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Analysis of Energy Saving Impacts of ASHRAE 90.1-2004 for the State of New York

K. Gowri
M.A. Halverson
E. E. Richman

August 2007

Prepared for
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Summary

At the request of the New York State Energy Research and Development Authority (NYSERDA) and New York State Department of State (DOS), DOE's Building Energy Codes Program (BECP)[1] undertook an analysis of the energy savings and cost impacts associated with the proposed adoption of ANSI/ASHRAE/IESNA Standard 90.1-2004 and compared it with the current requirements based on ANSI/ASHRAE/IESNA Standards 90.1-1999 and 90.1-2001. Standard 90.1-1999 was not analyzed because there are no differences between Standard 90.1-1999 and Standard 90.1-2001 requirements for the building models used in this study.

Five building types were modeled – offices, schools, hospitals, retail buildings and multi-family buildings. These buildings were modeled in three climate zones covering the range of weather conditions within the State of New York based on the Standard 90.1-2004 Climate Zone map. Envelope and mechanical requirements for all of these building types are the same under both Standard 90.1-1999/2001 and Standard 90.1-2004. Although new climate zones were introduced in Standard 90.1-2004, the envelope requirements remain the same as in the 1999/2001 versions of the Standard for the three locations analyzed in this study.

The analysis results show that buildings constructed to Standard 90.1-2004 would save a significant amount of energy for all building types in New York and in all climate zones. Savings would range from 2.6% to 9.7% in site energy, 5.8% to 11% in source energy, and 6.0% to 13% in energy cost. Typically, the savings would be lowest for multi-family buildings and highest for retail buildings, with offices, hospitals, and schools falling in between. The savings associated with Standard 90.1-2004 (for the buildings simulated) come entirely from reduced lighting power density and the associated reduction in cooling load (offset by an increase in heating load). This variation in energy savings by building type is related to the relative magnitude of lighting power reduction and its impact on the internal gains in these building types.

An economic analysis of the savings associated with adoption of Standard 90.1-2004 was also performed. Energy cost savings for the operation of buildings simulated ranged from $0.12 per square foot to $0.26 per square foot. An analysis of how lighting power density reductions were determined for buildings built to Standard 90.1-2004 indicated that the installation costs of the newer efficient lighting would actually be less than those required by Standard 90.1-1999 because fewer lighting fixtures are used. If adoption of Standard 90.1-2004 would result in buildings with both energy cost savings and reduced first cost as per this analysis, then the simple payback for adoption of this Standard is instantaneous, and certainly less than the 10-year payback period mandated by New York State Law.

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1. Background and Scope

The New York State Energy Research and Development Authority (NYSERDA) and New York State Department of State (DOS) is considering the adoption of ANSI/ASHRAE/IESNA Standard 90.1-2004 (ASHRAE 2004) as part of the Energy Conservation Construction Code of New York State. New York State mandates a maximum 10-year simple pay back period from the adoption of the new standard. NYSERDA and DOS requested assistance from DOE's Building Energy Codes Program (BECP) to estimate the annual building energy savings and cost impacts, and the payback period from adopting the requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004 (ASHRAE 2004). This report summarizes the analysis methodology and results of energy simulation in response to that request.

The analysis conducted in this report looked at the whole building impact of the most significant changes associated with Standard 90.1-2004. These include changes in interior lighting power allowance and restructuring of climate zones for building envelope and economizer requirements. The single largest impact, by far, is associated with the interior lighting power allowance reduction. However, it should be noted that ASHRAE incorporated many more changes into Standard 90.1-2004 from previous versions. Standard 90.1-2001 incorporates 34 addenda to Standard 90.1-1999 as shown in Table F-1 in Appendix F of Standard 90.1-2001. Standard 90.1-2004 incorporated 31 addenda to Standard 90.1-2001 as shown in Table F-1 in Appendix F of Standard 90.1-2004[2].

Many of the addenda incorporated into Standards 90.1-2001 and 90.1-2004 are intended to clarify the requirements of the standard and therefore have minimal energy impact. Many other addenda could potentially have impact on specific building designs that incorporate specific systems or features, but have minimal energy impact on commercial buildings as a whole. However, there are also addenda that do potentially have energy impacts on commercial buildings as a whole, but that impact is beyond the scope of this analysis. Some of these addenda are listed below:

Addenda m to Standard 90.1-2001	Addition of heat pump pool heater requirements
Addenda q to Standard 90.1-2001	Revision of exterior lighting power allowances
Addenda y to Standard 90.1-2001	Part load fan power limitation for VAV systems
Addenda x to Standard 90.1-2001	Addition of ventilation fan control requirements

DOE lists and discusses all changes to Standard 90.1-2004 in the qualitative portion of its formal determination of energy savings. However, only changes that can be quantified are included in the quantitative portion of its determination. This report mirrors the efforts undertaken in the quantitative portion of DOE's determinations. The complete DOE determination for Standard 90.1-2004 should be published in fall of 2007.

[2] There are actually 32 addenda shown in Table F-1 in Appendix F of Standard 90.1-2004. Addenda 90.1 ak was inadvertently listed in this table. This addenda will become an addenda to Standard 90.1-2004 and will be incorporated into Standard 90.1-2007.

2. Simulation Description

This section describes the process of simulating buildings for this study. Climate zones, standards (baseline, target) requirements, and modeling of the buildings are discussed.

2.1 Building Types

The following five building types were selected for analysis as requested by NYSERDA: office, health care, educational, retail and multi-family.

Prototypes for office, health care, educational, and retail buildings were developed as part of ongoing work within DOE's Commercial Building Integration Program. The four building prototypes used were the medium office, primary school, hospital, and stand-alone retail building prototypes developed at the National Renewable Energy Laboratory for use as "benchmarks" for tracking DOE's progress to its goal of Zero Energy Buildings (Deru and Griffith 2006). These are developmental prototypes representing 70% of all the new commercial building construction, and it is possible that the final benchmark prototypes used by DOE will be slightly different. DOE's benchmark prototypes were developed using data from the 2003 Commercial Building Energy Consumption Survey (EIA 2005) and the equipment and systems recommendations of Appendix G - Performance Rating Method of ANSI/ASHRAE/IESNA Standard 90.1-2004 (ASHRAE 2004). The benchmarks consist of documented input files for EnergyPlus (DOE 2006) and EnergyPlus Version 2.0 was used for simulation of these four building types. (See Appendix A for general descriptions of the buildings as modeled and the specific systems and performance parameters used in the simulations.)

NYSERDA requested the analysis of multi-family buildings as part of this study. Since multi-family building prototype was not included in the DOE's benchmark prototypes, PNNL developed a multi-family building prototype model in collaboration with Maria Karpman, NYSERDA consultant and based on the simulation guidelines of the NYSERDA Multi-family Building Performance Program (NYSERDA 2006). The multi-family building model was developed and analyzed using Equest Version 3.6 (eQUEST 2006).

2.2 Climate Locations

All counties in New York State are covered by one of the following three climate zones: 4, 5 or 6, as defined by Table B-1 of Standard 90.1-2004. New York City, Buffalo and Albany were selected to represent these three climate zones.

2.3 Discussion of Simulation Modeling

Appendix A lists the modeled parameter for each of the five building prototypes. All building types were modeled as steel-framed buildings. This is in compliance with the requirements in Appendix G of Standard 90.1-2004. The envelope requirements for all components (e.g., the insulation levels for exterior walls and roofs, the window U-factor and SHGC requirements) remain the same for all building types in both the building models for Standard 90.1-2001 and Standard 90.1-2004.

HVAC system and equipment efficiencies were modeled based on Appendix G of Standard 90.1-2004. Since there are no changes in equipment efficiency requirements between Standard 90.1-2001 and Standard 90.1-2004, identical equipment and efficiencies were modeled as listed in Appendix A. The heating and cooling equipment capacity was determined from automatic sizing calculations provided by the simulation software.

Water heating was not modeled for any of the building types except multi-family building. Water heating is not a very significant end-use for office or retail buildings, but is a significant end-use for schools and hospitals. However, given that energy use for hot water heating is driven primarily by equipment efficiency and the same equipment efficiency would be assumed for both the baseline and the target standard, the modeling of hot water would not show any difference between the two models. However, the results of the simulations should be viewed with this fact in mind. “Real” educational and health care buildings will have significant hot water loads and, therefore, higher utility bills. In the case of multi-family buildings, a central water heater is assumed to meet the demand requirements as per the New York Energy Smart Multifamily Building Performance Program simulation guidelines (NYSERDA, 2006).

Standards 90.1-2001 and 90.1-2004 contain identical provisions for additional lighting power allowances for retail buildings. The additional lighting power allowances for retail buildings are based on display area, not floor area, and therefore, are highly dependent on how the display area is organized. These allowances are not included in the lighting power estimates for the retail building. The implication is that “real” retail buildings may have somewhat higher interior lighting power and may, therefore, have higher cooling loads and lower heating loads than those modeled here.

Standards 90.1-2001 and 90.1-2004 contain requirements for exterior building grounds and parking lot lighting, for lighting powered by the building service. The exterior lighting power density requirements in Standard 90.1-2004 are more detailed than in Standard 90.1-2001. There are no good references available for “typical” amounts of parking lot or grounds lighting associated with various building types. However, the DOE benchmark prototype building models used in this study assume minimal exterior lighting with an astronomic clock control. This exterior lighting is assumed to be the same for both the 90.1-2001 and 90.1-2004 building models. In cases where buildings do have significant exterior lighting, “real” buildings may have higher utility bills than those modeled here.

3. Economic Analysis

The economic analysis portion of this study focused simply on comparing the first costs associated with improving the energy efficiency for the five prototypical buildings (by bringing them up to compliance with 90.1-2004) and the decreased utility costs brought about by decreased energy usage attributable to use of 90.1-2004.

3.1 Fuel Costs Used in this Study

The following fuel prices for electricity and natural gas were provided by NYSERDA to calculate the energy costs in this study:

Electricity	$0.1518 per kWh
Natural Gas	$1.35 per therm

The electricity price represents the blended rate used by the NYSERDA multi-family program and the gas price represents the blended rate based on 2006 Con Edison EL-8 (Multiple Dwelling, Redistribution) and GS-2 (Firm Service) rates. These fuel prices are chosen to provide conservative estimates of energy cost savings for all building types because these represent the lowest multi-family building rates (Mark Eggers, e-mail dated April 11, 2007).

3.2 First Costs Used in This Study

Changes in first costs associated with reduced lighting power density requirements were developed to do simple life-cycle costing of the different levels of standards. Because there is no change to envelope, mechanical or service water heating requirements from Standard 90.1-1999/2001 to Standard 90.1-2004, there are no changes to related costs used in the economic analysis.

3.3 Economic Analysis Methodology

The basis of the economic methodology is to compare the increased first costs of the prototypical buildings with estimated annual energy cost savings by adopting Standard 90.1-2004. Because the only change between the Standard 90.1-2001 and Standard 90.1-2004 building models simulated for this study was lighting power density, the overall equation for increased first cost for any prototype building is:

Incremental First Cost of Building =
Floor Area X Incremental Cost of Lower Lighting Power Density

The overall equation for annual energy cost savings is:
Annual Energy Cost Savings = Floor Area X Incremental Energy Costs

A simple payback period is calculated by:
Simple Payback = Incremental First Cost of Building / Annual Energy Cost Savings

4. Discussion of Simulation Results

This section provides an aggregate level discussion of the simulation results for all building types. Tables B-1 through B-15 (in Appendix B) provide detailed data on the simulated buildings.

4.1 Site and Source Energy Usage and Energy Cost Results

All building prototypes in all three climate zone locations achieved significant site and source energy savings when modeled to comply with Standard 90.1-2004, as compared to prototypes modeled to comply with Standard 90.1-2001. The savings are primarily due to reduction in allowable lighting power. Tables 1 through 3 provide a summary of the site energy use, source energy use and energy cost, by building types, for all the locations analyzed.

Table 1 Site Energy Use (kBtu/sq. ft. per year)

	Office	School	Hospital	Retail	Multi-family
New York City					
90.1-2001	48.4	49.3	77.0	52.0	43.2
90.1-2004	45.2	45.7	72.4	47.0	41.7
Buffalo					
90.1-2001	47.7	53.3	78.6	53.4	47.6
90.1-2004	45.2	49.5	74.4	48.9	46.3
Albany					
90.1-2001	48.3	54.7	79.7	54.9	48.6
90.1-2004	45.9	50.8	75.5	50.9	47.4

Table 2 Source Energy Use (kBtu/sq. ft per year)

	Office	School	Hospital	Retail	Multi-family
New York City					
90.1-2001	68.5	62.8	108.2	70.4	91.9
90.1-2004	63.7	57.8	101.3	62.5	86.0
Buffalo					
90.1-2001	77.6	73.3	124.9	80.4	94.0
90.1-2004	72.6	67.4	117.1	71.7	88.3
Albany					
90.1-2001	78.3	74.7	125.9	81.8	95.4
90.1-2004	73.3	68.7	118.3	74.0	89.9

Table 3 Energy Cost ($ per sq. ft. per year)

	Office	School	Hospital	Retail	Multi-family
New York City					
90.1-2001	$2.04	$1.59	$3.19	$1.96	$1.34
90.1-2004	$1.88	$1.45	$2.96	$1.70	$1.25
Buffalo					
90.1-2001	$1.93	$1.58	$3.05	$1.88	$1.36
90.1-2004	$1.79	$1.44	$2.84	$1.64	$1.28
Albany					
90.1-2001	$1.94	$1.60	$3.07	$1.90	$1.38
90.1-2004	$1.80	$1.46	$2.86	$1.68	$1.30

Tables 4 and 5 show the incremental percent reduction in building site and source energy use, and energy cost, for prototype buildings modeled to comply with the 2004 edition of the Standard 90.1, as compared to those modeled to comply with 1999/2001 editions of the Standard.

Table 4 Incremental Percent Energy Use Reduction and Energy Cost Savings
(Standard 90.1-2004 Compared to Standard 90.1-1999/2001)

	Office	School	Hospital	Retail	Multi-family
New York City					
Total Site Energy	6.58%	7.39%	5.89%	9.69%	3.55%
Total Source Energy	7.10%	7.93%	6.38%	11.05%	6.46%
Total Energy Cost per sq. ft.	7.77%	8.87%	7.02%	13.04%	6.65%
Buffalo					
Total Site Energy	5.32%	7.13%	5.42%	8.55%	2.73%
Total Source Energy	6.37%	8.05%	6.24%	10.80%	6.34%
Total Energy Cost per sq. ft.	7.15%	8.97%	6.87%	12.70%	6.21%
Albany					
Total Site Energy	5.20%	7.06%	5.20%	7.34%	2.55%
Total Source Energy	6.29%	7.99%	6.10%	9.58%	5.80%
Total Energy Cost per sq. ft.	7.10%	8.91%	6.78%	11.50%	6.03%

For the five building types modeled and the prototypical buildings used, the new standard requires greater energy efficiency and would save energy. The new standards would also reduce building energy costs. Table 5 provides the differential energy cost savings per square foot for the five building prototypes.

Table 5 Differential Energy Cost Savings Per Square Foot
(Standard 90.1-1999/2001 to Standard 90.1-2004)

	Office	School	Hospital	Retail	Multi-family
New York City	$0.16	$0.14	$0.23	$0.26	$0.09
Buffalo	$0.14	$0.14	$0.21	$0.24	$0.08
Albany	$0.14	$0.14	$0.21	$0.22	$0.08

Energy cost reductions range from a high of 26 cents per square foot in retail buildings in New York City, to a low of 8 cents per square foot in multi-family buildings in Buffalo and Albany, moving from Standard 90.1-2001 to Standard 90.1-2004. These energy cost savings will be balanced against the first costs associated with achieving those savings in the next section.

5. Cost Effectiveness of ASHRAE 90.1-2004

While Standard 90.1-2004 saves energy and associated cost, saving energy and energy dollars implies doing something to a building design that would not have been required under 90.1-1999/90.1-2001. For this analysis, lighting systems are the single most significant building parameter that is changed to meet the ASHRAE 90.1-2004 requirements. All envelope requirements remain the same in all climate zones between 90.1-2001 and 90.1-2004. So the only difference analyzed for cost effectiveness is based on the lighting requirement as below:

Lighting Power Density Change from Standard 90.1-1999/2001 to Standard 90.1-2004:

Office – 1.3 to 1.0 watts per square foot
School – 1.5 to 1.2 watts per square foot
Hospital – 1.6 to 1.2 watts per square foot
Retail – 1.9 to 1.5 watts per square foot
Multi-family – 1.0 to 0.7 watts per square foot

In this case, the change is simply a reduction in the allowed lighting wattage between Standards 90.1-1999/2001 and Standard 90.1-2004, which is based on updated costs, technology efficiency, light loss factors, and the latest IESNA light level recommendations. The basis for these changes and this cost-effectiveness analysis does not, however, incorporate any changes in basic fixture type. The same basic, commonly available efficient products are used in both sets of models to determine cost effectiveness. The energy and cost efficiency is primarily driven by appropriate design using reasonably efficient equipment and following the latest recommended light level guidance and do not require the use of cutting edge technology or other cost prohibitive equipment. This interior lighting cost and cost-effectiveness analysis is described in detail in Appendix C.

In estimating the first costs, variations such as retail versus wholesale costs, whether or not additional markups for profit should be included, whether or not the product is "standard" or "special order" in a particular market location, and the simple variation in products that are not really "commodities" (such as windows) were all considered. These variations in first cost can lead to widely varying estimates of cost effectiveness of particular measures. The first cost estimates used are fully documented (Richman, 2004) to ensure that the analysis of cost effectiveness can be redone by other interested parties if other first cost data is used.

The incremental costs associated with the interior lighting power changes were fed into a spreadsheet that estimated the incremental cost of the building built to meet the lighting requirements of Standard 90.1-2004. These incremental costs were then compared with the incremental energy savings associated with Standard 90.1-2001 to develop the simple payback period. The results of this analysis were applied to all of the five building types in New York City, Buffalo and Albany, and are shown in Table 6. (Negative dollar values are shown in the format ($x.xx) and in red font in electronic versions of this report. Negative payback periods are shown in the format –xx years.)

Table 6 Overall Cost Effectiveness - Standard 90.1-2001 to 90.1-2004

	Office	School	Hospital	Retail	Multi-family
Total Conditioned Floor Area (sq. ft.)	75057	122372	241435	238571	167200
Incremental Lighting Cost ($/sq. ft.)	($1.00)	($0.31)	($1.16)	($1.96)	($0.43)
Total incremental cost ($)	($75,057.00)	($38,046.92)	($280,064.60)	($467,599.16)	($71,896.00)
New York City					
Total Incremental Savings ($)	$11,868.00	$17,339.00	$54,030.00	$60,876.00	$14,874.81
Simple Payback Period (Years)	***-6.32***	***-2.19***	***-5.18***	***-7.68***	***-4.80***
Buffalo					
Total Incremental Savings ($)	$10,343.00	$17,379.00	$50,646.00	$56,931.00	$14,124.47
Simple Payback Period (Years)	***-7.26***	***-2.19***	***-5.53***	***-8.21***	***-5.1***
Albany					
Total Incremental Savings ($)	$10,339.00	$17,472.00	$50,201.00	$52,079.00	$13,920.33
Simple Payback Period (Years)	***-7.26***	***-2.18***	***-5.58***	***-8.98***	***-5.2***

In all cases, the new lighting requirements are cost effective in all building types and in all climate zones with an instant payback because of the reduced first cost and reduced incremental energy cost. An instant payback of this type easily meets the New York State requirements for a 10-year payback or less for code adoption activities.

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APPENDIX A

Simulation Modeling

APPENDIX A. Simulation Modeling

Table A-1 below lists the modeled parameters for all climate zones and building types. All envelope components were modeled to meet the prescriptive requirements in Standards 90.1-2004 and 90.1-1999/2001. Both Standards have identical requirements for all components in all climate zones, unless otherwise specifically noted.

Table A-1 Modeling Parameters by Building Type

Building Type	Office	School	Hospital	Retail	Multi-family
Building Characteristics					
Conditioned Floor Area (sq. ft.)	75, 057	122, 732	241, 435	238, 571	167, 200
Building Shape	Rectangle	Rectangle	Rectangle	Rectangle	Rectangle
Aspect Ratio	2.2	5	2	1.5	2.75
Number of Floors	3	1	4	2	20
Window-Wall Ratio	0.4	0.18	0.25	0.15	0.15
Envelope					
Roof Type	Built-up roof, metal deck	Built-up roof, metal deck	Built-up roof, metal deck	Built-up roof, metal deck	Built-up roof, metal deck
Roof U-factor (Btu/h.ft^2.ºF)	0.063	0.063	0.063	0.063	0.063
Roof Area (sq. ft.)	25, 018	122, 732	60, 358	119, 285	8,360
Exterior Wall Type	Steel-framed	Steel -framed	Steel-framed	Steel-framed	Steel-framed
Exterior Wall U-factor (Btu/h.ft^2.ºF)	0.084 (0.124 in Zone 4)	0.084 (0.124 in Zone 4)	0.084 (0.124 in Zone 4)	0.084 (0.124 in Zone 4)	0.064
Net Wall Area (sq. ft.)	15, 968	20, 036	40, 643	43, 140	73, 610
Window Type	Double glazed, 3mm air gap	Double glazed, 3mm air gap	Double glazed, 3mm air gap	Double glazed, 3mm air gap	Double glazed, 3mm air gap
Window U-factor (Btu/h.ft^2.ºF)[3]	0.57	0.57	0.57	0.57	0.57
Window SHGC[4]	0.39	0.39	0.39	0.39	0.45
Window Area (sq. ft.)	10645	4398	13548	7617	13,330
Foundation Type	Slab-on-grade	Slab-on-grade	Slab-on-grade	Slab-on-grade	Slab-on-grade
Foundation R-value (ft^2·h·ºF/Btu)	2.11	2.11	2.11	2.11	1.68
Total Floor Area (sq. ft.)	25, 018	122, 732	60, 358	119, 285	8,360

[3] Window U-factor requirements represent ‘fixed’ windows.
[4] Window SHGC requirements for multi-family building model are based on the average SHGC requirement for ‘north’ orientation and ‘all’ orientations; SHGC requirements for all other building types are based on the ‘all orientation’ requirement.

Table A-1 Modeling Parameters by Building Type (continued)

Building Type	Office	School	Hospital	Retail	Multi-family
HVAC					
Heating Equipment					
Type	Gas Boiler	Gas Boiler	Gas Boiler	Gas Boiler	Gas Boiler
Efficiency	0.8	0.8	0.8	0.8	0.8
Size (kBtu/h)	Autosize(250)	Autosize(336)	Autosize(592)	Autosize(1072)	Autosize
Cooling Equipment					
Type	Direct Expansion / VAV	Direct Expansion / VAV	Chilled Water / VAV	Chilled Water / VAV	PTAC
Efficiency (COP)	2.73	4.9	5.5	4.9	9.2 EER
Size (tons)	Autosize (118)	Autosize (220)	Autosize (473)	Autosize (592)	Autosize (20 kBtu/hr) per unit
Internal Load					
Lighting Power Density (W/sq. ft.) (90.1-2001 / 90.1-2004)	1.3 / 1.0	1.5 / 1.2	1.6 / 1.2	1.9 / 1.5	1.0/0.7[5]
Plug Load (W/sq. ft.)	1.3	0.8	2.2	0.5	0.468
Occupancy (per 1000 sq. ft.)	3.64	13.33	5	3.33	1.65
Water Heating	Not modeled	Not modeled	Not modeled	Not modeled	Natural Gas
Energy Cost					
Electricity ($/kWh)	0.1518	0.1518	0.1518	0.1518	0.1518
Gas ($/therm)	1.35	1.35	1.35	1.35	1.35

[5] Multi-family lighting power density represents the LPD requirements for common areas (corridor and service units). Living units are assumed to have 1.1 W/sq. ft with a daily lighting time of 2.34 hours according to the New York Energy Smart Multi-family Building Performance Program Simulation Guidelines (NYSERDA, 2006)

APPENDIX B

Simulation Results

APPENDIX B. Simulation Results

Tables B-1 through B-5 show the results for buildings in New York City by building type. Tables B-6 through B-10 show the results for buildings in Buffalo by building type. Tables B-11 through B-15 show the results for buildings in Albany by building type.

Table B-1 Office Building Results for New York City

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	75057	75057	
Total Site Energy (GJ)	3832	3580	6.58%
Total Source Energy (GJ)	5426	5041	7.10%
Total Site Energy (MJ/m^2)	550	513	6.73%
Total Source Energy (MJ/m^2)	778	723	7.07%
Heating - Natural Gas (GJ)	299	341	-14.05%
Cooling - Electricity (GJ)	614	563	8.31%
Interior Lighting - Electricity (GJ)	1006	774	23.06%
Exterior Lighting - Electricity (GJ)	5	5	0.00%
Interior Equipment - Electricity (GJ)	1556	1556	0.00%
Fans - Electricity (GJ)	352	341	3.13%
Pumps - Electricity (GJ)			
Heat Rejection - Electricity (GJ)			
Total Electrical Energy (GJ)	3533	3240	8.29%
Total Natural Gas Energy (GJ)	299	341	-14.05%
Total Electrical Energy (kWh)	981389	900000	8.29%
Total Natural Gas Energy (MBtu)	283	323	-14.05%
Electricity Conumption (kWh/sq. ft.)	13.08	11.99	8.29%
Natural Gas Consumption (kBtu/sq. ft.)	3.78	4.31	-14.05%
Total Cost (Electricity)	148989	136591	8.32%
Total Cost (Natural Gas)	3830	4360	-13.84%
Total Energy Cost	***$152,819.00***	***$140,951.00***	7.77%
Total Energy Cost per sq. ft.	$2.04	$1.88	7.77%
Site Energy Savings over 90.1-2001		6.58%	
Cost Savings over 90.1-2001		7.77%	

Table B-2 School Building Results for New York City

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	122732	122732	
Total Site Energy (GJ)	6385	5913	7.39%
Total Source Energy (GJ)	8131	7486	7.93%
Total Site Energy (MJ/m^2)	560	519	7.32%
Total Source Energy (MJ/m^2)	713	657	7.85%
Heating - Natural Gas (GJ)	2513	2426	3.46%
Cooling - Electricity (GJ)	279	262	6.09%
Interior Lighting - Electricity (GJ)	1680	1344	20.00%
Exterior Lighting - Electricity (GJ)	15	15	0.00%
Interior Equipment - Electricity (GJ)	1204	1204	0.00%
Fans - Electricity (GJ)	270	255	5.56%
Pumps - Electricity (GJ)	277	267	
Heat Rejection - Electricity (GJ)	147	142	
Total Electrical Energy (GJ)	3872	3487	9.94%
Total Natural Gas Energy (GJ)	2513	2426	3.46%
Total Electrical Energy (kWh)	1075556	968611	9.94%
Total Natural Gas Energy (MBtu)	2382	2300	3.46%
Electricity Conumption (kWh/sq. ft.)	8.76	7.89	9.94%
Natural Gas Consumption (kBtu/sq. ft.)	19.41	18.74	3.46%
Total Cost (Electricity)	163293	147067	9.94%
Total Cost (Natural Gas)	32151	31038	3.46%
Total Energy Cost	***$195,444.00***	***$178,105.00***	8.87%
Total Energy Cost per sq. ft.	$1.59	$1.45	8.87%
Site Energy Savings over 90.1-2001		7.39%	
Cost Savings over 90.1-2001		8.87%	

Table B-3 Hospital Building Results for New York City

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	241435	241435	
Total Site Energy (GJ)	19596	18441	5.89%
Total Source Energy (GJ)	27558	25800	6.38%
Total Site Energy (MJ/m^2)	874	822	5.95%
Total Source Energy (MJ/m^2)	1229	1150	6.43%
Heating - Natural Gas (GJ)	1944	2125	-9.31%
Cooling - Electricity (GJ)	1326	1217	8.22%
Interior Lighting - Electricity (GJ)	4243	3182	25.01%
Exterior Lighting - Electricity (GJ)	8	8	0.00%
Interior Equipment - Electricity (GJ)	9511	9511	0.00%
Fans - Electricity (GJ)	1038	983	5.30%
Pumps - Electricity (GJ)	1037	957	
Heat Rejection - Electricity (GJ)	490	458	
Total Electrical Energy (GJ)	17653	16316	7.57%
Total Natural Gas Energy (GJ)	1944	2125	-9.31%
Total Electrical Energy (kWh)	4903611	4532222	7.57%
Total Natural Gas Energy (MBtu)	1843	2014	-9.31%
Electricity Conumption (kWh/sq. ft.)	20.31	18.77	7.57%
Natural Gas Consumption (kBtu/sq. ft.)	7.63	8.34	-9.31%
Total Cost (Electricity)	744418	688072	7.57%
Total Cost (Natural Gas)	24869	27185	-9.31%
Total Energy Cost	***$769,287.00***	***$715,257.00***	7.02%
Total Energy Cost per sq. ft.	$3.19	$2.96	7.02%
Site Energy Savings over 90.1-2001		5.89%	
Cost Savings over 90.1-2001		7.02%	

Table B-4 Retail Building Results for New York City

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	238571	238571	
Total Site Energy (GJ)	13108	11838	9.69%
Total Source Energy (GJ)	17698	15743	11.05%
Total Site Energy (MJ/m^2)	591	534	9.64%
Total Source Energy (MJ/m^2)	799	710	11.14%
Heating - Natural Gas (GJ)	2929	3179	-8.54%
Cooling - Electricity (GJ)	806	685	15.01%
Interior Lighting - Electricity (GJ)	5936	4686	21.06%
Exterior Lighting - Electricity (GJ)	11	11	0.00%
Interior Equipment - Electricity (GJ)	1982	1982	0.00%
Fans - Electricity (GJ)	523	475	9.18%
Pumps - Electricity (GJ)	627	559	
Heat Rejection - Electricity (GJ)	293	261	
Total Electrical Energy (GJ)	10178	8659	14.92%
Total Natural Gas Energy (GJ)	2929	3179	-8.54%
Total Electrical Energy (kWh)	2827222	2405278	14.92%
Total Natural Gas Energy (MBtu)	2776	3013	-8.54%
Electricity Conumption (kWh/sq. ft.)	11.85	10.08	14.92%
Natural Gas Consumption (kBtu/sq. ft.)	11.64	12.63	-8.54%
Total Cost (Electricity)	429219	365143	14.93%
Total Cost (Natural Gas)	37481	40681	-8.54%
Total Energy Cost	***$466,700***	***$405,824***	13.04%
Total Energy Cost per sq. ft.	$1.96	$1.70	13.04%
Site Energy Savings over 90.1-2001		9.69%	
Cost Savings over 90.1-2001		13.04%	

Table B-5 Multi-family Building Results for New York City

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	167200	167200	
Total Site Energy (GJ)	7625	7354	3.55%
Total Source Energy (GJ)	16210	15162	6.46%
Total Site Energy (MJ/m^2)	490	473	3.47%
Total Source Energy (MJ/m^2)	1043	976	6.42%
Heating - Natural Gas (GJ)	1473	1591	-7.99%
Cooling - Electricity (GJ)	836	771	7.67%
Interior Lighting - Electricity (GJ)	1270	947	25.47%
Exterior Lighting - Electricity (GJ)			
Interior Equipment - Electricity (GJ)	1098	1098	0.00%
Fans - Electricity (GJ)	1056	1055	0.09%
Pumps - Electricity (GJ)	32	32	0.33%
Heat Rejection - Electricity (GJ)			
Total Electrical Energy (GJ)	4292	3904	9.05%
Total Natural Gas Energy (GJ)	3332	3450	-3.54%
Total Electrical Energy (kWh)	1192691	1084741	9.05%
Total Natural Gas Energy (MBtu)	3160	3272	-3.54%
Electricity Conumption (kWh/sq. ft.)	7.13	6.49	9.05%
Natural Gas Consumption (kBtu/sq. ft.)	18.90	19.57	-3.54%
Total Cost (Electricity)	$181,050.49	$164,663.68	9.05%
Total Cost (Natural Gas)	$42,658.65	$44,170.65	-3.54%
Total Energy Cost	***$223,709.14***	***$208,834.33***	6.65%
Total Energy Cost per sq. ft.	$1.34	$1.25	6.65%
Site Energy Savings over 90.1-2001		3.55%	
Cost Savings over 90.1-2001		6.65%	

Table B-6 Office Building Results for Buffalo

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	75057	75057	
Total Site Energy (GJ)	3779	3578	5.32%
Total Source Energy (GJ)	6140	5749	6.37%
Total Site Energy (MJ/m^2)	542	513	5.35%
Total Source Energy (MJ/m^2)	881	824	6.47%
Heating - Natural Gas (GJ)	500	563	-12.60%
Cooling - Electricity (GJ)	345	323	6.38%
Interior Lighting - Electricity (GJ)	1006	774	23.06%
Exterior Lighting - Electricity (GJ)	5	5	0.00%
Interior Equipment - Electricity (GJ)	1556	1556	0.00%
Fans - Electricity (GJ)	367	356	3.00%
Pumps - Electricity (GJ)			
Heat Rejection - Electricity (GJ)			
Total Electrical Energy (GJ)	3279	3014	8.08%
Total Natural Gas Energy (GJ)	500	563	-12.60%
Total Electrical Energy (kWh)	910833	837222	8.08%
Total Natural Gas Energy (MBtu)	474	534	-12.60%
Electricity Conumption (kWh/sq. ft.)	12.14	11.15	8.08%
Natural Gas Consumption (kBtu/sq. ft.)	6.31	7.11	-12.60%
Total Cost (Electricity)	138291	127134	8.07%
Total Cost (Natural Gas)	6394	7208	-12.73%
Total Energy Cost	***$144,685.00***	***$134,342.00***	7.15%
Total Energy Cost per sq. ft.	$1.93	$1.79	7.15%
Site Energy Savings over 90.1-2001		5.32%	
Cost Savings over 90.1-2001		7.15%	

Table B-7 School Building Results for Buffalo

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	122732	122732	
Total Site Energy (GJ)	6901	6409	7.13%
Total Source Energy (GJ)	9486	8722	8.05%
Total Site Energy (MJ/m^2)	605	562	7.11%
Total Source Energy (MJ/m^2)	832	765	8.05%
Heating - Natural Gas (GJ)	3312	3196	3.50%
Cooling - Electricity (GJ)	180	168	6.67%
Interior Lighting - Electricity (GJ)	1680	1344	20.00%
Exterior Lighting - Electricity (GJ)	15	15	0.00%
Interior Equipment - Electricity (GJ)	1204	1204	0.00%
Fans - Electricity (GJ)	260	244	6.15%
Pumps - Electricity (GJ)	165	157	
Heat Rejection - Electricity (GJ)	85	80	
Total Electrical Energy (GJ)	3590	3212	10.53%
Total Natural Gas Energy (GJ)	3312	3196	3.50%
Total Electrical Energy (kWh)	997222	892222	10.53%
Total Natural Gas Energy (MBtu)	3139	3029	3.50%
Electricity Conumption (kWh/sq. ft.)	8.13	7.27	10.53%
Natural Gas Consumption (kBtu/sq. ft.)	25.58	24.68	3.50%
Total Cost (Electricity)	151370	135469	10.50%
Total Cost (Natural Gas)	42374	40896	3.49%
Total Energy Cost	***$193,744.00***	***$176,365.00***	8.97%
Total Energy Cost per sq. ft.	$1.58	$1.44	8.97%
Site Energy Savings over 90.1-2001		7.13%	
Cost Savings over 90.1-2001		8.97%	

Table B-8 Hospital Building Results for Buffalo

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	241435	241435	
Total Site Energy (GJ)	20039	18953	5.42%
Total Source Energy (GJ)	31823	29836	6.24%
Total Site Energy (MJ/m^2)	893	845	5.38%
Total Source Energy (MJ/m^2)	1419	1330	6.27%
Heating - Natural Gas (GJ)	3672	3837	-4.49%
Cooling - Electricity (GJ)	756	695	8.07%
Interior Lighting - Electricity (GJ)	4243	3182	25.01%
Exterior Lighting - Electricity (GJ)	8	8	0.00%
Interior Equipment - Electricity (GJ)	9511	9511	0.00%
Fans - Electricity (GJ)	1058	1001	5.39%
Pumps - Electricity (GJ)	561	505	
Heat Rejection - Electricity (GJ)	230	214	
Total Electrical Energy (GJ)	16367	15116	7.64%
Total Natural Gas Energy (GJ)	3672	3837	-4.49%
Total Electrical Energy (kWh)	4546389	4198889	7.64%
Total Natural Gas Energy (MBtu)	3481	3637	-4.49%
Electricity Conumption (kWh/sq. ft.)	18.83	17.39	7.64%
Natural Gas Consumption (kBtu/sq. ft.)	14.42	15.06	-4.49%
Total Cost (Electricity)	690197	637443	7.64%
Total Cost (Natural Gas)	46986	49094	-4.49%
Total Energy Cost	***$737,183.00***	***$686,537.00***	6.87%
Total Energy Cost per sq. ft.	$3.05	$2.84	6.87%
Site Energy Savings over 90.1-2001		5.42%	
Cost Savings over 90.1-2001		6.87%	

Table B-9 Retail Building Results for Buffalo

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	238571	238571	
Total Site Energy (GJ)	13459	12308	8.55%
Total Source Energy (GJ)	20228	18043	10.80%
Total Site Energy (MJ/m^2)	607	555	8.57%
Total Source Energy (MJ/m^2)	913	814	10.84%
Heating - Natural Gas (GJ)	4057	4344	-7.07%
Cooling - Electricity (GJ)	452	379	16.15%
Interior Lighting - Electricity (GJ)	5936	4686	21.06%
Exterior Lighting - Electricity (GJ)	11	11	0.00%
Interior Equipment - Electricity (GJ)	1982	1982	0.00%
Fans - Electricity (GJ)	515	468	9.13%
Pumps - Electricity (GJ)	365	316	
Heat Rejection - Electricity (GJ)	140	123	
Total Electrical Energy (GJ)	9402	7965	15.28%
Total Natural Gas Energy (GJ)	4057	4344	-7.07%
Total Electrical Energy (kWh)	2611667	2212500	15.28%
Total Natural Gas Energy (MBtu)	3845	4118	-7.07%
Electricity Conumption (kWh/sq. ft.)	10.95	9.27	15.28%
Natural Gas Consumption (kBtu/sq. ft.)	16.12	17.26	-7.07%
Total Cost (Electricity)	396475	335877	15.28%
Total Cost (Natural Gas)	51911	55578	-7.06%
Total Energy Cost	***$448,386***	***$391,455***	12.70%
Total Energy Cost per sq. ft.	$1.88	$1.64	12.70%
Site Energy Savings over 90.1-2001		8.55%	
Cost Savings over 90.1-2001		12.70%	

Table B-10 Multi-family Building Results for Buffalo

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	167200	167200	
Total Site Energy (GJ)	8396	8167	2.73%
Total Source Energy (GJ)	16631	15576	6.34%
Total Site Energy (MJ/m^2)	540	526	2.73%
Total Source Energy (MJ/m^2)	1067	1002	6.06%
Heating - Natural Gas (GJ)	2327	2478	-6.51%
Cooling - Electricity (GJ)	627	570	9.08%
Interior Lighting - Electricity (GJ)	1270	947	25.47%
Exterior Lighting - Electricity (GJ)			
Interior Equipment - Electricity (GJ)	1098	1098	0.00%
Fans - Electricity (GJ)	1057	1056	0.05%
Pumps - Electricity (GJ)	33	33	
Heat Rejection - Electricity (GJ)			
Total Electrical Energy (GJ)	4086	3705	9.32%
Total Natural Gas Energy (GJ)	4310	4462	-3.52%
Total Electrical Energy (kWh)	1135227	1029383	9.32%
Total Natural Gas Energy (MBtu)	4088	4232	-3.52%
Electricity Conumption (kWh/sq. ft.)	6.79	6.16	9.32%
Natural Gas Consumption (kBtu/sq. ft.)	24.45	25.31	-3.52%
Total Cost (Electricity)	$172,327.46	$156,260.34	9.32%
Total Cost (Natural Gas)	$55,183.95	$57,126.60	-3.52%
Total Energy Cost	***$227,511.41***	***$213,386.94***	6.21%
Total Energy Cost per sq. ft.	$1.36	$1.28	6.21%
Site Energy Savings over 90.1-2001		2.73%	
Cost Savings over 90.1-2001		6.21%	

Table B-11 Office Building Results for Albany

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	75057	75057	
Total Site Energy (GJ)	3832	3580	6.58%
Total Source Energy (GJ)	5426	5041	7.10%
Total Site Energy (MJ/m^2)	550	513	6.73%
Total Source Energy (MJ/m^2)	778	723	7.07%
Heating - Natural Gas (GJ)	299	341	-14.05%
Cooling - Electricity (GJ)	614	563	8.31%
Interior Lighting - Electricity (GJ)	1006	774	23.06%
Exterior Lighting - Electricity (GJ)	5	5	0.00%
Interior Equipment - Electricity (GJ)	1556	1556	0.00%
Fans - Electricity (GJ)	352	341	3.13%
Pumps - Electricity (GJ)			
Heat Rejection - Electricity (GJ)			
Total Electrical Energy (GJ)	3533	3240	8.29%
Total Natural Gas Energy (GJ)	299	341	-14.05%
Total Electrical Energy (kWh)	981389	900000	8.29%
Total Natural Gas Energy (MBtu)	283	323	-14.05%
Electricity Conumption (kWh/sq. ft.)	13.08	11.99	8.29%
Natural Gas Consumption (kBtu/sq. ft.)	3.78	4.31	-14.05%
Total Cost (Electricity)	148989	136591	8.32%
Total Cost (Natural Gas)	3830	4360	-13.84%
Total Energy Cost	***$152,819.00***	***$140,951.00***	7.77%
Total Energy Cost per sq. ft.	$2.04	$1.88	7.77%
Site Energy Savings over 90.1-2001		6.58%	
Cost Savings over 90.1-2001		7.77%	

Table B-12 School Building Results for Albany

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	122732	122732	
Total Site Energy (GJ)	7078	6578	7.06%
Total Source Energy (GJ)	9666	8894	7.99%
Total Site Energy (MJ/m^2)	621	577	7.09%
Total Source Energy (MJ/m^2)	848	780	8.02%
Heating - Natural Gas (GJ)	3484	3361	3.53%
Cooling - Electricity (GJ)	198	185	6.57%
Interior Lighting - Electricity (GJ)	1680	1344	20.00%
Exterior Lighting - Electricity (GJ)	15	15	0.00%
Interior Equipment - Electricity (GJ)	1204	1204	0.00%
Fans - Electricity (GJ)	253	237	6.32%
Pumps - Electricity (GJ)	162	154	
Heat Rejection - Electricity (GJ)	83	78	
Total Electrical Energy (GJ)	3594	3217	10.49%
Total Natural Gas Energy (GJ)	3484	3361	3.53%
Total Electrical Energy (kWh)	998333	893611	10.49%
Total Natural Gas Energy (MBtu)	3302	3186	3.53%
Electricity Conumption (kWh/sq. ft.)	8.13	7.28	10.49%
Natural Gas Consumption (kBtu/sq. ft.)	26.91	25.96	3.53%
Total Cost (Electricity)	151559	135666	10.49%
Total Cost (Natural Gas)	44581	43002	3.54%
Total Energy Cost	***$196,140.00***	***$178,668.00***	8.91%
Total Energy Cost per sq. ft.	$1.60	$1.46	8.91%
Site Energy Savings over 90.1-2001		7.06%	
Cost Savings over 90.1-2001		8.91%	

Table B-13 Hospital Building Results for Albany

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	241435	241435	
Total Site Energy (GJ)	20295	19239	5.20%
Total Source Energy (GJ)	32074	30118	6.10%
Total Site Energy (MJ/m^2)	905	858	5.19%
Total Source Energy (MJ/m^2)	1430	1343	6.08%
Heating - Natural Gas (GJ)	3935	4128	-4.90%
Cooling - Electricity (GJ)	797	735	7.78%
Interior Lighting - Electricity (GJ)	4243	3182	25.01%
Exterior Lighting - Electricity (GJ)	8	8	0.00%
Interior Equipment - Electricity (GJ)	9511	9511	0.00%
Fans - Electricity (GJ)	1043	987	5.37%
Pumps - Electricity (GJ)	540	485	
Heat Rejection - Electricity (GJ)	217	202	
Total Electrical Energy (GJ)	16360	15111	7.63%
Total Natural Gas Energy (GJ)	3935	4128	-4.90%
Total Electrical Energy (kWh)	4544444	4197500	7.63%
Total Natural Gas Energy (MBtu)	3730	3913	-4.90%
Electricity Conumption (kWh/sq. ft.)	18.82	17.39	7.63%
Natural Gas Consumption (kBtu/sq. ft.)	15.45	16.21	-4.90%
Total Cost (Electricity)	689896	637229	7.63%
Total Cost (Natural Gas)	50350	52816	-4.90%
Total Energy Cost	***$740,246.00***	***$690,045.00***	6.78%
Total Energy Cost per sq. ft.	$3.07	$2.86	6.78%
Site Energy Savings over 90.1-2001		5.20%	
Cost Savings over 90.1-2001		6.78%	

Table B-14 Retail Building Results for Albany

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	238571	238571	
Total Site Energy (GJ)	13825	12810	7.34%
Total Source Energy (GJ)	20592	18619	9.58%
Total Site Energy (MJ/m^2)	624	578	7.37%
Total Source Energy (MJ/m^2)	929	840	9.58%
Heating - Natural Gas (GJ)	4427	4743	-7.14%
Cooling - Electricity (GJ)	480	417	13.13%
Interior Lighting - Electricity (GJ)	5936	4686	21.06%
Exterior Lighting - Electricity (GJ)	11	11	0.00%
Interior Equipment - Electricity (GJ)	1982	1982	0.00%
Fans - Electricity (GJ)	500	493	1.40%
Pumps - Electricity (GJ)	358	349	
Heat Rejection - Electricity (GJ)	132	129	
Total Electrical Energy (GJ)	9398	8067	14.16%
Total Natural Gas Energy (GJ)	4427	4743	-7.14%
Total Electrical Energy (kWh)	2610556	2240833	14.16%
Total Natural Gas Energy (MBtu)	4196	4496	-7.14%
Electricity Conumption (kWh/sq. ft.)	10.94	9.39	14.16%
Natural Gas Consumption (kBtu/sq. ft.)	17.59	18.84	-7.14%
Total Cost (Electricity)	396321	340199	14.16%
Total Cost (Natural Gas)	56645	60688	-7.14%
Total Energy Cost	***$452,966***	***$400,887***	11.50%
Total Energy Cost per sq. ft.	$1.90	$1.68	11.50%
Site Energy Savings over 90.1-2001		7.34%	
Cost Savings over 90.1-2001		11.50%	

Table B-15 Multi-family Building Results for Albany

	90.1-2001	90.1-2004	Savings
Floor Area (sq. ft.)	167200	167200	
Total Site Energy (GJ)	8574	8355	2.55%
Total Source Energy (GJ)	16824	15848	5.80%
Total Site Energy (MJ/m^2)	552	538	2.47%
Total Source Energy (MJ/m^2)	1083	1020	5.77%
Heating - Natural Gas (GJ)	2450	2609	-6.52%
Cooling - Electricity (GJ)	666	612	8.16%
Interior Lighting - Electricity (GJ)	1270	947	25.47%
Exterior Lighting - Electricity (GJ)			
Interior Equipment - Electricity (GJ)	1058	1057	0.08%
Fans - Electricity (GJ)	33	33	0.00%
Pumps - Electricity (GJ)	2000	2000	0.00%
Heat Rejection - Electricity (GJ)			
Total Electrical Energy (GJ)	4125	3746	9.18%
Total Natural Gas Energy (GJ)	4449	4609	-3.59%
Total Electrical Energy (kWh)	1146102	1040918	9.18%
Total Natural Gas Energy (MBtu)	4219	4371	-3.59%
Electricity Conumption (kWh/sq. ft.)	6.85	6.23	9.18%
Natural Gas Consumption (kBtu/sq. ft.)	25.24	26.14	-3.59%
Total Cost (Electricity)	$173,978.28	$158,011.35	9.18%
Total Cost (Natural Gas)	$56,960.55	$59,007.15	-3.59%
Total Energy Cost	***$230,938.83***	***$217,018.50***	6.03%
Total Energy Cost per sq. ft.	$1.38	$1.30	6.03%
Site Energy Savings over 90.1-2001		2.55%	
Cost Savings over 90.1-2001		6.03%	

APPENDIX C

Evaluation of Lighting Cost Effectiveness

APPENDIX C. Evaluation of Lighting Cost Effectiveness

Appendix C is adopted directly from a previous report generated by PNNL's Building Energy Codes Program for the State of New York. (Richman 2004).

The adoption of a new energy code will provide the legislative and administrative basis for improved energy efficiency in buildings. The amount of lighting energy saved in buildings and the long-term cost effectiveness of the code's application will depend on several factors including:

- The mix of buildings in the state
- Local or regional construction costs
- Differences in lighting requirements in the code
- Energy cost variances over the life of the energy-using equipment
- The operating characteristics of each building.

It is important to note that this kind of analysis is a point-to-point comparison, where a fixed level of real world activity is assumed. It is understood that buildings are not built precisely to code levels, and that actual percentage of compliance above and below codes will vary among individual buildings and building types. However, without specific knowledge of this real world activity for all buildings in existence and in the future (post-code adoption), it is not possible to analyze actual effects of code adoption. However, it is possible to compare code levels and determine the potential effect of changes from one code requirement level to another. This is the comparison and effectiveness assessment provided by this analysis.

Analysis Method

The basis for this analysis is the set of models that are used to derive the LPD values in the different versions of Standard 90.1. The basic models are mathematical representations of typical "good quality" lighting designs for approximately 120 different space types commonly found in buildings. The output of these models is an LPD for each space type, which forms the space type LPD requirements in the standards. These space type LPDs are further applied to a dataset of detailed space type square footage data take-offs for 246 individual, recently constructed real buildings from across the nation. This application generates whole building LPDs based on the weighting of space type LPD values in real buildings. The dataset contains multiple individual buildings for each building type, and the LPD results for these are averaged to represent a typical building type LPD requirement.

Cost Analysis Basis

These 90.1 LPD models are modified for the current analysis to generate cost-effectiveness data. The original models provide information on generic lighting technology types and the relative quantities of each that represent the lighted space type. This lighting technology information is directly used to develop a typical cost for each space type model for the 90.1-2001 and 90.1-2004 sets of models. These derived space type costs can then be compared and combined with estimated energy savings to develop the cost effectiveness of the adoption of the new LPD values. It is important to note that this comparison between code levels incorporates updated costs, technology efficiency, light loss factors, and the latest IESNA light level recommendations. It does not, however, incorporate any changes in basic fixture type. The same basic commonly available efficient products are used in both sets of models to determine cost effectiveness. The energy and cost efficiency is primarily driven by appropriate design using reasonably efficient equipment and following the latest recommended light level guidance but not the use of cutting edge technology or other cost prohibitive equipment.

Cost data for commodities such as lighting are always very difficult to apply to analysis efforts because of the great variability. Lighting products that provide similar light at similar efficiencies and distribution characteristics can come in a wide variety of styles and formats that have greatly varying costs. This is unlike other major building energy components, such as mechanical systems and envelope materials, where the cost is generally driven by the efficiency or quantity of the material. Lighting, however, includes a very large decorative or visible art component that impacts cost.

To make this analysis a fair and reasonable comparison, a set of equitable costs was required. The basis for these depends on the use of basic light producing equipment (minus any decorative or art components) at a nationally consistent and recognizable cost structure. The LPD models are already based on standard basic equipment representing good quality but low decorative components. The source for consistent cost data is centered on the R.S. Means cost data reference (R. S. Means 2005) and the Grainger Supply catalog (W. W. Grainger 2004). The R.S. Means data is a well recognized and used source for building construction cost estimating that provides material, labor, and overhead estimates for a variety of lighting products. R.S. Means also tracks location-specific cost indexes for adjusting basic cost data. The Grainger Supply catalog represents a major retail source of lighting equipment with nationally consistent prices. The Grainger catalog provides additional detail on specific equipment that is not available in the Means data source and is used to supplement the base Means estimates.

Each of the LPD models is populated with lighting fixture data from 1 and 3 different fixture types from a list of 34 defined fixture types. Fixture costs for each of the 34 types were developed from the two cost sources, which are in turn applied to the space type models. This development included deriving a base fixture cost and associated installation labor, adjustment to New York cost indexes, and assignment of a wattage for cost assignment. The Means and Grainger sources were used, where applicable, to derive an installed cost for each fixture. The Means city cost indexes for New York cities were used to derive weighted state indexes using city population data from the U.S. Census. The resulting costs used for this analysis include material plus labor adjusted by the weighted New York state indexes but do not include overhead/profit adders. The Grainger catalog was used to assign a typical wattage to each fixture type. These wattages are used to apply the appropriate cost for each of the one to three fixture types in the model based on the model's use of them based on wattage and lighting technology efficacy.

The individual space type model formulas were modified to derive costs (instead of LPD) based on the developed fixture costs and index. While the sets of models used are the same, some of the characteristics of the models are different, including different fixture choices and, of course, the quantities of fixtures needed to provide the lighting represented by the LPD value. These differences drive the difference in cost for each model. For consistency of the analysis, the efficiencies of the fixtures applied in the models and the building set data used to develop the whole building values were based (for both code levels) on the latest data used in the 2004 Standard development. This provides a consistent basis because new construction designed to meet either code would apply the same equipment at current efficiencies.

Lighting Power Density and Equipment Cost Comparison

The models provide detailed data that can be used to compare individual space type characteristics and changes. However, these individual comparisons cannot provide an overall effect on code adoption at a state level. Therefore, the whole building cost data derived in the analysis is used for comparisons. The models are used to derive both difference in cost and difference in energy (power density) between the application of the various standards to each building type. The cost variation is the difference between the whole building lighting cost per square foot derived using the various models. The energy variation is the wattage (power density) difference per square foot. These values for the 32 building types are shown in Table C-1.

Table C–1 Whole Building Model Comparison – 90.1-2001 to 90.1-2004

Building Type	Equipment Cost "Change" in $/sq ft	LPD Energy "Change" in W/sq ft
Automotive Repair	(1.20)	(0.60)
Convention Center	(0.25)	(0.20)
Courthouse	(0.79)	(0.20)
Dining-Bar Lounge/Leisure	(0.29)	(0.20)
Dining-Café/Fast Food	0.11	(0.40)
Dining-Family	0.40	(0.30)
Dormitory	(3.33)	(0.50)
Exercise Center	(0.13)	(0.40)
Fire Station	(0.66)	(0.50)
Gymnasium	(0.02)	(0.60)
Healthcare-Hospital	(1.16)	(0.40)
Hotel	(2.48)	(0.70)
Library	(0.32)	(0.20)
Manufacturing	(1.35)	(0.90)
Motel	(2.99)	(1.00)
Multi-Family	(0.43)	(0.30)
Museum	(0.86)	(0.50)
Office	(1.00)	(0.30)
Parking Garage	0.12	0.00
Penitentiary	(0.68)	(0.20)
Police Station	(0.74)	(0.30)
Post Office	(1.46)	(0.50)
Religious	(1.45)	(0.90)
Retail	(1.96)	(0.40)
School-College	(0.31)	(0.30)
Sports Arena	(1.17)	(0.40)
Theater-Performing Arts	0.04	0.10
Theatre-Motion Picture	(0.54)	(0.40)
Town Hall	(0.87)	(0.30)
Transportation	(0.16)	(0.20)
Warehouse	(0.29)	(0.40)
Workshop	(0.22)	(0.30)
Average	***(0.82)***	***(0.40)***

It is clear from the table that the majority of the building types (28) exhibit both a decrease in cost and a decrease in energy between the two code levels. For these cases, there is a clear advantage in both cost and energy to moving to the new code level. The remaining four building types are worth examining individually.

Dining - Cafeteria Fast Food
The energy savings of 0.40 watts per square foot for this building type will offset the additional equipment cost. This is calculated using an estimated weekly lighting operation time for this building type of 84 hours (EIA 1999, Commercial Bldg Energy Conservation Survey) and the 2003 yearly average NY State Commercial electricity cost of 13 cents per kilowatt (U.S. DOE 2004). For this building type, the estimated simple payback is 0.47 years.

Dining – Family
The energy savings of 0.30 watts per square foot for this building type will also offset the additional equipment cost. In this case, the estimated simple payback is 2.4 years.

Parking Garage
The parking garage building type is the only one that experiences no change in lighting power density for whole building. The whole building values represent aggregations of multiple individual space types and building space characteristics. These combinations of changes in the models can produce a null effect such as this for energy with a definite effect in cost (or visa-versa). In this case, while there is no energy savings, there is a small increase in cost resulting from small changes in technology choices. Therefore, technically, the additional small cost per square foot will never be repaid with energy savings for this building type.

Performing Arts Theatre
In this case, both the cost and energy are expected to increase with a change in code levels. The cost change is very small at $0.04 per square foot with a moderate rise in energy use at 0.10 watt per square foot. Again in this case, there can be no repayment of the additional equipment cost for this building type.

To be able to evaluate the effect of the code change across New York, it is important to look at the weighted effect of all building type changes. In the absence of NY State specific data, a national representation of building square footage by building type (EIA 1999) was used to weight the effect of the code change. The results of this analysis are a weighted decrease in equipment cost of $0.88 per square foot for all buildings and a decrease in energy of 0.39 watts per square foot for all buildings.

Analysis Results

Primary results from this comparison analysis are:

- 31 of the 32 building types analyzed show a **decrease** in allowed power density with adoption of the new code. The Performing Arts Theatre building type increases by 0.1 watt per square foot allowed (1.5 to 1.6) and Parking Garage shows no change in energy.

- 28 of the 32 building types show estimated **decreases** in lighting installation cost in complying with the new IECC 2003 code LPD levels. This is primarily caused by the new models reflecting the current light level recommendations and applying current equipment efficiencies and design practices that allow less equipment to be able to provide the necessary lighting. Cafeteria/Fast Food Dining, Family Dining, Parking Garage, and Performing Arts Theatre building types experience small to moderate increases in equipment costs.

- The weighted average power density change across all building types is an estimated **decrease** of 0.39 watts per square foot in lighting power density across the state based on a typical nationwide building mix.

- The weighted average effect of the cost change across all building types is an estimated **decrease** in lighting installation costs of $0.88 per square foot across the state based on a typical nationwide building mix.

These results make it clear that on a State level, adoption of the new lower LPD values found in ASHRAE 90.1-2004 are cost effective at any cost recovery base period and well below a 10-year recovery base.

Additional Adoption Considerations

There are three other lighting-related factors discussed below – exterior lighting power densities, lighting controls-occupancy sensors, and the relationship between compliance and additional lighting power allowances.

<u>Exterior Lighting Power Densities</u>

One of the major additions to the 2004 version of the 90.1 Standard is a greatly expanded set of exterior lighting power density values. The previous Standard (1999) only included specific power limits for four common exterior applications (building entrances and exits, canopies, and facades only) compared to 17 in the 2004 Standard (covering effectively all expected exterior applications). These values work in the same way as the interior LPDs in that they specify maximum power limits for specific exterior applications. The set of requirements includes tradable as well as non-tradable application LPDs. The tradable applications offer the same trade-off capability among applications as the interior LPDs. The non-tradable applications have specific power limits that must be used for the specific application and cannot be traded off to other applications.

This expanded set of power limits should have a similar energy saving and cost reducing effect as the revised interior LPDs analyzed in this report. The result of this expanded set of values is that large exterior areas previously unrestrained by a power limit must now comply with one. The actual energy savings will depend on the individual design application, but these requirements will have the effect of reducing exterior lighting energy use. The installation cost of exterior lighting will likely also be reduced because the power limits will cause designs to be re-evaluated, with the likely result being fewer or smaller exterior fixtures.

Lighting Controls – Occupancy Sensors

One important addition to the 2004 version of the 90.1 Standard is a limited requirement for occupancy sensors in most classrooms, conference/meeting rooms, and employee lunch and break rooms. The existing automatic shutoff control requirement for lighting (in both 1999 and 2004 versions) allows the use of occupancy sensors as one compliance option. Note that the language for this requirement in the 1999 version is decidedly unclear. [This language has been corrected in the 90.1–2001 and 2004 Standard.] This new requirement in the 2004 version makes the use of occupancy sensors mandatory for these spaces.

The savings potential from occupancy sensor control has been studied, and the results indicate large but quite variable potential. It is generally impossible to evaluate actual savings potential given the multiple variables of the building stock and use characteristics for an entire state. However, some discussion of the effect of this requirement can be useful.

Research finds that some building spaces are better candidates than others for these sensors, both from a cost effectiveness and operational standpoint. For example, most of the study results show that “common” type spaces such as lunchrooms, conference rooms, restrooms, and/or photocopy rooms provide the best energy savings opportunities. Conversely, those studies show that some but not all individual offices can provide little savings. While the conditions are extremely variable, the study results show potential payback periods for occupancy sensors in the range of 0.7 to 7.8 years (depending on capacity of installed lighting) for “common” spaces and 4.0 to 9.1 years for office type Federal energy rates of around $0.08 per kWh (well below the rates of $0.1518 per kWh used in this study for New York.) Therefore, this new requirement for occupancy sensors in limited common space types will be a cost-effective addition to energy code requirements for New York.

Compliance and Additional Lighting Power Allowances

In addition to the cost-effectiveness considerations for new code adoption, other factors may merit consideration. It is clear that in many building types, lighting can be an important part of design, art, and commerce.

It is also understood by code developers that the prominent art element of lighting (not found in envelope and mechanical energy concerns) creates potential problems with meeting specific code levels. This "art element" is the driver behind the additional lighting power allowances provided in the 90.1 Standard. Because of the unfamiliarity of codes and application, some interested parties may not have a full understanding of the use of the additional allowances. Therefore, the adoption of more stringent codes such as 90.1-2004 could be eased within the lighting design community by emphasis and education placed on these allowances.