (kBtu/sqft)	7.4	-1.4	-1.2	-2.8
Aspect ratio	2.25		Energy cost (\$/sqft)	\$1.06	\$0.03	\$0.11	\$0.13
Core ratio	0.44		Life-cycle cost (\$/sqft)		\$0.54	\$1.21	\$1.70
Window-wall ratio	0.18		Savings-to-invest. Ratio		Invest. < 0	5.6	29.6
Economizer (?)	no		Adjusted IRR		Invest. < 0	11.7%	16.5%
<b>Small Office (WWR=0.38)</b>			Normalized Results	Base	Savings Relative to Base		
Key Characteristics			Energy Use:				
Floor space	10,000		Electricity (kBtu/sqft)	41.8	-2.4	5.1	2.8
No. of floors	1		Nat. Gas (kBtu/sqft)	13.8	1.7	-1.9	0.0
Aspect ratio	2.25		Energy cost (\$/sqft)	\$1.07	-\$0.04	\$0.10	\$0.06
Core ratio	0.44		Life-cycle cost (\$/sqft)		\$0.76	\$1.08	\$1.89
Window-wall ratio	0.38		Savings-to-invest. Ratio		Invest. < 0	5.1	Invest. < 0
Economizer (?)	no		Adjusted IRR		Invest. < 0	11.4%	Invest. < 0
<b>Large Office (WWR=0.18)</b>			Normalized Results	Base	Savings Relative to Base		
Key Characteristics			Energy Use:				
Floor space	60,000		Electricity (kBtu/sqft)	41.7	1.1	4.7	5.8
No. of floors	3		Nat. Gas (kBtu/sqft)	4.2	-0.8	-0.8	-1.7
Aspect ratio	2.25		Energy cost (\$/sqft)	\$0.99	\$0.02	\$0.10	\$0.12
Core ratio	0.59		Life-cycle cost (\$/sqft)		\$0.27	\$1.08	\$1.33
Window-wall ratio	0.18		Savings-to-invest. Ratio		Invest. < 0	5.1	6.6
Economizer (?)	yes		Adjusted IRR		Invest. < 0	11.4%	12.2%
<b>Large Office (WWR=0.38)</b>			Normalized Results	Base	Savings Relative to Base		
Key Characteristics			Energy Use:				
Floor space	60,000		Electricity (kBtu/sqft)	40.7	-1.8	4.7	2.9
No. of floors	3		Nat. Gas (kBtu/sqft)	8.0	1.0	-1.3	-0.1
Aspect ratio	2.25		Energy cost (\$/sqft)	\$1.00	-\$0.03	\$0.10	\$0.07
Core ratio	0.59		Life-cycle cost (\$/sqft)		\$0.38	\$1.02	\$1.41
Window-wall ratio	0.38		Savings-to-invest. Ratio		Invest. < 0	4.9	Invest. < 0
Economizer (?)	yes		Adjusted IRR		Invest. < 0	11.3%	Invest. < 0

### Summary of Results by Building (continued)

Wall Type: Steel Frame		Standard Level			
		90.1-1989 Base	90.1-1999 Envelope Only	90.1- 1999 Lighting Only	90.1-1999 Envelope & Lighting
<b>Retail</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	24,000	Electricity (kBtu/sqft)	50.0	0.6	8.2
No. of floors	1	Nat. Gas (kBtu/sqft)	2.6	-0.4	-0.9
Aspect ratio	2.50	Energy cost (\$/sqft)	\$1.17	\$0.01	\$0.18
Core ratio	0.61	Life-cycle cost (\$/sqft)		\$0.39	\$1.96
Window-wall ratio	0.07	Savings-to-invest. Ratio		Invest. < 0	5.6
Economizer (?)	no	Adjusted IRR		Invest. < 0	11.7%
					14.6%
<b>Education (elementary)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	50,000	Electricity (kBtu/sqft)	28.4	0.7	3.3
No. of floors	1	Nat. Gas (kBtu/sqft)	19.9	-1.6	-1.5
Aspect ratio	6.00	Energy cost (\$/sqft)	\$0.81	\$0.00	\$0.06
Core ratio	0.63	Life-cycle cost (\$/sqft)		\$0.23	\$0.59
Window-wall ratio	0.18	Savings-to-invest. Ratio		Invest. < 0	3.5
Economizer (?)	yes	Adjusted IRR		Invest. < 0	10.4%
					16.1%
<b>Education (two-story)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	80,000	Electricity (kBtu/sqft)	29.3	0.9	3.3
No. of floors	2	Nat. Gas (kBtu/sqft)	17.5	-1.4	-1.4
Aspect ratio	5.00	Energy cost (\$/sqft)	\$0.82	\$0.01	\$0.06
Core ratio	0.62	Life-cycle cost (\$/sqft)		\$0.18	\$0.61
Window-wall ratio	0.18	Savings-to-invest. Ratio		Invest. < 0	3.6
Economizer (?)	yes	Adjusted IRR		Invest. < 0	10.5%
					11.8%

**APPENDIX C**  
**Mass Wall Results**  
**90.1-1989 Baseline**

**Small Office (WWR=0.18)**

Wall Type: **Mass Wall**  
 Bldg. Size: **10,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	433	U-factor	0.125	not req'd		not req'd
	(feet)	cost (\$/ft)*	\$2.08	\$2.08		\$2.08
		*24-inch depth				
Envelope Cost (incremental)			\$32,241	\$28,380		\$28,380
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$15,670		\$17,504	\$17,504
<b>Construction Cost</b>			\$47,911	\$44,049	\$49,745	\$45,884
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	114	96	101	85
Natural Gas		MMBtu	83	108	97	126
<b>Total Annual Energy Cost</b>			\$10,648	\$10,461	\$9,556	\$9,414
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$6,083</b>	<b>\$11,736</b>	<b>\$17,214</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	5.4	Invest. < 0
Adjusted IRR				Invest. < 0	11.6%	Invest. < 0

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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 Wall**  
 Bldg. Size: **10,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	433 (feet)	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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$15,670		\$17,504	\$17,504
<b>Construction Cost</b>			\$62,884	\$50,029	\$64,718	\$51,864
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	321	321	281	281
Electricity, HVAC		MMBtu	96	120	85	108
Natural Gas		MMBtu	148	136	168	153
<b>Total Annual Energy Cost</b>			\$10,785	\$11,223	\$9,770	\$10,179
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$8,517</b>	<b>\$10,707</b>	<b>\$19,613</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	5.0	Invest. < 0
Adjusted IRR				Invest. < 0	11.4%	Invest. < 0

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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 Wall**

Bldg. Size: **60,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$94,018		\$105,026	\$105,026
<b>Construction Cost</b>			\$198,647	\$189,073	\$209,655	\$200,081
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$59,301	\$58,507	\$53,229	\$52,548
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$18,878</b>	<b>\$64,269</b>	<b>\$81,577</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	5.1	12.5
Adjusted IRR				Invest. < 0	11.4%	14.0%

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

Discount Rate = 7.0%

Life-cycle cost savings includes replacement costs and residual values

**Large Office (WWR=0.38)**

Wall Type: **Mass Wall**

Bldg. Size: **60,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.63		1.30	1.30
Lighting Cost		\$/sqft	\$1.57		\$1.75	\$1.75
Total Lighting Cost			\$94,018		\$105,026	\$105,026
<b>Construction Cost</b>			\$262,172	\$214,443	\$273,179	\$225,451
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$59,909	\$61,822	\$54,080	\$55,944
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$28,283</b>	<b>\$60,914</b>	<b>\$89,881</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	4.8	Invest. < 0
Adjusted IRR				Invest. < 0	11.3%	Invest. < 0

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

Discount Rate = 7.0%

Life-cycle cost savings includes replacement costs and residual values

<b>Retail</b> Wall Type: <b>Mass Wall</b> Bldg. Size: <b>24,000 sq. ft.</b>			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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	
Slab perimeter	(feet) 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	
<b>Lighting</b>						
Lighting Power Density		watts/sqft	2.36	1.90	1.90	
Lighting Cost		\$/sqft	\$1.57	\$1.80	\$1.80	
Total Lighting Cost			\$37,722	\$43,159	\$43,159	
<b>Construction Cost</b>			\$95,704	\$86,311	\$101,142	
<b>Annual Energy Consumption</b>						
Electricity, lights and plugs		MMBtu	899	899	754	
Electricity, HVAC		MMBtu	294	279	230	
Natural Gas		MMBtu	73	100	136	
<b>Total Annual Energy Cost</b>			\$27,974	\$27,848	\$23,707	
<b>Economic Measures</b>						
Life-Cycle Cost Savings			<b>\$11,046</b>	<b>\$46,105</b>	<b>\$55,755</b>	
Savings-to-Investment Ratio (SIR)			Invest. < 0	5.5	75.9	
Adjusted IRR			Invest. < 0	11.7%	19.2%	

**Notes:**

1 Economizer used

2 2003 electricity price = 7.8 cents/kWh

3 Years for Analysis = 40

2003 gas price = \$8.13 /MMBtu

Discount Rate = 7.0%

Life-cycle cost savings includes replacement costs and residual values

**Education (elementary)**

Wall Type: **Mass Wall**  
 Bldg. Size: **50,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	(feet) 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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		\$/sqft	\$1.79		\$1.95	\$1.95
Total Lighting Cost			\$89,599		\$97,629	\$97,629
<b>Construction Cost</b>			\$211,763	\$196,479	\$219,794	\$204,510
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$40,696	\$40,857	\$37,566	\$37,764
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$12,538</b>	<b>\$29,117</b>	<b>\$41,149</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	3.4	Invest. < 0
Adjusted IRR				Invest. < 0	10.4%	Invest. < 0

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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 Wall**  
 Bldg. Size: **80,000 sq. ft.**

			<b>Standard Level</b>			
			<i>90.1-1989 Base</i>	<i>90.1-1999 Envelope Only</i>	<i>90.1-1999 Lighting Only</i>	<i>90.1-1999 Envelope &amp; Lighting</i>
<b>Envelope</b>	<b>Area (sq. ft.)</b>					
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
Slab perimeter	1,073 (feet)	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
<b>Lighting</b>						
Lighting Power Density		watts/sqft	1.79		1.50	1.50
Lighting Cost		\$/sqft	\$1.79		\$1.95	\$1.95
Total Lighting Cost			\$143,358		\$156,207	\$156,207
<b>Construction Cost</b>			\$288,248	\$273,163	\$301,097	\$286,012
<b>Annual Energy Consumption</b>						
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
<b>Total Annual Energy Cost</b>			\$65,110	\$64,949	\$59,970	\$59,886
<b>Economic Measures</b>						
Life-Cycle Cost Savings				<b>\$15,695</b>	<b>\$48,403</b>	<b>\$63,043</b>
Savings-to-Investment Ratio (SIR)				Invest. < 0	3.5	14.5
Adjusted IRR				Invest. < 0	10.4%	14.4%

**Notes:**

- 1 Economizer used
  - 2 2003 electricity price = 7.8 cents/kWh                      2003 gas price = \$8.13 /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
<b>Small Office (WWR=0.18)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	10,000	Electricity (kBtu/sqft)	43.5	1.7	5.3
No. of floors	1	Nat. Gas (kBtu/sqft)	8.3	-2.5	-1.4
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.06	\$0.02	\$0.11
Core ratio	0.44	Life-cycle cost (\$/sqft)		\$0.61	\$1.17
Window-wall ratio	0.18	Savings-to-invest. Ratio		Invest. < 0	5.4
Economizer (?)	no	Adjusted IRR		Invest. < 0	11.6%
				Invest. < 0	Invest. < 0
<b>Small Office (WWR=0.38)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	10,000	Electricity (kBtu/sqft)	41.7	-2.4	5.1
No. of floors	1	Nat. Gas (kBtu/sqft)	14.8	1.3	-1.9
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.08	-\$0.04	\$0.10
Core ratio	0.44	Life-cycle cost (\$/sqft)		\$0.85	\$1.07
Window-wall ratio	0.38	Savings-to-invest. Ratio		Invest. < 0	5.0
Economizer (?)	no	Adjusted IRR		Invest. < 0	11.4%
				Invest. < 0	Invest. < 0
<b>Large Office (WWR=0.18)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	60,000	Electricity (kBtu/sqft)	41.4	1.1	4.7
No. of floors	3	Nat. Gas (kBtu/sqft)	4.7	-1.4	-0.9
Aspect ratio	2.25	Energy cost (\$/sqft)	\$0.99	\$0.01	\$0.10
Core ratio	0.59	Life-cycle cost (\$/sqft)		\$0.31	\$1.07
Window-wall ratio	0.18	Savings-to-invest. Ratio		Invest. < 0	5.1
Economizer (?)	yes	Adjusted IRR		Invest. < 0	11.4%
				Invest. < 0	12.5
				Invest. < 0	14.0%
<b>Large Office (WWR=0.38)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	60,000	Electricity (kBtu/sqft)	40.5	-1.7	4.7
No. of floors	3	Nat. Gas (kBtu/sqft)	8.6	0.8	-1.3
Aspect ratio	2.25	Energy cost (\$/sqft)	\$1.00	-\$0.03	\$0.10
Core ratio	0.59	Life-cycle cost (\$/sqft)		\$0.47	\$1.02
Window-wall ratio	0.38	Savings-to-invest. Ratio		Invest. < 0	4.8
Economizer (?)	yes	Adjusted IRR		Invest. < 0	11.3%
				Invest. < 0	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
<b>Retail</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	24,000	Electricity (kBtu/sqft)	49.7	0.6	8.1
No. of floors	1	Nat. Gas (kBtu/sqft)	3.1	-1.1	-1.1
Aspect ratio	2.50	Energy cost (\$/sqft)	\$1.17	\$0.01	\$0.18
Core ratio	0.61	Life-cycle cost (\$/sqft)		\$0.46	\$1.92
Window-wall ratio	0.07	Savings-to-invest. Ratio		Invest. < 0	5.5
Economizer (?)	no	Adjusted IRR		Invest. < 0	11.7%
					75.9
					19.2%
<b>Education (elementary)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	50,000	Electricity (kBtu/sqft)	28.2	0.7	3.3
No. of floors	1	Nat. Gas (kBtu/sqft)	20.5	-2.4	-1.6
Aspect ratio	6.00	Energy cost (\$/sqft)	\$0.81	\$0.00	\$0.06
Core ratio	0.63	Life-cycle cost (\$/sqft)		\$0.25	\$0.58
Window-wall ratio	0.18	Savings-to-invest. Ratio		Invest. < 0	3.4
Economizer (?)	yes	Adjusted IRR		Invest. < 0	10.4%
					Invest. < 0
					Invest. < 0
<b>Education (two-story)</b>		Normalized Results	Base	Savings Relative to Base	
Key Characteristics		Energy Use:			
Floor space	80,000	Electricity (kBtu/sqft)	29.0	0.9	3.3
No. of floors	2	Nat. Gas (kBtu/sqft)	18.2	-2.2	-1.5
Aspect ratio	5.00	Energy cost (\$/sqft)	\$0.81	\$0.00	\$0.06
Core ratio	0.62	Life-cycle cost (\$/sqft)		\$0.20	\$0.61
Window-wall ratio	0.18	Savings-to-invest. Ratio		Invest. < 0	3.5
Economizer (?)	yes	Adjusted IRR		Invest. < 0	10.4%
					14.5
					14.4%