ESL-TR-11-10-02

COST-EFFECTIVE ENERGY EFFICIENCY MEASURES FOR ABOVE CODE (ASHRAE 90.1-2001 and 2007): SMALL RETAIL BUILDINGS IN THE CITY OF ARLINGTON

A Research Project for the City of Arlington

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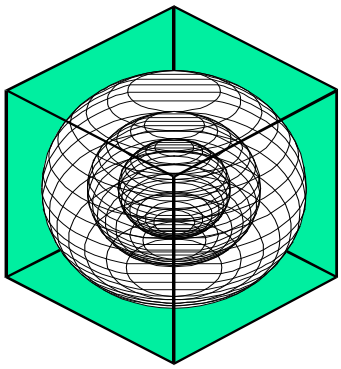

ENERGY SYSTEMS LABORATORY

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EXECUTIVE SUMMARY

The Energy Systems Laboratory was requested to develop cost-effective recommendations to maximize energy savings for residential and commercial buildings in the City of Arlington (CoA). This report presents the analysis results for small retail buildings in the CoA.

For more realistic recommendations, the CoA provided two years of commercial building energy compliance reports from 2008 to 2010 which exceeded the energy efficiency requirements of the CoA (i.e., ASHRAE 90.1-2001). From a statistical analysis of energy compliance reports provided for eleven commercial, above-code approaches that had been made in the CoA were summarized for commercial applications[1]. Based on a summary of above-code approaches, recommendations were developed to achieve above-code energy performance based on the ASHRAE 90.1-2001 and 2007 standard reference buildings, for small retail buildings in the CoA

The deliverables for the CoA in this report are:

- Recommendations of 16 energy efficiency measures (EEMs) to maximize energy savings for small retail buildings in the CoA with estimated cost of the improvement, simple payback calculations, and emissions savings.

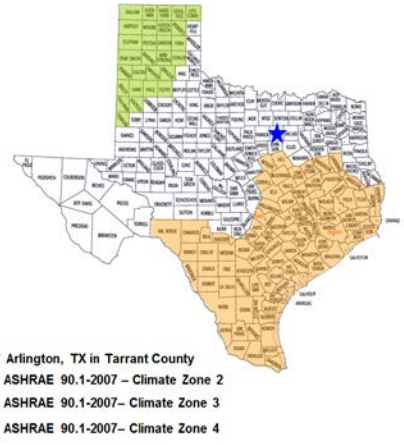
A total of 16 recommendations based on the energy savings above the base-case building were selected. These measures include building envelope and fenestration, HVAC system, service hot water (SHW) system, lighting, and renewable options. The implementation costs of each individual measure were also calculated along with simple payback calculations. Figures 1 and 2 present a description of the individual measures and combinations of these measures which achieve 15% source energy savings above the ASHRAE 90.1-2001 and 2007 code-compliant building. Annual energy savings, estimated costs, simple payback, and NOx, SO_2, and CO_2 emissions reduction are provided.

[1] The results of the review are presented in Kim et al. (2011).

[ASHRAE 90.1-2001 Code-Compliant Small Retail Building]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Annual Demand Savings (%)	Annual Demand Savings ($/year)[3]	Combined Savings (Energy+Demand) ($/year)	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source					Marginal Cost[4]	New System Cost[5]	
A	**Envelope and Fenestration Measures**									
1	Increased Roof and Wall Insulation R-Value (from 15 to 25 for roof and none to 11.4c.i. for walls)	13.8%	6.6%	$1,066	1.8%	$65	$1,131	$22,832 - $34,248		20.2 - 30.3
2	Decreased Glazing U-Value (from 1.22 to 0.35)	5.5%	2.0%	$245	0.1%	$4	$249	$23,511 - $35,266		94.3 - 141
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	-0.9%	0.5%	$184	2.5%	$87	$271		$33,384 - $50,076	123 - 185
4	High Albedo Roof (Roof Absorptance from 0.7 to 0.3)	-0.1%	0.8%	$213	1.9%	$67	$280	$6,600 - $9,900		23.6 - 35.3
B	**HVAC System Measures**									
5	CO_2 Based Demand-Controlled Ventilation (DCV)	6.2%	3.5%	$622	0.9%	$32	$654		$5,894 - $8,841	9.0 - 13.5
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	3.8%	4.7%	$1,064	8.2%	$293	$1,357	$9,830 - $14,746		7.2 - 10.9
7	Improved Furnace Efficiency (from 80% to 90% Et)	2.7%	1.2%	$172	0.0%	$0	$172	$6,320 - $9,480		36.7 - 55.0
8	Improved Fan Efficiency (from 55% to 65%)	1.5%	2.4%	$565	2.3%	$81	$646	$5,651 - $8,477		8.7 - 13.1
C	**Service Hot Water Measures**									
9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	0.9%	0.4%	$56	0.0%	$0	$56	$920 - $1,380		16.4 - 24.6
10	Tankless Gas Water Heater	0.8%	0.3%	$50	0.0%	$0	$50	$600 - $900		12.0 - 18.1
11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	2.3%	1.0%	$159	-0.2%	-$6	$154		$2,880 - $4,320	18.7 - 28.1
D	**Lighting Measures**									
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	7.8%	11.5%	$2,701	12.9%	$458	$3,159	$6,312 - $9,468		2.0 - 3.0
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.9 to 1.25 W/sq.ft.)	10.0%	14.9%	$3,502	16.7%	$595	$4,097	$8,214 - $12,321		2.0 - 3.0
14	Daylight Dimming Control	7.5%	10.8%	$2,523	13.7%	$486	$3,009		$15,723 - $23,584	5.2 - 7.8
15	Sky light (3% SRR,U-0.34 & 0.19 SHGC) with Dimming Control	16.2%	23.9%	$5,596	27.0%	$960	$6,556		$55,700 - $83,550	8.5 - 12.7
E	**Renewable Power Measure**									
16	28 kW Photovoltaic Array	15.3%	18.7%	$4,227	17.1%	$607	$4,834		$140,000 - $210,000	29.0 - 43.4



Description of Combined Measures

	Combination of Measures[6]	Combined Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Demand Savings (%)	Combined Demand Savings ($/year)[3]	Combined Savings (Energy+Demand) ($/year)	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source					Marginal Cost[4]	New System Cost[5]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons/yr)
	Combination 1												
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	11.4%	15.9%	$3,695	20.7%	$736	$4,430	$6,312 - $9,468		3.6 - 5.5	61.9	40.3	25.6
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)							$9,830 - $14,746					
	Combination 2												
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	8.9%	15.0%	$3,440	17.0%	$604	$4,045	$6,312 - $9,468		4.6 - 6.9	57.9	39.0	23.5
8	Improved Fan Efficiency (from 55% to 65%)							$5,651 - $8,477					
4	High Albedo Roof (Roof Absorptance from 0.7 to 0.3)							$6,600 - $9,900					
	Combination 3												
14	Daylight Dimming Control	13.9%	15.0%	$3,154	14.6%	$518	$3,672		$15,723 - $23,584	5.9 - 8.8	52.1	30.9	22.6
5	CO_2 Based Demand-Controlled Ventilation (DCV)								$5,894 - $8,841				
	Combination 4												
15	Sky light (3% SRR,U-0.34 & 0.19 SHGC) with Dimming Control	16.2%	23.9%	$5,596	27.0%	$960	$6,556		$55,700 - $83,550	8.5 - 12.7	93.9	62.0	38.6

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Savings depend on fuel mix used.
   * Energy Cost: Electricity = $0.095/kWh & Demand = $5.00/kW
     Natural gas = $0.65/therm
3. Yearly demand cost = Sum of monthly demand cost for 12 months
4. Marginal cost = new system cost - original system cost
5. New system cost = new system cost only
6. See individual measures above for specific savings

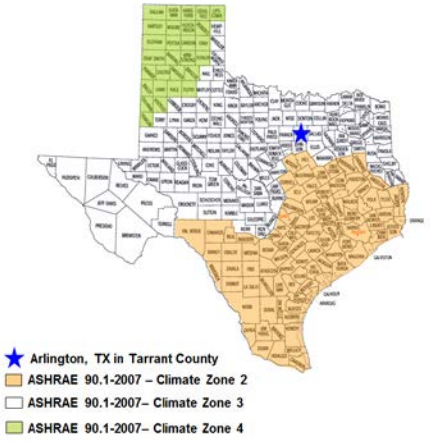
[ASHRAE 90.1-2001 Code-Compliant Retail Building Description]
* Building type: Small Retail (Strip Mall Type)
* Gross area: 15,000 sq-ft
* Building dimension: 61 ft x 245 ft x 17 ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 17 ft
* Window-to-wall ratio: 70% for Front Wall Only (28% for an Entire Building)
* HVAC system: SEER 13 or EER 11 Rooftop PSZ & 80% Et Furnace
* DHW: 0.59 EF Gas Water heater

Figure 1. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2001 Code-Compliant Small Retail Building for the CoA

[ASHRAE 90.1-2007 Code-Compliant Small Retail Building]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Annual Demand Savings (%)	Annual Demand Savings ($/year)[3]	Combined Savings (Energy+Demand) ($/year)	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source					Marginal Cost[4]	New System Cost[5]	
A	**Envelope and Fenestration Measures**									
1	Increased Roof and Wall Insulation R-Value (from 20 to 25 for roof and 7.6c.i. to 11.4c.i. for walls)	1.2%	0.5%	$75	0.1%	$3	$78	$8,517 - $12,776		110 - 164
2	Decreased Glazing U-Value (from 0.6 for window & 0.9 for door to 0.35)	3.1%	1.0%	$97	0.1%	$3	$100	$9,866 - $14,799		98.2 - 147
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	-1.0%	0.7%	$197	2.9%	$92	$289		$33,384 - $50,076	115 - 173
B	**HVAC System Measures**									
5	CO_2 Based Demand-Controlled Ventilation (DCV)	6.3%	3.5%	$541	3.5%	$110	$651		$5,894 - $8,841	9.1 - 13.6
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	4.4%	5.1%	$988	8.7%	$275	$1,263	$9,830 - $14,746		7.8 - 11.7
7	Improved Furnace Efficiency (from 80% to 90% Et)	2.1%	0.9%	$109	0.0%	$0	$109	$6,320 - $9,480		58.2 - 87.3
8	Improved Fan Efficiency (from 55% to 65%)	1.8%	2.8%	$558	2.5%	$78	$635	$5,651 - $8,477		8.9 - 13.3
C	**Service Hot Water Measures**									
9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	1.1%	0.4%	$56	0.0%	$0	$56	$920 - $1,380		16.4 - 24.6
10	Tankless Gas Water Heater	1.0%	0.4%	$50	0.0%	$0	$50	$600 - $900		12.0 - 18.1
11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	2.9%	1.2%	$156	-0.2%	-$6	$151		$2,880 - $4,320	19.1 - 28.6
D	**Lighting Measures**									
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	2.0%	2.8%	$550	3.0%	$93	$643	$1,247 - $1,871		1.9 - 2.9
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	4.8%	6.9%	$1,375	7.4%	$234	$1,609	$3,149 - $4,723		2.0 - 2.9
14	Daylight Dimming Control	7.4%	10.1%	$2,011	12.8%	$402	$2,413		$15,723 - $23,584	6.5 - 9.8
15	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	15.3%	21.9%	$4,369	25.1%	$789	$5,158		$55,700 - $83,550	10.8 - 16.2
E	**Renewable Power Measure**									
16	28 kW Photovoltaic Array	18.7%	21.9%	$4,224	20.9%	$657	$4,881		$140,000 - $210,000	28.7 - 43.0



Description of Combined Measures

	Combination of Measures[6]	Combined Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Demand Savings (%)	Combined Demand Savings ($/year)[3]	Combined Savings (Energy+Demand) ($/year)	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source					Marginal Cost[4]	New System Cost[5]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons/yr)
	Combination 1												
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	11.0%	15.4%	$3,062	18.4%	$580.00	$3,642	$3,149 - $4,723		5.2 - 7.8	51.4	33.8	21.1
14	Daylight Dimming Control								$15,723 - $23,584				
	Combination 2												
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	15.4%	15.1%	$2,814	18.5%	$584.00	$3,398	$3,149 - $4,723		5.6 - 8.3	46.5	27.4	20.2
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)							$9,830 - $14,746					
5	CO_2 Based Demand-Controlled Ventilation (DCV)								$5,894 - $8,841				
	Combination 3												
14	Daylight Dimming Control	15.9%	16.6%	$3,124	18.6%	$586.50	$3,711		$15,723 - $23,584	7.3 - 11.0	51.8	31.2	22.3
5	CO_2 Based Demand-Controlled Ventilation (DCV)								$5,894 - $8,841				
8	Improved Fan Efficiency (from 55% to 65%)							$5,651 - $8,477					
	Combination 4												
15	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	15.3%	21.9%	$4,369	25.1%	$789	$5,158		$55,700 - $83,550	10.8 - 16.2	73.4	48.4	30.1

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Savings depend on fuel mix used.
   * Energy Cost: Electricity = $0.095/kWh & Demand = $5.00/kW
     Natural gas = $0.65/therm
3. Yearly demand cost = Sum of monthly demand cost for 12 months
4. Marginal cost = new system cost - original system cost
5. New system cost = new system cost only
6. See individual measures above for specific savings

[ASHRAE 90.1-2007 Code-Compliant Retail Building Description]
* Building type: Small Retail (Strip Mall Type)
* Gross area: 15,000 sq-ft
* Building dimension: 61 ft x 245 ft x 17 ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 17 ft
* Window-to-wall ratio: 70% for Front Wall Only (28% for an Entire Building)
* HVAC system: SEER 13 or EER 11 Rooftop PSZ & 80% Et Furnace
* DHW: 0.59 EF Gas Water heater

Figure 2. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building for the CoA

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The Energy Systems Laboratory was requested to develop cost-effective recommendations to maximize energy savings for residential and commercial buildings in the City of Arlington (CoA). This report presents the analysis results for small retail buildings in the CoA.

For more realistic recommendations, the CoA provided two years of commercial building energy compliance reports from 2008 to 2010 which exceeded the energy efficiency requirements of the CoA (i.e., ASHRAE 90.1-2001). From a statistical analysis of energy compliance reports provided for eleven commercial, above-code approaches that had been made in the CoA were summarized for commercial applications[2]. Based on a summary of above-code approaches, recommendations were developed to achieve above-code energy performance based on the ASHRAE 90.1-2001 and 2007 standard reference buildings, for small retail buildings in the CoA

The deliverables for the CoA in this report are:

- Recommendations of 16 energy efficiency measures (EEMs) to maximize energy savings for small retail buildings in the CoA with estimated cost of the improvement, simple payback calculations, and emissions savings.

1.1 Organization of the Report

The report is organized in the following order:

- Section 1 presents the introduction and purpose of the report.
- Section 2 presents the methodology that was used.
- Section 3 presents the proposed energy efficiency measures for small retail buildings in the CoA, including savings from 16 individual measures along with the simple payback calculations.
- Section 4 is a summary which is followed by references.

[2] The results of the review are presented in Kim et al. (2011).

2 METHODOLOGY

This section describes the methodology and assumptions that were used in this analysis: to develop the cost-effective recommendations for achieving energy performance better than ASHRAE 90.1-2001 and 2007 code-compliant buildings for small retails in the CoA. Section 2.1 presents the overall approach used in this analysis. Section 2.2 describes the base-case building characteristics. Section 2.3 presents assumptions used in cost analysis.

2.1 Overview

Based on the summary of commercial above-code approaches (Kim et al. 2011), recommendations were developed to achieve above-code energy performance based on the ASHRAE 90.1-2001 and 2007 standard reference building, for small retails in the CoA. The analysis was performed using the eQuest 3.64 simulation software (JJH. 2009) based on the DOE-2.2 simulation of ASHRAE 90.1-2001 and 2007 code-compliant, small retail buildings for Tarrant County where the CoA is located and the Fort Worth TMY2 weather file (Figure 5). A total of 16 energy efficiency measures were then applied to the base-case models to determine the savings of each measure. These measures were simulated by modifying the selected parameters used for the DOE-2 simulation tool. The solar measures including solar PV and solar SHW were simulated using the PV-F Chart (Klein and Beckman 1994) and F-Chart (Klein and Beckman 1983) programs, respectively. The implementation costs of each measure were also calculated along with simple payback calculations.

The measures were then combined to achieve the total source energy savings of the group which is 15% above the base-case ASHRAE 90.1-2001 and 2007 code-compliant buildings. The results from individual measures and cost analysis were used to guide the selection of measures. As a result, four combinations were proposed for each base case. Each combination was formed to have a different payback period. Finally, the corresponding emissions savings of each combination were calculated based on the eGrid for Texas.

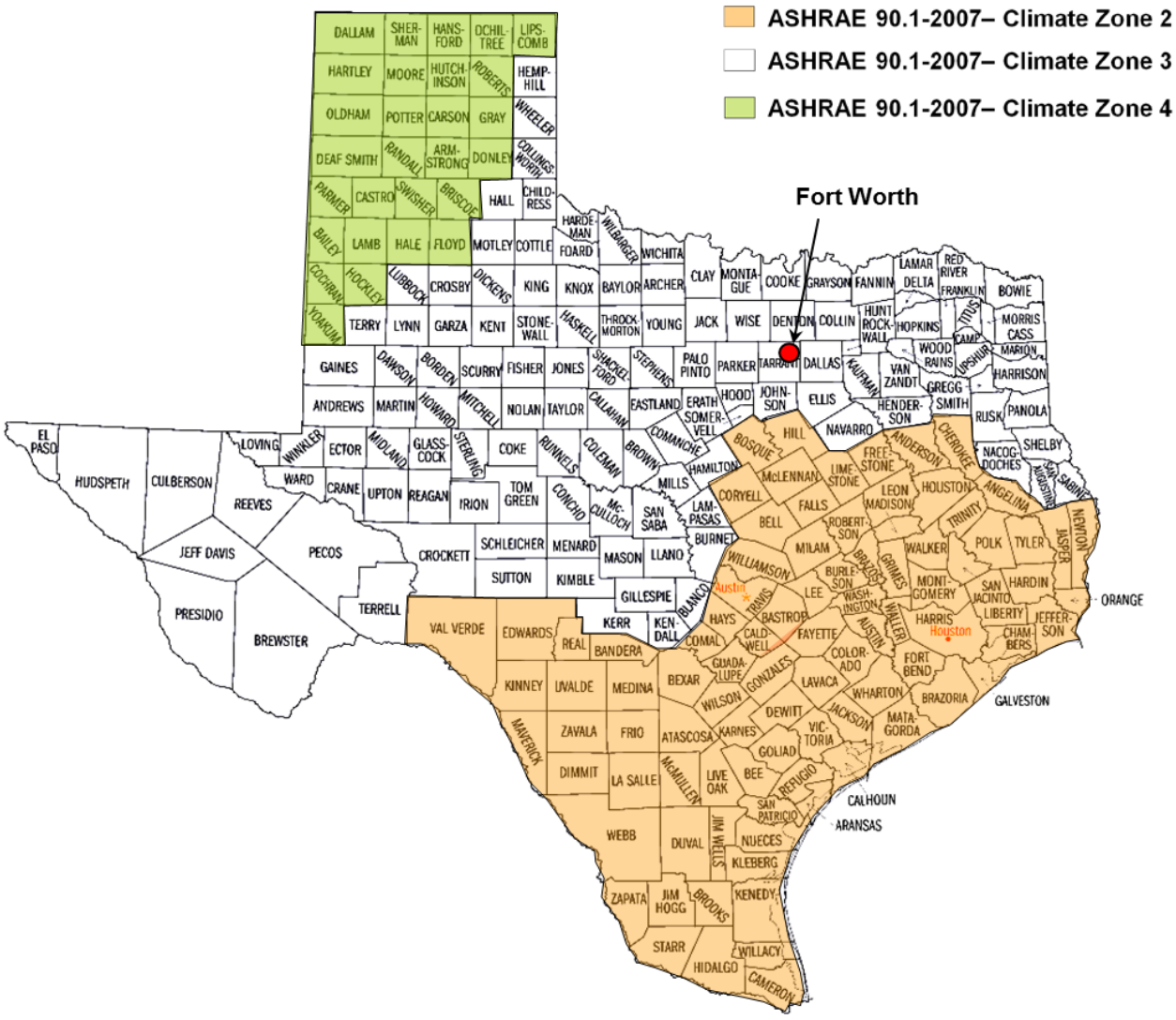


Figure 3. Tarrant County and Fort Worth TMY2 Weather File Used in the Analysis

2.2 **Base-Case Building Description**

The base-case building simulation model in this analysis is based on the *standard* design as defined in the ASHRAE 90.1-2001[3] and 2007[4] and certain assumptions, which are described throughout this document. The base-case building is a 15,000 sq. ft., one story, structural mass concrete strip mall oriented south with a 70% window-to-wall ratio for front wall only[5]. The overall dimensions of the building were set at 245 ft wide by 61 ft deep with a floor-to-ceiling height of 17 feet, consisting of eight stores (Figure 4). Each store was zoned as a single zone. The other envelope and system characteristics were determined from the general characteristics and the climate-specific characteristics as specified in the ASHRAE 90.1-2001 and 2007. Table 1 summarizes the base-case, ASHRAE 90.1-2001 and 2007 code-compliance building characteristics used in the DOE-2 simulation tool in this analysis.

2.3 **Assumptions for Cost Analysis**

The cost analysis for different measures was carried out based on utility costs of $0.095/kWh for electricity, $5.00/kW for demand charge, and $0.65/therm for natural gas. The electricity rate was determined based on the annual average prices of Texas commercial electricity for 2010 published by the U.S. DOE EIA (2011), and demand charges were from the previous study by Cho et al. (2007). For natural gas rates, the annual average rates calculated for Arlington were used (Atmos Energy 2011).

[3] per 2003 IECC Section 801.2
[4] per 2009 IECC Section 501.2
[5] 28% window-to-wall ratio for an entire building

Table 1. Base-Case Building Description

Characteristics	Information Source	Assumptions		Comments
		ASHRAE 90.1-2001	ASHRAE 90.1-2007	
Building				
Building Type		Small retail-Stripmall		Number of occupants = 120
Gross Area (sq. ft.)	CoA	15,000		
Aspect Ratio	PNNL-20405 (Thornton et al. 2011)	4:1		245 ft (L) X 61 ft (W)
Number of Floors	PNNL-20405 (Thornton et al. 2011)	1		
Floor-to-Floor Height (ft.)	PNNL-20405 (Thornton et al. 2011)	17		Floor-to-Ceiling Height = 17 ft
Orientation	PNNL-20405 (Thornton et al. 2011)	South facing		
Construction				
Wall Construction	CoA	Mass (8-in concrete, 140 lb/ft^3)		
Roof Configuration	PNNL-20405 (Thornton et al. 2011)	Flat built-up, Insulation entirely above deck		
Foundation Construction	PNNL-20405 (Thornton et al. 2011)	6" concrete slab-on-grade floor		
Wall Absorptance	DOE 2.1E BDL SUMMARY, Page 12	0.75		Assuming gray, light oil paint
Wall Insulation (hr-sq.ft.-°F/Btu)	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	None	R-7.6 ci	Assembly maximum u-value for ASHRAE 90.1-2001 = 0.580
Roof Absorptance	ASHRAE 90.1-1999 11.4.2b and ASHRAE 90.1-2007 Sec. 5.5.3.1.1	0.7	0.3	Roof reflectance = 0.3 for 2001 and 0.7 for 2007
Roof Insulation (hr-sq.ft.-°F/Btu)	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	R-15 ci	R-20 ci	
Slab Perimeter Insulation	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	None		Slab-on-grade floor, unheated
Ground Reflectance	DOE 2.1E BDL SUMMARY, Page 20	0.24		Assuming grass
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	1.22	0.6 (Window) 0.9 (Door)	Fixed fenestration
Solar Heat Gain Coefficient (SHGC)	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	0.25		
Window Area	PNNL-16031 (Liu et al. 2006)	70% Window to wall ratio for front wall only		28% WWR for an entire building
Exterior Shading	ASHRAE 90.1-2001 Sec. 11.4.2c and ASHRAE 90.1-2007 Table 11.3.1 No.5	None		
Infiltration	PNNL-20405 (Thornton et al. 2011)	Peak: 0.2016 cfm/sq.ft. of above grade exterior wall surface area (when fans are off)		
Space Conditions				
Space Heating Set point	PNNL-16031 (Liu et al. 2006)	70 F(Occupied), 5 F setback		
Space Cooling Set point		75 F(Occupied), 5 F setup		
Lighting Power Density (W/ft^2)	ASHRAE 90.1-2001 Table 9.3.1.1 and ASHRAE 90.1-2007 Table 9.5.1	1.9	1.5	
Equipment Power Density (W/ft^2)	PNNL-20405 (Thornton et al. 2011)	0.4		
Mechanical Systems				
HVAC System Type	ASHRAE 90.1-2001 11.4.3 and ASHRAE 90.1-2007 11.3.2	Packaged rooftop air conditioner (CAV, DX, gas furnace)		
Air Conditioning System Efficiency	FEDERAL MINIMUM EFFICIENCY STANDARDS	13 SEER (<65,000 Btu/h) 11 EER (≥655,000 Btu/h and <135,000 Btu/h)		
Heating System Efficiency (%)	ASHRAE 90.1-2001 Table 6.2.1E and ASHRAE 90.1-2007 Table 6.8.1E	80% Et		Gas-fired furnace Capacity < 225,000 Btu/hr
Cooling Capacity (Btu/hr)	ASHRAE 90.1-2007 Appendix G and ASHRAE HOF-2009	Autosized based on design day (1% db and wb cooling design temperature), 15% Oversized		PNNL-20405 (Thornton et al. 2011): Internal loads schedule = 1.0 (fraction)
Heating Capacity (Btu/hr)	ASHRAE 90.1-2007 Appendix G and ASHRAE HOF-2009	Autosized based on design day (99.6% heating design temperature), 25% oversized		PNNL-20405 (Thornton et al. 2011): Internal loads schedule = 0.0 (fraction)
Economizer	ASHRAE 90.1-2001 Table 6.3.1 and ASHRAE 90.1-2007 Table 6.5.1	No		
Ventilation (cfm/sq.ft.)	ASHRAE 62.1-1999 and ASHRAE 62.1-2004	0.12 (Total: 1800 cfm)	0.18 (Total: 2700 cfm)	ASHRAE 62.1-1999: 15cfm/person; and ASHRAE 62.1-2004: 7.5 cfm/person & 0.12 cfm/sq.ft.
Supply Air Flow (cfm/sq.ft.)		1		
SHW System Type	PNNL-16031 (Liu et al. 2006)	Gas-fired storage water heater (40 gallon, 40,000 Btu/hr)		
SHW Heater Efficiency (%)	FEDERAL ENERGY CONSERVATION STANDARDS	0.59 EF		
SHW Temperature Setpoint (F)	PNNL-20405 (Thornton et al. 2011)	120 F		

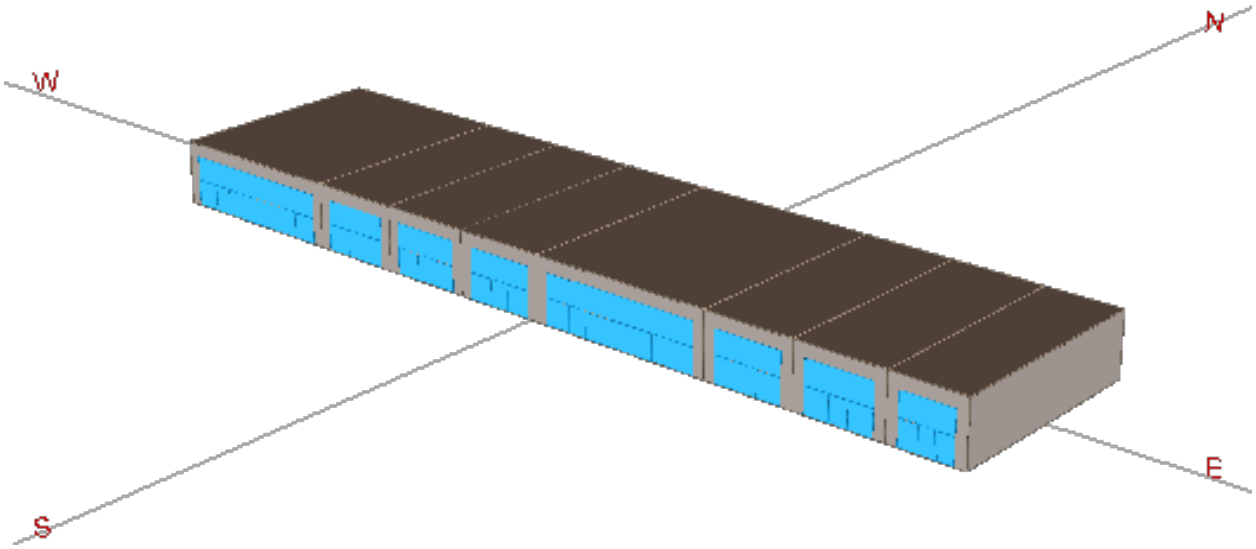


Figure 4. eQuest Model of the Small Retail Prototype (Strip mall Type)

3 PROPOSED ENERGY EFFICIENCY MEASURES FOR SMALL RETAIL BUILDINGS

This section documents 16 energy efficiency measures (EEMs) for small retail buildings to achieve above-code energy performance based on the ASHRAE 90.1-2001 and 2007 code-compliant small retail building in Tarrant County, Texas, where the CoA is located. Section 3.1 gives a brief description of 16 individual EEMs and provides input parameters used in the simulation of each EEM. Section 3.2 presents the results of simulation and cost analysis.

3.1 **Individual EEMs**

Table 2 lists energy efficiency measures considered in this analysis. These include measures for the building envelope and fenestration, HVAC system, service hot water (SHW) system, lighting, and renewable options. These measures were simulated by modifying the selected parameters used for the DOE-2 simulation tool. Tables 3 and 4 show the details on the simulation input parameters.

Table 2. Energy Efficiency Measures

	EEM No.	EEM Description
Envelope and Fenestration Measures	1	Increased Roof and Wall Insulation R-Value (ASHRAE 90.1-2001: from 15 to 25 for roof and 0 c.i. to 11.4 c.i. for walls; and ASHRAE 90.1-2007: from 20 to 25 for roof and 7.6 c.i. to 11.4 c.i. for walls)
	2	Decreased Glazing U-Value (ASHRAE 90.1-2001: from 1.22 to 0.35; and ASHRAE 90.1-2007: from 0.6 for window & 0.9 for door to 0.35)
	3	0.5 PF Window Shading (None to 6.75 ft. Overhang)
	4	High Albedo Roof for ASHRAE 90.1-2001 (Roof Absorptance from 0.7 to 0.3)
HVAC System Measures	5	CO_2-Based Demand-Controlled Ventilation (DCV)
	6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)
	7	Improved Furnace Efficiency (from 80% to 90% Et)
	8	Improved Fan Efficiency (from 55% to 65%)
Service Hot Water Measures	9	Improved SHW Heater Efficiency (from 0.59 EF to 0.86 EF)
	10	Tankless Gas Water Heater
	11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)
Lighting Measures	12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (ASHRAE 90.1-2001: from 1.9 to 1.4 W/sq.ft.; and ASHRAE 90.1-2007: from 1.5 to 1.4 W/sq.ft.)
	13	Decreased Lighting Power Density based on AEDG-SR-2006 (ASHRAE 90.1-2001: from 1.9 to 1.25 W/sq.ft.; and ASHRAE 90.1-2007: from 1.5 to 1.25 W/sq.ft.)
	14	Daylight Dimming Control
	15	Sky light (3% Skylight-roof-ratio, U-0.34 & 0.19 SHGC) with Dimming Control
Renewable Power Measure	16	28 kW Photovoltaic Array

Table 3. Simulation Input Parameters of Individual EEMs for ASHRAE 90.1-2001 Code-Compliant Small Retail Building in CoA

	EEM #	Energy Efficiency Measure	Roof Insulation R-Value	Wall C.I. R-Value	Window Glazing U-Value	Glass Door U-Value	Shading (ft)				Roof Absorptance	OA Demand Control	EER for Small Units	EER for Large Units	Furnace Eff.(%)	Fan Mechanical Eff. (%)	SHW EF	Lighting Power Density (W/ft^2)	Dimming Control	Sky Light (% of Roof Area)
							Front	Right	Back	Left										
		90.1-2001 Base case (CoA)	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	0.594	1.9	N	0
Envelope and Fenestration Measures	1	Increased Roof and Wall Insulation R-Value (from 15 to 25 for roof and none to 11.4c.i. for walls)	**25**	**11.4**	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	0.594	1.9	N	0
	2	Decreased Glazing U-Value (from 1.22 to 0.35)	15	0	**0.35**	**0.35**	0	0	0	0	0.7	N	13	11	80	55	0.594	1.9	N	0
	3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	15	0	1.22	1.22	**6.75**	0	0	0	0.7	N	13	11	80	55	0.594	1.9	N	0
	4	High Albedo Roof (Roof Absorptance from 0.7 to 0.3)	15	0	1.22	1.22	0	0	0	0	**0.3**	N	13	11	80	55	0.594	1.9	N	0
HVAC Measures	5	CO_2-Based Demand-Controlled Ventilation (DCV)	15	0	1.22	1.22	0	0	0	0	0.7	**Y**	13	11	80	55	0.594	1.9	N	0
	6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	15	0	1.22	1.22	0	0	0	0	0.7	N	**18**	**13.5**	80	55	0.594	1.9	N	0
	7	Improved Furnace Efficiency (from 80% to 90% Et)	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	**90**	55	0.594	1.9	N	0
	8	Improved Fan Efficiency (from 55% to 65%)	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	**65**	0.594	1.9	N	0
SHW Measures	9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	**0.86**	1.9	N	0
	10	Tankless Gas Water Heater	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	**0.82**	1.9	N	0
	11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	0.594	1.9	N	0
Lighting Measures	12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	0.594	**1.4**	N	0
	13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.9 to 1.25 W/sq.ft.)	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	0.594	**1.25**	N	0
	14	Daylight Dimming Control	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	0.594	1.9	**Y**	0
	15	Sky light (3% SRR,U-0.34 & 0.19 SHGC) with Dimming Control	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	0.594	1.9	**Y**	**3%**
Renewable Measure	16	28 kW Photovoltaic Array	15	0	1.22	1.22	0	0	0	0	0.7	N	13	11	80	55	0.594	1.9	N	0

Table 4. Simulation Input Parameters of Individual EEMs for ASHRAE 90.1-2007 Code-Compliant Small Retail Building in CoA

	EEM #	Energy Efficiency Measure	Roof Insulation R-Value	Wall C.I. R-Value	Window Glazing U-Value	Glass Door U-Value	Shading (ft)				Roof Absorptance	OA Demand Control	EER for Small Units	EER for Large Units	Furnace Eff.(%)	Fan Mechanical Eff. (%)	SHW EF	Lighting Power Density (W/ft^2)	Dimming Control	Sky Light (% of Roof Area)
							Front	Right	Back	Left										
		90.1-2007 Base case (CoA)	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	0.594	1.5	N	0
Envelope and Fenestration Measures	1	Increased Roof and Wall Insulation R-Value (from 20 to 25 for roof and 7.6c.i. to 11.4c.i. for walls)	**25**	**11.4**	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	0.594	1.5	N	0
	2	Decreased Glazing U-Value (from 0.6 for window & 0.9 for door to 0.35)	20	7.6	**0.35**	**0.35**	0	0	0	0	0.3	N	13	11	80	55	0.594	1.5	N	0
	3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	20	7.6	0.6	0.9	**6.75**	0	0	0	0.3	N	13	11	80	55	0.594	1.5	N	0
HVAC Measures	5	CO_2-Based Demand-Controlled Ventilation (DCV)	20	7.6	0.6	0.9	0	0	0	0	0.3	**Y**	13	11	80	55	0.594	1.5	N	0
	6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	20	7.6	0.6	0.9	0	0	0	0	0.3	N	**18**	**13.5**	80	55	0.594	1.5	N	0
	7	Improved Furnace Efficiency (from 80% to 90% Et)	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	**90**	55	0.594	1.5	N	0
	8	Improved Fan Efficiency (from 55% to 65%)	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	**65**	0.594	1.5	N	0
SHW Measures	9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	**0.86**	1.5	N	0
	10	Tankless Gas Water Heater	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	**0.82**	1.5	N	0
	11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	0.594	1.5	N	0
Lighting Measures	12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	0.594	**1.4**	N	0
	13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	0.594	**1.25**	N	0
	14	Daylight Dimming Control	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	0.594	1.5	**Y**	0
	15	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	0.594	1.5	**Y**	**3%**
Renewable Measure	16	28 kW Photovoltaic Array	20	7.6	0.6	0.9	0	0	0	0	0.3	N	13	11	80	55	0.594	1.5	N	0

3.2 **Results of Simulation and Cost Analysis**

3.2.1 Base-Case Energy Use

The annual total energy consumption of the ASHRAE 90.1-2001 base case:

a) Site energy use by end-uses: 993.1 MMBtu/yr, including
   - 18.1% for cooling;
   - 24.8% for heating;
   - 41.6% for lighting and equipment;
   - 12.5% for fans and pumps; and
   - 2.9% for service water heating.

b) Source energy use by fuel type: 2,270 MMBtu/yr, including
   - 88.2% for electricity; and
   - 11.8% for natural gas.

The annual total energy consumption of the ASHRAE 90.1-2007 base case:

a) Site energy use by end-uses: 812.9 MMBtu/yr, including
   - 20.6% for cooling;
   - 19.0% for heating;
   - 42.0% for lighting and equipment;
   - 14.8% for fans and pumps; and
   - 3.5% for service water heating.

b) Source energy use by fuel type: 1,989 MMBtu/yr, including
   - 90.8% for electricity; and
   - 9.2% for natural gas.

These results suggest that the measures that reduce the lighting and equipment energy use would have the highest impact on the total energy use for small retail buildings in the CoA. Since the above-code performance is determined based on source energy consumption, the measures reducing electricity consumption will yield higher savings percentage than the measures decreasing natural gas consumption.

3.2.2 Energy Savings from Various Individual EEMs

Tables 5 and 6 summarize the savings achieved from proposed EEMs and cost analysis for the ASHRAE 90.1-2001 and 2007 code-compliant small retail buildings, including:

- Annual site energy consumption for different end-uses and total;
- Annual source energy consumption for different fuel types;
- Above-code savings (%) for site and source and $ savings;
- Increased cost of implementation (obtained from various resources listed in Appendix A); and
- Simple payback period for each measure.

The annual site energy use was obtained from the BEPS report of the DOE-2 output and then converted to source energy[6]. Figures 5-10 provide a graphical representation of the site/source energy consumption of the individual EEMs for the ASHRAE 90.1-2001 and 2007 code-compliant base-case small retail building.

[6] The source energy multipliers used in this analysis were 3.16 for electricity and 1.1 for natural gas based on Section 405.3 of the 2009 IECC.

The savings results are:

a) Increased Roof and Wall Insulation R-Value:
- ASHRAE 90.1-2001: 13.8% (site energy savings) and 6.6% (source energy savings) and
- ASHRAE 90.1-2007: 1.2% (site energy savings) and 0.5% (source energy savings).

b) Decreased Glazing U-Value:
- ASHRAE 90.1-2001: 5.5% (site energy savings) and 2.0% (source energy savings) and
- ASHRAE 90.1-2007: 3.1% (site energy savings) and 1.0% (source energy savings).

c) 0.5 PF Window Shading:
- ASHRAE 90.1-2001: -0.9% (site energy savings) and 0.5% (source energy savings) and
- ASHRAE 90.1-2007: -1.0% (site energy savings) and 0.7% (source energy savings).

d) High Albedo Roof:
- ASHRAE 90.1-2001: -0.1% (site energy savings) and 0.8% (source energy savings).

e) CO_2-Based Demand-Controlled Ventilation:
- ASHRAE 90.1-2001: 6.2% (site energy savings) and 3.5% (source energy savings) and
- ASHRAE 90.1-2007: 6.3% (site energy savings) and 3.5% (source energy savings).

f) Improved Air Conditioner Efficiency:
- ASHRAE 90.1-2001: 3.8% (site energy savings) and 4.7% (source energy savings) and
- ASHRAE 90.1-2007: 4.4% (site energy savings) and 5.1% (source energy savings).

g) Improved Furnace Efficiency:
- ASHRAE 90.1-2001: 2.7% (site energy savings) and 1.2% (source energy savings) and
- ASHRAE 90.1-2007: 2.1% (site energy savings) and 0.9% (source energy savings).

h) Improved Fan Efficiency:
- ASHRAE 90.1-2001: 1.5% (site energy savings) and 2.4% (source energy savings) and
- ASHRAE 90.1-2007: 1.8% (site energy savings) and 2.8% (source energy savings).

i) Improved SHW Heater Efficiency:
- ASHRAE 90.1-2001: 0.9% (site energy savings) and 0.4% (source energy savings) and
- ASHRAE 90.1-2007: 1.1% (site energy savings) and 0.4% (source energy savings).

j) Tankless Gas Water Heater:
- ASHRAE 90.1-2001: 0.8% (site energy savings) and 0.3% (source energy savings) and
- ASHRAE 90.1-2007: 1.0% (site energy savings) and 0.4% (source energy savings).

k) Solar SHW System (64 sq. ft. collector, 80 gal tank):
- ASHRAE 90.1-2001: 2.3% (site energy savings) and 1.0% (source energy savings) and
- ASHRAE 90.1-2007: 2.9% (site energy savings) and 1.2% (source energy savings).

l) Decreased Lighting Power Density to 1.4 W/sq.ft.:
- ASHRAE 90.1-2001: 7.8% (site energy savings) and 11.5% (source energy savings) and
- ASHRAE 90.1-2007: 2.0% (site energy savings) and 2.8% (source energy savings).

m) Decreased Lighting Power Density to 1.25 W/sq.ft.:
- ASHRAE 90.1-2001: 10.0% (site energy savings) and 14.9% (source energy savings) and
- ASHRAE 90.1-2007: 4.8% (site energy savings) and 6.9% (source energy savings).

n) Daylight Dimming Control:
- ASHRAE 90.1-2001: 7.5% (site energy savings) and 10.8% (source energy savings) and
- ASHRAE 90.1-2007: 7.4% (site energy savings) and 10.1% (source energy savings).

o) Skylight (3% SRR, U-0.34 and 0.19 SHGC) with Dimming Control:
- ASHRAE 90.1-2001: 16.2% (site energy savings) and 23.9% (source energy savings) and
- ASHRAE 90.1-2007: 15.3% (site energy savings) and 21.9% (source energy savings).

p) 28 kW Photovoltaic Array:
- ASHRAE 90.1-2001: 15.3% (site energy savings) and 18.7% (source energy savings) and
- ASHRAE 90.1-2007: 18.7% (site energy savings) and 21.9% (source energy savings).

Of the 16 measures for both ASHRAE 90.1-2001 and 2007 code-compliant buildings, solar PV and skylight measures present the most savings: 18.7% to 23.9% source energy savings. A daylight dimming control measure also shows a high source energy savings for both base cases (10.8% and 10.1%), while a decreased lighting power density measure yields much higher savings for an ASHRAE 90.1-2001 base case compared to an ASHRAE 90.1-2007 base-case building. Among the envelope and fenestration measures, increased roof and wall insulation and decreased glazing u-value measures result in a high site energy savings for an ASHRAE 90.1-2001 base case: 13.8% (EEM1) and 5.5% (EEM 2), but the source energy savings becomes lower due to a high savings in natural gas. Among the HVAC system measures, an improved air conditioner efficiency measure results in a high source energy savings: 4.7% and 5.1%. Two other measures, such as CO_2-based demand-controlled ventilation and improved fan efficiency, yield 2.4% to 3.5% source energy saving. In service hot water measures, all three measures result in low savings: 0.3% to 1.2% source energy savings.

3.2.3 Cost Effectiveness of Various Individual EEMs

It should be noted that, due to the difference in the unit cost of electricity and gas, the energy cost savings for a measure will not always coincide with the energy savings. These savings depend on the fuel type associated with the end use affected from that measure. Because of this, measures that reduce electricity use for space cooling or lighting and equipment resulted in significant energy cost savings compared to the measures that reduce only gas use.

The solar PV and lighting measures that show a significant reduction in electricity use are very effective in reducing the overall energy cost. The measures that reduce electricity use for cooling and fans and pumps also result in high energy cost savings. These measures include improved air conditioner efficiency and improved fan efficiency. A CO_2 based demand-controlled ventilation measure also yields a relatively high cost savings. An increased roof and wall insulation measure is effective only for an ASHRAE 90.1-2001 base case.

To estimate the cost-effectiveness of measures, the implementation costs of each measure (obtained from various resources listed in Appendix B), were surveyed along with simple payback calculations. The cost-effectiveness of a measure depends upon the energy cost savings versus the cost of implementation. Decreased lighting power density measures (EEM 12 and 13) are the most cost-effective with the shortest

payback periods of 1.9 to 3.0 years for both base cases. Another lighting measure, daylight dimming control (EEM 14) yields a short payback also: 5.2 to 7.8 years (ASHRAE 90.1-2001 base case) and 6.5 to 9.8 years (ASHRAE 90.1-2007 base case). Improved fan efficiency (EEM 8) and improved A/C efficiency (EEM 6) measures also yield relatively short payback periods: 8.7 to 13.1 years (ASHRAE 90.1-2001 base case) and 8.9 to 13.3 years (ASHRAE 90.1-2007 base case) for EEM 8; and 7.2 to 10.9 years (ASHRAE 90.1-2001 base case) and 7.8 to 11.7 years (ASHRAE 90.1-2007 base case) for EEM 6.

3.2.4 Combined EEMs

Grouped measures are the combination of individual measures. The results from individual measures and cost analysis were used to guide the selection of measures for this group analysis. The measures were combined to achieve the total source energy savings[7] of the group that is 15% above the base-case simulation of each ASHRAE 90.1-2001 and 2007 code-compliant small retail building. Because the measures are interdependent in many cases, the resultant savings of grouped measures are not always the same as the sum of the savings of the individual measures. In a similar fashion as the analysis of the individual measures, the group measures were simulated by modifying all the parameters of combined individual measures.

As shown in Figures 32 and 33, four group measures were proposed for each base case. In each figure, the first table summarizes the results obtained from individual measures in terms of annual site energy savings, annual source energy savings, annual demand savings, energy cost savings, estimated costs for each measure implemented individually, and payback period. The second table summarizes the results obtained by implementing combined measures to achieve 15% or more total source energy savings, and includes: energy savings, energy cost savings, estimated costs, payback period for each combination, and annual NOx, SO_2, and CO_2 emission savings.

The example groups represent one way of grouping to achieve 15% savings above the base case. In this analysis, each combination was intended to have a different payback period. The most cost-effective combination (combination 1) has a payback period of:

a) ASHRAE 90.1-2001: 3.6 to 5.5 years and
b) ASHRAE 90.1-2007: 5.2 to 7.8 years.

A payback period of the least cost-effective combination (combination 3) is:

a) ASHRAE 90.1-2001: 8.5 to 12.7 years and
b) ASHRAE 90.1-2007: 10.8 to 16.2 years.

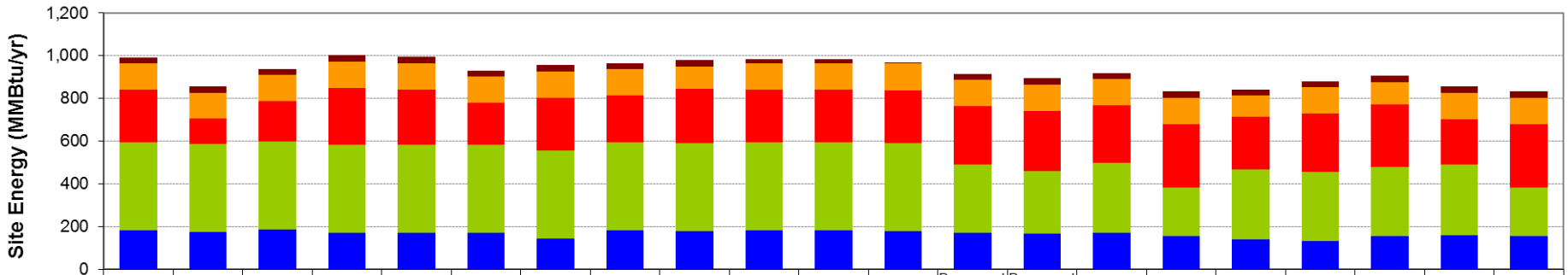
[7] The estimated total source energy savings include heating, cooling, lighting, equipment, and SHW for emissions reductions determination.

Table 5. Simulation Results of Individual EEMs for an ASHRAE 90.1-2001 Code-Compliant Small Retail Building in the CoA

	EEM #	Energy Efficiency Measure	Site Energy Use by End-Uses (MMBtu/yr)						Source Energy Use by Fuel Type (MMBtu)		Savings Above Base case (%)		$ Savings ($/year)	Increased Marginal Cost ($)	Increased New System Cost ($)	Payback (yrs)
			Cooling	Heating	Ltg & Equip	Fans &Pumps	DHW	Total	Elec.	Gas	Site	Source				
		90.1-2001 Base case (CoA)	180.1	246.1	413.5	124.6	28.8	993.1	2,270	302.4	0.0%	0.0%	$0			
Envelope and Fenestration Measures	1	Increased Roof and Wall Insulation R-Value (from 15 to 25 for roof and none to 11.4c.i. for walls)	174.6	118.6	413.5	120.7	28.8	856.2	2,240	162.1	13.8%	6.6%	$1,066	$22,832 - $34,248		20.2 - 30.3
	2	Decreased Glazing U-Value (from 1.22 to 0.35)	185.4	186.5	413.5	124.0	28.8	938.2	2,284	236.8	5.5%	2.0%	$245	$23,511 - $35,266		94 - 141
	3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	170.3	266.4	413.5	123.2	28.8	1002.2	2,234	324.7	-0.9%	0.5%	$184		$33,384 - $50,076	123 - 185
	4	High Albedo Roof (Roof Absorptance from 0.7 to 0.3)	171.1	256.9	413.5	123.5	28.8	993.8	2,238	314.3	-0.1%	0.8%	$213	$6,600 - $9,900		23.6 - 35.3
HVAC Measures	5	CO_2-Based Demand-Controlled Ventilation (DCV)	169.3	195.2	413.5	124.6	28.8	931.4	2,235	246.4	6.2%	3.5%	$622		$5,894 - $8,841	9.0 - 13.5
	6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	141.9	246.1	413.5	124.6	28.8	954.9	2,149	302.4	3.8%	4.7%	$1,064	$9,830 - $14,746		7.2 - 10.9
	7	Improved Furnace Efficiency (from 80% to 90% Et)	180.1	218.8	413.5	124.6	28.8	965.8	2,270	272.4	2.7%	1.2%	$172	$6,320 - $9,480		36.7 - 55.0
	8	Improved Fan Efficiency (from 55% to 65%)	176.9	253.7	413.5	105.8	28.8	978.7	2,200	310.8	1.5%	2.4%	$565	$5,651 - $8,477		8.7 - 13.1
SHW Measures	9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	180.1	246.1	413.5	124.6	19.9	984.2	2,270	292.6	0.9%	0.4%	$56	$920 - $1,380		16.4 - 24.6
	10	Tankless Gas Water Heater	180.1	246.1	413.5	124.6	20.9	985.2	2,270	293.7	0.8%	0.3%	$50	$600 - $900		12.0 - 18.1
	11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	178.6	246.1	413.5	125.5	6.1	969.8	2,268	277.4	2.3%	1.0%	$159		$2,880 - $4,320	18.7 - 28.1
Lighting Measures	12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	168.4	271.7	323.3	123.7	28.8	915.9	1,945	330.6	7.8%	11.5%	$2,701	$6,312 - $9,468		2.0 - 3.0
	13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.9 to 1.25 W/sq.ft.)	165.0	279.8	296.3	123.5	28.8	893.4	1,848	339.5	10.0%	14.9%	$3,502	$8,214 - $12,321		2.0 - 3.0
	14	Daylight Dimming Control	168.6	266.8	331.1	123.2	28.8	918.5	1,968	325.2	7.5%	10.8%	$2,523		$15,723 - $23,584	5.2 - 7.8
	15	Sky light (3% SRR,U-0.34 & 0.19 SHGC) with Dimming Control	154.8	298.3	227.4	123.2	28.8	832.5	1,597	359.8	16.2%	23.9%	$5,596		$55,700 - $83,550	8.5 - 12.7
Renewable Measure	16	28 kW Photovoltaic Array	140.9	246.1	327.0	98.5	28.8	841.3	1,790	302.4	15.3%	18.7%	$4,227		$140,000 - $210,000	29.0 - 43.4

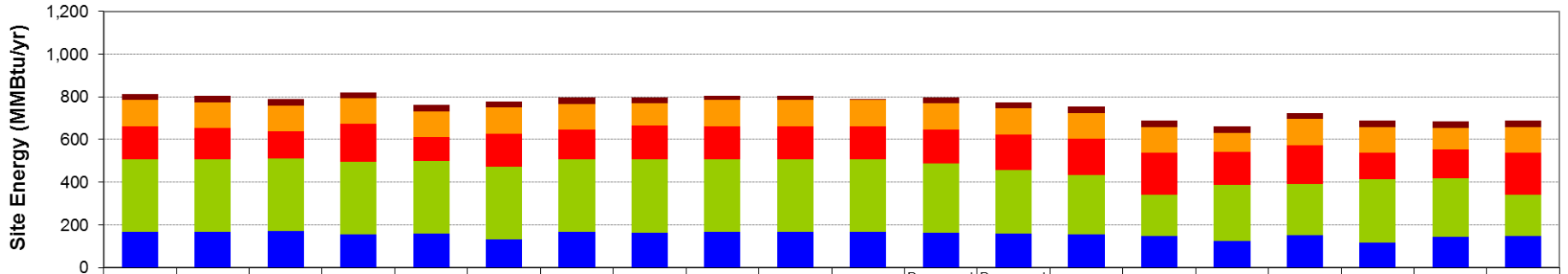
Table 6. Simulation Results of Individual EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in the CoA

	EEM #	Energy Efficiency Measure	Site Energy Use by End-Uses (MMBtu/yr)						Source Energy Use by Fuel Type (MMBtu)		Savings Above Base case (%)		$ Savings ($/year)	Increased Marginal Cost ($)	Increased New System Cost ($)	Payback (yrs)
			Cooling	Heating	Ltg & Equip	Fans &Pumps	DHW	Total	Elec.	Gas	Site	Source				
		90.1-2007 Base case (CoA)	167.3	154.8	341.3	120.7	28.8	812.9	1,989	202.0	0.0%	0.0%	$0			
Envelope and Fenestration Measures	1	Increased Roof and Wall Insulation R-Value (from 20 to 25 for roof and 7.6c.i. to 11.4c.i. for walls)	166.7	145.6	341.3	120.7	28.8	803.1	1,987	191.8	1.2%	0.5%	$75	$8,517 - $12,776		110 - 164
	2	Decreased Glazing U-Value (from 0.6 for window & 0.9 for door to 0.35)	170.1	127.0	341.3	120.7	28.8	787.9	1,997	171.4	3.1%	1.0%	$97	$9,866 - $14,799		98.2 - 147
	3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	155.7	174.7	341.3	120.7	28.8	821.2	1,952	223.9	-1.0%	0.7%	$197		$33,384 - $50,076	115 - 173
HVAC Measures	5	CO_2-Based Demand-Controlled Ventilation (DCV)	157.3	113.2	341.3	120.7	28.8	761.3	1,957	156.2	6.3%	3.5%	$541		$5,894 - $8,841	9.1 - 13.6
	6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	131.8	154.8	341.3	120.7	28.8	777.4	1,876	202.0	4.4%	5.1%	$988	$9,830 - $14,746		7.8 - 11.7
	7	Improved Furnace Efficiency (from 80% to 90% Et)	167.3	137.6	341.3	120.7	28.8	795.7	1,989	183.0	2.1%	0.9%	$109	$6,320 - $9,480		58.2 - 87.3
	8	Improved Fan Efficiency (from 55% to 65%)	163.9	161.7	341.3	102.5	28.8	798.2	1,920	209.6	1.8%	2.8%	$558	$5,651 - $8,477		8.9 - 13.3
SHW Measures	9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	167.3	154.8	341.3	120.7	19.9	804.0	1,989	192.2	1.1%	0.4%	$56	$920 - $1,380		16.4 - 24.6
	10	Tankless Gas Water Heater	167.3	154.8	341.3	120.7	20.9	805.0	1,989	193.3	1.0%	0.4%	$50	$600 - $900		12.0 - 18.1
	11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	165.9	154.8	341.3	121.6	6.1	789.7	1,987	177.0	2.9%	1.2%	$156		$2,880 - $4,320	19.1 - 28.6
Lighting Measures	12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	164.4	159.8	323.3	120.7	28.8	797.0	1,923	207.5	2.0%	2.8%	$550	$1,247 - $1,871		1.9 - 2.9
	13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	160.0	167.7	296.3	120.7	28.8	773.5	1,823	216.2	4.8%	6.9%	$1,375	$3,149 - $4,723		2.0 - 2.9
	14	Daylight Dimming Control	156.5	170.5	276.3	120.7	28.8	752.8	1,749	219.2	7.4%	10.1%	$2,011		$15,723 - $23,584	6.5 - 9.8
	15	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	147.8	196.6	194.4	120.7	28.8	688.3	1,463	247.9	15.3%	21.9%	$4,369		$55,700 - $83,550	10.8 - 16.2
Renewable Measure	16	28 kW Photovoltaic Array	125.9	154.8	259.8	91.9	28.8	661.2	1,509	202.0	18.7%	21.9%	$4,224		$140,000 - $210,000	28.7 - 43.0



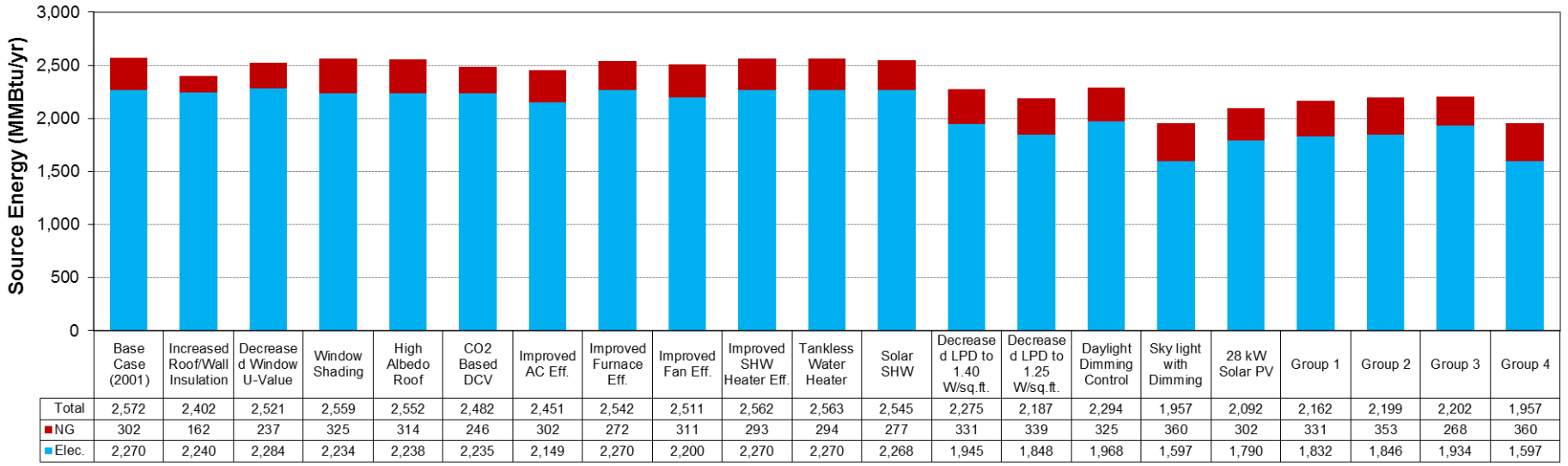
	Base Case (2001)	Increased Roof/Wall Insulation	Decreased Window U-Value	Window Shading	High Albedo Roof	CO2 Based DCV	Improved AC Eff.	Improved Furnace Eff.	Improved Fan Eff.	Improved SHW Heater Eff.	Tankless Water Heater	Solar SHW	Decreased LPD to 1.40 W/sq.ft.	Decreased LPD to 1.25 W/sq.ft.	Daylight Dimming Control	Sky light with Dimming	28 kW Solar PV	Group 1	Group 2	Group 3	Group 4
Total	993	856	938	1,002	994	931	955	966	979	984	985	970	916	893	919	833	841	880	905	855	833
SHW	29	29	29	29	29	29	29	29	29	20	21	6	29	29	29	29	29	29	29	29	29
Fans+Pumps	125	121	124	123	124	125	125	125	106	125	125	126	124	124	123	123	99	124	104	123	123
Heating	246	119	187	266	257	195	246	219	254	246	246	246	272	280	267	298	246	272	292	214	298
Lgt+Appl	414	414	414	414	414	414	414	414	414	414	414	414	323	296	331	227	327	323	323	331	227
Cooling	180	175	185	170	171	169	142	180	177	180	180	179	168	165	169	155	141	133	157	158	155

Figure 5. Site Energy Use of Various EEMs for an ASHRAE 90.1-2001 Code-Compliant Small Retail Building in the CoA



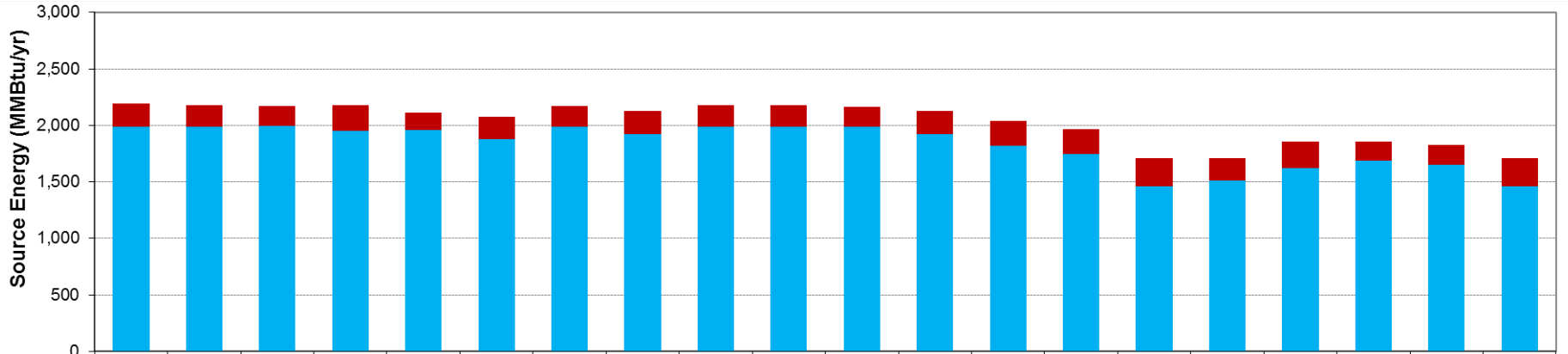
	Base Case (2007)	Increased Roof/Wall Insulation	Decreased Window U-Value	Window Shading	CO2 Based DCV	Improved AC Eff.	Improved Furnace Eff.	Improved Fan Eff.	Improved SHW Heater Eff.	Tankless Water Heater	Solar SHW	Decreased LPD to 1.40 W/sq.ft.	Decreased LPD to 1.25 W/sq.ft.	Daylight Dimming Control	Sky light with Dimming	28 kW Solar PV	Group 1	Group 2	Group 3	Group 4
Total	813	803	788	821	761	777	796	798	804	805	790	797	774	753	688	661	724	688	684	688
SHW	29	29	29	29	29	29	29	29	20	21	6	29	29	29	29	29	29	29	29	29
Fans+Pumps	121	121	121	121	121	121	121	103	121	121	122	121	121	121	121	92	121	121	103	121
Heating	155	146	127	175	113	155	138	162	155	155	155	160	168	171	197	155	181	124	133	197
Lgt+Appl	341	341	341	341	341	341	341	341	341	341	341	323	296	276	194	260	242	296	276	194
Cooling	167	167	170	156	157	132	167	164	167	167	166	164	160	157	148	126	151	118	143	148

Figure 6. Site Energy Use of Various EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in the CoA



	Base Case (2001)	Increased Roof/Wall Insulation	Decreased Window U-Value	Window Shading	High Albedo Roof	CO2 Based DCV	Improved AC Eff.	Improved Furnace Eff.	Improved Fan Eff.	Improved SHW Heater Eff.	Tankless Water Heater	Solar SHW	Decreased LPD to 1.40 W/sq.ft.	Decreased LPD to 1.25 W/sq.ft.	Daylight Dimming Control	Sky light with Dimming	28 kW Solar PV	Group 1	Group 2	Group 3	Group 4
Total	2,572	2,402	2,521	2,559	2,552	2,482	2,451	2,542	2,511	2,562	2,563	2,545	2,275	2,187	2,294	1,957	2,092	2,162	2,199	2,202	1,957
NG	302	162	237	325	314	246	302	272	311	293	294	277	331	339	325	360	302	331	353	268	360
Elec.	2,270	2,240	2,284	2,234	2,238	2,235	2,149	2,270	2,200	2,270	2,270	2,268	1,945	1,848	1,968	1,597	1,790	1,832	1,846	1,934	1,597

Figure 7. Source Energy Use of Various EEMs for an ASHRAE 90.1-2001 Code-Compliant Small Retail Building in the CoA



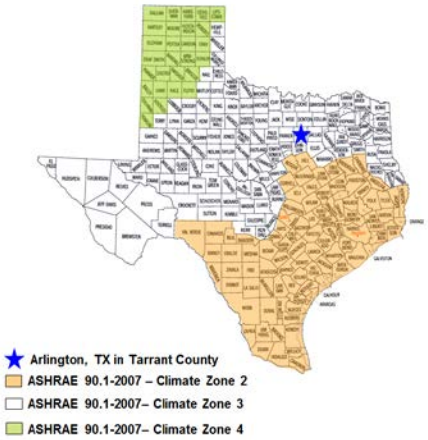
	Base Case (2007)	Increased Roof/Wall Insulation	Decreased Window U-Value	Window Shading	CO2 Based DCV	Improved AC Eff.	Improved Furnace Eff.	Improved Fan Eff.	Improved SHW Heater Eff.	Tankless Water Heater	Solar SHW	Decreased LPD to 1.40 W/sq.ft.	Decreased LPD to 1.25 W/sq.ft.	Daylight Dimming Control	Sky light with Dimming	28 kW Solar PV	Group 1	Group 2	Group 3	Group 4
Total	2,191	2,179	2,169	2,176	2,113	2,078	2,172	2,130	2,181	2,182	2,164	2,130	2,039	1,968	1,711	1,711	1,853	1,859	1,827	1,711
NG	202	192	171	224	156	202	183	210	192	193	177	207	216	219	248	202	231	168	178	248
Elec.	1,989	1,987	1,997	1,952	1,957	1,876	1,989	1,920	1,989	1,989	1,987	1,923	1,823	1,749	1,463	1,509	1,622	1,691	1,650	1,463

Figure 8. Source Energy Use of Various EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in the CoA

[ASHRAE 90.1-2001 Code-Compliant Small Retail Building]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Annual Demand Savings (%)	Annual Demand Savings ($/year)[3]	Combined Savings (Energy+Demand) ($/year)	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source					Marginal Cost[4]	New System Cost[5]	
A	**Envelope and Fenestration Measures**									
1	Increased Roof and Wall Insulation R-Value (from 15 to 25 for roof and none to 11.4c.i. for walls)	13.8%	6.6%	$1,066	1.8%	$65	$1,131	$22,832 - $34,248		20.2 - 30.3
2	Decreased Glazing U-Value (from 1.22 to 0.35)	5.5%	2.0%	$245	0.1%	$4	$249	$23,511 - $35,266		94.3 - 141
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	-0.9%	0.5%	$184	2.5%	$87	$271		$33,384 - $50,076	123 - 185
4	High Albedo Roof (Roof Absorptance from 0.7 to 0.3)	-0.1%	0.8%	$213	1.9%	$67	$280	$6,600 - $9,900		23.6 - 35.3
B	**HVAC System Measures**									
5	CO_2 Based Demand-Controlled Ventilation (DCV)	6.2%	3.5%	$622	0.9%	$32	$654		$5,894 - $8,841	9.0 - 13.5
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	3.8%	4.7%	$1,064	8.2%	$293	$1,357	$9,830 - $14,746		7.2 - 10.9
7	Improved Furnace Efficiency (from 80% to 90% Et)	2.7%	1.2%	$172	0.0%	$0	$172	$6,320 - $9,480		36.7 - 55.0
8	Improved Fan Efficiency (from 55% to 65%)	1.5%	2.4%	$565	2.3%	$81	$646	$5,651 - $8,477		8.7 - 13.1
C	**Service Hot Water Measures**									
9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	0.9%	0.4%	$56	0.0%	$0	$56	$920 - $1,380		16.4 - 24.6
10	Tankless Gas Water Heater	0.8%	0.3%	$50	0.0%	$0	$50	$600 - $900		12.0 - 18.1
11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	2.3%	1.0%	$159	-0.2%	-$6	$154		$2,880 - $4,320	18.7 - 28.1
D	**Lighting Measures**									
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	7.8%	11.5%	$2,701	12.9%	$458	$3,159	$6,312 - $9,468		2.0 - 3.0
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.9 to 1.25 W/sq.ft.)	10.0%	14.9%	$3,502	16.7%	$595	$4,097	$8,214 - $12,321		2.0 - 3.0
14	Daylight Dimming Control	7.5%	10.8%	$2,523	13.7%	$486	$3,009		$15,723 - $23,584	5.2 - 7.8
15	Sky light (3% SRR,U-0.34 & 0.19 SHGC) with Dimming Control	16.2%	23.9%	$5,596	27.0%	$960	$6,556		$55,700 - $83,550	8.5 - 12.7
E	**Renewable Power Measure**									
16	28 kW Photovoltaic Array	15.3%	18.7%	$4,227	17.1%	$607	$4,834		$140,000 - $210,000	29.0 - 43.4



Description of Combined Measures

	Combination of Measures[6]	Combined Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Demand Savings (%)	Combined Demand Savings ($/year)[3]	Combined Savings (Energy+Demand) ($/year)	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source					Marginal Cost[4]	New System Cost[5]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons/yr)
	Combination 1												
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	11.4%	15.9%	$3,695	20.7%	$736	$4,430	$6,312 - $9,468		3.6 - 5.5	61.9	40.3	25.6
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)							$9,830 - $14,746					
	Combination 2												
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	8.9%	15.0%	$3,440	17.0%	$604	$4,045	$6,312 - $9,468		4.6 - 6.9	57.9	39.0	23.5
8	Improved Fan Efficiency (from 55% to 65%)							$5,651 - $8,477					
4	High Albedo Roof (Roof Absorptance from 0.7 to 0.3)							$6,600 - $9,900					
	Combination 3												
14	Daylight Dimming Control	13.9%	15.0%	$3,154	14.6%	$518	$3,672		$15,723 - $23,584	5.9 - 8.8	52.1	30.9	22.6
5	CO_2 Based Demand-Controlled Ventilation (DCV)								$5,894 - $8,841				
	Combination 4												
15	Sky light (3% SRR,U-0.34 & 0.19 SHGC) with Dimming Control	16.2%	23.9%	$5,596	27.0%	$960	$6,556		$55,700 - $83,550	8.5 - 12.7	93.9	62.0	38.6

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Savings depend on fuel mix used.
   * Energy Cost: Electricity = $0.095/kWh & Demand = $5.00/kW
     Natural gas = $0.65/therm
3. Yearly demand cost = Sum of monthly demand cost for 12 months
4. Marginal cost = new system cost - original system cost
5. New system cost = new system cost only
6. See individual measures above for specific savings

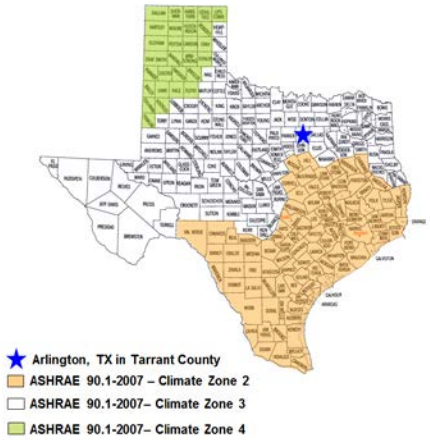
[ASHRAE 90.1-2001 Code-Compliant Retail Building Description]
* Building type: Small Retail (Strip Mall Type)
* Gross area: 15,000 sq-ft
* Building dimension: 61 ft x 245 ft x 17 ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 17 ft
* Window-to-wall ratio: 70% for Front Wall Only (28% for an Entire Building)
* HVAC system: SEER 13 or EER 11 Rooftop PSZ & 80% Et Furnace
* DHW: 0.59 EF Gas Water heater

Figure 9. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2001 Code-Compliant Small Retail Building for the CoA

[ASHRAE 90.1-2007 Code-Compliant Small Retail Building]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Annual Demand Savings (%)	Annual Demand Savings ($/year)[3]	Combined Savings (Energy+Demand) ($/year)	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source					Marginal Cost[4]	New System Cost[5]	
A	**Envelope and Fenestration Measures**									
1	Increased Roof and Wall Insulation R-Value (from 20 to 25 for roof and 7.6c.i. to 11.4c.i. for walls)	1.2%	0.5%	$75	0.1%	$3	$78	$8,517 - $12,776		110 - 164
2	Decreased Glazing U-Value (from 0.6 for window & 0.9 for door to 0.35)	3.1%	1.0%	$97	0.1%	$3	$100	$9,866 - $14,799		98.2 - 147
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	-1.0%	0.7%	$197	2.9%	$92	$289		$33,384 - $50,076	115 - 173
B	**HVAC System Measures**									
5	CO_2 Based Demand-Controlled Ventilation (DCV)	6.3%	3.5%	$541	3.5%	$110	$651		$5,894 - $8,841	9.1 - 13.6
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	4.4%	5.1%	$988	8.7%	$275	$1,263	$9,830 - $14,746		7.8 - 11.7
7	Improved Furnace Efficiency (from 80% to 90% Et)	2.1%	0.9%	$109	0.0%	$0	$109	$6,320 - $9,480		58.2 - 87.3
8	Improved Fan Efficiency (from 55% to 65%)	1.8%	2.8%	$558	2.5%	$78	$635	$5,651 - $8,477		8.9 - 13.3
C	**Service Hot Water Measures**									
9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	1.1%	0.4%	$56	0.0%	$0	$56	$920 - $1,380		16.4 - 24.6
10	Tankless Gas Water Heater	1.0%	0.4%	$50	0.0%	$0	$50	$600 - $900		12.0 - 18.1
11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	2.9%	1.2%	$156	-0.2%	-$6	$151		$2,880 - $4,320	19.1 - 28.6
D	**Lighting Measures**									
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	2.0%	2.8%	$550	3.0%	$93	$643	$1,247 - $1,871		1.9 - 2.9
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	4.8%	6.9%	$1,375	7.4%	$234	$1,609	$3,149 - $4,723		2.0 - 2.9
14	Daylight Dimming Control	7.4%	10.1%	$2,011	12.8%	$402	$2,413		$15,723 - $23,584	6.5 - 9.8
15	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	15.3%	21.9%	$4,369	25.1%	$789	$5,158		$55,700 - $83,550	10.8 - 16.2
E	**Renewable Power Measure**									
16	28 kW Photovoltaic Array	18.7%	21.9%	$4,224	20.9%	$657	$4,881		$140,000 - $210,000	28.7 - 43.0



Description of Combined Measures

	Combination of Measures[6]	Combined Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Demand Savings (%)	Combined Demand Savings ($/year)[3]	Combined Savings (Energy+Demand) ($/year)	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source					Marginal Cost[4]	New System Cost[5]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons/yr)
	Combination 1												
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	11.0%	15.4%	$3,062	18.4%	$580.00	$3,642	$3,149 - $4,723		5.2 - 7.8	51.4	33.8	21.1
14	Daylight Dimming Control								$15,723 - $23,584				
	Combination 2												
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	15.4%	15.1%	$2,814	18.5%	$584.00	$3,398	$3,149 - $4,723		5.6 - 8.3	46.5	27.4	20.2
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)							$9,830 - $14,746					
5	CO_2 Based Demand-Controlled Ventilation (DCV)								$5,894 - $8,841				
	Combination 3												
14	Daylight Dimming Control	15.9%	16.6%	$3,124	18.6%	$586.50	$3,711		$15,723 - $23,584	7.3 - 11.0	51.8	31.2	22.3
5	CO_2 Based Demand-Controlled Ventilation (DCV)								$5,894 - $8,841				
8	Improved Fan Efficiency (from 55% to 65%)							$5,651 - $8,477					
	Combination 4												
15	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	15.3%	21.9%	$4,369	25.1%	$789	$5,158		$55,700 - $83,550	10.8 - 16.2	73.4	48.4	30.1

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Savings depend on fuel mix used.
   * Energy Cost: Electricity = $0.095/kWh & Demand = $5.00/kW
     Natural gas = $0.65/therm
3. Yearly demand cost = Sum of monthly demand cost for 12 months
4. Marginal cost = new system cost - original system cost
5. New system cost = new system cost only
6. See individual measures above for specific savings

[ASHRAE 90.1-2007 Code-Compliant Retail Building Description]
* Building type: Small Retail (Strip Mall Type)
* Gross area: 15,000 sq-ft
* Building dimension: 61 ft x 245 ft x 17 ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 17 ft
* Window-to-wall ratio: 70% for Front Wall Only (28% for an Entire Building)
* HVAC system: SEER 13 or EER 11 Rooftop PSZ & 80% Et Furnace
* DHW: 0.59 EF Gas Water heater

Figure 10. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building for the CoA

4 SUMMARY

This report presents cost-effective recommendations to maximize energy savings for small retail buildings in the City of Arlington (CoA). Based on a summary of above-code approaches, recommendations were developed to achieve above-code energy performance based on the ASHRAE 90.1-2001 and 2007 standard reference buildings, for small retail buildings in the CoA.

A total of 16 recommendations based on the energy savings above the base-case small retail building were selected. These measures include building envelope and fenestration, HVAC system, service hot water (SHW) system, lighting, and renewable options. The implementation costs of each individual measure were also calculated along with simple payback calculations. These measures were then combined to achieve the total source energy savings of the group is 15% above the base-case, ASHRAE 90.1-2001 and 2007 code-compliant small retail buildings. As a result, four combinations were proposed for each base case. Each combination was formed to have a different payback period. Finally, the corresponding emissions savings (NOx, SO_2, and CO_2) of each combination were calculated based on the eGrid for Texas.

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APPENDIX A

Appendix A provides the implementation cost of each EEM obtained from various resources. Tables B-1 and B-2 summarize the cost information for all measures.

Table A-1. Summary of the Cost Information for an ASHRAE 90.1-2001 Code-Compliant Base Case

	EEMs for ASHRAE 90.1-2001 Base Case (CoA)	Description of EEM			Increased Cost per Unit		Number of units/Total Area			Avg. Total Cost	Implementation Costs for Whole Building			References
		Unit/Category	Base Case	EEM	Unit	$/Unit	Unit (#)	Length (ft)	Area (sqft)		-20%	(Avg)	+20%	
1	Increased Roof and Wall Insulation R-Value (from 15 to 25 for roof and none to 11.4c.i. for walls)	hr-sq.ft.-°F/Btu	15	25	sq.ft.	$1.21			15,000	$18,075	$22,832	$28,540	$34,248	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
		hr-sq.ft.-°F/Btu	0 c.i.	11.4c.i.	sq.ft.	$1.40			7,489	$10,465				
2	Decreased Glazing U-Value (from 1.22 to 0.35)	U-Value	1.22	0.35	sq.ft.	$10.1			2,916	$29,388	$23,511	$29,388	$35,266	PNNL AEDG TSD-Somall Office (Jarnagin et al. 2006)
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	Depth (ft)	0	6.75	length feet	$214		195		$41,730	$33,384	$41,730	$50,076	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
4	High Albedo Roof (Roof Absorptance from 0.7 to 0.3)	Roof Absorptance	0.7	0.3	sq.ft.	$0.55			15,000	$8,250	$6,600	$8,250	$9,900	Thomton et al. 2010
5	CO_2-Based Demand-Controlled Ventilation (DCV)	OA Demand Control	No	Yes	each	$921	8			$7,367	$5,894	$7,367	$8,841	E source. 2006
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	SEER (<65 kBtu/h) EER (≥65 and <135 kBtu/h)	13 SEER 11 EER	18 SEER 13.5 EER	each	$1,536	8			$12,288	$9,830	$12,288	$14,746	Kim el al. 2010
7	Improved Furnace Efficiency (from 80% to 90% Et)	Et (%)	80%	90%	each	$988	8			$7,900	$6,320	$7,900	$9,480	Kim el al. 2010
8	Improved Fan Efficiency (from 55% to 65%)	Fan Efficiency (%)	55%	65%	each	$761 $1,249	6 2			$7,064	$5,651	$7,064	$8,477	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	EF	0.59	0.86	each	$1,150	1			$1,150	$920	$1,150	$1,380	ACEEE 2011
10	Tankless Gas Water Heater	EF	0.59	0.82	each	$750	1			$750	$600	$750	$900	ACEEE 2011
11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	Solar SHW system	No	64 sq.ft. collector, 80 gal tank	each	$3,600	1			$3,600	$2,880	$3,600	$4,320	Kim el al. 2010
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	W/sq.ft.	1.9	1.4	each	$41.0 $40.3	28 167			$7,890	$6,312	$7,890	$9,468	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.9 to 1.25 W/sq.ft.)	W/sq.ft.	1.9	1.25	each	$41.0 $40.3	86 167			$10,267	$8,214	$10,267	$12,321	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
14	Daylight Dimming Control	Daylight Dimming Controls	No	Yes	each	$1,228	16			$19,653	$15,723	$19,653	$23,584	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
15	Sky light (3% SRR,U-0.34 & 0.19 SHGC) with Dimming Control	Sky light Dimming Control	0% of roof area No	3% of roof area Yes	each	$1,228 $101	16		496	$69,625	$55,700	$69,625	$83,550	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
16	28 kW Photovoltaic Array	PV	No	28 kW Photovoltaic Array	$/watt	$6.25	28			$175,000	$140,000	$175,000	$210,000	Kim el al. 2010

Table A-2. Summary of the Cost Information for an ASHRAE 90.1-2007 Code-Compliant Base Case

	EEMs for ASHRAE 90.1-2007 Base Case (CoA)	Description of EEM			Increased Cost per Unit		Number of units/Total Area			Avg. Total Cost	Implementation Costs for Whole Building			References
		Unit/Category	Base Case	EEM	Unit	$/Unit	Unit (#)	Length (ft)	Area (sqft)		-20%	(Avg)	+20%	
1	Increased Roof and Wall Insulation R-Value (from 15 to 25 for roof and none to 11.4c.i. for walls)	hr-sq.ft.-°F/Btu	15	25	sq.ft.	$0.55			15,000	$8,250	$8,517	$10,646	$12,776	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
		hr-sq.ft.-°F/Btu	7.6 c.i.	11.4c.i.	sq.ft.	$0.32			7,489	$2,396				
2	Decreased Glazing U-Value (from 0.6 for window & 0.9 for door to 0.35)	U-Value	0.6 (Window) 0.9 (Door)	0.35	sq.ft.	$4.23			2,916	$12,333	$9,866	$12,333	$14,799	PNNL AEDG TSD-Somall Office (Jarnagin et al. 2006)
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	Depth (ft)	0	6.75	length feet	$214		195		$41,730	$33,384	$41,730	$50,076	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
5	CO_2-Based Demand-Controlled Ventilation (DCV)	OA Demand Control	No	Yes	each	$921	8			$7,367	$5,894	$7,367	$8,841	Thomton et al. 2010
6	Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	SEER (<65 kBtu/h) EER (≥65 and <135 kBtu/h)	13 SEER 11 EER	18 SEER 13.5 EER	each	$1,536	8			$12,288	$9,830	$12,288	$14,746	Kim el al. 2010
7	Improved Furnace Efficiency (from 80% to 90% Et)	Et (%)	80%	90%	each	$988	8			$7,900	$6,320	$7,900	$9,480	Kim el al. 2010
8	Improved Fan Efficiency (from 55% to 65%)	Fan Efficiency (%)	55%	65%	each	$761 $1,249	6 2			$7,064	$5,651	$7,064	$8,477	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
9	Improved Gas Water Heater Efficiency (from 0.59 EF to 0.86 EF)	EF	0.59	0.86	each	$1,150	1			$1,150	$920	$1,150	$1,380	ACEEE 2011
10	Tankless Gas Water Heater	EF	0.59	0.82	each	$750	1			$750	$600	$750	$900	ACEEE 2011
11	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	Solar SHW system	No	64 sq.ft. collector, 80 gal tank	each	$3,600	1			$3,600	$2,880	$3,600	$4,320	Kim el al. 2010
12	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	W/sq.ft.	1.5	1.4	each	$41.0 $23.3	28 18			$1,559	$1,247	$1,559	$1,871	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
13	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	W/sq.ft.	1.5	1.25	each	$41.0 $23.3	86 18			$3,936	$3,149	$3,936	$4,723	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
14	Daylight Dimming Control	Daylight Dimming Controls	No	Yes	each	$1,228	16			$19,653	$15,723	$19,653	$23,584	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
15	Sky light (3% SRR,U-0.34 & 0.19 SHGC) with Dimming Control	Sky light Dimming Control	0% of roof area No	3% of roof area Yes	each	$1,228 $101	16		496	$69,625	$55,700	$69,625	$83,550	RSMeans CostWorks ver. 4.7.0 (RCD 2011)
16	28 kW Photovoltaic Array	PV	No	28 kW Photovoltaic Array	$/watt	$6.25	28			$175,000	$140,000	$175,000	$210,000	Kim el al. 2010