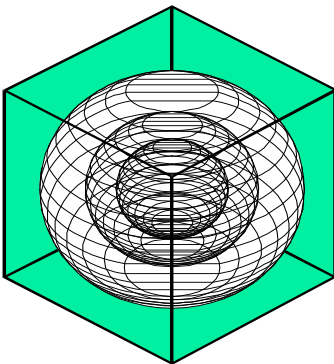


**RECOMMENDATIONS FOR 15% ABOVE ASHRAE 90.1-2007
CODE-COMPLIANT BUILDING ENERGY EFFICIENCY MEASURES
FOR SMALL RETAIL BUILDINGS**

**A Project for
Texas' Senate Bill 5 Legislation
For Reducing Pollution in
Nonattainment and Affected Areas**

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March 2012



ENERGY SYSTEMS LABORATORY

**Texas Engineering Experiment Station
The Texas A&M University System**

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EXECUTIVE SUMMARY

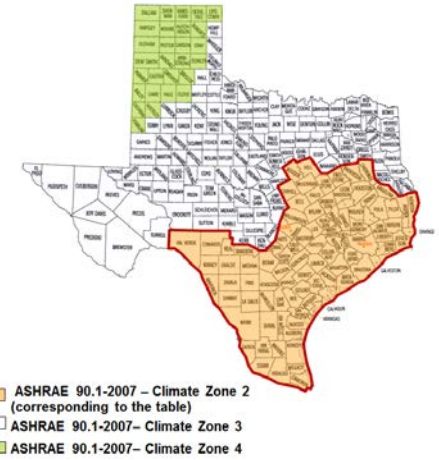
In the 79th Legislature (2005) the Energy Systems Laboratory was required to develop three alternative methods for achieving 15% above-code energy savings in new residential, commercial and industrial construction. The Laboratory continues to work closely with code officials, energy raters, manufacturers, state officials and other stakeholders to develop cost effective energy efficiency measures. This report presents detailed information about the recommendations for achieving 15% above code-compliant building energy performance, which are based on the ASHRAE Standard 90.1-2007, for small retail buildings across the State of Texas. The recommendations were developed for three ASHRAE Standard 90.1-2007 climate zones in Texas along with simple payback calculations.

The analysis was performed using the eQuest 3.64 simulation software (JJH. 2009) based on the DOE-2.2 simulation of ASHRAE 90.1-2007 code-compliant, small retail building and the appropriate TMY2 weather files. According to the ASHRAE Standard 90.1-2007 Climate Zone, a representative county was selected in each climate zone: Harris County for Climate Zone 2, Tarrant County for Climate Zone 3, and Potter County for Climate Zone 4. The ASHRAE 90.1-2007 code-compliant, small retail base-case models were then constructed for each climate zone.

A total of 15 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. These measures were then combined to achieve the total source energy savings of the group is 15% above the base-case ASHRAE 90.1-2007 code-compliant small retail building. As a result, three example combinations were proposed for each climate zone. Each combination was formed to have a different payback period. Figures 1 to 3 present a description of the individual measures and combinations of these measures which achieve 15% source energy savings above the ASHRAE 90.1-2007 code-compliant building. Annual energy savings, estimated costs, simple payback, and NO_x, SO₂, and CO₂ emissions reduction are provided.

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 5.7c.i. to 11.4c.i. for walls)		\$410	2.6%	\$86	\$496	\$9,179 - \$13,769		18.5 - 27.8
2	Decreased Glazing U-Value (from 0.7 for window & 1.1 for door to 0.35)		\$351	2.6%	\$86	\$438	\$14,414 - \$21,621		32.9 - 49.4
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)		\$201	2.3%	\$76	\$278	\$33,384 - \$50,076		120 - 180
B HVAC System Measures									
4	CO ₂ Based Demand-Controlled Ventilation (DCV)		\$597	4.7%	\$156	\$753	\$5,894 - \$8,841		7.8 - 11.7
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)		\$1,108	9.0%	\$299	\$1,408	\$9,830 - \$14,746		7.0 - 10.5
6	Improved Furnace Efficiency (from 80% to 90% Et)		\$72	0.0%	\$0	\$72	\$6,320 - \$9,480		88.3 - 132
7	Improved Fan Efficiency (from 55% to 65%)		\$584	2.4%	\$80	\$664	\$5,651 - \$8,477		8.5 - 12.8
C Service Hot Water Measures									
8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)		\$53	0.0%	\$0	\$53	\$920 - \$1,380		17.2 - 25.9
9	Tankless Gas Water Heater		\$47	0.0%	\$0	\$47	\$600 - \$900		12.7 - 19.1
10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)		\$97	-0.2%	-\$6	\$91	\$2,880 - \$4,320		31.7 - 47.5
D Lighting Measures									
11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)		\$573	2.9%	\$95	\$668	\$1,247 - \$1,871		1.9 - 2.8
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$1,433	7.2%	\$239	\$1,671	\$3,149 - \$4,723		1.9 - 2.8
13	Daylight Dimming Control		\$2,144	12.2%	\$405	\$2,549	\$15,723 - \$23,584		6.2 - 9.3
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		\$4,727	24.2%	\$802	\$5,529	\$55,700 - \$83,550		10.1 - 15.1
E Renewable Power Measure									
15	28 kW Photovoltaic Array		\$3,688	20.8%	\$689	\$4,377	\$140,000 - \$210,000		32.0 - 48.0



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 Annual (lbs/yr)	SO ₂ Emissions Savings Annual (lbs/yr)	CO ₂ Emissions Savings Annual (tons/yr)
	Site	Source					Marginal Cost ⁴	New System Cost ⁵				
Combination 1												
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$3,215	17.6%	\$581	\$3,797	\$3,149 - \$4,723		5.0 - 7.5	53.8	34.8	22.3
13	Daylight Dimming Control							\$15,723 - \$23,584				
Combination 2												
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$3,005	19.6%	\$650	\$3,656	\$3,149 - \$4,723		5.2 - 7.7	49.8	30.1	21.4
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)							\$9,830 - \$14,746				
4	CO ₂ Based Demand-Controlled Ventilation (DCV)							\$5,894 - \$8,841				
Combination 3												
13	Daylight Dimming Control		\$3,326	19.0%	\$629	\$3,955	\$15,723 - \$23,584		6.9 - 10.3	55.3	33.9	23.6
4	CO ₂ Based Demand-Controlled Ventilation (DCV)							\$5,894 - \$8,841				
7	Improved Fan Efficiency (from 55% to 65%)							\$5,651 - \$8,477				
Combination 4												
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		\$4,727	24.2%	\$802	\$5,529	\$55,700 - \$83,550		10.1 - 15.1	79.2	51.6	32.7

Note:

- Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
- Savings depend on fuel mix used.
* Energy Cost: Electricity = \$0.095/kWh & Demand = \$5.00/kWh
Natural gas = \$0.63/therm
- Yearly demand cost = Sum of monthly demand cost for 12 months
- Marginal cost = new system cost - original system cost
- New system cost = new system cost only
- See individual measures above for specific savings

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

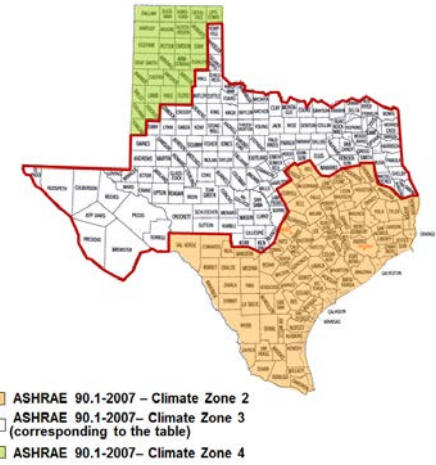
- * Building type: Small Retail (Strip Mall Type)
- * Gross area: 15,000 sq-ft
- * Building dimension: 61 ft x 245 ft x 17 ft (WxLxH)
- * Number of floors: 1
- * Floor-to-floor height: 17 ft
- * Window-to-w all ratio: 70% for Front Wall Only (28% for an Entire Building)
- * HVAC system: SEER 13 or EER 11.2 Rooftop PSZ & 80% Et Furnace
- * DHW: 0.594 EF Gas Water heater



Figure 1. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building for Climate Zone 2

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%	0.6%	\$76	0.1%	\$3	\$78	\$8,337 - \$12,506		106 - 159
2 Decreased Glazing U-Value (from 0.6 for window & 0.9 for door to 0.35)	3.0%	1.0%	\$95	0.0%	\$1	\$96	\$9,866 - \$14,799		102 - 153
3 0.5 PF Window Shading (None to 6.75 ft. Overhang)	-1.0%	0.6%	\$184	2.9%	\$90	\$274	\$33,384 - \$50,076		122 - 183
B HVAC System Measures									
4 CO ₂ Based Demand-Controlled Ventilation (DCV)	6.2%	3.5%	\$525	3.4%	\$105	\$630	\$5,894 - \$8,841		9.4 - 14.0
5 Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)	4.1%	4.8%	\$924	8.3%	\$259	\$1,183	\$9,830 - \$14,746		8.3 - 12.5
6 Improved Furnace Efficiency (from 80% to 90% Et)	2.1%	0.8%	\$104	0.0%	\$0	\$104	\$6,320 - \$9,480		60.6 - 91.0
7 Improved Fan Efficiency (from 55% to 65%)	1.9%	2.8%	\$557	2.5%	\$78	\$635	\$5,651 - \$8,477		8.9 - 13.3
C Service Hot Water Measures									
8 Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)	1.1%	0.5%	\$56	0.0%	\$0	\$56	\$920 - \$1,380		16.5 - 24.7
9 Tankless Gas Water Heater	1.0%	0.4%	\$50	0.0%	\$0	\$50	\$600 - \$900		12.1 - 18.1
10 Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	2.7%	1.0%	\$118	-0.2%	-\$6	\$113	\$2,880 - \$4,320		25.5 - 38.3
D Lighting Measures									
11 Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	2.0%	2.8%	\$552	3.0%	\$93	\$645	\$1,247 - \$1,871		1.9 - 2.9
12 Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	5.0%	7.0%	\$1,376	7.5%	\$233	\$1,609	\$3,149 - \$4,723		2.0 - 2.9
13 Daylight Dimming Control	7.8%	10.6%	\$2,086	13.1%	\$408	\$2,494	\$15,723 - \$23,584		6.3 - 9.5
14 Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	14.3%	22.5%	\$4,514	26.8%	\$836	\$5,350	\$55,700 - \$83,550		10.4 - 15.6
E Renewable Power Measure									
15 28 kW Photovoltaic Array	18.7%	21.9%	\$4,185	21.1%	\$657	\$4,842	\$140,000 - \$210,000		28.9 - 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 Annual (lbs/yr)	SO ₂ Emissions Savings Annual (lbs/yr)	CO ₂ Emissions Savings Annual (tons/yr)
	Site	Source					Marginal Cost ⁴	New System Cost ⁵				
Combination 1												
12 Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	11.4%	15.8%	\$3,109	18.6%	\$579	\$3,688	\$3,149 - \$4,723		5.1 - 7.7	52.1	34.2	21.5
13 Daylight Dimming Control								\$15,723 - \$23,584				
Combination 2												
12 Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	16.9%	17.6%	\$3,273	20.5%	\$638	\$3,911	\$3,149 - \$4,723		6.3 - 9.4	54.2	32.7	23.4
5 Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)								\$9,830 - \$14,746				
4 CO ₂ Based Demand-Controlled Ventilation (DCV)								\$5,894 - \$8,841				
7 Improved Fan Efficiency (from 55% to 65%)								\$5,651 - \$8,477				
Combination 3												
13 Daylight Dimming Control	16.3%	17.1%	\$3,186	18.9%	\$590	\$3,775	\$15,723 - \$23,584		7.2 - 10.8	52.8	32.0	22.7
4 CO ₂ Based Demand-Controlled Ventilation (DCV)								\$5,894 - \$8,841				
7 Improved Fan Efficiency (from 55% to 65%)								\$5,651 - \$8,477				
Combination 4												
14 Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	14.3%	22.5%	\$4,514	26.8%	\$836	\$5,350	\$55,700 - \$83,550		10.4 - 15.6	76.0	51.2	30.8

Note:

- Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
- Savings depend on fuel mix used.
* Energy Cost: Electricity = \$0.095/kWh & Demand = \$5.00/kWh
Natural gas = \$0.63/therm
- Yearly demand cost = Sum of monthly demand cost for 12 months
- Marginal cost = new system cost - original system cost
- New system cost = new system cost only
- 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 11.2 Rooftop PSZ & 80% Et Furnace
- * DHW: 0.594 EF Gas Water heater

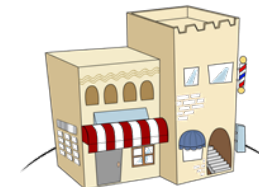
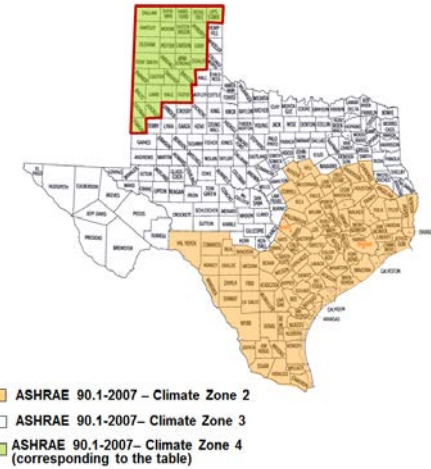


Figure 2. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building for Climate Zone 3

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 9.5c.i. to 11.4c.i. for walls)		0.8%	0.4%	\$43	-0.2%	-\$5	\$38	\$7,788 - \$11,681	206 - 309
2	Decreased Glazing U-Value (from 0.5 for window & 0.85 for door to 0.35)		3.8%	1.6%	\$170	-0.2%	-\$5	\$165	\$6,671 - \$10,006	40.4 - 60.5
3	0.2 PF Window Shading (None to 2.7 ft. Overhang)		-1.4%	0.1%	\$100	3.1%	\$90	\$190	\$19,968 - \$29,952	105 - 158
B HVAC System Measures										
4	CO ₂ Based Demand-Controlled Ventilation (DCV)		7.9%	3.8%	\$476	1.2%	\$34	\$510	\$5,894 - \$8,841	11.6 - 17.3
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)		2.2%	3.0%	\$560	7.3%	\$210	\$770	\$9,830 - \$14,746	12.8 - 19.2
6	Improved Furnace Efficiency (from 80% to 90% Et)		3.7%	1.7%	\$208	0.0%	\$0	\$208	\$6,320 - \$9,480	30.3 - 45.5
7	Improved Fan Efficiency (from 55% to 65%)		1.3%	2.6%	\$521	2.7%	\$79	\$600	\$5,651 - \$8,477	9.4 - 14.1
C Service Hot Water Measures										
8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)		1.2%	0.5%	\$66	0.0%	\$0	\$66	\$920 - \$1,380	14.0 - 20.9
9	Tankless Gas Water Heater		1.0%	0.5%	\$59	0.0%	\$0	\$59	\$600 - \$900	10.2 - 15.3
10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)		2.8%	1.2%	\$140	-0.2%	-\$6	\$134	\$2,880 - \$4,320	21.4 - 32.2
D Lighting Measures										
11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)		1.5%	2.6%	\$514	3.2%	\$93	\$607	\$1,247 - \$1,871	2.1 - 3.1
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		3.7%	6.5%	\$1,284	8.1%	\$233	\$1,517	\$3,149 - \$4,723	2.1 - 3.1
13	Daylight Dimming Control		5.9%	10.1%	\$1,986	14.5%	\$417	\$2,403	\$15,723 - \$23,584	6.5 - 9.8
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		8.5%	20.5%	\$4,208	29.4%	\$849	\$5,056	\$55,700 - \$83,550	11.0 - 16.5
E Renewable Power Measure										
15	28 kW Photovoltaic Array		18.3%	24.2%	\$4,570	25.3%	\$729	\$5,298	\$140,000 - \$210,000	26.4 - 39.6



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 Annual (lbs/yr)	SO ₂ Emissions Savings Annual (lbs/yr)	CO ₂ Emissions Savings Annual (tons/yr)	
	Site	Source					Marginal Cost ⁴	New System Cost ⁵					
Combination 1													
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$2,996	20.1%	\$579	\$3,575	\$3,149 - \$4,723	\$15,723 - \$23,584	5.4 - 8.2	50.3	33.2	20.7	
13	Daylight Dimming Control												
9	Tankless Gas Water Heater												
Combination 2													
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$2,817	18.6%	\$537	\$3,353	\$3,149 - \$4,723	\$5,894 - \$8,841	7.3 - 11.0	46.4	26.5	20.5	
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)												
4	CO ₂ Based Demand-Controlled Ventilation (DCV)												
7	Improved Fan Efficiency (from 55% to 65%)												
Combination 3													
13	Daylight Dimming Control		\$3,017	18.5%	\$533	\$3,550	\$15,723 - \$23,584	\$5,894 - \$8,841	7.7 - 11.5	49.8	28.9	21.8	
4	CO ₂ Based Demand-Controlled Ventilation (DCV)												
7	Improved Fan Efficiency (from 55% to 65%)												
Combination 4													
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		8.5%	20.5%	\$4,208	29.4%	\$849	\$5,056	\$55,700 - \$83,550	11.0 - 16.5	71.3	50.3	28.2

Note:

- Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
- Savings depend on fuel mix used.
* Energy Cost: Electricity = \$0.095/kWh & Demand = \$5.00/kWh
Natural gas = \$0.63/therm
- Yearly demand cost = Sum of monthly demand cost for 12 months
- Marginal cost = new system cost - original system cost
- New system cost = new system cost only
- 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-w all ratio: 70% for Front Wall Only (28% for an Entire Building)
- * HVAC system: SEER 13 or EER 11.2 Rooftop PSZ & 80% Et Furnace
- * DHW: 0.594 EF Gas Water heater

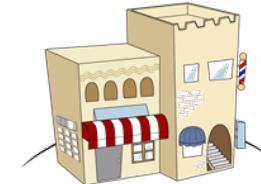


Figure 3. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building for Climate Zone 4

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1 INTRODUCTION

This report presents detailed information about the recommendations for achieving 15% above code-compliant building energy performance, which are based on the ASHRAE Standard 90.1-2007 for small retail buildings across the State of Texas. To estimate savings (%) above the ASHRAE 90.1-2007 code-compliant building from energy efficiency measures, the total source energy savings from heating, cooling, lighting, equipment, and DHW were considered. The recommendations were developed for three ASHRAE 90.1-2007 climate zones in Texas along with simple payback calculations¹. This information is useful to builders, utility demand side energy managers, building owners and others who wish to construct small retail buildings that exceed the minimum national energy code requirements. The analysis was performed using the eQuest 3.64 simulation software (JJH. 2009) based on the DOE-2.2 simulation of ASHRAE 90.1-2007 code-compliant, small retail building and the appropriate TMY2 weather files.

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 gives a brief description of 15 individual energy efficiency measures and simulation input.
- Section 4 provides the results of simulation and cost analysis, including savings from individual measures along with the simple payback calculations and group measures to achieve 15% above the base-case ASHRAE Standard 90.1-2007 code-compliant building.
- Section 5 is a summary which is followed by references.

¹ According to the ASHRAE 90.1-2007 Climate Zone, a representative county was selected in each climate zone: Harris County for Climate Zone 2, Tarrant County for Climate Zone 3, and Potter County for Climate Zone 4.

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 90.1-2007 code-compliant building for small retails across the State of Texas. Section 2.1 presents an 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

The analysis was performed using the eQuest 3.64 simulation software (JJH. 2009) based on the DOE-2.2 simulation of ASHRAE 90.1-2007 code-compliant, small retail building and the appropriate TMY2 weather files. According to the ASHRAE Standard 90.1-2007 Climate Zone, a representative county was selected in each climate zone: Harris County for Climate Zone 2, Tarrant County for Climate Zone 3, and Potter County for Climate Zone 4 (Figure 4). The ASHRAE 90.1-2007 code-compliant, small retail base-case models were constructed for each climate zone.

A total of 15 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 DHW 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. These measures were then combined to achieve the total source energy savings of the group is 15% above the base-case ASHRAE 90.1-2007 code-compliant small retail building. The results from individual measures and cost analysis were used to guide the selection of measures for this group analysis. Another set of simulations was performed with the selected measures applied in combination. As a result, four example combinations were proposed for each base case in each climate zone. Each combination was formed to have a different payback period. Finally, the corresponding emissions savings (NO_x, SO₂, and CO₂) of each combination were calculated based on the eGrid for Texas.

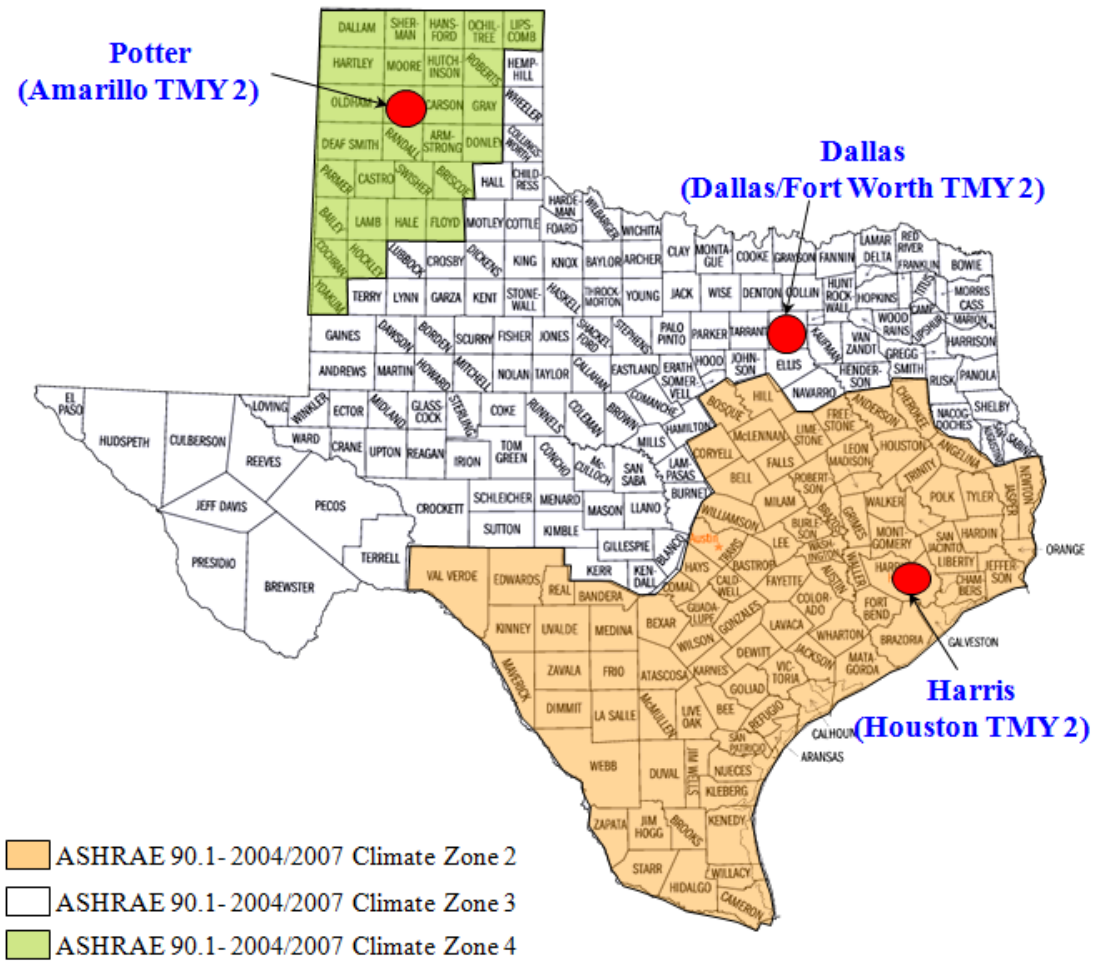


Figure 4. Climate Zones in ASHRAE Standard 90.1-2004/2007 and Three Selected Counties

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 Standard 90.1-2007² 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 only³. 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 5). 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 90.1-2007. Table 1 summarizes the base-case, ASHRAE 90.1-2007 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 \$0.63/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 natural gas rates for 2011 were surveyed and averaged for the following five area categories in Texas: San Antonio, Dallas, all cities except Dallas in Mid-Texas, Amarillo inside city limit, and Amarillo outside city limit (Atmos Energy 2011).

² per 2009 IECC Section 501.2

³ 28% window-to-wall ratio for an entire building

Table 1. Base-Case Building Description

Characteristics	Information Source	ASHRAE 90.1-2007 Code-Compliant Retail			Comments
		Harris County (CZ 2A)	Tarrant County (CZ 3A)	Potter County (CZ 4B)	
Building					
Building Type		Small retail-Stripmall			Number of occupants = 120
Gross Area (sq. ft.)	PNNL-16031 (Liu et al. 2006)	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	PNNL-16031 (Liu et al. 2006)	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 90.1-2007 Table 5.5-2, 5.5-3, and 5.5-4	R-5.7 ci	R-7.6 ci	R-9.5 ci	Assembly maximum u-value for ASHRAE 90.1-2001 = 0.580
Roof Absorptance	ASHRAE 90.1-2007 Sec. 5.5.3.1.1	0.3			Roof reflectance = 0.3 for 2001 and 0.7 for 2007
Roof Insulation (hr-sq.ft.-°F/Btu)	ASHRAE 90.1-2007 Table 5.5-2, 5.5-3, and 5.5-4	R-20 ci			
Slab Perimeter Insulation	ASHRAE 90.1-2007 Table 5.5-2, 5.5-3, and 5.5-4	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 90.1-2007 Table 5.5-2, 5.5-3, and 5.5-4	0.7 (Window) 1.1 (Door)	0.6 (Window) 0.9 (Door)	0.5 (Window) 0.85 (Door)	Fixed fenestration
Solar Heat Gain Coefficient (SHGC)	ASHRAE 90.1-2007 Table 5.5-2, 5.5-3, and 5.5-4	0.25	0.25	0.4	
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 90.1-2007 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		70 F(Occupied), 5 F setback			
Space Cooling Set point	PNNL-16031 (Liu et al. 2006)	75 F(Occupied), 5 F setup			
Lighting Power Density (W/ft ²)	ASHRAE 90.1-2007 Table 9.5.1	1.5			
Equipment Power Density (W/ft ²)	PNNL-20405 (Thornton et al. 2011)	0.4			
Mechanical Systems					
HVAC System Type	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) 11.2 EER (≥65,000 Btu/h and <135,000 Btu/h)			
Heating System Efficiency (%)	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	Autosized			
Heating Capacity (Btu/hr)	ASHRAE 90.1-2007 Appendix G	Autosized			
Economizer	ASHRAE 90.1-2007 Table 6.5.1	No	Yes (≥65,000 Btu/h)		
Ventilation (cfm/sq.ft.)	ASHRAE 62.1-2004	0.18			Total = 2,700 cfm based on 7.5 cfm/person & 0.12 cfm.sq.ft (ASHRAE 62.1-2004)
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			

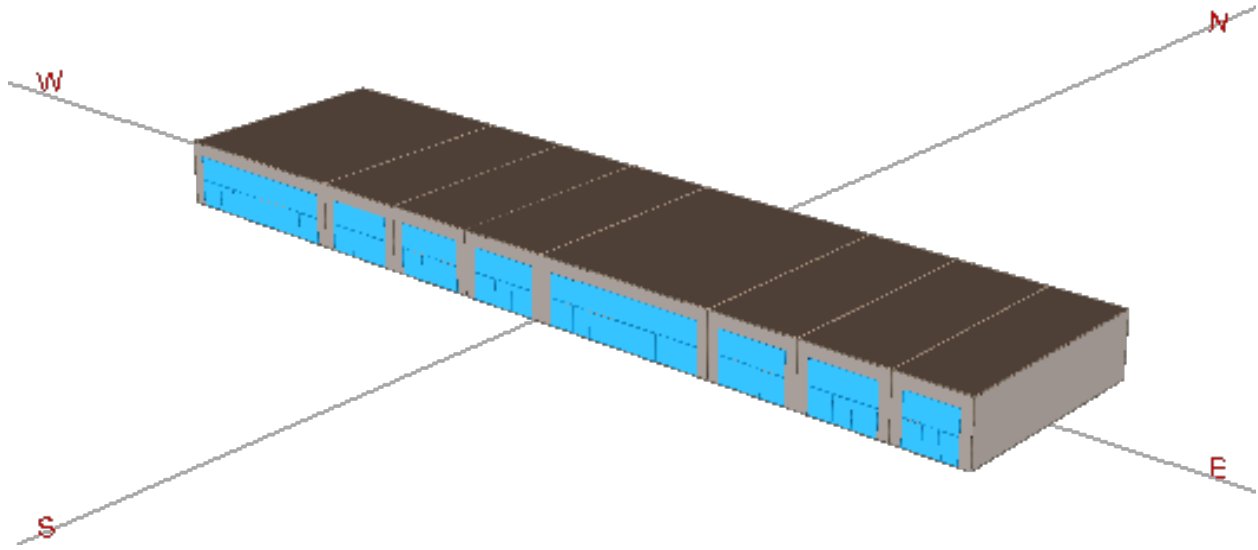


Figure 5. eQuest Model of the Small Retail Prototype (Strip mall Type)

3 PROPOSED ENERGY EFFICIENCY MEASURES FOR SMALL RETAIL BUILDINGS

This section documents 15 energy efficiency measures (EEMs) for small retail buildings to achieve above-code energy performance based on the ASHRAE 90.1- 2007 code-compliant small retail building in Texas. Section 3.1 gives a brief description of 15 individual EEMs. Section 3.2 provides input parameters used in the simulation of each EEM.

3.1 Individual EEMs

Table 2 lists 15 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.

3.2 Simulation Input for Individual EEMs

Tables 3 to 5 list the input parameters used for the base case and individual EEMs for each climate zone. The entire row of shaded cells presents the parameters used in the base-case runs. The remaining rows show the parameters used in the simulation of the individual energy efficiency measures. The shaded cells in each row indicate the change in the value of the parameter used to simulate the measure.

Table 2. Energy Efficiency Measures

	EEM No.	EEM Description
Envelope and Fenestration Measures	1	Increased Roof and Wall Insulation R-Value (from 20 to 25 for roof and from 5.7c.i. (CZ2), 7.6c.i. (CZ3), and 9.5c.i. (CZ4) to 11.4c.i. for walls)
	2	Decreased Glazing U-Value (from 0.7 & 1.1 (CZ2), 0.6 & 0.9 (CZ3), and 0.5 & 0.85 (CZ4) to 0.35)
	3	0.5 & 0.2 PF Window Shading (None to 6.75 ft. (CZ2 & CZ3), and 2.7 ft. (CZ4) Overhang)
HVAC System Measures	4	CO ₂ -Based Demand-Controlled Ventilation (DCV)
	5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)
	6	Improved Furnace Efficiency (from 80% to 90% Et)
	7	Improved Fan Efficiency (from 55% to 65%)
Service Hot Water Measures	8	Improved SHW Heater Efficiency (from 0.594 EF to 0.86 EF)
	9	Tankless Gas Water Heater
	10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)
Lighting Measures	11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)
	12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)
	13	Daylight Dimming Control
	14	Sky light (3% Skylight-roof-ratio, U-0.34 & 0.19 SHGC) with Dimming Control
Renewable Power Measure	15	28 kW Photovoltaic Array

Table 3. Simulation Input Parameters of Individual EEMs for ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Harris County (Climate Zone 2)

	EEM #	Energy Efficiency Measure	Roof Insulation R-Value	Wall C.I. R-Value	Window Glazing U-Value	Glass Door U-Value	Shading (ft)				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 (Harris County)	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	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 5.7c.i. to 11.4c.i. for walls)	25	11.4	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
	2	Decreased Glazing U-Value (from 0.7 for window & 1.1 for door to 0.35)	20	5.7	0.35	0.35	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
	3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	20	5.7	0.7	1.1	6.75	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
HVAC Measures	4	CO ₂ -Based Demand-Controlled Ventilation (DCV)	20	5.7	0.7	1.1	0	0	0	0	Y	13	11.2	80	55	0.594	1.5	N	0
	5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)	20	5.7	0.7	1.1	0	0	0	0	N	18	13.5	80	55	0.594	1.5	N	0
	6	Improved Furnace Efficiency (from 80% to 90% Et)	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	90	55	0.594	1.5	N	0
	7	Improved Fan Efficiency (from 55% to 65%)	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	65	0.594	1.5	N	0
SHW Measures	8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.86	1.5	N	0
	9	Tankless Gas Water Heater	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.82	1.5	N	0
	10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
Lighting Measures	11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.594	1.4	N	0
	12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.594	1.25	N	0
	13	Daylight Dimming Control	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.594	1.5	Y	0
	14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.594	1.5	Y	3%
Renewable Measure	15	28 kW Photovoltaic Array	20	5.7	0.7	1.1	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0

Table 4. Simulation Input Parameters of Individual EEMs for ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Tarrant County (Climate Zone 3)

	EEM #	Energy Efficiency Measure	Roof Insulation R-Value	Wall C.I. R-Value	Window Glazing U-Value	Glass Door U-Value	Shading (ft)				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 (Tarrant County)	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	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	N	13	11.2	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	N	13	11.2	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	N	13	11.2	80	55	0.594	1.5	N	0
HVAC Measures	4	CO ₂ -Based Demand-Controlled Ventilation (DCV)	20	7.6	0.6	0.9	0	0	0	0	Y	13	11.2	80	55	0.594	1.5	N	0
	5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)	20	7.6	0.6	0.9	0	0	0	0	N	18	13.5	80	55	0.594	1.5	N	0
	6	Improved Furnace Efficiency (from 80% to 90% Et)	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	90	55	0.594	1.5	N	0
	7	Improved Fan Efficiency (from 55% to 65%)	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	80	65	0.594	1.5	N	0
SHW Measures	8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	80	55	0.86	1.5	N	0
	9	Tankless Gas Water Heater	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	80	55	0.82	1.5	N	0
	10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
Lighting Measures	11	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	N	13	11.2	80	55	0.594	1.4	N	0
	12	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	N	13	11.2	80	55	0.594	1.25	N	0
	13	Daylight Dimming Control	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	80	55	0.594	1.5	Y	0
	14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	80	55	0.594	1.5	Y	3%
Renewable Measure	15	28 kW Photovoltaic Array	20	7.6	0.6	0.9	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0

Table 5. Simulation Input Parameters of Individual EEMs for ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Potter County (Climate Zone 4)

	EEM #	Energy Efficiency Measure	Roof Insulation R-Value	Wall C.I. R-Value	Window Glazing U-Value	Glass Door U-Value	Shading (ft)				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 (Potter County)	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	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 9.5c.i. to 11.4c.i. for walls)	25	11.4	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
	2	Decreased Glazing U-Value (from 0.5 for window & 0.85 for door to 0.35)	20	9.5	0.35	0.35	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
	3	0.2 PF Window Shading (None to 2.7 ft. Overhang)	20	9.5	0.5	0.85	2.7	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
HVAC Measures	4	CO ₂ Based Demand-Controlled Ventilation (DCV)	20	9.5	0.5	0.85	0	0	0	0	Y	13	11.2	80	55	0.594	1.5	N	0
	5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)	20	9.5	0.5	0.85	0	0	0	0	N	18	13.5	80	55	0.594	1.5	N	0
	6	Improved Furnace Efficiency (from 80% to 90% Et)	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	90	55	0.594	1.5	N	0
	7	Improved Fan Efficiency (from 55% to 65%)	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	65	0.594	1.5	N	0
SHW Measures	8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.86	1.5	N	0
	9	Tankless Gas Water Heater	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.82	1.5	N	0
	10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0
Lighting Measures	11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.594	1.4	N	0
	12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.594	1.25	N	0
	13	Daylight Dimming Control	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.594	1.5	Y	0
	14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.594	1.5	Y	3%
Renewable Measure	15	28 kW Photovoltaic Array	20	9.5	0.5	0.85	0	0	0	0	N	13	11.2	80	55	0.594	1.5	N	0

4 RESULTS

This section presents the results of simulation and cost analysis. Section 4.1 provides the detailed results for three representative counties in each climate zone such as Harris County for Climate Zone 2, Tarrant County for Climate Zone 3 and Potter County for Climate Zone 4. Section 4.2 presents the group measures which are the combinations of individual measures for achieving 15% savings above the base-case, ASHRAE 90.1-2007 code-compliant building.

4.1 Results of Simulation and Cost Analysis

Tables 6 to 8 summarize the results of simulation and cost analysis for Harris, Tarrant, and Potter Counties, including:

- Annual site energy consumption for different end-uses and total;
- Annual source energy consumption for different fuel types and total;
- Above-code savings (%) for site and source;
- Annual energy and demand cost savings;
- Increased cost of implementation (obtained from various resources listed in Appendix A⁴); and
- Simple payback period.

The annual site energy use was obtained from the BEPS report of the DOE-2 output and then converted to source energy⁵. Figures 6 to 11 provide a graphical representation of the site/source energy consumption of the EEMs for the ASHRAE 90.1- 2007 code-compliant base-case small retail building for Harris, Tarrant, and Potter Counties.

4.1.1 Base-Case Energy Use

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

- a) Site energy use by end-uses: 785 MMBtu/yr, including
 - 24.7% for cooling;
 - 13.1% for heating;
 - 43.5% for lighting and equipment;
 - 15.3% for fans and pumps; and
 - 3.5% for service water heating.
- b) Source energy use by fuel type: 2,212 MMBtu/yr, including
 - 93.5% for electricity; and
 - 6.5% for natural gas.

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

- a) Site energy use by end-uses: 802 MMBtu/yr, including
 - 20.2% for cooling;
 - 18.6% for heating;
 - 42.6% for lighting and equipment;
 - 15.1% for fans and pumps; and
 - 3.6% for service water heating.

⁴ The ranges of total implementation cost for some measures were modified according to the recommendations of stakeholders.

⁵ 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.

- b) Source energy use by fuel type: 2,167 MMBtu/yr, including
 - 91.0% for electricity; and
 - 9.0% for natural gas.

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

- a) Site energy use by end-uses: 896 MMBtu/yr, including
 - 12.2% for cooling;
 - 37.3% for heating;
 - 42.6% for lighting and equipment;
 - 15.5% for fans and pumps; and
 - 4.2% for service water heating.
- b) Source energy use by fuel type: 2,147 MMBtu/yr, including
 - 82.9% for electricity; and
 - 17.1% 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 Texas, and for Potter County in Climate Zone 4, the measures that reduce the heating energy use would have higher impact on the total energy use compared to Climate Zone 2 and 3. It is also noted that 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.

4.1.2 Energy Savings from Various Individual EEMs

The savings results are:

- a) Increased Roof and Wall Insulation R-Value:
 - Harris County: 2.9% (site energy savings) and 2.3% (source energy savings);
 - Tarrant County: 1.2% (site energy savings) and 0.6% (source energy savings); and
 - Potter County: 0.8% (site energy savings) and 0.4% (source energy savings).
- b) Decreased Glazing U-Value:
 - Harris County: 3.9% (site energy savings) and 2.2% (source energy savings);
 - Tarrant County: 3.0% (site energy savings) and 1.0% (source energy savings); and
 - Potter County: 3.8% (site energy savings) and 1.6% (source energy savings).
- c) Window Shading:
 - Harris County: -0.1% (site energy savings) and 0.8% (source energy savings);
 - Tarrant County: -1.0% (site energy savings) and 0.6% (source energy savings); and
 - Potter County: -1.4% (site energy savings) and 0.1% (source energy savings).
- d) CO₂-Based Demand-Controlled Ventilation:
 - Harris County: 5.4% (site energy savings) and 3.5% (source energy savings);
 - Tarrant County: 6.2% (site energy savings) and 3.5% (source energy savings); and
 - Potter County: 7.9% (site energy savings) and 3.8% (source energy savings).
- e) Improved Air Conditioner Efficiency:
 - Harris County: 5.1% (site energy savings) and 5.7% (source energy savings);

- Tarrant County: 4.1% (site energy savings) and 4.8% (source energy savings); and
 - Potter County: 2.2% (site energy savings) and 3.0% (source energy savings).
- f) Improved Furnace Efficiency:
- Harris County: 1.5% (site energy savings) and 0.6% (source energy savings);
 - Tarrant County: 2.1% (site energy savings) and 0.8% (source energy savings); and
 - Potter County: 3.7% (site energy savings) and 1.7% (source energy savings).
- g) Improved Fan Efficiency:
- Harris County: 2.2% (site energy savings) and 2.9% (source energy savings);
 - Tarrant County: 1.9% (site energy savings) and 2.8% (source energy savings); and
 - Potter County: 1.3% (site energy savings) and 2.6% (source energy savings).
- h) Improved SHW Heater Efficiency:
- Harris County: 1.1% (site energy savings) and 0.4% (source energy savings);
 - Tarrant County: 1.1% (site energy savings) and 0.5% (source energy savings); and
 - Potter County: 1.2% (site energy savings) and 0.5% (source energy savings).
- i) Tankless Gas Water Heater:
- Harris County: 1.0% (site energy savings) and 0.4% (source energy savings);
 - Tarrant County: 1.0% (site energy savings) and 0.4% (source energy savings); and
 - Potter County: 1.0% (site energy savings) and 0.5% (source energy savings).
- j) Solar SHW System (64 sq. ft. collector, 80 gal tank):
- Harris County: 2.4% (site energy savings) and 0.8% (source energy savings);
 - Tarrant County: 2.7% (site energy savings) and 1.0% (source energy savings); and
 - Potter County: 2.8% (site energy savings) and 1.2% (source energy savings).
- k) Decreased Lighting Power Density to 1.4 W/sq.ft.:
- Harris County: 2.3% (site energy savings) and 2.9% (source energy savings);
 - Tarrant County: 2.0% (site energy savings) and 2.8% (source energy savings); and
 - Potter County: 1.5% (site energy savings) and 2.6% (source energy savings).
- l) Decreased Lighting Power Density to 1.25 W/sq.ft.:
- Harris County: 5.7% (site energy savings) and 7.2% (source energy savings);
 - Tarrant County: 5.0% (site energy savings) and 7.0% (source energy savings); and
 - Potter County: 3.7% (site energy savings) and 6.5% (source energy savings).
- m) Daylight Dimming Control:
- Harris County: 8.8% (site energy savings) and 10.8% (source energy savings);
 - Tarrant County: 7.8% (site energy savings) and 10.6% (source energy savings); and
 - Potter County: 5.9% (site energy savings) and 10.1% (source energy savings).
- n) Skylight with Dimming Control:
- Harris County: 18.3% (site energy savings) and 23.7% (source energy savings);
 - Tarrant County: 14.3% (site energy savings) and 22.5% (source energy savings); and
 - Potter County: 8.5% (site energy savings) and 20.5% (source energy savings).

o) 28 kW Photovoltaic Array:

- Harris County: 16.9% (site energy savings) and 18.9% (source energy savings);
- Tarrant County: 18.7% (site energy savings) and 21.9% (source energy savings); and
- Potter County: 18.3% (site energy savings) and 24.2% (source energy savings).

Of the 15 measures, skylight and solar PV measures present the most savings (23.7%, 22.5%, and 20.5% source energy savings for skylight; and 18.9%, 21.9%, and 24.2% source energy savings for solar PV measure) across the counties. A daylight dimming control and decreased lighting power density to 1.25 W/sq.ft measures also resulted in considerable savings (10.8%, 10.6%, and 10.1% source energy savings with daylight dimming control measure; and 7.2%, 7.0%, and 6.5% source energy savings with decreased lighting power density to 1.25 W/sq.ft measure). Among the envelope and fenestration measures, a decreased glazing u-value measure shows a high site energy savings (3.9%, 3.0%, and 3.8% site energy savings), while the source energy savings becomes lower (2.2%, 1.0%, and 1.6% source energy savings) due to a high savings in natural gas and the increased cooling energy penalty. Among the HVAC system measures, an improved air conditioner efficiency measure results in high source energy savings across the counties (5.7%, 4.8%, and 3.0% source energy savings). Two other measures, such as CO₂-based demand-controlled ventilation and improved fan efficiency, yield 3.5%, 3.5%, and 3.8% source energy savings and 2.9%, 2.8%, and 2.6% source energy savings, respectively. In service hot water measures, all three measures result in low savings: 0.4% to 1.2% source energy savings.

4.1.3 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 CO₂ based demand-controlled ventilation measure also yields a relatively high cost savings.

To estimate the cost-effectiveness of measures, the implementation costs of each measure (obtained from various resources listed in Appendix A) 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 11 and 12) are the most cost-effective with the shortest payback periods of 1.9 to 2.8 years for Harris County, 1.9 to 2.9 years for Tarrant County, and 2.1 to 3.1 years for Potter County. Another lighting measure, daylight dimming control (EEM 13) yields a short payback also: 6.2 to 9.3 years for Harris County, 6.3 to 9.5 years for Tarrant County, and 6.5 to 9.8 years for Potter County.

4.2 **Combined EEMs: 15% Source Energy Savings Above ASHRAE 90.1-2007 Code-Compliant Building**

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 savings⁶ of the group is 15% above the base-case simulation of ASHRAE 90.1- 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 12 and 14, three 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 NO_x, SO₂, and CO₂ 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) Harris County: 5.0 to 7.5 years;
- b) Tarrant County: 5.1 to 7.7 years; and
- c) Potter County: 5.4 to 8.2 years.

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

- a) Harris County: 6.9 to 10.3 years;
- b) Tarrant County: 7.2 to 10.8 years; and
- c) Potter County: 7.7 to 11.5 years.

⁶ The estimated total source energy savings include heating, cooling, lighting, equipment, and SHW.

Table 6. Simulation Results of Individual EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Harris County (Climate Zone 2)

	EEM #	Energy Efficiency Measure	Site Energy Use by End-Uses (MMBtu/yr)					Source Energy Use by Fuel Type (MMBtu)			Savings Above Base case (%)		Annual Energy Savings (\$/yr)	Annual Demand Savings (\$/yr)	Increased Marginal Cost (\$)	Increased New System Cost (\$)	Payback (yrs)
			Cooling	Heating	Ltg & Equip	Fans & Pumps	DHW	Total	Total	Elec.	Gas	Site					
		90.1-2007 Base case (Harris County)	194	102	341	120	27	785	2212	2,069	143	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 5.7c.i. to 11.4c.i. for walls)	181	92	341	120	27	762	2161	2,030	131	2.9%	2.3%	\$410	\$86	\$9,179 - \$13,769	18.5 - 27.8
	2	Decreased Glazing U-Value (from 0.7 for window & 1.1 for door to 0.35)	186	79	341	120	27	754	2163	2,046	117	3.9%	2.2%	\$351	\$86	\$14,414 - \$21,621	32.9 - 49.4
	3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	184	113	341	120	27	785	2193	2,039	154	-0.1%	0.8%	\$201	\$76	\$33,384 - \$50,076	120 - 180
HVAC Measures	4	CO ₂ -Based Demand-Controlled Ventilation (DCV)	178	75	341	120	27	742	2134	2,021	113	5.4%	3.5%	\$597	\$156	\$5,894 - \$8,841	7.8 - 11.7
	5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)	154	102	341	120	27	745	2086	1,943	143	5.1%	5.7%	\$1,108	\$299	\$9,830 - \$14,746	7.0 - 10.5
	6	Improved Furnace Efficiency (from 80% to 90% Et)	194	91	341	120	27	773	2199	2,069	130	1.5%	0.6%	\$72	\$0	\$6,320 - \$9,480	88.3 - 132
	7	Improved Fan Efficiency (from 55% to 65%)	190	107	341	102	27	767	2147	2,000	148	2.2%	2.9%	\$584	\$80	\$5,651 - \$8,477	8.5 - 12.8
SHW Measures	8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)	194	102	341	120	19	776	2202	2,069	133	1.1%	0.4%	\$53	\$0	\$920 - \$1,380	17.2 - 25.9
	9	Tankless Gas Water Heater	194	102	341	120	20	777	2204	2,069	134	1.0%	0.4%	\$47	\$0	\$600 - \$900	12.7 - 19.1
	10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	194	102	341	121	8	766	2193	2,072	121	2.4%	0.8%	\$97	-\$6	\$2,880 - \$4,320	31.7 - 47.5
Lighting Measures	11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	190	106	323	120	27	766	2148	2,002	146	2.3%	2.9%	\$573	\$95	\$1,247 - \$1,871	1.9 - 2.8
	12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	185	111	296	120	27	739	2052	1,901	152	5.7%	7.2%	\$1,433	\$239	\$3,149 - \$4,723	1.9 - 2.8
	13	Daylight Dimming Control	181	113	275	120	27	716	1973	1,818	154	8.8%	10.8%	\$2,144	\$405	\$15,723 - \$23,584	6.2 - 9.3
	14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	169	136	188	120	27	641	1688	1,509	179	18.3%	23.7%	\$4,727	\$802	\$55,700 - \$83,550	10.1 - 15.1
Renewable Measure	15	28 kW Photovoltaic Array	154	102	272	96	27	652	1793	1,651	143	16.9%	18.9%	\$3,688	\$689	\$140,000 - \$210,000	32.0 - 48.0

Table 7. Simulation Results of Individual EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Tarrant County (Climate Zone 3)

	EEM #	Energy Efficiency Measure	Site Energy Use by End-Uses (MMBtu/yr)					Source Energy Use by Fuel Type (MMBtu)			Savings Above Base case (%)		Annual Energy Savings (\$/yr)	Annual Demand Savings (\$/yr)	Increased Marginal Cost (\$)		Increased New System Cost (\$)		Payback (yrs)	
			Cooling	Heating	Ltg & Equip	Fans & Pumps	DHW	Total	Total	Elec.	Gas	Site			Source					
		90.1-2007 Base case (Tarrant County)	162	149	341	121	29	802	2167	1,971	196	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)	161	140	341	121	29	792	2155	1,969	186	1.2%	0.6%	\$76	\$3	\$8,337	\$12,506		106 - 159	
	2	Decreased Glazing U-Value (from 0.6 for window & 0.9 for door to 0.35)	165	122	341	121	29	777	2146	1,980	166	3.0%	1.0%	\$95	\$1	\$9,866	\$14,799		102 - 153	
	3	0.5 PF Window Shading (None to 6.75 ft. Overhang)	151	168	341	121	29	810	2154	1,937	217	-1.0%	0.6%	\$184	\$90			\$33,384	\$50,076	122 - 183
HVAC Measures	4	CO ₂ -Based Demand-Controlled Ventilation (DCV)	152	109	341	121	29	752	2092	1,940	152	6.2%	3.5%	\$525	\$105			\$5,894	\$8,841	9.4 - 14.0
	5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)	129	149	341	121	29	769	2062	1,866	196	4.1%	4.8%	\$924	\$259	\$9,830	\$14,746		8.3 - 12.5	
	6	Improved Furnace Efficiency (from 80% to 90% Et)	162	133	341	121	29	785	2149	1,971	178	2.1%	0.8%	\$104	\$0	\$6,320	\$9,480		60.6 - 91.0	
	7	Improved Fan Efficiency (from 55% to 65%)	159	156	341	103	29	787	2106	1,903	203	1.9%	2.8%	\$557	\$78	\$5,651	\$8,477		8.9 - 13.3	
SHW Measures	8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)	162	149	341	121	20	793	2157	1,971	186	1.1%	0.5%	\$56	\$0	\$920	\$1,380		16.5 - 24.7	
	9	Tankless Gas Water Heater	162	149	341	121	21	794	2158	1,971	187	1.0%	0.4%	\$50	\$0	\$600	\$900		12.1 - 18.1	
	10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	162	149	341	122	6	780	2145	1,974	171	2.7%	1.0%	\$118	-\$6			\$2,880	\$4,320	25.5 - 38.3
Lighting Measures	11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	159	154	323	121	29	786	2106	1,905	201	2.0%	2.8%	\$552	\$93	\$1,247	\$1,871		1.9 - 2.9	
	12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	155	162	296	121	29	762	2016	1,806	209	5.0%	7.0%	\$1,376	\$233	\$3,149	\$4,723		2.0 - 2.9	
	13	Daylight Dimming Control	150	165	274	121	29	739	1936	1,723	213	7.8%	10.6%	\$2,086	\$408			\$15,723	\$23,584	6.3 - 9.5
	14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	140	211	188	121	29	687	1678	1,415	263	14.3%	22.5%	\$4,514	\$836			\$55,700	\$83,550	10.4 - 15.6
Renewable Measure	15	28 kW Photovoltaic Array	123	149	259	92	29	651	1692	1,496	196	18.7%	21.9%	\$4,185	\$657			\$140,000	\$210,000	28.9 - 43.4

Table 8. Simulation Results of Individual EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Potter County (Climate Zone 4)

	EEM #	Energy Efficiency Measure	Site Energy Use by End-Uses (MMBtu/yr)					Source Energy Use by Fuel Type (MMBtu)			Savings Above Base case (%)		Annual Energy Savings (\$/yr)	Annual Demand Savings (\$/yr)	Increased Marginal Cost (\$)	Increased New System Cost (\$)	Payback (yrs)	
			Cooling	Heating	Ltg & Equip	Fans & Pumps	DHW	Total	Total	Elec.	Gas	Site						Source
		90.1-2007 Base case (Potter County)	98	299	341	125	34	896	2147	1,781	366	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 9.5c.i. to 11.4c.i. for walls)	98	291	341	125	34	889	2139	1,782	358	0.8%	0.4%	\$43	-\$5	\$7,455 - \$11,182		197 - 296
	2	Decreased Glazing U-Value (from 0.5 for window & 0.85 for door to 0.35)	100	263	341	124	34	862	2114	1,787	326	3.8%	1.6%	\$170	-\$5	\$6,671 - \$10,006		40.4 - 60.5
	3	0.2 PF Window Shading (None to 2.7 ft. Overhang)	89	320	341	125	34	909	2144	1,754	390	-1.4%	0.1%	\$100	\$90		\$19,968 - \$29,952	105 - 158
HVAC Measures	4	CO ₂ Based Demand-Controlled Ventilation (DCV)	96	230	341	125	34	826	2066	1,776	290	7.9%	3.8%	\$476	\$34		\$5,894 - \$8,841	11.6 - 17.3
	5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)	78	299	341	125	34	876	2084	1,717	366	2.2%	3.0%	\$560	\$210	\$9,830 - \$14,746		12.8 - 19.2
	6	Improved Furnace Efficiency (from 80% to 90% Et)	98	266	341	125	34	863	2111	1,781	330	3.7%	1.7%	\$208	\$0	\$6,320 - \$9,480		30.3 - 45.5
	7	Improved Fan Efficiency (from 55% to 65%)	95	308	341	106	34	885	2092	1,715	376	1.3%	2.6%	\$521	\$79	\$5,651 - \$8,477		9.4 - 14.1
SHW Measures	8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)	98	299	341	125	24	886	2136	1,781	355	1.2%	0.5%	\$66	\$0	\$920 - \$1,380		14.0 - 20.9
	9	Tankless Gas Water Heater	98	299	341	125	25	887	2137	1,781	356	1.0%	0.5%	\$59	\$0	\$600 - \$900		10.2 - 15.3
	10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	98	299	341	126	8	871	2121	1,784	337	2.8%	1.2%	\$140	-\$6		\$2,880 - \$4,320	21.4 - 32.2
Lighting Measures	11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)	96	306	323	125	34	883	2091	1,718	374	1.5%	2.6%	\$514	\$93	\$1,247 - \$1,871		2.1 - 3.1
	12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)	93	316	296	125	34	864	2008	1,623	385	3.7%	6.5%	\$1,284	\$233	\$3,149 - \$4,723		2.1 - 3.1
	13	Daylight Dimming Control	89	322	273	125	34	843	1931	1,539	392	5.9%	10.1%	\$1,986	\$417		\$15,723 - \$23,584	6.5 - 9.8
	14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control	81	395	185	125	34	820	1707	1,235	472	8.5%	20.5%	\$4,208	\$849		\$55,700 - \$83,550	11.0 - 16.5
Renewable Measure	15	28 kW Photovoltaic Array	69	299	242	88	34	732	1628	1,262	366	18.3%	24.2%	\$4,570	\$729		\$140,000 - \$210,000	26.4 - 39.6

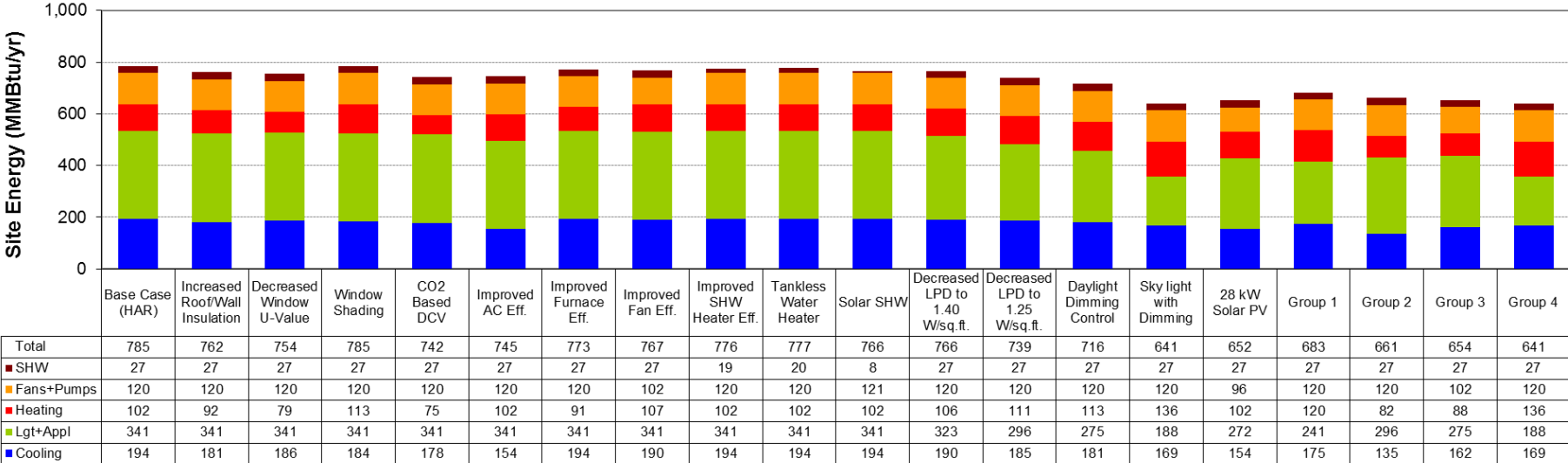


Figure 6. Site Energy Use of Various EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Harris County (Climate Zone 2)

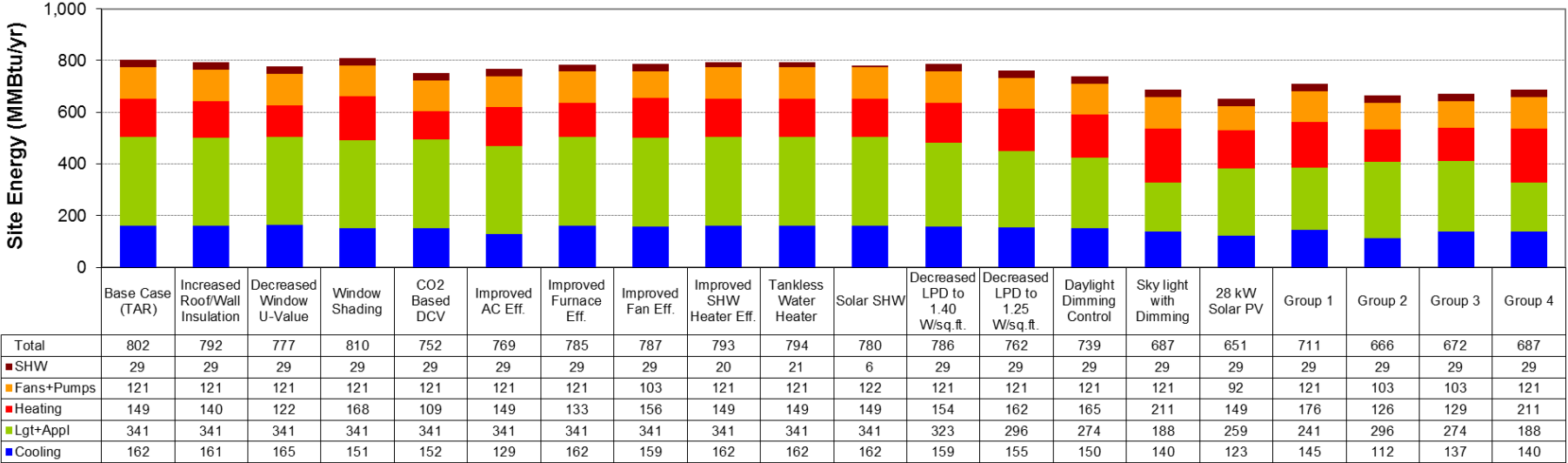


Figure 7. Site Energy Use of Various EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Tarrant County (Climate Zone 3)

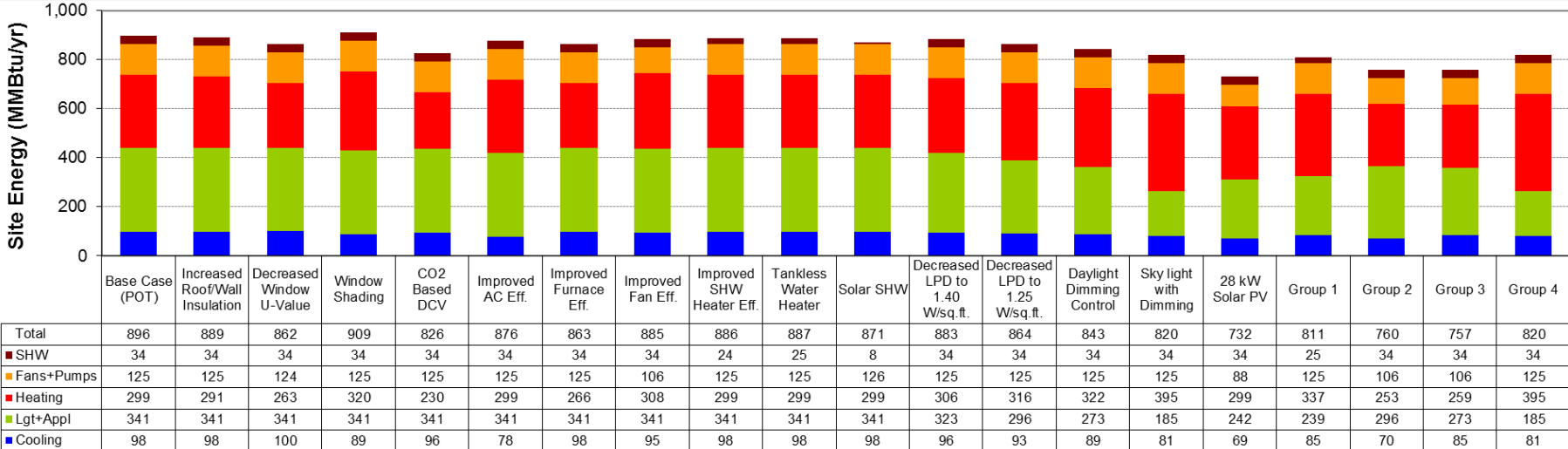


Figure 8. Site Energy Use of Various EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Potter County (Climate Zone 4)

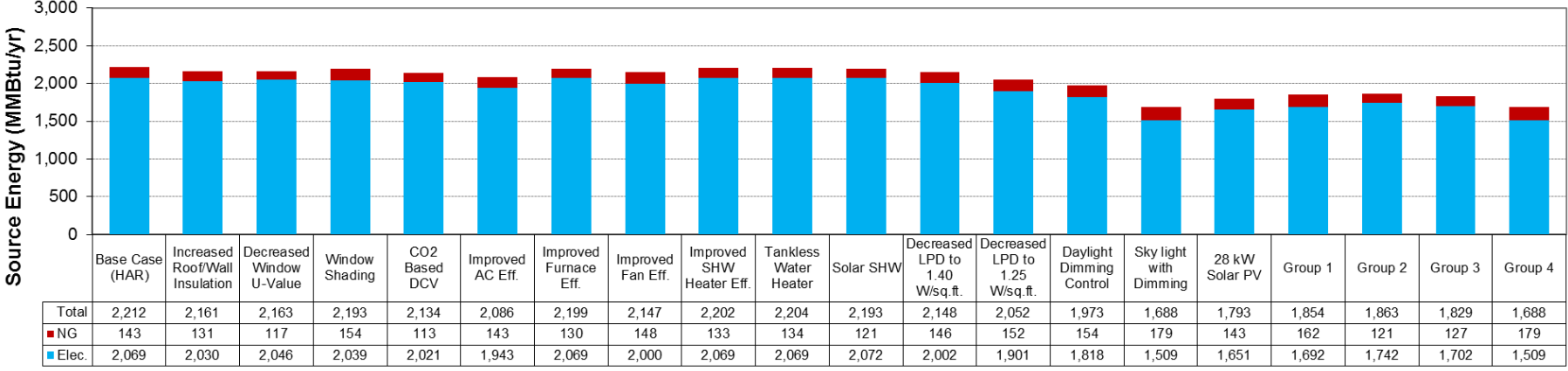


Figure 9. Source Energy Use of Various EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Harris County (Climate Zone 2)

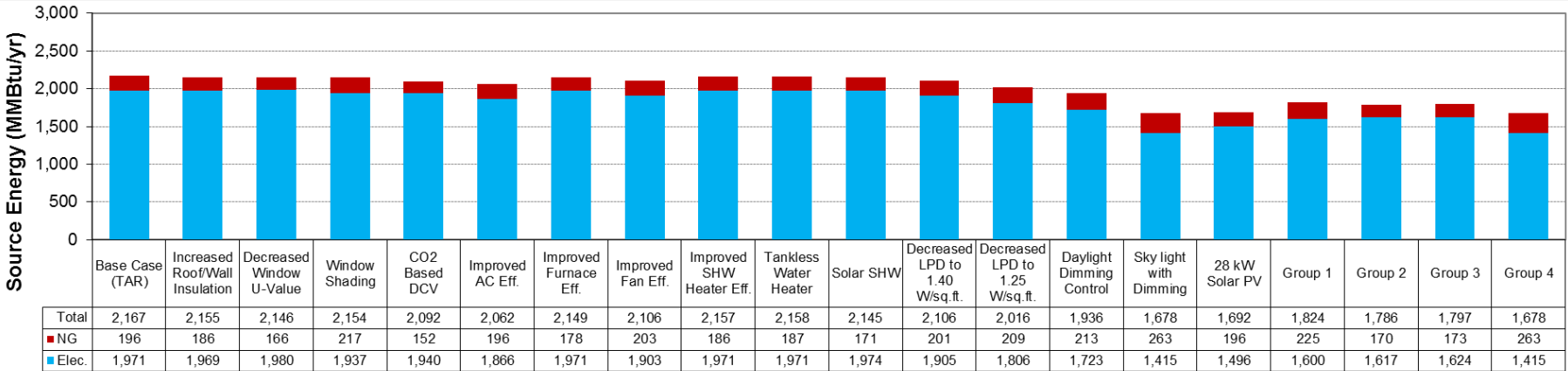


Figure 10. Source Energy Use of Various EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Tarrant County (Climate Zone 3)

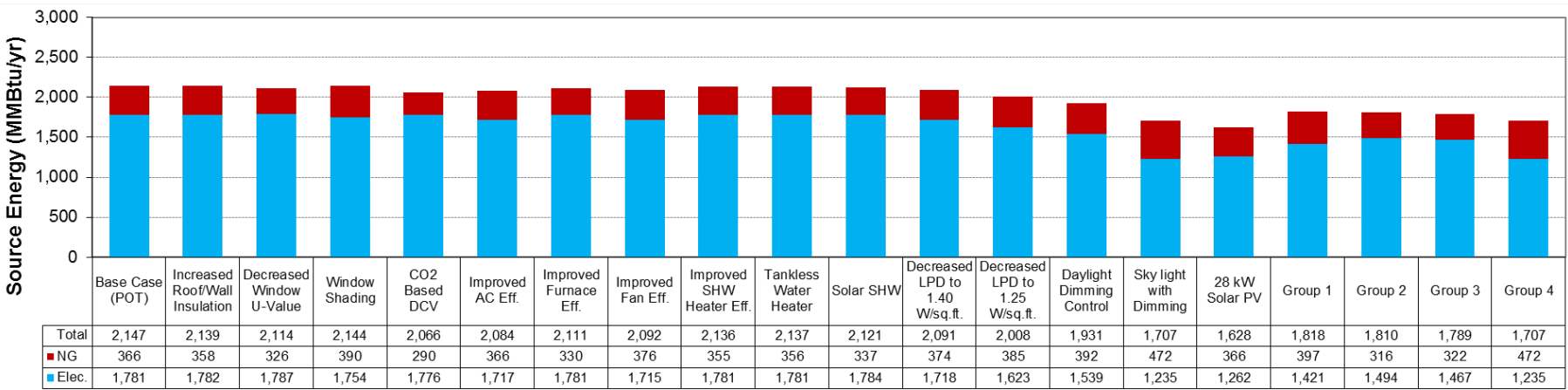
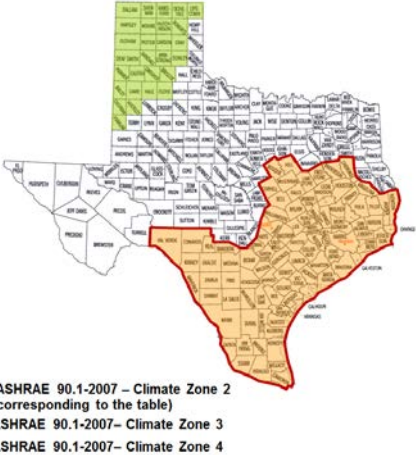


Figure 11. Source Energy Use of Various EEMs for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building in Potter County (Climate Zone 4)

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 5.7c.i. to 11.4c.i. for walls)		\$410	2.6%	\$86	\$496	\$9,179 - \$13,769		18.5 - 27.8
2	Decreased Glazing U-Value (from 0.7 for window & 1.1 for door to 0.35)		\$351	2.6%	\$86	\$438	\$14,414 - \$21,621		32.9 - 49.4
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)		\$201	2.3%	\$76	\$278	\$33,384 - \$50,076		120 - 180
B HVAC System Measures									
4	CO ₂ Based Demand-Controlled Ventilation (DCV)		\$597	4.7%	\$156	\$753	\$5,894 - \$8,841		7.8 - 11.7
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)		\$1,108	9.0%	\$299	\$1,408	\$9,830 - \$14,746		7.0 - 10.5
6	Improved Furnace Efficiency (from 80% to 90% Et)		\$72	0.0%	\$0	\$72	\$6,320 - \$9,480		88.3 - 132
7	Improved Fan Efficiency (from 55% to 65%)		\$584	2.4%	\$80	\$664	\$5,651 - \$8,477		8.5 - 12.8
C Service Hot Water Measures									
8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)		\$53	0.0%	\$0	\$53	\$920 - \$1,380		17.2 - 25.9
9	Tankless Gas Water Heater		\$47	0.0%	\$0	\$47	\$600 - \$900		12.7 - 19.1
10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)		\$97	-0.2%	-\$6	\$91	\$2,880 - \$4,320		31.7 - 47.5
D Lighting Measures									
11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)		\$573	2.9%	\$95	\$668	\$1,247 - \$1,871		1.9 - 2.8
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$1,433	7.2%	\$239	\$1,671	\$3,149 - \$4,723		1.9 - 2.8
13	Daylight Dimming Control		\$2,144	12.2%	\$405	\$2,549	\$15,723 - \$23,584		6.2 - 9.3
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		\$4,727	24.2%	\$802	\$5,529	\$55,700 - \$83,550		10.1 - 15.1
E Renewable Power Measure									
15	28 kW Photovoltaic Array		\$3,688	20.8%	\$689	\$4,377	\$140,000 - \$210,000		32.0 - 48.0



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 Annual (lbs/yr)	SO ₂ Emissions Savings Annual (lbs/yr)	CO ₂ Emissions Savings Annual (tons/yr)
	Site	Source					Marginal Cost ⁴	New System Cost ⁵				
Combination 1												
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$3,215	17.6%	\$581	\$3,797	\$3,149 - \$4,723		5.0 - 7.5	53.8	34.8	22.3
13	Daylight Dimming Control						\$15,723 - \$23,584					
Combination 2												
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)						\$3,149 - \$4,723					
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)		\$3,005	19.6%	\$650	\$3,656	\$9,830 - \$14,746		5.2 - 7.7	49.8	30.1	21.4
4	CO ₂ Based Demand-Controlled Ventilation (DCV)						\$5,894 - \$8,841					
Combination 3												
13	Daylight Dimming Control						\$15,723 - \$23,584					
4	CO ₂ Based Demand-Controlled Ventilation (DCV)		\$3,326	19.0%	\$629	\$3,955	\$5,894 - \$8,841		6.9 - 10.3	55.3	33.9	23.6
7	Improved Fan Efficiency (from 55% to 65%)						\$5,651 - \$8,477					
Combination 4												
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		\$4,727	24.2%	\$802	\$5,529	\$55,700 - \$83,550		10.1 - 15.1	79.2	51.6	32.7

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/kWh
 Natural gas = \$0.63/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-w all ratio: 70% for Front Wall Only (28% for an Entire Building)
 * HVAC system: SEER 13 or EER 11.2 Rooftop PSZ & 80% Et Furnace
 * DHW: 0.594 EF Gas Water heater



Figure 12. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building for Climate Zone 2

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)		\$76	0.1%	\$3	\$78	\$8,337 - \$12,506		106 - 159
2	Decreased Glazing U-Value (from 0.6 for window & 0.9 for door to 0.35)		\$95	0.0%	\$1	\$96	\$9,866 - \$14,799		102 - 153
3	0.5 PF Window Shading (None to 6.75 ft. Overhang)		\$184	2.9%	\$90	\$274	\$33,384 - \$50,076		122 - 183
B HVAC System Measures									
4	CO ₂ Based Demand-Controlled Ventilation (DCV)		\$525	3.4%	\$105	\$630	\$5,894 - \$8,841		9.4 - 14.0
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)		\$924	8.3%	\$259	\$1,183	\$9,830 - \$14,746		8.3 - 12.5
6	Improved Furnace Efficiency (from 80% to 90% Et)		\$104	0.0%	\$0	\$104	\$6,320 - \$9,480		60.6 - 91.0
7	Improved Fan Efficiency (from 55% to 65%)		\$557	2.5%	\$78	\$635	\$5,651 - \$8,477		8.9 - 13.3
C Service Hot Water Measures									
8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)		\$56	0.0%	\$0	\$56	\$920 - \$1,380		16.5 - 24.7
9	Tankless Gas Water Heater		\$50	0.0%	\$0	\$50	\$600 - \$900		12.1 - 18.1
10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)		\$118	-0.2%	-\$6	\$113	\$2,880 - \$4,320		25.5 - 38.3
D Lighting Measures									
11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)		\$552	3.0%	\$93	\$645	\$1,247 - \$1,871		1.9 - 2.9
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$1,376	7.5%	\$233	\$1,609	\$3,149 - \$4,723		2.0 - 2.9
13	Daylight Dimming Control		\$2,086	13.1%	\$408	\$2,494	\$15,723 - \$23,584		6.3 - 9.5
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		\$4,514	26.8%	\$836	\$5,350	\$55,700 - \$83,550		10.4 - 15.6
E Renewable Power Measure									
15	28 kW Photovoltaic Array		\$4,185	21.1%	\$657	\$4,842	\$140,000 - \$210,000		28.9 - 43.4



■ ASHRAE 90.1-2007 – Climate Zone 2
■ ASHRAE 90.1-2007 – Climate Zone 3 (corresponding to the table)
■ ASHRAE 90.1-2007 – Climate Zone 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 Annual (lbs/yr)	SO ₂ Emissions Savings Annual (lbs/yr)	CO ₂ Emissions Savings Annual (tons/yr)
	Site	Source					Marginal Cost ⁴	New System Cost ⁵				
Combination 1												
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$3,109	18.6%	\$579	\$3,688	\$3,149 - \$4,723		5.1 - 7.7	52.1	34.2	21.5
13	Daylight Dimming Control							\$15,723 - \$23,584				
Combination 2												
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		\$3,273	20.5%	\$638	\$3,911	\$3,149 - \$4,723		6.3 - 9.4	54.2	32.7	23.4
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)							\$9,830 - \$14,746				
4	CO ₂ Based Demand-Controlled Ventilation (DCV)							\$5,894 - \$8,841				
7	Improved Fan Efficiency (from 55% to 65%)							\$5,651 - \$8,477				
Combination 3												
13	Daylight Dimming Control		\$3,186	18.9%	\$590	\$3,775	\$15,723 - \$23,584		7.2 - 10.8	52.8	32.0	22.7
4	CO ₂ Based Demand-Controlled Ventilation (DCV)							\$5,894 - \$8,841				
7	Improved Fan Efficiency (from 55% to 65%)							\$5,651 - \$8,477				
Combination 4												
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		\$4,514	26.8%	\$836	\$5,350	\$55,700 - \$83,550		10.4 - 15.6	76.0	51.2	30.8

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/kWh
 Natural gas = \$0.63/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

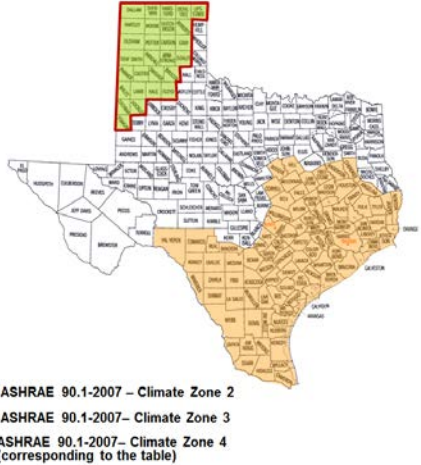
[ASHRAE 90.1-2007 Code-Compliant Retail Building Description]
 * Building type: Small Retail (Strip Mall Type)
 * Gross area: 15,000 sq-ft
 * Building dimension: 61 ft x 245 ft x 17 ft (WxLxH)
 * Number of floors: 1
 * Floor-to-floor height: 17 ft
 * Window-to-wall ratio: 70% for Front Wall Only (28% for an Entire Building)
 * HVAC system: SEER 13 or EER 11.2 Rooftop PSZ & 80% Et Furnace
 * DHW: 0.594 EF Gas Water heater



Figure 13. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building for Climate Zone 3

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 9.5c.i. to 11.4c.i. for walls)		0.8%	0.4%	\$43	-0.2%	-\$5	\$38	\$7,788 - \$11,681	206 - 309
2	Decreased Glazing U-Value (from 0.5 for window & 0.85 for door to 0.35)		3.8%	1.6%	\$170	-0.2%	-\$5	\$165	\$6,671 - \$10,006	40.4 - 60.5
3	0.2 PF Window Shading (None to 2.7 ft. Overhang)		-1.4%	0.1%	\$100	3.1%	\$90	\$190	\$19,968 - \$29,952	105 - 158
B HVAC System Measures										
4	CO ₂ Based Demand-Controlled Ventilation (DCV)		7.9%	3.8%	\$476	1.2%	\$34	\$510	\$5,894 - \$8,841	11.6 - 17.3
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)		2.2%	3.0%	\$560	7.3%	\$210	\$770	\$9,830 - \$14,746	12.8 - 19.2
6	Improved Furnace Efficiency (from 80% to 90% Et)		3.7%	1.7%	\$208	0.0%	\$0	\$208	\$6,320 - \$9,480	30.3 - 45.5
7	Improved Fan Efficiency (from 55% to 65%)		1.3%	2.6%	\$521	2.7%	\$79	\$600	\$5,651 - \$8,477	9.4 - 14.1
C Service Hot Water Measures										
8	Improved Gas Water Heater Efficiency (from 0.594 EF to 0.86 EF)		1.2%	0.5%	\$66	0.0%	\$0	\$66	\$920 - \$1,380	14.0 - 20.9
9	Tankless Gas Water Heater		1.0%	0.5%	\$59	0.0%	\$0	\$59	\$600 - \$900	10.2 - 15.3
10	Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)		2.8%	1.2%	\$140	-0.2%	-\$6	\$134	\$2,880 - \$4,320	21.4 - 32.2
D Lighting Measures										
11	Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.4 W/sq.ft.)		1.5%	2.6%	\$514	3.2%	\$93	\$607	\$1,247 - \$1,871	2.1 - 3.1
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		3.7%	6.5%	\$1,284	8.1%	\$233	\$1,517	\$3,149 - \$4,723	2.1 - 3.1
13	Daylight Dimming Control		5.9%	10.1%	\$1,986	14.5%	\$417	\$2,403	\$15,723 - \$23,584	6.5 - 9.8
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		8.5%	20.5%	\$4,208	29.4%	\$849	\$5,056	\$55,700 - \$83,550	11.0 - 16.5
E Renewable Power Measure										
15	28 kW Photovoltaic Array		18.3%	24.2%	\$4,570	25.3%	\$729	\$5,298	\$140,000 - \$210,000	26.4 - 39.6



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 Annual (lbs/yr)	SO ₂ Emissions Savings Annual (lbs/yr)	CO ₂ Emissions Savings Annual (tons/yr)	
	Site	Source					Marginal Cost ⁴	New System Cost ⁵					
Combination 1													
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		9.6%	15.3%	\$2,996	20.1%	\$579	\$3,575	\$3,149 - \$4,723	5.4 - 8.2	50.3	33.2	20.7
13	Daylight Dimming Control								\$15,723 - \$23,584				
9	Tankless Gas Water Heater								\$600 - \$900				
Combination 2													
12	Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)		15.2%	15.7%	\$2,817	18.6%	\$537	\$3,353	\$3,149 - \$4,723	7.3 - 11.0	46.4	26.5	20.5
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)								\$9,830 - \$14,746				
4	CO ₂ Based Demand-Controlled Ventilation (DCV)								\$5,894 - \$8,841				
7	Improved Fan Efficiency (from 55% to 65%)								\$5,651 - \$8,477				
Combination 3													
13	Daylight Dimming Control		15.6%	16.7%	\$3,017	18.5%	\$533	\$3,550	\$15,723 - \$23,584	7.7 - 11.5	49.8	28.9	21.8
4	CO ₂ Based Demand-Controlled Ventilation (DCV)								\$5,894 - \$8,841				
7	Improved Fan Efficiency (from 55% to 65%)								\$5,651 - \$8,477				
Combination 4													
14	Sky light (3% SRR, U-0.34 & 0.19 SHGC) with Dimming Control		8.5%	20.5%	\$4,208	29.4%	\$849	\$5,056	\$55,700 - \$83,550	11.0 - 16.5	71.3	50.3	28.2

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/kWh
 Natural gas = \$0.63/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-w all ratio: 70% for Front Wall Only (28% for an Entire Building)
 * HVAC system: SEER 13 or EER 11.2 Rooftop PSZ & 80% Et Furnace
 * DHW: 0.594 EF Gas Water heater



Figure 14. Individual and Combined Energy Efficiency Measures for an ASHRAE 90.1-2007 Code-Compliant Small Retail Building for Climate Zone 4

5 SUMMARY

This report presents cost-effective recommendations to maximize energy savings for small retail buildings across the State of Texas. A total of 15 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. These measures were then combined to achieve the total source energy savings of the group is 15% above the base-case, ASHRAE 90.1-2007 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 (NO_x, SO₂, and CO₂) 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. Table A-1 summarizes the cost information for all measures, and the detailed product information and resources are listed in Table A-2 to Table A-6.

Table A-1. Summary of the Cost Information for an ASHRAE 90.1-2007 Code-Compliant Base Case

EEMs for ASHRAE 90.1-2007 Base Case	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 20 to 25 for roof and from 5.7c.i. (CZ2), 7.6c.i. (CZ3), and 9.5c.i. (CZ4) to 11.4c.i. for walls)	hr-sq.ft.-°F/Btu	20	25	sq.ft.	\$0.55			15,000	\$8,250	\$9,179	\$11,474	\$13,769	RSMMeans CostWorks ver. 4.7.0 (RCD 2011)			
			5.7 c.i.	11.4c.i.	sq.ft.	\$0.43			7,489	\$3,224							
			20	25	sq.ft.	\$0.55			15,000	\$8,250							
			7.6 c.i.	11.4c.i.	sq.ft.	\$0.29			7,489	\$2,172							
			20	25	sq.ft.	\$0.55			15,000	\$8,250							
			9.5 c.i.	11.4c.i.	sq.ft.	\$0.14			7,489	\$1,069	\$7,455	\$9,319	\$11,182				
2	Decreased Glazing U-Value (from 0.7 & 1.1 (CZ2), 0.6 & 0.9 (CZ3), and 0.5 & 0.85 (CZ4) to 0.35)	U-Value	0.7 (Window) 1.1 (Door)	0.35	sq.ft.	\$6.18			2,916	\$18,018	\$14,414	\$18,018	\$21,621	PNNL AEDG TSD- Small Office (Jamagin et al. 2006)			
			0.6 (Window) 0.9 (Door)	0.35	sq.ft.	\$4.23			2,916	\$12,333					\$9,866	\$12,333	\$14,799
			0.5 (Window) 0.85 (Door)	0.35	sq.ft.	\$2.86			2,916	\$8,338					\$6,671	\$8,338	\$10,006
3	Window Shading (None to 6.75 ft. (0.5 PF for CZ2&3) and 2.70 ft (0.2 PF for CZ4) Overhang)	Depth (ft)	0	6.75	length feet	\$214			195	\$41,730	\$33,384	\$41,730	\$50,076	RSMMeans CostWorks ver. 4.7.0 (RCD 2011)			
			0	2.7	length feet	\$128			195	\$24,960					\$19,968	\$24,960	\$29,952
4	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			
5	Improved Air Conditioner Efficiency (from 13 SEER & 11.2 EER to 18 SEER & 13.5 EER)	SEER (<65 kBtu/h) EER (≥65 and <135 kBtu/h)	13 SEER 11.2 EER	18 SEER 13.5 EER	each	\$1,536	8			\$12,288	\$9,830	\$12,288	\$14,746	Kim et al. 2010			
6	Improved Furnace Efficiency (from 80% to 90% Et)	Et (%)	80%	90%	each	\$988	8			\$7,900	\$6,320	\$7,900	\$9,480	Kim et al. 2010			
7	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	RSMMeans CostWorks ver. 4.7.0 (RCD 2011)			
8	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			
9	Tankless Gas Water Heater	EF	0.59	0.82	each	\$750	1			\$750	\$600	\$750	\$900	ACEEE 2011			
10	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 et al. 2010			
11	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	RSMMeans CostWorks ver. 4.7.0 (RCD 2011)			
12	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	RSMMeans CostWorks ver. 4.7.0 (RCD 2011)			
13	Daylight Dimming Control	Daylight Dimming Controls	No	Yes	each	\$1,228	16			\$19,653	\$15,723	\$19,653	\$23,584	RSMMeans CostWorks ver. 4.7.0 (RCD 2011)			
14	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	RSMMeans CostWorks ver. 4.7.0 (RCD 2011)			
15	28 kW Photovoltaic Array	PV	No	28 kW Photovoltaic Array	\$/watt	\$6.25	28			\$175,000	\$140,000	\$175,000	\$210,000	Kim et al. 2010			

Table A-2. Cost Information for Envelope and Fenestration Measures

EEM 1:
Increased Roof and Wall Insulation R-Value

	Description	Total Roof/Wall Area (sq.ft.)	Increased Unit Cost (\$/sq.ft.)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007 (Harris, CZ2)	Roof Insulation R-Value: R = 20	15,000	\$ -	\$ -	\$ -	\$ -	Table <i>Increased Roof Insulation R-Value (1)</i> and <i>Increased Wall Insulation R-Value (1)</i>
	Wall Insulation R-Value: R = 13 + 5.7 c.i.	7,489	\$ -	\$ -	\$ -	\$ -	
EEM	Roof Insulation R-Value: R = 25	15,000	\$ 0.55	\$ 6,600	\$ 8,250	\$ 9,900	
	Wall Insulation R-Value: R = 13 + 11.4 c.i.	7,489	\$ 0.43	\$ 2,579	\$ 3,224	\$ 3,869	
Base Case_2007 (Tarrant, CZ3)	Roof Insulation R-Value: R = 20	15,000	\$ -	\$ -	\$ -	\$ -	
	Wall Insulation R-Value: R = 13 + 7.6 c.i.	7,489	\$ -	\$ -	\$ -	\$ -	
EEM	Roof Insulation R-Value: R = 25	15,000	\$ 0.55	\$ 6,600	\$ 8,250	\$ 9,900	
	Wall Insulation R-Value: R = 13 + 11.4 c.i.	7,489	\$ 0.29	\$ 1,737	\$ 2,172	\$ 2,606	
Base Case_2007 (Potter, CZ4)	Roof Insulation R-Value: R = 20	15,000	\$ -	\$ -	\$ -	\$ -	
	Wall Insulation R-Value: R = 13 + 9.5 c.i.	7,489	\$ -	\$ -	\$ -	\$ -	
EEM	Roof Insulation R-Value: R = 25	15,000	\$ 0.55	\$ 6,600	\$ 8,250	\$ 9,900	
	Wall Insulation R-Value: R = 13 + 11.4 c.i.	7,489	\$ 0.14	\$ 855	\$ 1,069	\$ 1,282	

References:
Increased Roof Insulation R-Value (1)

	Description	Mat. Cost (\$/sq.ft.)	Labor Cost (\$/sq.ft.)	Bare Total (\$/sq.ft.)	Total O&P (\$/sq.ft.)	Total Roof Area (sq.ft.)	Total Roof Cost (\$)	Total Increased Cost	Source
Base Case_2007	Extruded polystyrene insulation, for roof decks, 3" thick, R15, 15 PSI compressive strength	\$ 1.04	\$ 0.19	\$ 1.23	\$ 1.47	\$ 15,000	\$ 22,050	\$ -	RSMean-CostWorks for Dallas Year 2011
	Roof Deck Insulation, extruded polystyrene, 3" thick, R15, 25 PSI compressive strength	\$ 1.58	\$ 0.19	\$ 1.77	\$ 2.06	\$ 15,000	\$ 30,900		
EEM	Roof Deck Insulation, install polystyrene insulation, 4" thick, R20, 15 PSI compressive	\$ 1.37	\$ 0.19	\$ 1.56	\$ 1.83	\$ 15,000	\$ 27,450	\$ 8,250	
	Roof Deck Insulation, extruded polystyrene, 4" thick, R20, 25 PSI compressive strength	\$ 2.26	\$ 0.19	\$ 2.45	\$ 2.80	\$ 15,000	\$ 42,000		

Increased Wall Insulation R-Value (1)

	Description	Mat. Cost (\$/sq.ft.)	Labor Cost (\$/sq.ft.)	Bare Total (\$/sq.ft.)	Total O&P (\$/sq.ft.)	Total Wall Area (sq.ft.)	Total Wall Cost (\$)	Total Increased Cost	Source
Base Case_2007 (Harris, CZ2)	Wall Insulation, Rigid, expanded polystyrene, 1.5" thick, estimated R5.77	\$ 0.39	\$ 0.31	\$ 0.70	\$ 0.91	\$ 7,489	\$ 6,810	\$ -	RSMeans-CostWorks for Dallas Year 2011 ver. 4.10 (Accessed date: 2/14/12)
Base Case_2007 (Tarrant, CZ3)	Wall Insulation, Rigid, expanded polystyrene, 2" thick, R7.69	\$ 0.52	\$ 0.31	\$ 0.83	\$ 1.05	\$ 7,489	\$ 7,863	\$ -	
Base Case_2007 (Potter, CZ4)	Wall Insulation, Rigid, expanded polystyrene, 2.5" thick, estimated R9.59	\$ 0.65	\$ 0.31	\$ 0.96	\$ 1.20	\$ 7,489	\$ 8,966	\$ -	
EEM(Harris, CZ2)	Wall Insulation, Rigid, expanded polystyrene, 3" thick, R11.49	\$ 0.78	\$ 0.31	\$ 1.09	\$ 1.34	\$ 7,489	\$ 10,035	\$ 3,224	
EEM(Tarrant, CZ3)	Wall Insulation, Rigid, expanded polystyrene, 3" thick, R11.50	\$ 0.78	\$ 0.31	\$ 1.09	\$ 1.34	\$ 7,489	\$ 10,035	\$ 2,172	
EEM(Potter, CZ4)	Wall Insulation, Rigid, expanded polystyrene, 3" thick, R11.51	\$ 0.78	\$ 0.31	\$ 1.09	\$ 1.34	\$ 7,489	\$ 10,035	\$ 1,069	

EEM 2:
Decreased Glazing U-value

	Description	Total Glass Area (sq.ft.)	Increased Unit Cost (\$/sq.ft.)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007 (Harris, CZ2)	Double pane windows: U = 0.70(window) & 1.1(door)	2,916	\$ -	\$ -	\$ -	\$ -	Table Decreased Glazing U-Value (2)
EEM	Double pane with low-e coating: U = 0.35	2,916	\$ 6.18	\$ 14,414	\$ 18,018	\$ 21,621	
Base Case_2007 (Tarrant, CZ3)	Double pane windows: U = 0.60(window) & 0.9(door)	2,916	\$ -	\$ -	\$ -	\$ -	
EEM	Double pane with low-e coating: U = 0.35	2,916	\$ 4.23	\$ 9,866	\$ 12,333	\$ 14,799	
Base Case_2007 (Potter, CZ4)	Double pane windows: U = 0.50(window) & 0.85(door)	2,916	\$ -	\$ -	\$ -	\$ -	
EEM	Double pane with low-e coating: U = 0.35	2,916	\$ 2.86	\$ 6,671	\$ 8,338	\$ 10,006	

References:

Decreased Glazing U-Value (1)

	Description	Mat. Cost (\$/sq.ft.)	Labor Cost (\$/sq.ft.)	Bare Total (\$/sq.ft.)	Total O&P (\$/sq.ft.)	Total Glass Area (sq.ft.)	Total Glazing Cost (\$)	Total Increased Cost	Source
Base Case_2007 (Tarrant, CZ3)	Insulating Glass, double glazed, 5/8" thick unit, 3/16" float, 15-30 S.F., clear	\$ 13.4	\$ 3.32	\$ 16.7	\$ 19.7	\$ 2,916	\$ 57,348	\$ -	RSMeans-CostWorks for Dallas Year 2011
	Spectrally selective film, on ext, blocks solar gain/allows 70% of light	\$ 10.1	\$ 3.15	\$ 13.3	\$ 15.9	\$ 2,916	\$ 46,211		
EEM	Code_2007 with spectrally selective film (low-e coating)	\$ 23.5	\$ 6.47	\$ 29.9	\$ 35.5	\$ 2,916	\$ 103,559	\$ 46,211	

Decreased Glazing U-value (2)

	Description	Increased Unit Cost (\$/sq.ft.)	Total Glass Area (sq.ft.)	Total Increased Cost (\$)	Source
Base Case_2007 (Harris, CZ2)	U-value (Btu/hr-sq.ft.-F): 0.72	\$ 3.90	2,916	\$ -	PNL AEDG TSD-Small Office Buildings: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16250.pdf
Base Case_2007 (Tarrant, CZ3)	U-value (Btu/hr-sq.ft.-F): 0.60	\$ 5.85	2,916	\$ -	
Base Case_2007 (Potter, CZ4)	U-value (Btu/hr-sq.ft.-F): 0.46	\$ 7.22	2,916	\$ -	
EEM(Harris, CZ2)	U-value (Btu/hr-sq.ft.-F): 0.36	\$ 9.56	2,916	\$ 18,018	
EEM(Tarrant, CZ3)	U-value (Btu/hr-sq.ft.-F): 0.34	\$ 10.6	2,916	\$ 12,333	
EEM(Potter, CZ4)	U-value (Btu/hr-sq.ft.-F): 0.34	\$ 10.1	2,916	\$ 8,338	

**EEM 3:
6.75' & 2.7' Overhang**

	Description	Total Overhang Length (ft.)	Increased Unit Cost (\$/ft.)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	No window shading	195	\$ -	\$ -	\$ -	\$ -	Table <i>Overhang (1)</i> and <i>(2)</i>
EEM (Harris, CZ2 & Tarrant, CZ3)	6.75' overhang	195	\$ 214	\$ 33,384	\$ 41,730	\$ 50,076	
EEM (Potter, CZ4)	2.70' overhang	195	\$ 128	\$ 19,968	\$ 24,960	\$ 29,952	

**References:
Overhang (1)**

	Description	Mat. Cost (\$/sq.ft. or ft.)	Labor Cost (\$/sq.ft. or ft.)	Bare Equipment (\$/sq.ft. or ft.)	Bare Total (\$/sq.ft.)	Total O&P (\$/sq.ft.)	Total Overhang Area(sq.ft.) or Length (ft.)	Total Overhang Cost (\$)	Increased Unit Cost (\$/ft.)	Source
EEM	Metal canopies, wall hung, .032", aluminum, prefinished, 8'X10'	\$ 26.9	\$ 8.33	\$ 2.05	\$ 37.3	\$ 45.9	1,316	\$ 60,477	\$ 214	RSMean-CostWorks for Dallas Year 2011
	Metal canopies, wall hung, .032", aluminum, prefinished, 8'X20'	\$ 26.7	\$ 4.93	\$ 1.21	\$ 32.9	\$ 39.1	1,316	\$ 51,520		
EEM	Awning, fabric, including acrylic canvas and frame, standard design, door and window, slope 3'high, 6' wide	\$ 119	\$ 11.4	\$ -	\$ 130	\$ 148	195	\$ 28,840		
	Awning, fabric, including acrylic canvas and frame, standard design, door and window, slope 3'high, 8' wide	\$ 110	\$ 9.99	\$ -	\$ 120	\$ 135	195	\$ 26,336		

Overhang (2)

	Description	Mat. Cost (\$/sq.ft. or ft.)	Labor Cost (\$/sq.ft. or ft.)	Bare Equipment (\$/sq.ft. or ft.)	Bare Total (\$/sq.ft.)	Total O&P (\$/sq.ft.)	Total Overhang Area(sq.ft.) or Length (ft.)	Total Overhang Cost (\$)	Increased Unit Cost (\$/ft.)	Source
EEM	Metal canopies, wall hung, .032", aluminum, prefinished, 8'X10'	\$ 26.9	\$ 8.33	\$ 2.05	\$ 37.3	\$ 45.9	527	\$ 24,191	\$ 128	RSMean-CostWorks for Dallas Year 2011
	Metal canopies, wall hung, .032", aluminum, prefinished, 8'X20'	\$ 26.7	\$ 4.93	\$ 1.21	\$ 32.9	\$ 39.1	527	\$ 20,608		
EEM	Awning, fabric, including acrylic canvas and frame, standard design, door and window, slope 3'high, 6' wide	\$ 119	\$ 11.4	\$ -	\$ 130	\$ 148	195	\$ 28,840		
	Awning, fabric, including acrylic canvas and frame, standard design, door and window, slope 3'high, 8' wide	\$ 110	\$ 9.99	\$ -	\$ 120	\$ 135	195	\$ 26,336		

Table A-3. Cost Information for HVAC System Measures

EEM 4:
Outside Air Demand Control

	Description	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	No Outside Air Demand Control	0	\$ -	\$ -	\$ -	\$ -	Table <i>Outside Air Demand Control(1)</i>
EEM	Outside Air Demand Control	8	\$ 921	\$ 5,894	\$ 7,367	\$ 8,841	

References:
Outside Air Demand Control (1)

	Company	Cost Per Unit (\$/unit)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source
EEM: Sensor	Digital Control Systems Inc.	\$ 262	8	\$ 321	\$ 2,567	esource: http://www.esource.com/BEA/hotbed/Xcel/PA_53.html
	Honeywell Control Products	\$ 350	8			
	Johnson Controls Inc.	\$ 630	8			
	Telaire Systems Inc.	\$ 150 to \$ 200	8			
	Texas Instruments Inc.	\$ 265 to \$ 318	8			
	Vaisala Inc.	\$ 335	8			
	Veris Industries Inc.	\$ 378	8			
EEM: Implementing	Implementing DCV on a newer DCV-ready RTU with an existing economizer	\$ 300 to \$ 900	8	\$ 600	\$ 4,800	

**EEM 5:
Improved Air Conditioner Efficiency**

	Description	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	SEER (<65,000 Btu/h): 13 SEER EER (≥135,000 Btu/h and <240,000 Btu/h): 11.2 EER	8	\$ -	\$ -	\$ -	\$ -	Table <i>Improved Air Conditioner Efficiency (1)</i>
EEM	SEER (<65,000 Btu/h): 18 SEER EER (≥135,000 Btu/h and <240,000 Btu/h): 13.5 EER	8	\$ 1,536	\$ 9,830	\$ 12,288	\$ 14,746	

**References:
Improved Air Conditioner Efficiency (1)**

	Description	Cost Per Unit (\$/unit)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source
Base Case_2007	R-22 phase out refrigerant: Pilot-free PowerHeat™ ignition	\$ 5,100	8	\$ -	\$ -	Residential Cost Analysis
	R-410A EPA complain refrigerant: Pilot-free PowerHeat™ ignition	\$ 5,100	8			
	Ref. Type: R-22, Gas Furnace: 135000 Btu/hr	\$ 3,987	8			
	\$12,000 includes duct work	\$ 4,500	8			
EEM	R-22 phase out refrigerant: Pilot-free PowerHeat™ ignition	\$ 6,400	8	\$ 1,536	\$ 12,288	
	R-410A EPA complain refrigerant: Pilot-free PowerHeat™ ignition	\$ 6,400	8			
	Ref. Type: R-410A, Gas Furnace: 135000 Btu/hr	\$ 6,295	8			
	\$13,000 includes duct work	\$ 5,500	8			

EEM 6:
Improved Furnace Efficiency

	Description	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	80%	8	\$ -	\$ -	\$ -	\$ -	Table <i>Improved Furnace Efficiency (1)</i>
EEM	90%	8	\$ 988	\$ 6,320	\$ 7,900	\$ 9,480	

References:
Improved Furnace Efficiency (1)

	Description	Cost Per Unit (\$/unit)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source
Base Case_2007	Performance 80 Gas Furnace; Induced-combustion; Enhanced comfort control with dual stages of heating; 4-5 speed blower; Pilot-free PowerHeat™ ignition	\$ 2,700	8	\$ -	\$ -	Residential Cost Analysis
	Up/Horiz	\$ 827	8			
EEM	Performance 93 Gas Furnace; Multipoise condensing; direct vent/non direct vent; 4-5 speed blower; Pilot-free PowerHeat™ ignition	\$ 3,460	8	\$ 988	\$ 7,900	
	Lennox Signature® Collection G61 94.1%AFUE Two-Stage, Multi-Speed Furnaces. Up/Horiz./Down	\$ 2,042	8			

EEM 7:
Improved Fan Efficiency

	Description	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	55%	6	\$ -	\$ -	\$ -	\$ -	Table <i>Improved Fan Efficiency (1)</i>
		2	\$ -				
EEM	65%	6	\$ 761	\$ 5,651	\$ 7,064	\$ 8,477	
		2	\$ 1,249				

References:

Improved Fan Efficiency (1)

	Description	Mat. Cost (\$/sq.ft.)	Labor Cost (\$/sq.ft.)	Bare Total (\$/sq.ft.)	Total O&P (\$/sq.ft.)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost	Source
Base Case_2007	Axial Flow, constant speed; Direct drive, 1/8" S.P.; 12", 1060 CFM, 1/6 HP	\$ 560	\$ 195	\$ 755	\$ 910	6	\$ -	\$ -	RSMeans-CostWorks for Dallas Year 2011
	Axial Flow, constant speed; Direct drive, 1/8" S.P.; 22", 4700 CFM, 3/4 HP	\$ 1,175	\$ 226	\$ 1,401	\$ 1,613	2			
EEM	In-line centrifugal, supply/exhaust booster; aluminum wheel/hub, disconnect switch; 1,380 CFM, 12" diameter connection	\$ 1,225	\$ 291	\$ 1,516	\$ 1,790	6	\$ 761	\$ 7,064	
	In-line centrifugal, supply/exhaust booster; aluminum wheel/hub, disconnect switch; 5,080 CFM, 20" diameter connection	\$ 1,875	\$ 775	\$ 2,650	\$ 3,228	2	\$ 1,249		

Table A-4 Cost Information for Service Hot Water Measures

EEM 8:
Improved SHW Heater Efficiency

	Description	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	85%	1	\$ -	\$ -	\$ -	\$ -	Table <i>Improved SHW Heater Efficiency (1)</i>
EEM	95%	1	\$ 1,150	\$ 920	\$ 1,150	\$ 1,380	

References:
Improve SHW Heater Efficiency (1)

	Description	Cost Per Unit (\$/unit)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source
Base Case_2007	Conventional Gas Storage	\$ 850	1	\$ -	\$ -	ACEEE 2011
EEM	Condensing Gas Storage	\$ 2,000	1	\$ 1,150	\$ 1,150	

EEM 9:
Tankless Gas Water Heater

	Description	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	DHW Tank Heat Loss: 0.74% DHW Pump Electric Power: 0.00381	1	\$ -	\$ -	\$ -	\$ -	Table <i>Tankless Gas Water Heater (1)</i>
EEM	DHW Tank Heat Loss: 0.13% DHW Pump Electric Power: 0	1	\$ 750	\$ 600	\$ 750	\$ 900	

References:
Tankless Gas Water Heater (1)

	Description	Cost Per Unit (\$/unit)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source
EEM	Conventional Gas Storage	\$ 850	1	\$ 750	\$ 750	ACEEE 2011
	Demand Gas (No Pilot) 5	\$ 1,600	1			

EEM 10:
Solar Service Hot Water System

	Description	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	No Solar Service Hot Water System		\$ -	\$ -	\$ -	\$ -	Table <i>Solar Service Hot Water System (1)</i>
EEM	64 sq.ft. collector, 80 gal tank	1	\$ 3,600	\$ 2,880	\$ 3,600	\$ 4,320	

References:
Solar Service Hot Water System (1)

	Description	2010 Equipment Cost (\$)	Installation Cost (\$)	Cost Per Unit (\$/unit)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source
EEM	64 sq. ft collector 80 Gallon	\$3200-\$4000	n/a	\$ 3,200 to \$ 4,000	1	\$ 3,600	\$ 3,600	Residential Cost Analysis

Table A-5. Cost Information for Lighting Measures

EEM 11:
Decreased Lighting Power Density based on ASHRAE 90.1-2010 (from 1.5 to 1.25 W/sq.ft.)

	Description		Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
					-20%	(AVG)	20%	
Base Case_2007	1.5 W/sq.ft. (Total Unit: 502)	Halogen	335	\$ -	\$ -	\$ -	\$ -	Table <i>Decreased Lighting Power Density (1)</i>
		LED	0					
		T12	0					
		T8	18					
		T5	149					
EEM	1.4 W/sq.ft. (Total Unit: 502)	Halogen	307	\$ -	\$ 1,247	\$ 1,559	\$ 1,871	
		LED	28	\$ 41.0				
		T12	0	\$ -				
		T8	0	\$ -				
		T5	167	\$ 23.3				

References:
Decreased Lighting Power Density (1)

	Description	Cost Per Unit (\$/unit)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source
Base Case_2007	Halogen	\$ 16.6	335	\$ -	\$ -	RSMMeans-CostWorks for Dallas Year 2011
	LED	\$ 57.6	0			
	T12	\$ 136	0			
	T8	\$ 153	18			
	T5	\$ 176	149			
EEM	Halogen	\$ 16.6	307	\$ -	\$ -	
	LED	\$ 57.6	28	\$ 41.0	\$ 1,140	
	T12	\$ 136	0	\$ -	\$ -	
	T8	\$ 153	0	\$ -	\$ -	
	T5	\$ 176	167	\$ 23.3	\$ 419	

EEM 12:
Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.5 to 1.25 W/sq.ft.)

	Description		Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
					-20%	(AVG)	20%	
Base Case_2007	1.5 W/sq.ft. (Total Unit: 502)	Halogen	335	\$ -	\$ -	\$ -	\$ -	Table <i>Decreased Lighting Power Density (2)</i>
		LED	0					
		T12	0					
		T8	18					
		T5	149					
EEM	1.25 W/sq.ft. (Total Unit: 502)	Halogen	249	\$ -	\$ 3,149	\$ 3,936	\$ 4,723	
		LED	86	\$ 41.0				
		T12	0	\$ -				
		T8	0	\$ -				
		T5	167	\$ 23.3				

References:

Decreased Lighting Power Density (2)

	Description	Cost Per Unit (\$/unit)	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source
Base Case_2007	Halogen	\$ 16.6	335	\$ -	\$ -	RSMMeans-CostWorks for Dallas Year 2011
	LED	\$ 57.6	0			
	T12	\$ 136	0			
	T8	\$ 153	18			
	T5	\$ 176	149			
EEM	Halogen	\$ 16.6	249	\$ -	\$ -	
	LED	\$ 57.6	86	\$ 41.0	\$ 3,517	
	T12	\$ 136	0	\$ -	\$ -	
	T8	\$ 153	0	\$ -	\$ -	
	T5	\$ 176	167	\$ 23.3	\$ 419	

**EEM 13:
Daylight Dimming Control**

	Description	Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	No daylight dimming control	16	\$ -				Table <i>Daylight Dimming Control (1)</i>
EEM	Daylihgdt dimming control	16	\$ 1,228	\$ 15,723	\$ 19,653	\$ 23,584	

References:

Daylight Dimming Control (1)

	Description	Cost Per Unit (\$/unit)		Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)	Source	
EEM (WattStopper)	Dimming Ballasts	\$ 50	\$ 100	\$ 1,032	16		http://www.wattstopper.com/	
	Dimming photocell	\$ 140						
	Handheld programming remote	\$ 25						
	OCC sensor	\$ 140						
	PowerPack	\$ 27						
EEM (CW Lighting)	Ballasts	\$ 50	\$ 100	\$ 1,230	16	\$ 1,228	\$ 19,653	http://www.cwlighting.com/
	Dimming control module	\$ 300						
	Lighting Sensors	\$ 150						
	Wiring	\$ 5						
	PowerPack	\$ 75						
EEM (RS Means)	Daylight dimming control module	\$ 615	included in unit costs	\$ 1,423	16		RSMMeans-CostWorks for Dallas Year 2011	
	Daylight Sensor, ceiling mounted	\$ 208						

EEM 14:
Sky light with Dimming Control

	Description	Total Sky Light Area (sq.ft.) or Unit	Increased Unit Cost (\$/unit)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	0% of roof area	496	\$ -				Table <i>Daylight Dimming Control (1)</i> and <i>Sky Light (1)</i>
	No daylight dimming control	16	\$ -				
EEM	3% of roof area (U-0.34 & 0.19 SHGC)	496	\$ 101	\$ 55,700	\$ 69,625	\$ 83,550	
	Dayliht dimming control	16	\$ 1,228				

References:
Sky Light (1)

	Description	Increased Unit Cost (\$/sq.ft.)	Total Glass Area (sq.ft.)	Total Increased Cost (\$)	Source
EEM	3% of roof area (U-0.34 & 0.19 SHGC)	101	496	\$ 49,972	RSMMeans-CostWorks for Dallas Year 2011

Table A-6. Cost Information for Renewable Power Measure

EEM 15:
Photovoltaic Array

	Description	Unit	Increased Unit Cost (\$/watt)	Total Increased Cost (\$)			Remarks
				-20%	(AVG)	20%	
Base Case_2007	No PV Array		\$ -	\$ -	\$ -	\$ -	Table <i>Photovoltaic Array (1)</i>
EEM	28kW PV Array	28	\$ 6.25	\$ 140,000	\$ 175,000	\$ 210,000	

References:
Photovoltaic Array (1)

	Description	Capacity	Equipment Cost (\$)	Installation Cost (\$)	Total Increased Cost (\$)	Source
EEM	4 kW PV Array	4 kW	\$10,000-\$20,000	\$10,000	\$20,000-\$30,000	Residential Cost Analysis