

COST-EFFECTIVE ENERGY EFFICIENCY MEASURES FOR 15% ABOVE 2009 IECC CODE-COMPLIANT HOUSE FOR RESIDENTIAL BUILDINGS IN TEXAS



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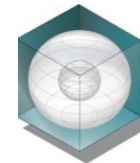
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Introduction

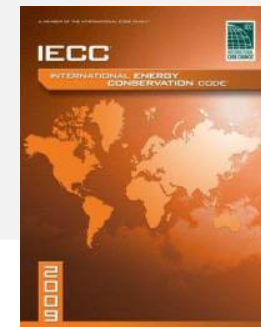
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The 79th Texas Legislature to enhance effectiveness of Senate Bill 5

requires the Laboratory to develop **three alternative methods for achieving 15% above-code energy savings** in new residential, commercial and industrial construction.

The 2009 International Residential code (IRC)

became effective on January 1, 2012 as the energy code in Texas for single-family construction



Hence, this paper presents

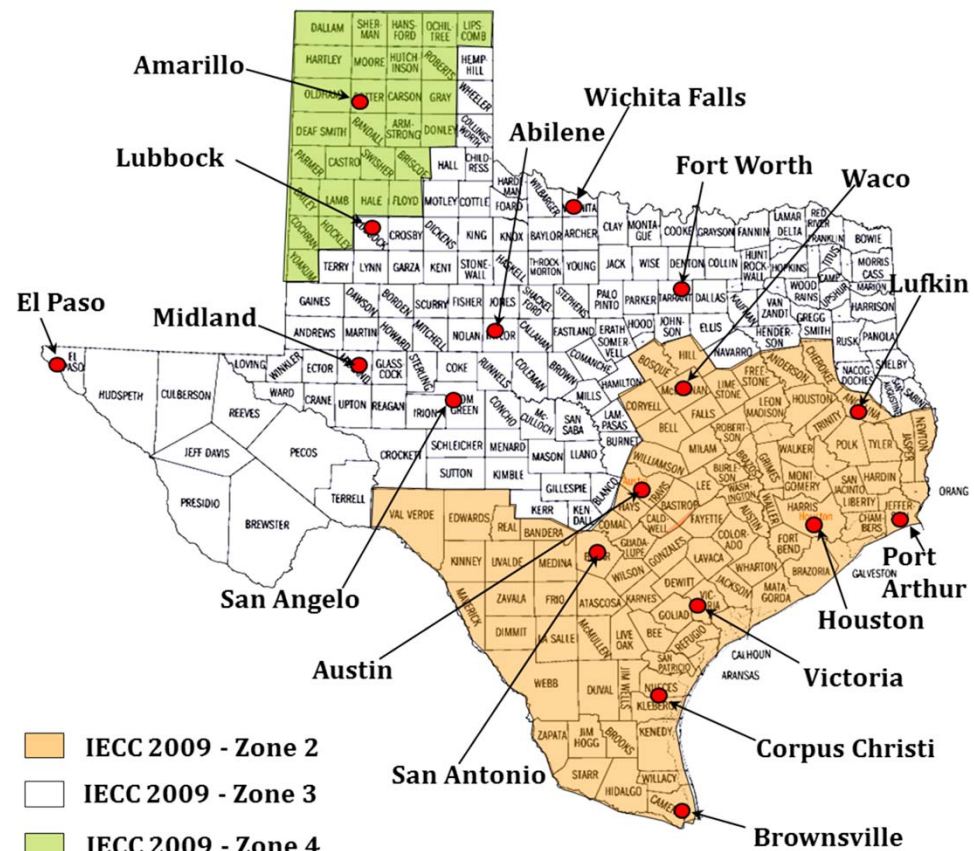
detailed information about the **recommendations for achieving 15% above 2009 International Energy Conservation Code (IECC) code-compliant house** energy performance for **single-family residences** across the State of Texas

Methodology (1/2)

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Overview

- ESL simulation model based on the DOE-2.1e of a 2009 IECC code-compliant, single-family residence for 17 counties in Texas



Methodology (2/2)

5

Overview

- Two options by the type of heating fuel
 - **Electric/gas house**: Electric cooling, Natural gas heating
 - **All-electric house**: Electric cooling, Heat pump heating
- **17 individual energy efficiency measures (EEMs)**
- Solar measures using PV-F Chart and F-Chart programs
- **Implementation costs** of each measure with simple **payback**
- **Three group measures** to achieve **15% source energy savings** above 2009 IECC code-compliant house
- **Total source energy savings from heating, cooling, lighting, equipment and DHW** for emissions reductions determination

Base-Case Building (1/3)

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Building Envelope

- 2,325 ft², square-shape, one story, single-family detached house
- Vented, **unconditioned attic**
- Light weight **wood frame** construction
- **15%** window-to-floor ratio (22.6% window-to-wall ratio)
- Climate-specific characteristics as per IECC 2009 Tables 402.1.1 and 402.1.3
 - Wall u-value: 0.082 (CZ 2, 3, & 4)
 - Roof u-value: 0.035 (CZ 2 & 3) and 0.030 (CZ 4)
 - Glazing u-value: 0.65 (CZ 2), 0.5 (CZ 3), and 0.35 (CZ 4)
 - Glazing SHGC: 0.3 (CZ 2 & 3) and 0.4 (CZ 4)
 - Slab insulation: None (CZ 2 & 3) and R-10 (CZ 4)



Base-Case Building (2/3)

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Space Conditions

- Thermostat per IECC 2009 Table 405.5.2(1)
 - **72 F** for heating
 - **75 F** for cooling
 - No set-back/set-up
- Internal gains per IECC 2009 Table 405.5.2(1)
 - **1.095 kW** for lighting and equipment
- 50% Energy Star permanent CFL or fluorescent lamps

HVAC System

- System Efficiency
 - Electric/gas house: **SEER 13 AC** and **0.78 AFUE** gas-fired furnace
 - All-electric house: **SEER 13 AC** and **HSPF 7.7** heat pump
- Duct leakage to outdoors per IECC 2009 Sec. 403.2.2
 - **5.6%** for supply
 - **5.6%** for return
- Duct insulation per IECC 2009 Sec. 403.2.1
 - **R-8** for supply
 - **R-6** for return



Base-Case Building (3/3)

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DHW System

- Electric/gas house
 - 40 gallon tank-type, w/ pilot light
 - **0.59 EF**
- All-electric house
 - 50 gallon tank-type, w/o pilot light
 - **0.90 EF**

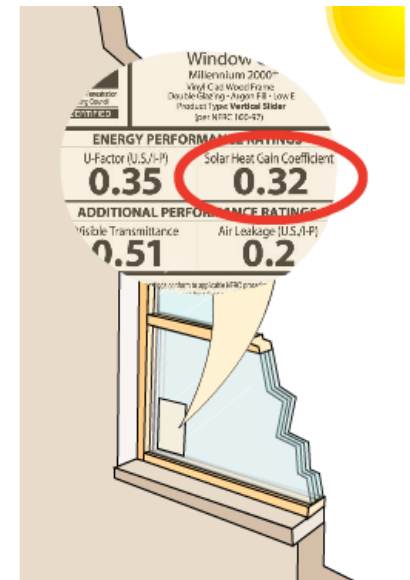
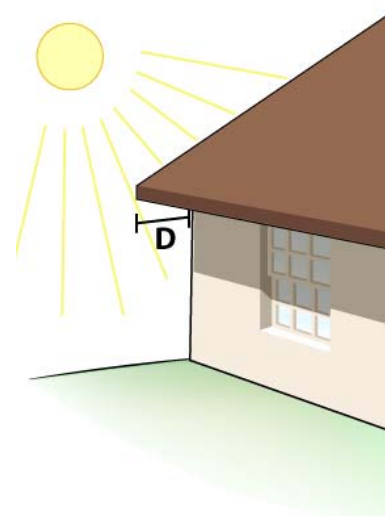
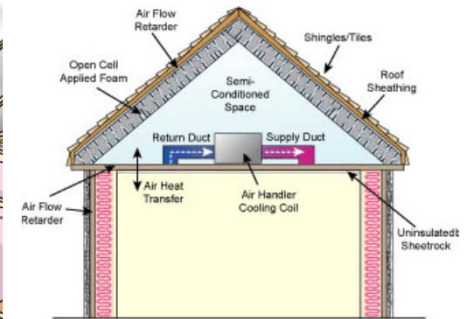
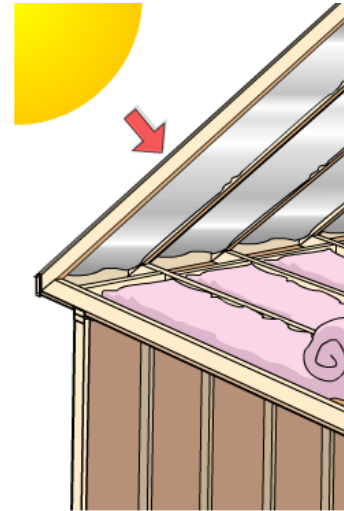


17 Energy Efficiency Measures (1/4)

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Envelope and Fenestration Measures

1. Radiant barrier in attics (w/ ducts in attics)
2. Sealed (Unvented) attic
3. Window shading
 - None to 2 ft eaves on all sides
4. Window shading and redistribution
 - 22.6% equal windows w/s shading to S=41%, N=23%, E/W=14% with 2 ft eaves
5. Decreased window SHGC
 - CZ 2&3: 0.3 to 0.2
6. Decreased window U-value
 - CZ 2: 0.65 to 0.3
 - CZ 3: 0.5 to 0.3
 - CZ 4: 0.35 to 0.3
7. Decreased window SHGC and U-value

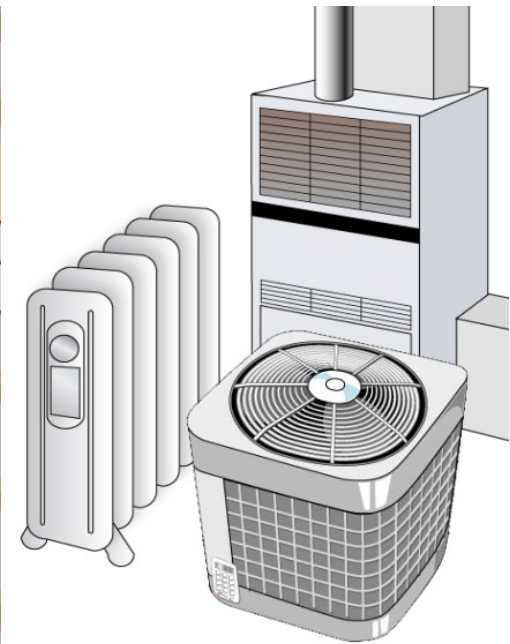
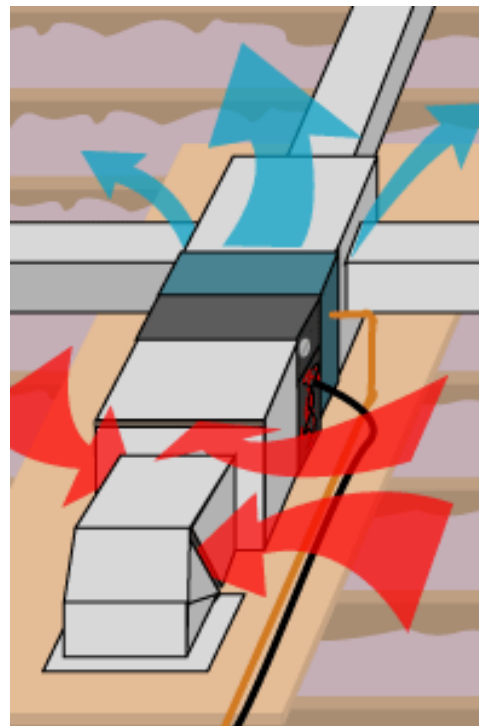


17 Energy Efficiency Measures (2/4)

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HVAC System Measures

8. Relocate mechanical systems within conditioned space
9. Improved AC efficiency
 - SEER 13 to 15 or
 - SEER 13 to 15 and HSPF 7.7 to 8.5
10. Improved furnace efficiency
 - From AFUE 0.78 to 0.93



17 Energy Efficiency Measures (3/4)

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DHW System Measures

- 11. Tankless gas water heater
- 12. Removal of pilot light from DHW system
- 13. Solar DHW system
 - 32 sq. ft. collector, 65 gal tank
- 14. Solar DHW system
 - 64 sq. ft. collector, 80 gal tank



17 Energy Efficiency Measures (4/4)

12

Lighting Measures

15. 75% Energy Star permanent CFL or fluorescent indoor lamps

16. 100% Energy Star permanent CFL or fluorescent indoor lamps



Renewable Power Measure

17. 4 kW photovoltaic array



Results: Approaches

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EEM Savings Analysis

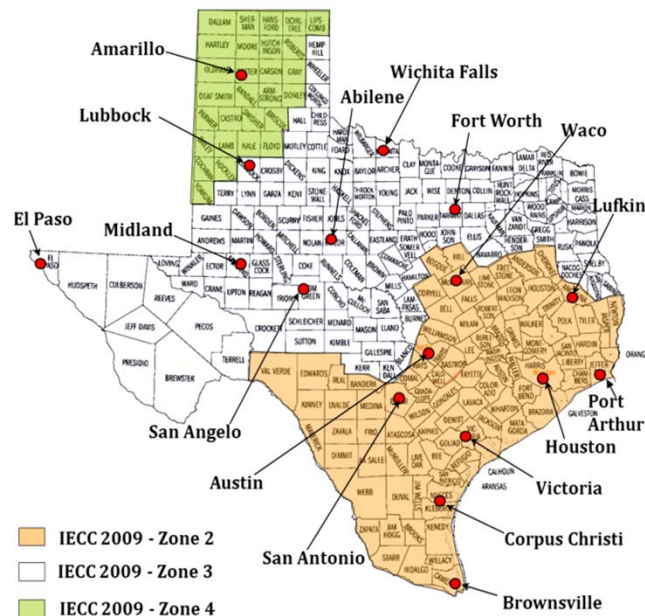
- Source energy savings
- % above base case

Cost Analysis

- Savings vs. Costs
- \$0.11/kW and \$0.84 or \$0.64/therm

PAYBACK
Number of Years

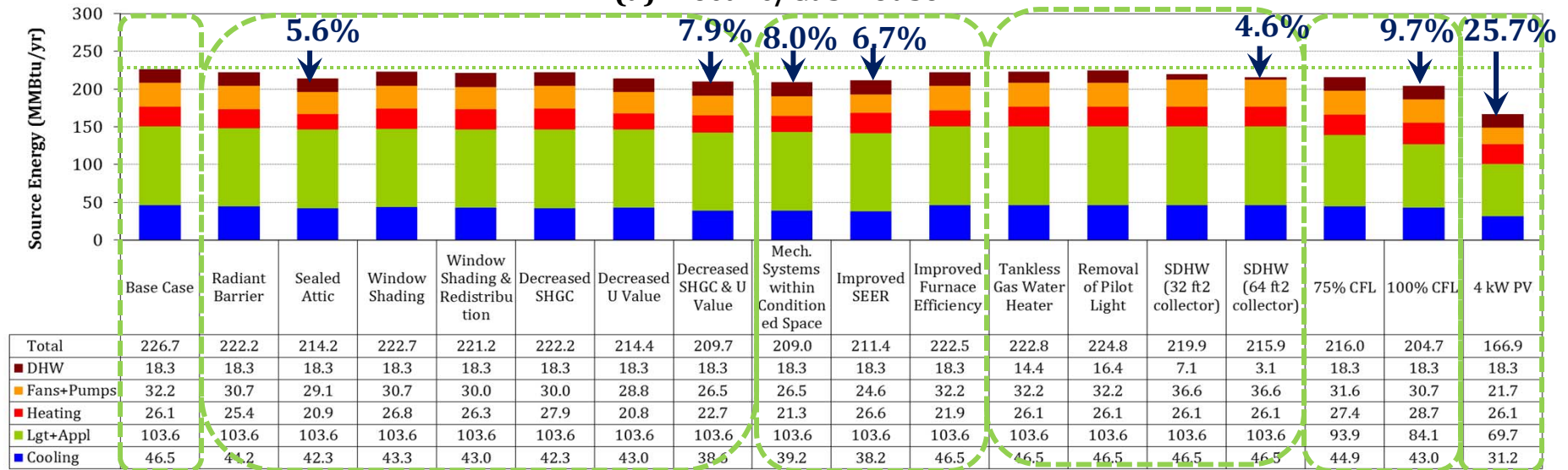
17 Counties



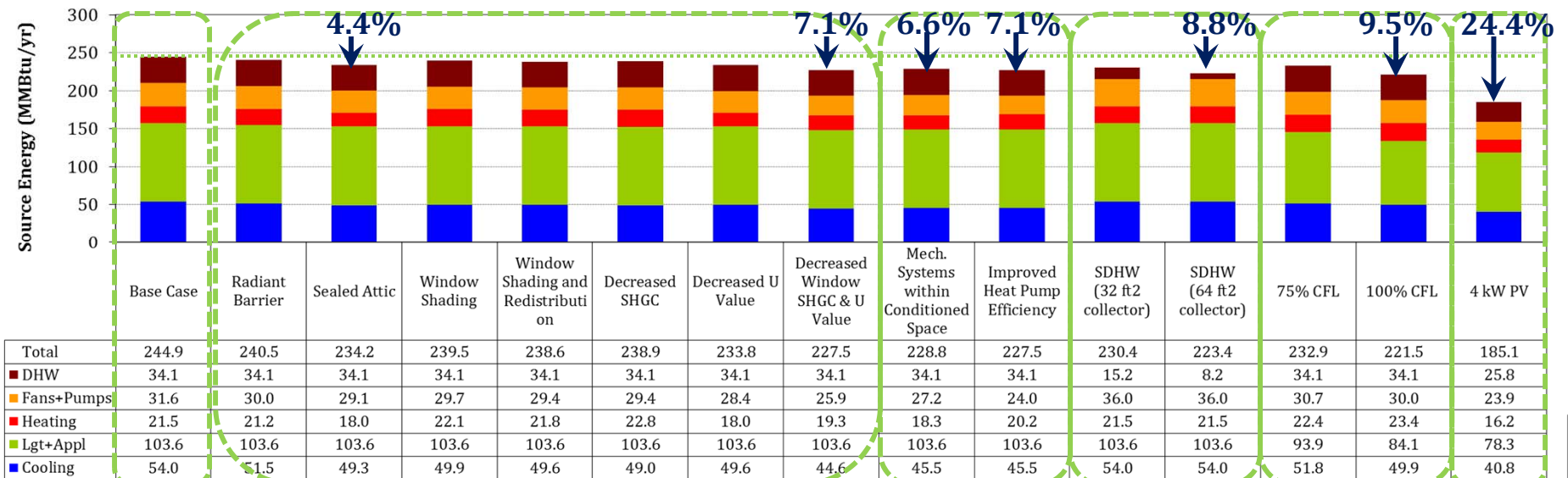
Results: EEM Analysis for Harris County (CZ 2)

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(a) Electric/Gas House



(b) All-Electric House



Results: Summary of % Above-Code

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EEM #	Energy Efficiency Measure (EEM)	Climate Zone 2										Min - Max	Climate Zone 3								Min - Max	Climate Zone 4 ¹⁾ POT
		By County											By County									
		CAM	NUE	VIC	BEX	HAR	JEF	TRA	ANG	MCL	TOM		MID	ELP	TAL	TAR	LUB	WIC				
(a) Electric/Gas House Base Case																						
1	Radiant Barrier in Attics (with Ducts in Attics)	1.6%	1.6%	2.0%	2.4%	2.0%	1.8%	2.1%	2.5%	2.1%	1.6% - 2.5%	2.1%	2.2%	3.1%	2.0%	2.0%	2.0%	1.6%	1.6% - 3.1%	1.6%		
2	Sealed (Unvented) Attic	5.4%	6.1%	5.4%	5.6%	5.6%	5.6%	5.4%	5.9%	6.6%	5.4% - 6.6%	6.2%	6.6%	6.3%	6.6%	5.7%	7.2%	7.2%	5.7% - 7.2%	7.7%		
3	Window Shading (2ft overhang on all sides)	2.6%	2.5%	2.3%	2.4%	2.2%	2.1%	2.2%	2.2%	2.0%	2.0% - 2.6%	2.0%	2.1%	2.8%	2.1%	2.0%	1.5%	1.6%	1.5% - 2.8%	1.4%		
4	Window Shading and Redistribution	2.9%	2.9%	2.8%	2.9%	2.8%	2.9%	3.0%	2.8%	2.7%	2.7% - 3.0%	3.1%	2.8%	3.5%	3.0%	3.0%	2.7%	2.7%	2.7% - 3.5%	2.8%		
5	Decreased SHGC	3.2%	2.9%	2.7%	2.4%	2.3%	2.2%	2.4%	1.9%	1.7%	1.7% - 3.2%	1.5%	1.3%	2.3%	1.5%	1.5%	0.4%	0.9%	0.4% - 2.3%	-		
6	Decreased U Value	4.8%	5.1%	5.3%	6.2%	5.7%	5.8%	6.1%	6.1%	6.7%	4.8% - 6.7%	4.2%	4.3%	4.7%	4.4%	4.2%	4.3%	4.2%	4.2% - 4.7%	1.4%		
7	Decreased SHGC & U Value	8.2%	8.0%	8.1%	8.6%	7.9%	8.0%	8.4%	8.1%	8.4%	7.9% - 8.6%	5.5%	5.5%	6.6%	5.9%	5.6%	4.4%	5.1%	4.4% - 6.6%	-		
8	Mechanical Systems Within Conditioned Spaces	7.5%	7.7%	7.7%	8.2%	8.0%	7.8%	8.2%	8.4%	8.5%	7.5% - 8.5%	8.4%	8.1%	7.6%	8.5%	8.2%	8.8%	9.3%	7.6% - 9.3%	2.4%		
9	Improved SEER (from 13 to 15)	8.5%	8.0%	7.2%	7.0%	6.7%	6.5%	6.8%	6.1%	6.2%	6.1% - 8.5%	5.6%	5.3%	6.1%	5.7%	6.0%	4.3%	5.6%	4.3% - 6.1%	2.2%		
10	Improved Furnace Efficiency (from .78 to .93 AFUE)	0.6%	1.0%	1.2%	1.7%	1.7%	1.7%	1.9%	2.1%	2.5%	0.6% - 2.5%	2.9%	3.0%	2.2%	2.9%	2.3%	4.0%	3.3%	2.2% - 4.0%	4.3%		
11	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	1.6%	1.7%	1.7%	1.6%	1.7%	1.7%	1.6%	1.7%	1.6%	1.6% - 1.7%	1.6%	1.7%	1.7%	1.6%	1.7%	1.6%	1.5%	1.5% - 1.7%	1.5%		
12	Removal of Pilot Light from DHW	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8% - 0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.7%	0.7% - 0.8%	0.7%		
13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	3.2%	3.2%	3.4%	3.6%	2.9%	3.3%	3.5%	3.5%	3.5%	2.9% - 3.6%	3.9%	4.3%	4.8%	3.8%	3.7%	4.0%	3.3%	3.3% - 4.8%	3.8%		
14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	4.3%	4.4%	4.7%	4.9%	4.6%	4.8%	4.8%	5.0%	4.8%	4.3% - 5.0%	5.3%	5.7%	6.0%	5.2%	5.0%	5.6%	4.7%	4.7% - 6.0%	5.7%		
15	75% Energy Star Permanent CFL or Fluorescent Lamps	5.1%	5.0%	5.1%	4.7%	5.0%	4.8%	4.5%	4.5%	4.3%	4.3% - 5.1%	4.2%	4.1%	4.5%	4.1%	4.3%	3.8%	3.7%	3.7% - 4.5%	3.6%		
16	100% Energy Star Permanent CFL or Fluorescent Lamps	10.3%	10.1%	9.9%	9.4%	9.7%	9.6%	9.2%	9.1%	8.5%	8.5% - 10%	8.4%	8.4%	9.0%	8.2%	8.7%	7.5%	7.4%	7.4% - 9.0%	7.1%		
17	4 kW PV Array	25.5%	25.3%	26.7%	28.0%	25.7%	26.6%	27.4%	27.5%	27.3%	25% - 28%	29.6%	31.6%	34.9%	29.2%	28.4%	29.6%	26.3%	26% - 35%	29%		
(b) All-Electric House ²⁾ Base Case																						
1	Radiant Barrier in Attics (with Ducts in Attics)	1.5%	1.5%	1.7%	2.0%	1.8%	1.7%	1.9%	2.2%	2.0%	1.5% - 2.2%	1.8%	1.9%	2.7%	1.7%	1.8%	1.8%	1.6%	1.6% - 2.7%	1.5%		
2	Sealed (Unvented) Attic	4.6%	5.2%	4.4%	4.4%	4.4%	4.5%	4.0%	4.5%	4.8%	4.0% - 5.2%	4.3%	4.9%	4.6%	4.7%	4.0%	5.4%	5.6%	4.0% - 5.6%	5.6%		
3	Window Shading (2ft overhang on all sides)	2.5%	2.4%	2.3%	2.4%	2.2%	2.4%	2.2%	2.3%	2.2%	2.2% - 2.5%	2.2%	2.1%	3.1%	2.2%	2.1%	1.8%	1.8%	1.8% - 3.1%	1.6%		
4	Window Shading and Redistribution	2.9%	2.8%	2.7%	2.8%	2.6%	3.0%	2.7%	2.7%	2.7%	2.6% - 3.0%	2.9%	2.9%	3.6%	2.7%	2.9%	2.7%	2.7%	2.7% - 3.6%	2.8%		
5	Decreased SHGC	3.1%	2.9%	2.9%	2.6%	2.5%	2.5%	2.5%	2.2%	2.1%	2.1% - 3.1%	1.8%	1.9%	2.8%	2.0%	2.0%	1.1%	1.4%	1.1% - 2.8%	-		
6	Decreased U Value	4.1%	4.3%	4.3%	5.1%	4.5%	4.7%	4.9%	4.9%	5.3%	4.1% - 5.3%	3.7%	3.9%	4.1%	3.7%	3.8%	3.8%	3.9%	3.7% - 4.1%	1.1%		
7	Decreased SHGC & U Value	7.5%	7.4%	7.3%	7.6%	7.1%	7.2%	7.5%	7.3%	7.5%	7.1% - 7.6%	5.5%	5.6%	6.5%	5.6%	5.6%	4.7%	5.2%	4.7% - 6.5%	-		
8	Mechanical Systems Within Conditioned Spaces	6.8%	6.8%	6.7%	6.9%	6.6%	6.6%	6.8%	6.7%	6.7%	6.6% - 6.9%	6.3%	6.0%	5.9%	6.2%	6.3%	6.3%	7.3%	5.9% - 7.3%	6.7%		
9	Improved SEER and Heat Pump Efficiency	8.3%	8.0%	7.3%	7.4%	7.1%	7.0%	7.2%	6.7%	7.0%	6.7% - 8.3%	6.5%	6.1%	6.7%	6.4%	6.7%	5.7%	6.8%	5.7% - 6.8%	5.6%		
13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	6.3%	6.4%	6.8%	7.3%	5.9%	6.7%	7.1%	7.1%	7.1%	5.9% - 7.3%	7.8%	8.5%	9.3%	7.8%	7.6%	7.9%	7.0%	7.0% - 9.3%	7.5%		
14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	8.1%	8.4%	9.1%	9.2%	8.8%	9.2%	9.0%	9.6%	9.2%	8.1% - 9.6%	9.9%	10.6%	10.9%	10.0%	9.7%	10.5%	9.0%	9.0% - 11%	10%		
15	75% Energy Star Permanent CFL or Fluorescent Lamps	5.0%	4.9%	5.1%	4.6%	4.9%	4.9%	4.5%	4.5%	4.4%	4.4% - 5.1%	4.0%	4.3%	4.5%	4.2%	4.3%	3.8%	3.8%	3.8% - 4.5%	3.6%		
16	100% Energy Star Permanent CFL or Fluorescent Lamps	10.1%	10.0%	9.9%	9.3%	9.5%	9.9%	9.1%	9.2%	8.6%	8.6% - 10%	8.3%	8.4%	9.0%	8.2%	8.8%	7.5%	7.5%	7.5% - 9.0%	6.9%		
17	4 kW PV Array	24.4%	24.3%	25.5%	26.6%	24.4%	25.5%	26.2%	26.2%	26.2%	24% - 27%	27.8%	29.7%	32.8%	27.7%	27.1%	27.7%	24.8%	25% - 33%	26%		

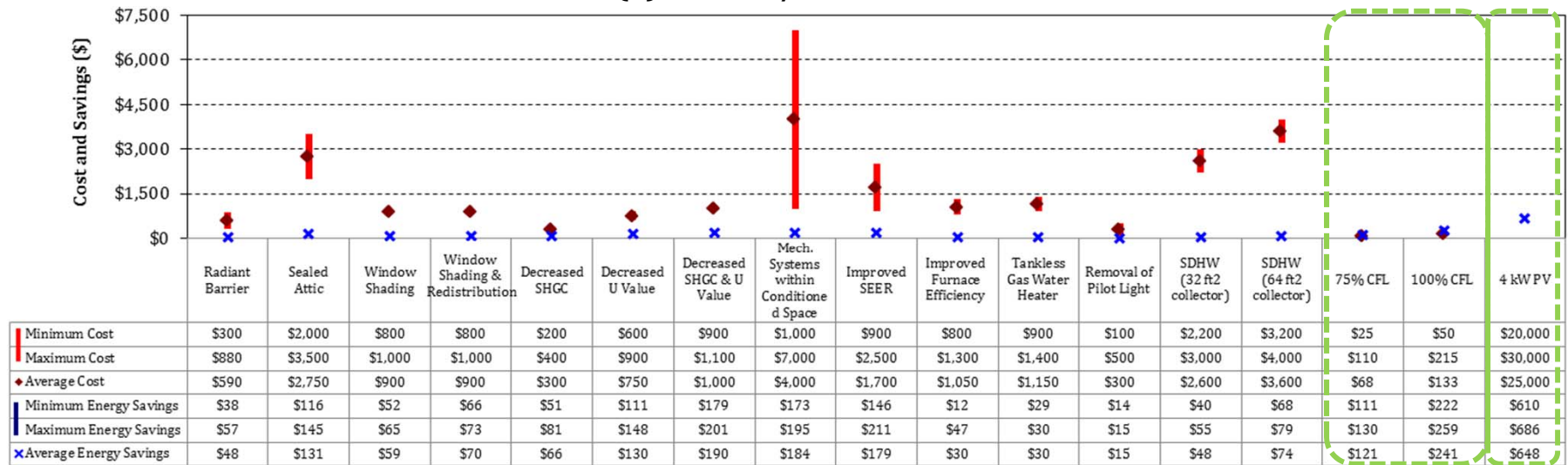
1) EEM 5 and 7 were not applied to Climate Zone 4.

2) EEM 10, 11 and 12 were not applied to All-Electric House.

Results: Cost Analysis for CZ 2

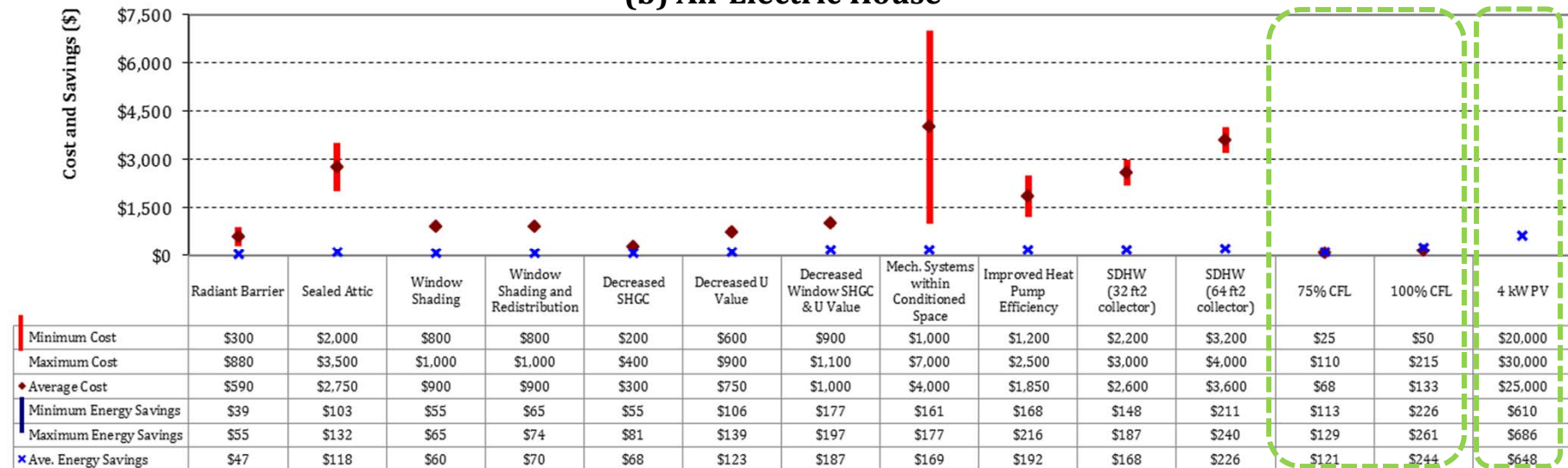
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(a) Electric/Gas House



Note. Minimum to maximum cost for the EEM "4kW PV" which is not displayed in the plot is \$20,000 to \$30,000.

(b) All-Electric House

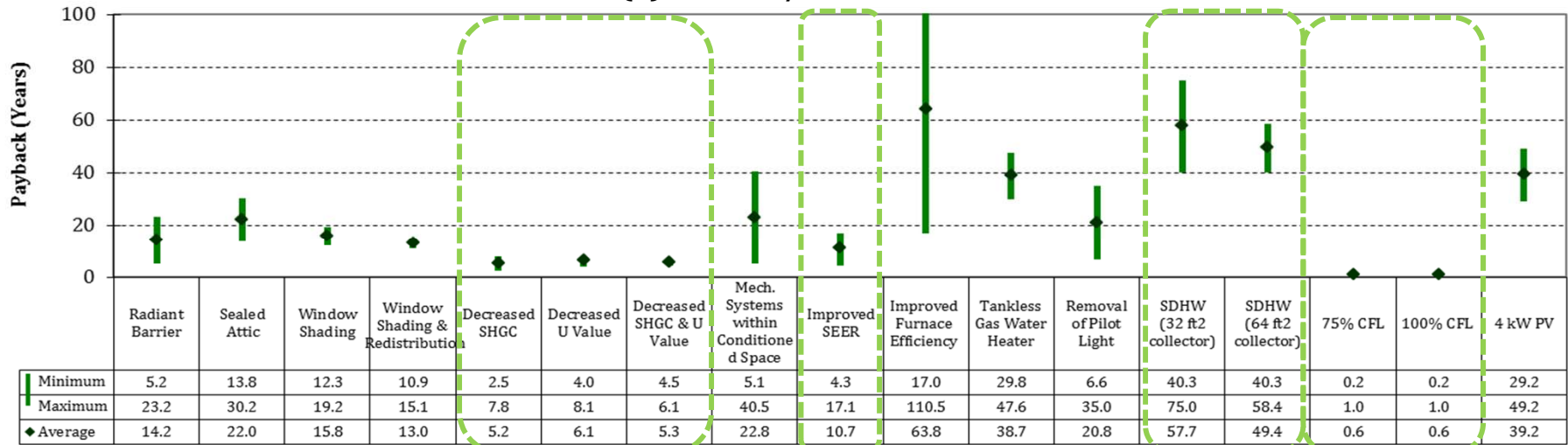


Note. Minimum to maximum cost for the EEM "4kW PV" which is not displayed in the plot is \$20,000 to \$30,000.

Results: Payback for CZ 2

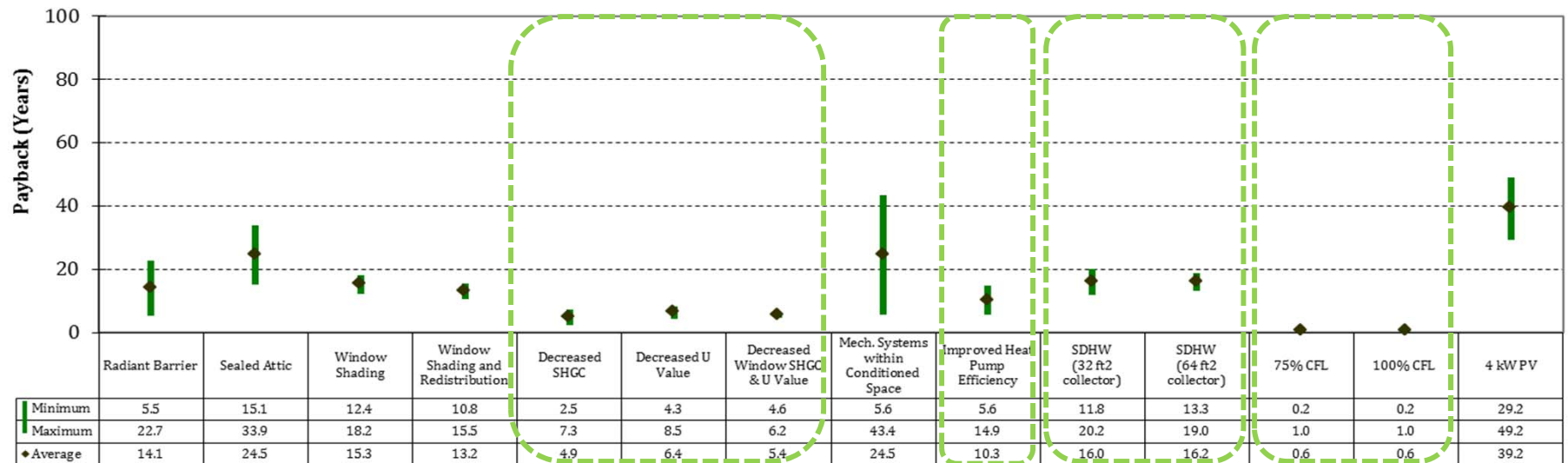
17

(a) Electric/Gas House



Note. A maximum payback period for the EEM "Improved furnace efficiency" is 110.5 years.

(b) All-Electric House



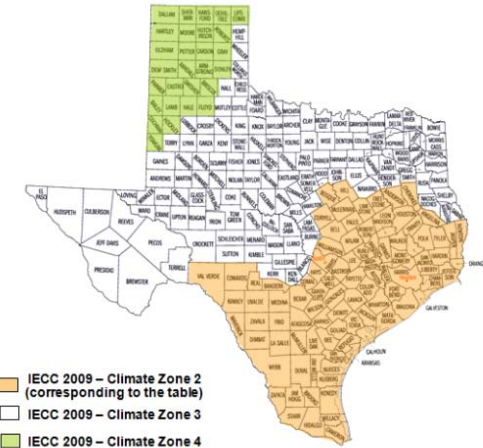
Results: Recommendations for CZ 2

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Natural Gas Heating (Climate Zone 2)

Description of Individual Measures

Individual Measures		Annual Source Energy Savings (%) ¹	Annual Energy Savings (\$/year) ²	Estimated Cost (\$)		Simple Estimated Payback (yrs)
				Marginal Cost ³	New System Cost ⁴	
A	Envelope and Fenestration Measures					
1	Radiant Barrier in Attics (with Ducts in Attics) (L;a;b;H:h) ⁷	1.6% - 2.5%	\$38 - \$57		\$300 - \$880	5.2 - 23.2
2	Sealed (Unvented) Attic (L;a;c,g;H;i)	5.4% - 6.6%	\$116 - \$145	\$2,000 - \$3,500		13.8 - 30.2
3	Window Shading (None to 2 ft. Eaves on All Sides) (L;i;H;a)	2.0% - 2.6%	\$52 - \$65		\$800 - \$1,000	12.3 - 19.2
4	Window Shading and Redistribution (22.6% Equal Windows on All Sides with No Shading to S=40.7%, N=22.6%, E/W = 13.6% with 2ft. Eaves on All Sides) (L;i;H;g)	2.7% - 3.0%	\$66 - \$73		\$800 - \$1,000	10.9 - 15.1
5	Decreased Window SHGC (Climate Zone 2: from 0.3 to 0.2) (L;i;H;a)	1.7% - 3.2%	\$51 - \$81	\$200 - \$400		2.5 - 7.8
6	Decreased Window U Value (Climate Zone 2: from 0.65 to 0.3) (L;a;H;i)	4.8% - 6.7%	\$111 - \$148	\$600 - \$900		4.0 - 8.1
7	Decreased Window SHGC & U Value (Climate Zone 2: from 0.3 to 0.2 SHGC & from 0.65 to 0.3 U-Value) (L;e;H;d)	8.6%	\$179 - \$201	\$900 - \$1,100		4.5 - 6.1
B	HVAC System Measures					
8	Relocate Mechanical Systems within Conditioned Space (L;a;H;i)	7.5% - 8.5%	\$173 - \$195	\$1,000 - \$7,000		5.1 - 40.5
9	Improved Air Conditioner SEER (from 13 to 15 SEER) (L;h;H;a)	6.1% - 8.5%	\$146 - \$211	\$900 - \$2,500		4.3 - 17.1
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE) (L;a;H;i)	0.6% - 2.5%	\$12 - \$47	\$800 - \$1,300		17.0 - 110.5
C	Domestic Hot Water Measures					
11	Tankless Gas Water Heater (without a Standing Pilot Light) (L;a,d,g,i;H;b,c,e,f,h)	1.0% - 1.7%	\$29 - \$30	\$900 - \$1,400		29.8 - 47.6
12	Removal of Pilot Light from Tank-Type Hot Water System (L=H;a,b,c,d,e,f,g,h,i)	0.8% - 0.8%	\$14 - \$15	\$100 - \$500		6.6 - 35.0
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank) (L;e;H;d)	2.9% - 3.6%	\$40 - \$55		\$2,200 - \$3,000	40.3 - 75.0
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank) (L;a;H;h)	4.3% - 5.0%	\$68 - \$79		\$3,200 - \$4,000	40.3 - 58.4
D	Lighting Measures					
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps (L;i;H;a,c)	4.3% - 5.1%	\$111 - \$130	\$25 - \$110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps (L;i;H;a)	8.5% - 10.3%	\$222 - \$259	\$50 - \$215		0.2 - 1.0
E	Renewable Power Measures					
17	5 kW Photovoltaic Array (L;b;H;d)	25.3% - 28.0%	\$610 - \$686		\$20,000 - \$30,000	29.2 - 49.2



Description of Combined Measures to Achieve 15% Savings Above 2009 IECC Code-Compliant House

Combination of Measures ⁵		Combined Source Energy Savings	Combined Energy Savings (\$/year) ²	Combined Estimated Cost (\$)		Simple Estimated Payback (yrs)	CO _x Emissions	SO ₂ Emissions	CO ₂ Emissions
				Marginal Cost ³	New System Cost ⁴		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons/yr) ⁶
Combination 1 (L;i;H;a) ⁷									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps (L;i;H;a)			\$50 - \$215					
7	Decreased Window SHGC & U Value (Climate Zone 2: from 0.3 to 0.2 SHGC & from 0.65 to 0.3 U-Value) (L;e;H;d)	9% - 18.6%	\$406 - \$461	\$900 - \$1,100		2.1 - 3.2	5.8 - 6.6	3.6 - 4.6	2.5 - 2.8
Combination 2 (L;f;H;a)									
7	Decreased Window SHGC & U Value (Climate Zone 2: from 0.3 to 0.2 SHGC & from 0.65 to 0.3 U-Value) (L;e;H;d)			\$900 - \$1,100					
9	Improved Air Conditioner SEER (from 13 to 15 SEER) (L;h;H;a)	15.0% - 16.6%	\$333 - \$406	\$900 - \$2,500		5.2 - 13.5	4.7 - 5.8	2.8 - 3.6	2.0 - 2.5
1	Radiant Barrier in Attics (with Ducts in Attics) (L;a,b;H;h)				\$300 - \$880				
Combination 3 (L;f;H;a)									
8	Relocate Mechanical Systems within Conditioned Space (L;a;H;i)			\$1,000 - \$7,000					
9	Improved Air Conditioner SEER (from 13 to 15 SEER) (L;h;H;a)	15.0% - 16.4%	\$338 - \$405	\$900 - \$2,500		6.7 - 31.1	4.8 - 5.8	2.8 - 3.6	2.1 - 2.5
3	Window Shading (None to 2 ft. Eaves on All Sides) (L;i;H;a)				\$800 - \$1,000				

Note:

- Total source energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
- Savings depend on fuel mix used.
* Energy Cost: Electricity = \$0.11/kWh
Natural gas = \$0.84/therm
- Marginal cost = new system cost - original system cost
- New system cost = new system cost only
- See individual measures above for specific savings
- Conversion factor: 1 ton = 2,000 lbs
- L = County with the lowest annual source energy savings; H = County with the highest annual source energy savings
County code: a = Cameron; b = Nueces; c = Victoria; d = Bexar; e = Harris; f = Jefferson; g = Travis; h = Angelina; i = McLennan

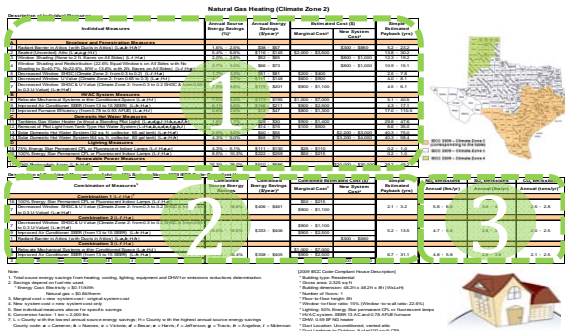
[2009 IECC Code-Compliant House Description]

- * Building type: Residential
- * Gross area: 2,325 sq-ft
- * Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
- * Number of floors: 1
- * Floor-to-floor height: 8ft
- * Window-to-floor ratio: 15% (Window-to-wall ratio: 22.6%)
- * Lighting: 50% Energy Star permanent CFL or fluorescent lamps
- * HVAC system: SEER 13 AC and 0.78 AFUE furnace
- * DHW: 0.59 EF NG heater
- * Duct Location: Unconditioned, vented attic
- * Duct Leakage to Outdoor: 8 cfm/100 sq-ft CFA



Results: Recommendations for CZ 2

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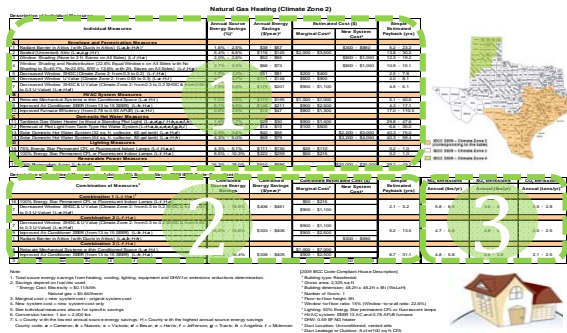


Description of Individual Measures

Individual Measures		Annual Source Energy Savings (%) ¹	Annual Energy Savings (\$/year) ²	Estimated Cost (\$)		Simple Estimated Payback (yrs)
				Marginal Cost ³	New System Cost ⁴	
A	Envelope and Fenestration Measures					
1	Radiant Barrier in Attics (with Ducts in Attics) (L: a , b ;H: h) ⁷	1.6% - 2.5%	\$38 - \$57		\$300 - \$880	5.2 - 23.2
2	Sealed (Unvented) Attic (L: a , c , g ;H: i)	5.4% - 6.6%	\$116 - \$145	\$2,000 - \$3,500		13.8 - 30.2
3	Window Shading (None to 2 ft. Eaves on All Sides) (L: i ;H: a)	2.0% - 2.6%	\$52 - \$65		\$800 - \$1,000	12.3 - 19.2
4	Window Shading and Redistribution (22.6% Equal Windows on All Sides with No Shading to S=40.7%, N=22.6%, E/W = 13.6% with 2ft. Eaves on All Sides) (L: i ;H: g)	2.7% - 3.0%	\$66 - \$73		\$800 - \$1,000	10.9 - 15.1
5	Decreased Window SHGC (Climate Zone 2: from 0.3 to 0.2) (L: i ;H: a)	1.7% - 3.2%	\$51 - \$81	\$200 - \$400		2.5 - 7.8
6	Decreased Window U Value (Climate Zone 2: from 0.65 to 0.3) (L: a ;H: i)	4.8% - 6.7%	\$111 - \$148	\$600 - \$900		4.0 - 8.1
7	Decreased Window SHGC & U Value (Climate Zone 2: from 0.3 to 0.2 SHGC & from 0.65 to 0.3 U-Value) (L: e ;H: d)	7.9% - 8.6%	\$179 - \$201	\$900 - \$1,100		4.5 - 6.1
B	HVAC System Measures					
8	Relocate Mechanical Systems within Conditioned Space (L: a ;H: i)	7.5% - 8.5%	\$173 - \$195	\$1,000 - \$7,000		5.1 - 40.5
9	Improved Air Conditioner SEER (from 13 to 15 SEER) (L: h ;H: a)	6.1% - 8.5%	\$146 - \$211	\$900 - \$2,500		4.3 - 17.1
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE) (L: a ;H: i)	0.6% - 2.5%	\$12 - \$47	\$800 - \$1,300		17.0 - 110.5
C	Domestic Hot Water Measures					
11	Tankless Gas Water Heater (without a Standing Pilot Light) (L: a , d , g , i ;H: b , c , e , f , h)	1.6% - 1.7%	\$29 - \$30	\$900 - \$1,400		29.8 - 47.6
12	Removal of Pilot Light from Tank-Type Hot Water System (L=H: a , b , c , d , e , f , g , h , i)	0.8% - 0.8%	\$14 - \$15	\$100 - \$500		6.6 - 35.0
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank) (L: e ;H: d)	2.9% - 3.6%	\$40 - \$55		\$2,200 - \$3,000	40.3 - 75.0
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank) (L: a ;H: h)	4.3% - 5.0%	\$68 - \$79		\$3,200 - \$4,000	40.3 - 58.4
D	Lighting Measures					
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps (L: i ;H: a , c)	4.3% - 5.1%	\$111 - \$130	\$25 - \$110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps (L: i ;H: a)	8.5% - 10.3%	\$222 - \$259	\$50 - \$215		0.2 - 1.0
E	Renewable Power Measures					
17	4 kW Photovoltaic Array (L: b ;H: d)	25.3% - 28.0%	\$610 - \$686		\$20,000 - \$30,000	29.2 - 49.2

Results: Recommendations for CZ 2

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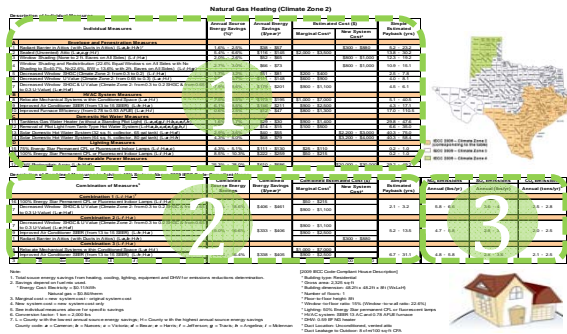
2

Description of Combined Measures to Achieve 15% Savings Above 2009 IECC Code-Compliant House

Combination of Measures ⁵		Combined Source Energy Savings	Combined Energy Savings (\$/year) ²	Combined Estimated Cost (\$)		Simple Estimated Payback (yrs)
				Marginal Cost ³	New System Cost ⁴	
Combination 1 (L:i;H:a)⁷						
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps (L:i;H:a)			\$50 - \$215		
7	Decreased Window SHGC & U Value (Climate Zone 2: from 0.3 to 0.2 SHGC & from 0.65 to 0.3 U-Value) (L:e;H:d)	16.9% - 18.6%	\$406 - \$461	\$900 - \$1,100		2.1 - 3.2
Combination 2 (L:f;H:a)						
7	Decreased Window SHGC & U Value (Climate Zone 2: from 0.3 to 0.2 SHGC & from 0.65 to 0.3 U-Value) (L:e;H:d)			\$900 - \$1,100		
9	Improved Air Conditioner SEER (from 13 to 15 SEER) (L:h;H:a)	15.0% - 16.6%	\$333 - \$406	\$900 - \$2,500		5.2 - 13.5
1	Radiant Barrier in Attics (with Ducts in Attics) (L:a,b;H:h)				\$300 - \$880	
Combination 3 (L:f;H:a)						
8	Relocate Mechanical Systems within Conditioned Space (L:a;H:i)			\$1,000 - \$7,000		
9	Improved Air Conditioner SEER (from 13 to 15 SEER) (L:h;H:a)	15.0% - 16.4%	\$338 - \$405	\$900 - \$2,500		6.7 - 31.1
3	Window Shading (None to 2 ft. Eaves on All Sides) (L:i;H:a)				\$800 - \$1,000	

Results: Recommendations for CZ 2

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Combination of Measures ⁵		NO _x Emissions Annual (lbs/yr)	SO ₂ Emissions Annual (lbs/yr)	CO ₂ Emissions Annual (tons/yr) ⁶
Combination 1 (L:i;H:a)⁷				
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps (L:i;H:a)			
7	Decreased Window SHGC & U Value (Climate Zone 2: from 0.3 to 0.2 SHGC & from 0.65 to 0.3 U-Value) (L:e;H:d)	5.8 - 6.6	3.6 - 4.1	2.5 - 2.8
Combination 2 (L:f;H:a)				
7	Decreased Window SHGC & U Value (Climate Zone 2: from 0.3 to 0.2 SHGC & from 0.65 to 0.3 U-Value) (L:e;H:d)	4.7 - 5.8	2.8 - 3.5	2.0 - 2.5
9	Improved Air Conditioner SEER (from 13 to 15 SEER) (L:h;H:a)			
1	Radiant Barrier in Attics (with Ducts in Attics) (L:a,b;H:h)			
Combination 3 (L:f;H:a)				
8	Relocate Mechanical Systems within Conditioned Space (L:a;H:i)			
9	Improved Air Conditioner SEER (from 13 to 15 SEER) (L:h;H:a)	4.8 - 5.8	2.8 - 3.6	2.1 - 2.5
3	Window Shading (None to 2 ft. Eaves on All Sides) (L:i;H:a)			

Summary (1/2)

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Recommendations for 15% Above 2009 IECC Code-Compliant House for SF Residences across Texas

- ESL simulation model based on the DOE-2.1e of a 2009 IECC code-compliant, single-family residence
- 17 counties in Texas
- 17 individual energy efficiency measures (EEMs)
- Implementation costs of each measure with simple payback
- Three group measures to achieve 15% total source energy savings above 2009 IECC code-compliant house

Summary (2/2)

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Results

- Cost-effective EEMs
 - Shortest payback periods (0.2 to 1.1 years) from lighting measures across the climate zones
 - Second shortest payback periods from improved window performance measures for Climate Zone 2 and 3 and from improved AC efficiency
- Three group measures
 - Shortest payback periods:
2.1 to 3.2 years for CZ 2; 2.9 to 5.6 years for CZ 3; and 4.8 to 9.0 years for CZ 4

Acknowledgement

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Acknowledgement

- Funding for this study was provided by the Texas State Legislature through the Texas Emissions Reduction Program (TERP).

Thank You!

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