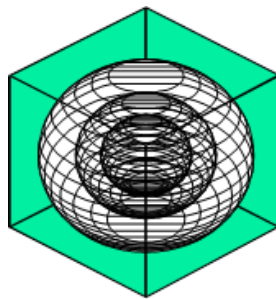


COST-EFFECTIVE ENERGY EFFICIENCY MEASURES FOR ABOVE CODE (ASHRAE 90.1-2001 and 2007) SMALL RETAIL BUILDINGS IN THE CITY OF ARLINGTON

A Research Project for the City of Arlington

**October 5, 2011
(Revised: January 5, 2012)**



ENERGY SYSTEMS LABORATORY

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

Background

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



Methodology

- ▶ ESL simulation model based on the DOE-2.2 of ASHRAE 90.1-2001 and 2007 code-compliant, small retail building for Tarrant County
- ▶ A total of 16 energy efficiency measures (EEMs)
- ▶ Solar measures using PV-F Chart and F-Chart programs
- ▶ Implementation costs of each measure with simple payback

Methodology

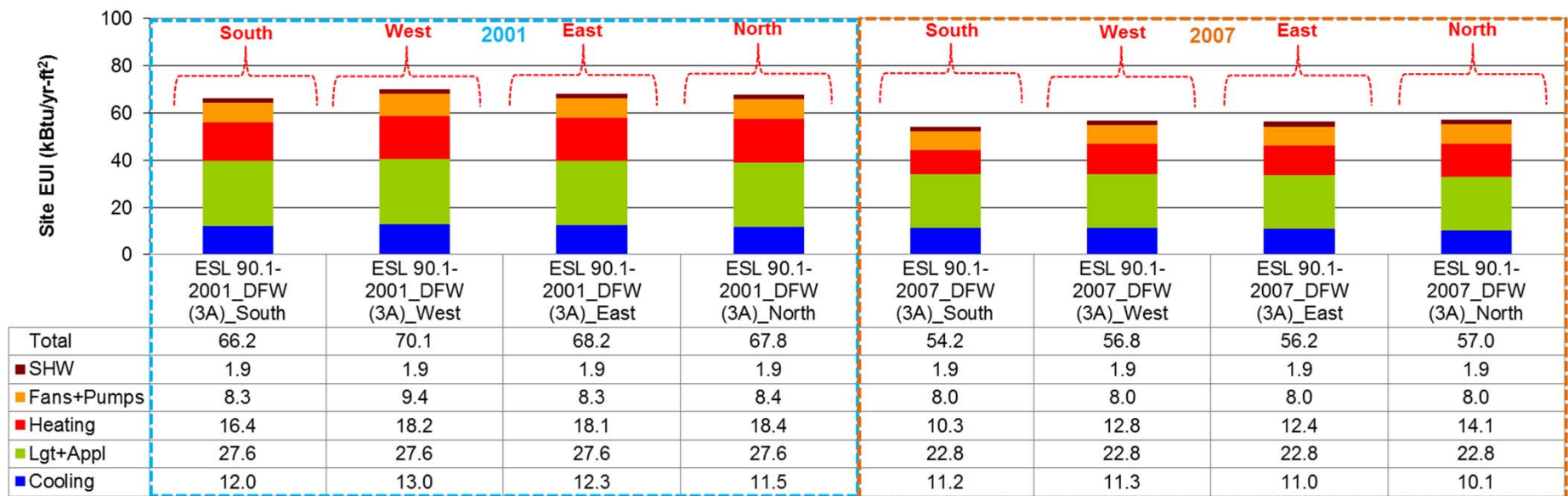
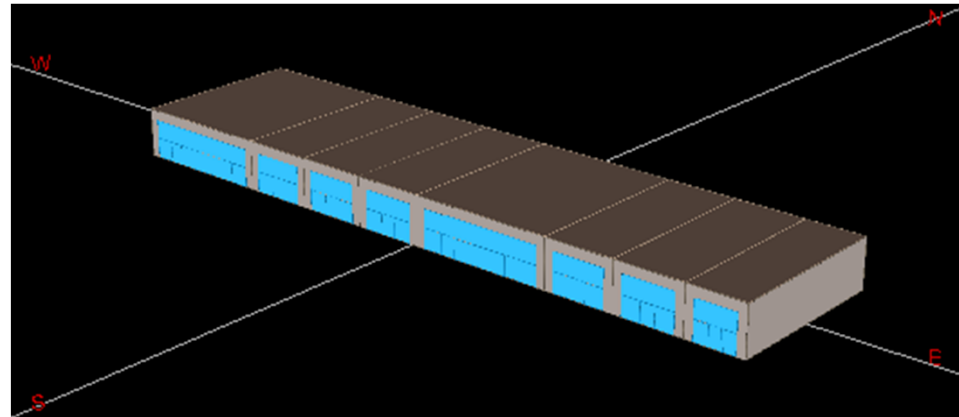
- ▶ 15,000 ft², one-story, strip mall building
- ▶ Mass wall construction
- ▶ 70% WWR for front wall only (28% WWR for an entire building)
- ▶ Packaged rooftop air conditioner (CAV, DX, gas furnace)

Characteristics	Information Source	Assumptions		Comments
		ASHRAE 90.1-2001	ASHRAE 90.1-2007	
Building				
Building Type		Small retail-Stripmall		Number of occupants = 120
Gross Area (sq. ft.)	CoA	15,000		
Aspect Ratio	PNNL 20405:ASHRAE 90.1-2010	4:1		245 ft (L) X 61 ft (W)
Number of Floors	PNNL 20405:ASHRAE 90.1-2010	1		
Floor-to-Floor Height (ft.)	PNNL 20405:ASHRAE 90.1-2010	17		Floor-to-Ceiling Height = 17 ft
Orientation	PNNL 20405:ASHRAE 90.1-2010	South facing		
Construction				
Wall Construction	CoA	Mass (8-in concrete, 140 lb/ft ³)		
Roof Configuration	PNNL 20405:ASHRAE 90.1-2010	Flat built-up, Insulation entirely above deck		
Foundation Construction	PNNL 20405:ASHRAE 90.1-2010	6" concrete slab-on-grade floor		
Wall Absorptance	DOE 2.1E BDL SUMMARY, Page 12	0.75		Assuming gray, light oil paint
Wall Insulation (hr-sq.ft.-°F/Btu)	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	None	R-7.6 ci	Assembly maximum u-value for ASHRAE 90.1-2001 = 0.580
Roof Absorptance	ASHRAE 90.1-1999 11.4.2b and ASHRAE 90.1-2007 Sec. 5.5.3.1.1	0.7	0.3	Roof reflectance = 0.3 for 2001 and 0.7 for 2007
Roof Insulation (hr-sq.ft.-°F/Btu)	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	R-15 ci	R-20 ci	
Slab Perimeter Insulation	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	None		Slab-on-grade floor, unheated
Ground Reflectance	DOE 2.1E BDL SUMMARY, Page 20	0.24		Assuming grass
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	1.22	0.6 (Window) 0.9 (Door)	Fixed fenestration
Solar Heat Gain Coefficient (SHGC)	ASHRAE 90.1-2001 Table B-8 and ASHRAE 90.1-2007 Table 5.5-3	0.25		
Window Area	PNNL TSD: AEDG-SR-2006	70% Window to wall ratio for front wall only		28% WWR for an entire building
Exterior Shading	ASHRAE 90.1-2001 Sec. 11.4.2c and ASHRAE 90.1-2007 Table 11.3.1 No.5	None		
Infiltration	PNNL 20405:ASHRAE 90.1-2010	Peak: 0.2016 cfm/sq.ft. of above grade exterior wall surface area (when fans are off)		
Space Conditions				
Space Heating Set point	PNNL TSD: AEDG-SR-2006	70 F(Occupied), 5 F setback		
Space Cooling Set point	PNNL TSD: AEDG-SR-2006	75 F(Occupied), 5 F setup		
Lighting Power Density (W/ft ²)	ASHRAE 90.1-2001 Table 9.3.1.1 and ASHRAE 90.1-2007 Table 9.5.1	1.9	1.5	
Equipment Power Density (W/ft ²)	PNNL 20405:ASHRAE 90.1-2010	0.4		
Mechanical Systems				
HVAC System Type	ASHRAE 90.1-2001 11.4.3 and ASHRAE 90.1-2007 11.3.2	Packaged rooftop air conditioner (CAV, DX, gas furnace)		
Air Conditioning System Efficiency	FEDERAL MINIMUM EFFICIENCY STANDARDS	13 SEER (<65,000 Btu/h) 11 EER (≥655,000 Btu/h and <135,000 Btu/h)		
Heating System Efficiency (%)	ASHRAE 90.1-2001 Table 6.2.1E and ASHRAE 90.1-2007 Table 6.8.1E	80% Et		Gas-fired furnace Capacity < 225,000 Btu/hr
Cooling Capacity (Btu/hr)	ASHRAE 90.1-2007 Appendix G and ASHRAE HOF-2009	Autosized based on design day (1% db and wb cooling design temperature), 15% Oversized		PNNL 20405:ASHRAE 90.1-2010: Internal loads schedule = 1.0 (fraction)
Heating Capacity (Btu/hr)	ASHRAE 90.1-2007 Appendix G and ASHRAE HOF-2009	Autosized based on design day (99.6% heating design temperature), 25% oversized		PNNL 20405:ASHRAE 90.1-2010: Internal loads schedule = 0.0 (fraction)
Economizer	ASHRAE 90.1-2001 Table 6.3.1 and ASHRAE 90.1-2007 Table 6.5.1	No		
Ventilation (cfm/sq.ft.)	ASHRAE 62.1-1999 and ASHRAE 62.1-2004	0.12 (Total: 1800 cfm)	0.18 (Total: 2700 cfm)	ASHRAE 62.1-1999: 15cfm/person; and ASHRAE 62.1-2004: 7.5 cfm/person & 0.12 cfm/sq.ft.
Supply Air Flow (cfm/sq.ft.)		1		
SHW System Type	PNNL TSD: AEDG-SR-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:ASHRAE 90.1-2010	120 F		



Methodology

- Selected south facing building for the EEM analysis



Methodology

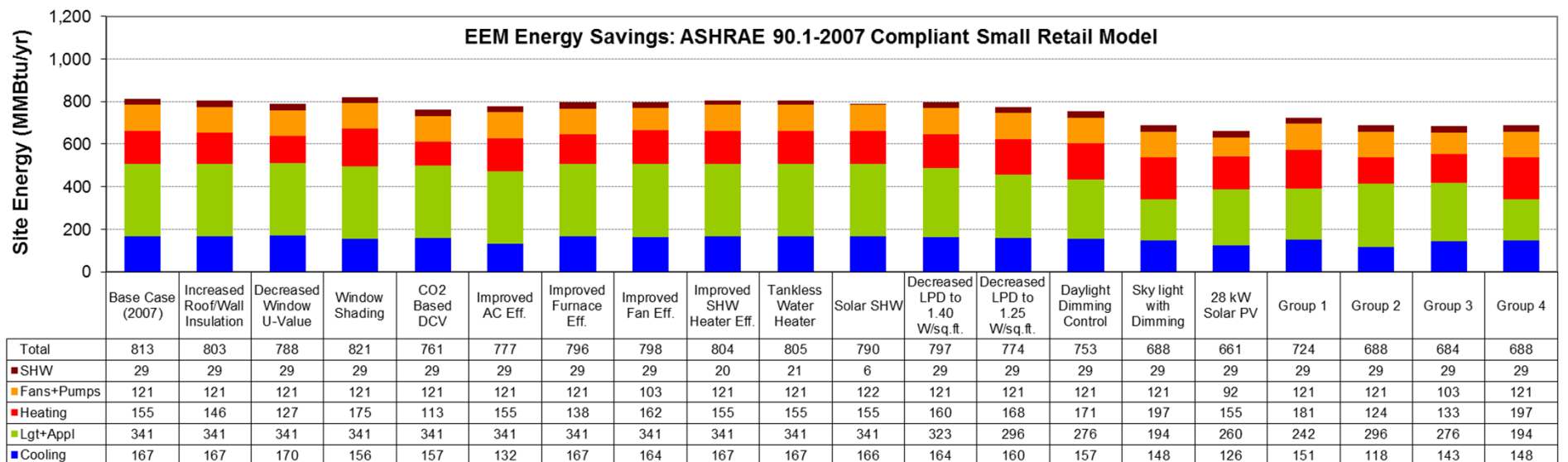
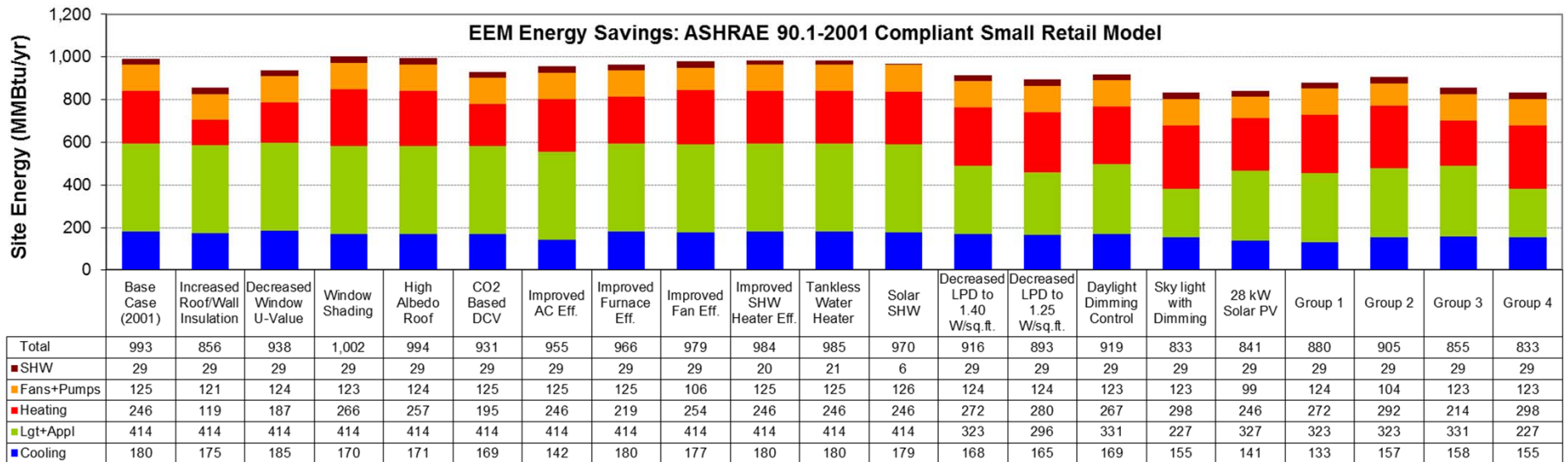
- ▶ 16 EEMs for envelope and fenestration, HVAC System, service hot water (SHW) system, lighting and renewable measures

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



Energy Savings from EEMs

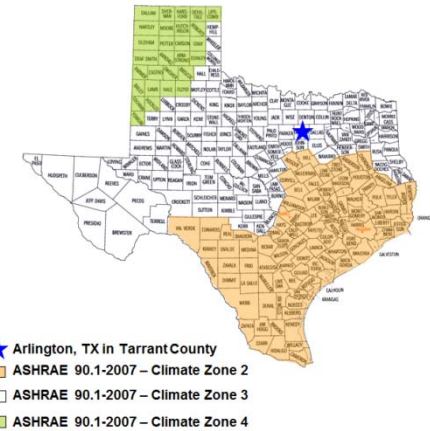
ASHRAE 90.1-2001/2007 Code-Compliant Small Retail Building



Proposed Energy Efficiency Measures (EEMs) ASHRAE 90.1-2001 Code-Compliant Small Retail Building

Description of Individual Measures

Individual Measures	Annual Energy Savings (%) ¹		Annual Energy Savings (\$/year) ²	Annual Demand Savings (%)	Annual Demand Savings (\$/year) ³	Combined Savings (Energy+Demand) (\$/year)	Estimated Cost (\$)		Simple Estimated Payback (yrs)
	Site	Source					Marginal Cost ⁴	New System Cost ⁵	
A Envelope and Fenestration Measures									
1 Increased Roof and Wall Insulation R-Value (from 15 to 25 for roof and none to 11.4c.i. for walls)	13.8%	6.6%	\$1,066	1.8%	\$65	\$1,131	\$22,832 - \$34,248		20.2 - 30.3
2 Decreased Glazing U-Value (from 1.22 to 0.35)	5.5%	2.0%	\$245	0.1%	\$4	\$249	\$23,511 - \$35,266		94.3 - 141
3 0.5 PF Window Shading (None to 6.75 ft. Overhang)	-0.9%	0.5%	\$184	2.5%	\$87	\$271		\$33,384 - \$50,076	123 - 185
4 High Albedo Roof (Roof Absorptance from 0.7 to 0.3)	-0.1%	0.8%	\$213	1.9%	\$67	\$280	\$6,600 - \$9,900		23.6 - 35.3
B HVAC System Measures									
5 CO ₂ Based Demand-Controlled Ventilation (DCV)	6.2%	3.5%	\$622	0.9%	\$32	\$654		\$5,894 - \$8,841	9.0 - 13.5
6 Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)	3.8%	4.7%	\$1,064	8.2%	\$293	\$1,357	\$9,830 - \$14,746		7.2 - 10.9
7 Improved Furnace Efficiency (from 80% to 90% Ef)	2.7%	1.2%	\$172	0.0%	\$0	\$172	\$6,320 - \$9,480		36.7 - 55.0
8 Improved Fan Efficiency (from 55% to 65%)	1.5%	2.4%	\$565	2.3%	\$81	\$646	\$5,651 - \$8,477		8.7 - 13.1
C Service Hot Water Measures									
9 Improved Gas Water Heater Efficiency (from 0.59 Ef to 0.86 Ef)	0.9%	0.4%	\$56	0.0%	\$0	\$56	\$920 - \$1,380		16.4 - 24.6
10 Tankless Gas Water Heater	0.8%	0.3%	\$50	0.0%	\$0	\$50	\$600 - \$900		12.0 - 18.1
11 Solar Service Hot Water System (64 sq.ft. collector, 80 gal tank)	2.3%	1.0%	\$159	-0.2%	-\$6	\$154		\$2,880 - \$4,320	18.7 - 28.1
D Lighting Measures									
12 Decreased Lighting Power Density based on ASHRAE90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	7.8%	11.5%	\$2,701	12.9%	\$458	\$3,159	\$6,312 - \$9,468		2.0 - 3.0
13 Decreased Lighting Power Density based on AEDG-SR-2006 (from 1.9 to 1.25 W/sq.ft.)	10.0%	14.9%	\$3,502	16.7%	\$595	\$4,097	\$8,214 - \$12,321		2.0 - 3.0
14 Daylight Dimming Control	7.5%	10.8%	\$2,523	13.7%	\$486	\$3,009		\$15,723 - \$23,584	5.2 - 7.8
15 Sky light (3% SRR,U-0.34 & 0.19 SHGC) w th Dimming Control	16.2%	23.9%	\$5,596	27.0%	\$960	\$6,556		\$55,700 - \$83,550	8.5 - 12.7
E Renewable Power Measure									
16 28 kW Photovoltaic Array	15.3%	18.7%	\$4,227	17.1%	\$607	\$4,834		\$140,000 - \$210,000	29.0 - 43.4



Description of Combined Measures

Combination of Measures ⁶	Combined Annual Energy Savings (%) ¹		Combined Energy Savings (\$/year) ²	Combined Demand Savings (%)	Combined Demand Savings (\$/year) ³	Combined Savings (Energy+Demand) (\$/year)	Combined Estimated Cost (\$)		Simple Estimated Payback (yrs)	NOx Emissions Savings 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 ASHRAE90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	11.4%	15.9%	\$3,695	20.7%	\$736	\$4,430	\$6,312 - \$9,468	\$9,830 - \$14,746	3.6 - 5.5	61.9	40.3	25.6
6 Improved Air Conditioner Efficiency (from 13 SEER & 11 EER to 18 SEER & 13.5 EER)												
Combination 2												
12 Decreased Lighting Power Density based on ASHRAE90.1-2010 (from 1.9 to 1.4 W/sq.ft.)	8.9%	15.0%	\$3,440	17.0%	\$604	\$4,045	\$6,312 - \$9,468	\$5,651 - \$8,477	4.6 - 6.9	57.9	39.0	23.5
8 Improved Fan Efficiency (from 55% to 65%)												
4 High Albedo Roof (Roof Absorptance from 0.7 to 0.3)												
Combination 3												
14 Daylight Dimming Control	13.9%	15.0%	\$3,154	14.6%	\$518	\$3,672		\$15,723 - \$23,584	5.9 - 8.8	52.1	30.9	22.6
5 CO ₂ Based Demand-Controlled Ventilation (DCV)							\$5,894 - \$8,841					
Combination 4												
15 Sky light (3% SRR,U-0.34 & 0.19 SHGC) w th Dimming Control	16.2%	23.9%	\$5,596	27.0%	\$960	\$6,556		\$55,700 - \$83,550	8.5 - 12.7	93.9	62.0	38.6

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

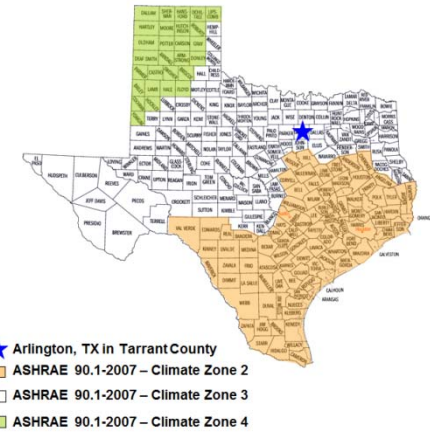
- [ASHRAE 90.1-2001 Code-Compliant Retail Building Description]
 * Building type: Small Retail (Strip Mall Type)
 * Gross area: 15,000 sq-ft
 * Building dimension: 61 ft x 245 ft x 17 ft (WxLxH)
 * Number of floors: 1
 * Floor-to-floor height: 17 ft
 * Window -to-w all ratio: 70% for Front Wall Only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



Proposed Energy Efficiency Measures (EEMs) ASHRAE 90.1-2007 Code-Compliant Small Retail Building

Description of Individual Measures

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



Description of Combined Measures

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

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

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



Questions?