

# Cost-Effectiveness of ASHRAE Standard 90.1-2010 for the State of Connecticut

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# ASHRAE Standard 90.1-2010 Provides Cost-Effective Savings for Commercial Buildings in the State of Connecticut

Moving to the ANSI/ASHRAE/IES Standard 90.1-2010 version from the Base Code (90.1-2007) is cost-effective for all building types and climate zones in the State of Connecticut.

Table 1 shows the statewide economic impact of upgrading to 90.1-2010 in terms of the annual energy cost savings in dollars per square foot, the additional cost per square foot required by the upgrade, and the simple payback period in years. Average values are weighted averages for all building types considered in all climate zones in the state, based on weightings shown in Table 6.

Table 1. Connecticut Average Savings and Cost Weighted by Climate Zone and Building Type

Weighted Cost Savings and Added Cost per Square Foot	
Annual Cost Savings, \$/ft <sup>2</sup>	\$0.333
Added Construction Cost, \$/ft <sup>2</sup>	\$1.154
State of Connecticut Average Simple Payback, years	3.5

The report provides analysis of two Life Cycle Cost (LCC) scenarios:

**Scenario 1**, representing publicly-owned buildings, considers initial costs, energy, maintenance and replacement costs without borrowing or taxes.

**Scenario 2**, representing privately-owned buildings, adds borrowing costs and tax impacts.

Table 2 shows the statewide weighted average LCC net present value of savings from both scenarios, that is, the remaining savings after initial and replacement costs have been paid for. Average values are weighted averages of all climate zones and building types in the state as shown in Table 6. Individual building type LCC results are shown in Figures 1 and 2.

Table 2. Connecticut Average LCC Results Weighted by Climate Zone and Building Type

Weighted Net Life Cycle Cost Savings, by Ownership Scenario	
Scenario 1 (Publicly-Owned), \$/ft <sup>2</sup>	\$4.75
Scenario 2 (Privately-Owned), \$/ft <sup>2</sup>	\$5.38

Figure 1. Scenario 1: Net Life Cycle Cost Savings

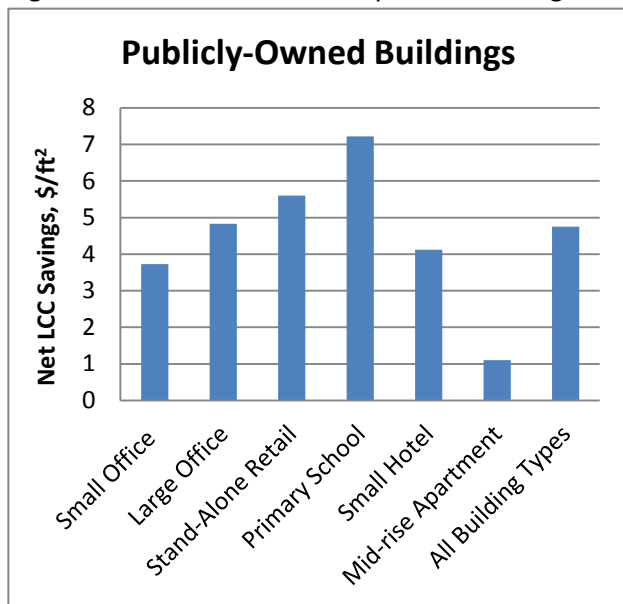
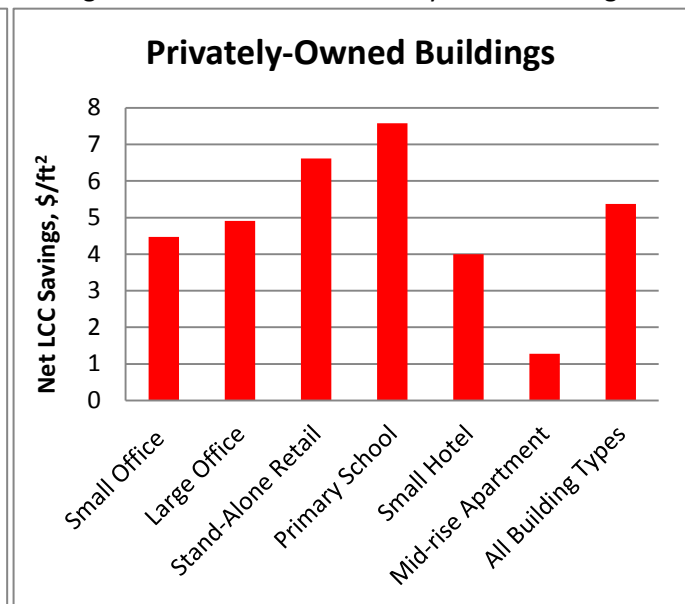


Figure 2. Scenario 2: Net Life Cycle Cost Savings



## Cost-Effectiveness Results for Standard 90.1-2010 in the State of Connecticut

Life Cycle Cost (LCC) savings is the primary measure DOE uses to assess the economic impact of building energy codes.

### Savings are computed for two scenarios:

**Scenario 1 (publicly-owned)** includes costs for initial equipment and construction, energy, maintenance and replacement and does not include loans or taxes.

**Scenario 2 (privately-owned)** includes the same costs as scenario 1 plus the initial investment is financed through a loan amortized over 30 years with corresponding tax deductions for interest and depreciation. Federal and state corporate income tax rates are applied.

Both scenarios include the residual value of equipment with remaining useful life at the end of the 30 years. Totals for all building types in the state overall are averages based on Table 6 weightings.

Factors such as inflation and discount rates are different between the two scenarios, as described in the Cost-Effectiveness Methodology section.

**Table 3** shows that the value today of the total LCC savings over 30 years for buildings in scenario 1 average \$4.75 per square foot for 90.1-2010.

**Table 4** shows that the LCC savings over 30 years average \$5.38 per square foot for scenario 2.

**Table 5** shows that the primary benefit of ASHRAE Standard 90.1-2010, annual energy cost savings, average \$0.333 per square foot for both scenarios.

Table 3. LCC Savings (30 Years) from ASHRAE Standard 90.1-2010, Scenario 1 (\$/ft<sup>2</sup>)

Climate Zone & Representative City	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-rise Apartment	All Building Types
5A Hartford Bradley	\$3.73	\$4.83	\$5.60	\$7.22	\$4.12	\$1.10	\$4.75

Table 4. LCC Savings (30 Years) from ASHRAE Standard 90.1-2010, Scenario 2 (\$/ft<sup>2</sup>)

Climate Zone & Representative City	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-rise Apartment	All Building Types
5A Hartford Bradley	\$4.47	\$4.91	\$6.62	\$7.58	\$4.00	\$1.28	\$5.38

Table 5. Annual Energy Cost Savings from ASHRAE Standard 90.1-2010, Scenarios 1 and 2 (\$/ft<sup>2</sup>)

Climate Zone & Representative City	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-rise Apartment	All Building Types
5A Hartford Bradley	\$0.293	\$0.285	\$0.429	\$0.430	\$0.201	\$0.077	\$0.333

The U.S. Department of Energy (DOE) provides estimates of energy and cost savings from code adoption at the National, Climate Zone, and State levels. For more information on how these estimates were developed, visit the DOE Building Energy Codes website:

[www.energycodes.gov/development/commercial](http://www.energycodes.gov/development/commercial)

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## Costs and Weightings for Standard 90.1-2010 in the State of Connecticut

### Construction Weighting of Results

Energy and economic impacts were determined and reported separately for each building type. Cost-effectiveness results are also reported as an average for all analyzed building prototypes in the state. To determine these averages, results were combined across the different building types using weighting factors shown in Table 6. These weighting factors are based on the floor area of new construction and major renovations for the six analyzed building prototypes in the state. The weighting factors were developed from construction start data from 2003 to 2007 based on an approach developed by Jarnagin and Bandyopadhyay (McGraw Hill Construction 2007, Jarnagin and Bandyopadhyay 2009).

Table 6. Construction Weights by Building Type

Climate Zone & Representative City	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-rise Apartment	All Building Types
5A Hartford Bradley	9.7%	4.8%	44.9%	17.1%	5.3%	18.3%	100.0%

### Incremental Construction Cost

Cost estimates were developed for the differences between the Base Code and ASHRAE Standard 90.1-2010 as implemented in the six prototype models. Costs for the initial construction include material, labor, commissioning, construction equipment, overhead and profit. These costs were developed using a commercial cost estimation firm, engineering design consultants and RS Means 2012 Cost Data (RS Means 2012a,b,c; 2004, Thornton et al. 2013).

Table 7 shows incremental initial cost for individual building types in the state and weighted average costs for all building types for moving to ASHRAE Standard 90.1-2010 from the Base Code. The incremental cost may be negative for some building types based on the downsizing of HVAC equipment resulting from reductions in heating and cooling loads due to improvements in ASHRAE Standard 90.1-2010, such as more efficient lighting systems and changes to the building thermal envelope.

Table 7. Incremental Construction Cost of ASHRAE 90.1-2010 (\$/ft<sup>2</sup>)

Climate Zone & Representative City	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-rise Apartment	All Building Types
5A Hartford Bradley	\$1.595	(\$0.407)	\$2.009	\$0.408	(\$0.412)	\$0.378	\$1.154

Table 8 shows simple payback results in years. Simple payback is the number of years required for energy cost savings to exceed the incremental first costs of a new code or code change proposals. Simple payback is not used as a measure of cost-effectiveness as it does not account for the time value of money, the value of energy cost savings that occur after payback is achieved, or any maintenance or replacement costs that occur after the initial investment.

Table 8. Simple Payback from ASHRAE Standard 90.1-2010, Scenarios 1 and 2 (Years)

Climate Zone & Representative City	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-rise Apartment	All Building Types
5A Hartford Bradley	5.4	Immediate	4.5	0.9	Immediate	4.9	3.5

# Cost-Effectiveness Methodology for Standard 90.1 in the State of Connecticut

LCC savings is the primary measure DOE uses to assess the cost-effectiveness of building energy codes.

## Cost-Effectiveness

DOE uses standard economic Life Cycle Cost (LCC) cost-effectiveness analysis methods in comparing ASHRAE Standard 90.1-2010 and the Base Code.

**LCC Savings:** LCC is the calculation of the present value of costs over a 30-year period including initial equipment and construction costs, energy savings, maintenance and replacement costs, and residual value of components at the end of the 30-year period. A separate LCC is determined for the Base Code and for ASHRAE Standard 90.1-2010. The LCC savings is the Base Code LCC minus the ASHRAE Standard 90.1-2010 LCC. Two cost scenarios are analyzed:

**Scenario 1** includes the costs listed above without borrowing or taxes.

**Scenario 2** includes the same costs as scenario 1 plus financing of the incremental costs through increased borrowing with associated tax impacts including mortgage interest deductions and depreciation. Corporate tax rates are applied.

Economic analysis factors such as discount rates are also different, as described in Table 10.

While not a true cost-effectiveness metric, Simple Payback is also calculated. Simple payback is the number of years required for accumulated annual energy cost savings to exceed the incremental first costs of a new code.

This analysis demonstrates that for all building types and climate zones in the State of Connecticut, ASHRAE Standard 90.1-2010 results in savings over the Base Code (ASHRAE Standard 90.1-2007).

**Hence, ASHRAE Standard 90.1-2010 is cost-effective in the State of Connecticut.**

The cost-effectiveness analysis compares the cost for new buildings meeting ASHRAE Standard 90.1-2010 compared to new buildings meeting a Base Code, ASHRAE Standard 90.1-2007 (ASHRAE 2010, ASHRAE 2007). The analysis includes energy savings estimates from building energy simulations and life cycle cost (LCC) and simple payback calculations using standard economic analysis parameters. The analysis builds on work documented in *Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010* (Thornton et al. 2011), and the cost-effectiveness analysis documented in *Cost-effectiveness of ASHRAE Standard 90.1-2010 Compared to ASHRAE Standard 90.1-2007* (Thornton et al. 2013).

## Building Prototypes and Energy Modeling

The cost-effectiveness analysis uses six building types represented by six “prototype” building energy models. These six are a subset of 16 prototype building energy models and represent 80% of commercial floor space. These models provide coverage of the significant changes in ASHRAE Standard 90.1 from 2007 to 2010 and are used to show the impacts of the changes on energy savings. The prototypes represent common construction practice and include the primary conventional heating, ventilating and air-conditioning (HVAC) systems most commonly used in commercial buildings. More information on the prototype buildings and savings analysis can be found at: [www.energycodes.gov/development/commercial/90.1\\_models](http://www.energycodes.gov/development/commercial/90.1_models).

Each prototype building is analyzed for each of the climate zones found within the state. Using the U.S. Department of Energy (DOE) EnergyPlus™ software, the six building prototypes summarized in Table 9 are simulated with characteristics meeting the requirements of the Base Code (ASHRAE Standard 90.1-2007) and then modified to meet the requirements of the next edition of the code (ASHRAE Standard 90.1-2010). The energy use and cost is then compared between the two sets of models.

**Table 9. Building Prototypes**

Building Prototype	Floor Area (ft <sup>2</sup> )	Number of Floors
Small Office	5,500	1
Large Office	498,640	13
Stand-Alone Retail	24,690	1
Primary School	73,970	1
Small Hotel	43,210	4
Mid-rise Apartment	33,740	4

## Climate Zones

Climate zones are defined in ASHRAE Standard 90.1 and include eight primary climate zones, the hottest being climate zone 1 and the coldest being climate zone 8. Letters A, B, and C are applied in some cases to denote the level of moisture, with A indicating moist or humid, B indicating dry, and C indicating marine. Figure 3 shows the national climate zones. For this state analysis, savings is analyzed for each climate zone in the state using weather data from a selected city within the climate zone and state, or where necessary, a city in an adjoining state with more robust weather data. The cities used are shown in Tables 3 through 8.





**Table 10. LCC Economic Parameters**

Economic Parameter		Scenario 1	Scenario 2
Study Period – Years <sup>1</sup>		30	30
Nominal Discount Rate <sup>2</sup>		3.90%	6.00%
Real Discount Rate <sup>2</sup>		3.00%	4.60%
Inflation <sup>3</sup>		0.90%	1.30%
Electricity Prices <sup>4</sup>	per kWh	\$0.1470	\$0.1470
Natural Gas Prices <sup>4</sup>	per therm	\$0.8200	\$0.8200
Energy Price Escalation Factors <sup>5</sup>		<i>Uniform present value factors</i>	<i>Annual escalation factors</i>
Electricity Price Escalation <sup>5</sup>		18.88	1.50%/year
Natural Gas Price Escalation <sup>5</sup>		20.90	2.72%/year
Loan Interest Rate <sup>6</sup>		NA	6.00%
Federal Corporate Tax Rate <sup>7</sup>		NA	34.00%
State Corporate Tax Rate <sup>8</sup>		NA	7.50%
Combined Income Tax Impact <sup>9</sup>		NA	38.95%
State and Average Local Sales Tax <sup>10</sup>		6.35%	6.35%

<sup>1</sup> A 30-year study period captures most building components useful lives and is a commonly used study period for building project economic analysis. This period is consistent with previous and related National 90.1 cost-effectiveness analysis (Thornton et al. 2013). It is also consistent with the cost-effectiveness analysis that was done for the residential energy code as described in multiple state reports and a summary report (DOE 2012). The federal building LCC method uses 25 years and the ASHRAE Standard 90.1 development process uses up to 40 years for building envelope code improvement analysis. Because of the time value of money, results are typically similar for any study periods of 20 years or more.

<sup>2</sup> The scenario 1 real and nominal discount rates are from the National Institute of Standards and Technology (NIST) 2011 annual LCC update for the federal LCC method (Rushing et al. 2011). The scenario 2 nominal discount rate is assumed to be the marginal cost of capital, which is set equal to the assumed loan interest rate (see footnote 6). The real discount rate is calculated from the nominal discount rate and inflation.

<sup>3</sup> The scenario 1 effective inflation rate is from the NIST 2011 annual LCC update for the federal LCC method (Rushing et al. 2011) consistent with the ASHRAE Standard 90.1 national cost-effectiveness analysis 30-year LCC analysis (Thornton et al. 2013). The scenario 2 inflation rate is the Producer Price Index for non-residential construction, February 2012 to February 2013 (Bureau of Labor Statistics 2013).

<sup>4</sup> Scenario 1 and 2 electricity and natural gas prices are state average prices from the United States Energy Information Agency (EIA) *Energy Outlook 2012* (EIA 2012).

<sup>5</sup> Scenario 1 energy price escalation rates are from NIST 2011 annual update for the FEMP LCC method (Rushing et al. 2011) consistent with the ASHRAE Standard 90.1 national cost-effectiveness 30-year LCC analysis (Thornton et al. 2013). The NIST uniform present value factors are multiplied by the first year annual energy cost to determine the present value of 30 years of energy costs and are based on a series of different annual escalation rates for 30 years. Scenario 2 uses national average annual real electricity price escalation rates for 2011 to 2040 (EIA 2013), 0.2% for electricity and 1.4% for natural gas. EIA publishes regional, but not state-specific, escalation rates; the regional rates are estimates and thought to not add additional accuracy to the state-level economic estimates. The effective nominal escalation rates calculated using the scenario 2 inflation rate of 1.3% are shown in the table above.

<sup>6</sup> The loan interest rate is estimated from multiple online sources listed in the references (Capital Funders 2012, Commercial Loan Direct 2013, and Steelhead Capital 2013).

<sup>7</sup> The highest federal marginal corporate income tax rate is assumed to apply.

<sup>8</sup> The highest marginal state corporate income tax rate is assumed to apply from the Federation of Tax Administrators (FTA 2013).

<sup>9</sup> The combined tax impact is based on state tax being a deduction for federal tax, and is applied to depreciation and loan interest.

<sup>10</sup> The state and average local sales tax is included in material costs in the cost estimate.

### Detailed Energy Use and Cost

On the following pages, specific detailed results for Connecticut are included:

Table 11 shows the average energy rates used.

Table 12 shows the per square foot energy costs for 90.1-2007 and 90.1-2010 and the cost savings from 90.1-2010.

Table 13 shows the per square foot energy use for 90.1-2007 and 90.1-2010 and the use savings from 90.1-2010.

Table 14 shows the energy end use by energy type for each climate zone in the state.



**Table 11. Energy Rates for the State of Connecticut, Average \$ per unit**

Electricity	\$0.1470	kWh
Gas	\$0.8200	therm

Source: Energy Information Administration (EIA 2012)

**Table 12. Energy Cost Saving Results for ASHRAE Standard 90.1 in the State of Connecticut, \$ per square foot**

Climate Zone:	5A			
Code:	90.1-2007	90.1-2010	Savings	
Small Office				
Electricity	\$1.625	\$1.334	\$0.292	18.0%
Gas	\$0.006	\$0.004	\$0.002	33.3%
Totals	\$1.631	\$1.338	\$0.293	18.0%
Large Office				
Electricity	\$3.121	\$2.859	\$0.262	8.4%
Gas	\$0.084	\$0.061	\$0.023	27.4%
Totals	\$3.205	\$2.920	\$0.285	8.9%
Stand-Alone Retail				
Electricity	\$2.113	\$1.748	\$0.365	17.3%
Gas	\$0.168	\$0.104	\$0.064	38.1%
Totals	\$2.281	\$1.852	\$0.429	18.8%
Primary School				
Electricity	\$2.077	\$1.727	\$0.350	16.9%
Gas	\$0.202	\$0.122	\$0.080	39.6%
Totals	\$2.279	\$1.848	\$0.430	18.9%
Small Hotel				
Electricity	\$1.896	\$1.693	\$0.203	10.7%
Gas	\$0.202	\$0.204	-\$0.002	-1.0%
Totals	\$2.098	\$1.897	\$0.201	9.6%
Mid-rise Apartment				
Electricity	\$1.729	\$1.672	\$0.058	3.4%
Gas	\$0.100	\$0.081	\$0.019	19.0%
Totals	\$1.829	\$1.752	\$0.077	4.2%

**Table 13. Energy Use Saving Results for ASHRAE Standard 90.1 in the State of Connecticut, Energy Use per Square Foot**

Climate Zone:	5A			
Code:	90.1-2007	90.1-2010	Savings	
<b>Small Office</b>				
Electricity, kWh/ft <sup>2</sup>	11.058	9.074	1.983	17.9%
Gas, therm/ft <sup>2</sup>	0.007	0.005	0.002	28.6%
Totals, kBtu/ft <sup>2</sup>	38.450	31.493	6.957	18.1%
<b>Large Office</b>				
Electricity, kWh/ft <sup>2</sup>	21.232	19.451	1.781	8.4%
Gas, therm/ft <sup>2</sup>	0.103	0.074	0.029	28.2%
Totals, kBtu/ft <sup>2</sup>	82.731	73.788	8.942	10.8%
<b>Stand-Alone Retail</b>				
Electricity, kWh/ft <sup>2</sup>	14.373	11.889	2.485	17.3%
Gas, therm/ft <sup>2</sup>	0.205	0.127	0.078	38.0%
Totals, kBtu/ft <sup>2</sup>	69.574	53.304	16.270	23.4%
<b>Primary School</b>				
Electricity, kWh/ft <sup>2</sup>	14.129	11.746	2.383	16.9%
Gas, therm/ft <sup>2</sup>	0.246	0.148	0.098	39.8%
Totals, kBtu/ft <sup>2</sup>	72.824	54.927	17.896	24.6%
<b>Small Hotel</b>				
Electricity, kWh/ft <sup>2</sup>	12.901	11.519	1.382	10.7%
Gas, therm/ft <sup>2</sup>	0.246	0.248	-0.002	-0.8%
Totals, kBtu/ft <sup>2</sup>	68.626	64.151	4.475	6.5%
<b>Mid-rise Apartment</b>				
Electricity, kWh/ft <sup>2</sup>	11.765	11.372	0.392	3.3%
Gas, therm/ft <sup>2</sup>	0.122	0.098	0.024	19.7%
Totals, kBtu/ft <sup>2</sup>	52.336	48.638	3.698	7.1%

**Table 14. Annual Energy Usage for Buildings in the State of Connecticut in Climate Zone 5A**

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-rise Apartment	
	Electric kWh/ ft <sup>2</sup> ·yr	Gas therms/ ft <sup>2</sup> ·yr	Electric kWh/ ft <sup>2</sup> ·yr	Gas therms/ ft <sup>2</sup> ·yr	Electric kWh/ ft <sup>2</sup> ·yr	Gas therms/ ft <sup>2</sup> ·yr	Electric kWh/ ft <sup>2</sup> ·yr	Gas therms/ ft <sup>2</sup> ·yr	Electric kWh/ ft <sup>2</sup> ·yr	Gas therms/ ft <sup>2</sup> ·yr	Electric kWh/ ft <sup>2</sup> ·yr	Gas therms/ ft <sup>2</sup> ·yr
<b>Base Code: 90.1-2007</b>												
Heating, Humidification	0.476	0.007	0.062	0.092	0.000	0.168	0.000	0.184	1.485	0.018	0.000	0.122
Cooling	0.952	0.000	3.300	0.000	1.810	0.000	1.998	0.000	1.802	0.000	0.900	0.000
Fans, Pumps, Heat Recovery	1.172	0.000	1.706	0.000	3.561	0.000	1.719	0.000	1.931	0.000	1.788	0.000
Lighting, Interior & Exterior	4.880	0.000	3.412	0.000	6.807	0.000	4.864	0.000	3.813	0.000	1.425	0.000
Plugs, Refrigeration, Other	2.666	0.000	12.753	0.000	2.196	0.000	5.442	0.046	3.870	0.092	4.262	0.000
Service Water Heating (SWH)	0.911	0.000	0.000	0.011	0.000	0.038	0.105	0.016	0.000	0.135	3.391	0.000
<b>Total</b>	<b>11.058</b>	<b>0.007</b>	<b>21.232</b>	<b>0.103</b>	<b>14.373</b>	<b>0.205</b>	<b>14.129</b>	<b>0.246</b>	<b>12.901</b>	<b>0.246</b>	<b>11.765</b>	<b>0.122</b>
<b>ASHRAE 90.1-2010</b>												
Heating, Humidification	0.473	0.005	1.017	0.063	0.000	0.091	0.000	0.086	1.430	0.021	0.000	0.098
Cooling	0.833	0.000	2.121	0.000	1.301	0.000	1.502	0.000	1.554	0.000	0.908	0.000
Fans, Pumps, Heat Recovery	1.074	0.000	1.491	0.000	2.736	0.000	1.668	0.000	1.821	0.000	1.675	0.000
Lighting, Interior & Exterior	3.311	0.000	2.496	0.000	5.661	0.000	3.152	0.000	2.916	0.000	1.188	0.000
Plugs, Refrigeration, Other	2.473	0.000	12.326	0.000	2.190	0.000	5.327	0.046	3.799	0.092	4.211	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.011	0.000	0.037	0.097	0.016	0.000	0.135	3.390	0.000
<b>Total</b>	<b>9.074</b>	<b>0.005</b>	<b>19.451</b>	<b>0.074</b>	<b>11.889</b>	<b>0.127</b>	<b>11.746</b>	<b>0.148</b>	<b>11.519</b>	<b>0.248</b>	<b>11.372</b>	<b>0.098</b>
<b>Total Savings</b>	<b>1.983</b>	<b>0.002</b>	<b>1.781</b>	<b>0.029</b>	<b>2.485</b>	<b>0.078</b>	<b>2.383</b>	<b>0.098</b>	<b>1.382</b>	<b>-0.002</b>	<b>0.392</b>	<b>0.024</b>

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