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COST-EFFECTIVE ENERGY EFFICIENCY MEASURES FOR ABOVE CODE (2003 AND 2009 IECC): RESIDENTIAL BUILDINGS IN THE CITY OF ARLINGTON

A Research Project for the City of Arlington

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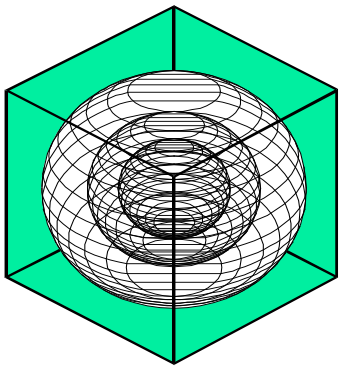

ENERGY SYSTEMS LABORATORY

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EXECUTIVE SUMMARY

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

For more realistic recommendations, the CoA provided two years of residential building energy compliance reports from 2008 to 2010 which exceeded the energy efficiency requirements of the CoA (i.e., 2003 International Energy Conservation Code (IECC)). Based on a statistical analysis of energy compliance reports provided for 21 residential, the above-code approaches that had been made in the CoA were summarized for residential applications. From this summary of above-code approaches, recommendations were developed to achieve above-code energy performance based on the 2003 and 2009 IECC standard reference buildings, for single-family residences in the CoA.

The deliverables for the CoA consist of three parts:

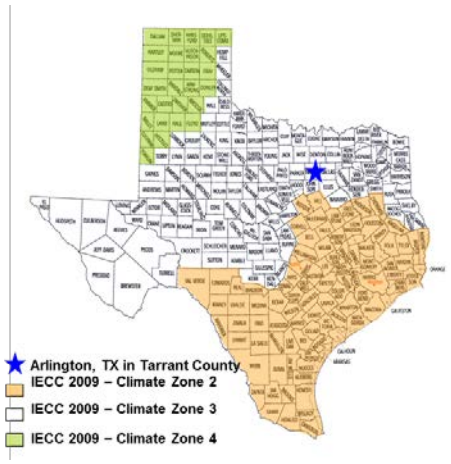
- A review of two years of building energy compliance reports from 2008 to 2010 for 21 residential projects in the CoA;
- A summary of above-code approaches that have been made in the CoA during the 2008-2010; and
- Recommendations of 17 energy efficiency measures (EEMs) to maximize energy savings for residential buildings in the CoA with estimated cost of the improvement, simple payback calculations, and emissions savings.

A total of 17 recommendations based on the energy savings above the base-case house were selected. These measures include building envelope and fenestration, HVAC system, domestic hot water (DHW) system, lighting and renewable options. The implementation costs of each individual measure were also calculated along with simple payback calculations. Figure 1 through Figure 4 present a description of the individual measures and combinations of these measures which achieve 15% savings above the 2003 and 2009 IECC code-compliant house. Annual energy savings, estimated costs, simple payback, and NOx, SO_2, and CO_2 emissions reduction are provided.

[Electric Cooling & Natural Gas Heating]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	**1.8%**	2.1%	$44		$300 - $880	6.7 - 19.8
2	Sealed (Unvented) Attic	**9.4%**	7.6%	$141	$2,000 - $3,500		14.2 - 24.8
3	Window Shading (None to 2 ft. Eaves on All Sides)	**1.3%**	3.1%	$75		$800 - $1,000	10.7 - 13.4
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)	**3.7%**	4.9%	$107		$800 - $1,000	7.5 - 9.3
5	Decreased Window SHGC (from .4 to .2)	**-1.0%**	3.8%	$111	$200 - $400		1.8 - 3.6
6	Decreased Window U Value (from .47 to .3)	**3.4%**	4.0%	$84	$600 - $900		7.1 - 10.7
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)	**1.6%**	7.1%	$183	$900 - $1,100		4.9 - 6.0
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	**11.1%**	10.4%	$205	$1,000 - $7,000		4.9 - 34.1
9	Improved Air Conditioner SEER (from 13 to 15 SEER)	**4.1%**	5.9%	$133	$900 - $2,500		6.8 - 18.8
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)	**3.5%**	1.6%	$20	$800 - $1,300		39.1 - 63.5
C	**Domestic Hot Water Measures**						
11	Tankless Gas Water Heater (without a Standing Pilot Light)	**3.9%**	1.8%	$23	$900 - $1,400		39.1 - 60.8
12	Removal of Pilot Light from Domestic Hot Water System	**1.8%**	0.9%	$11	$100 - $500		9.2 - 46.0
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	**11.6%**	4.1%	$32		$2,200 - $3,000	67.7 - 92.4
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	**14.6%**	5.6%	$51		$3,200 - $4,000	63.2 - 79.0
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**2.9%**	5.0%	$115	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**5.8%**	10.1%	$234	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	**23.2%**	31.3%	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**9.1%**	16.5%	$378	$50 - $215		3.3 - 5.8	5.4	3.6	2.2
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**12.9%**	16.9%	$362	$50 - $215		4.8 - 11.1	5.2	3.2	2.2
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	**16.8%**	15.9%	$308	$1,000 - $7,000		8.8 - 30.5	4.4	2.3	2.0
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
	Combination 4									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**15.0%**	18.0%	$380	$50 - $215		4.6 - 7.9	5.5	3.3	2.4
6	Decreased Window U Value (from .47 to .3)				$600 - $900					
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)					$800 - $1,000				
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 5									
15	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**17.2%**	19.0%	$389	$50 - $215		6.0 - 12.6	5.6	3.2	2.5
6	Decreased Window U Value (from .47 to .3)				$600 - $900					
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					

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 = $0.11/kWh
     Natural gas = $0.64/therm
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

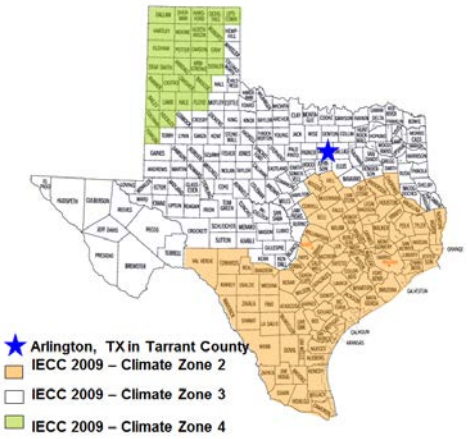
[2003 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 18% (Window-to-wall ratio: 27.1%)
* Lighting: 50% Energy Star permanent CFL 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: 14.5 cfm/100 sq-ft CFA

Figure 1. Individual and Combined Energy Efficiency Measures for 2003 IECC Code-Compliant House with Natural Gas Heating for CoA

[Electric Cooling & Heat Pump Heating]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	**2.0%**	2.0%	$48		$300 - $880	6.2 - 18.2
2	Sealed (Unvented) Attic	**6.4%**	6.4%	$152	$2,000 - $3,500		13.2 - 23.1
3	Window Shading (None to 2 ft. Eaves on All Sides)	**3.3%**	3.3%	$77		$800 - $1,000	10.3 - 12.9
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)	**4.7%**	4.7%	$113		$800 - $1,000	7.1 - 8.9
5	Decreased Window SHGC (from .4 to .2)	**4.5%**	4.5%	$106	$200 - $400		1.9 - 3.8
6	Decreased Window U Value (from .47 to .3)	**3.7%**	3.7%	$87	$600 - $900		6.9 - 10.3
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)	**7.6%**	7.6%	$181	$900 - $1,100		5.0 - 6.1
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	**8.5%**	8.5%	$203	$1,000 - $7,000		4.9 - 34.5
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)	**6.2%**	6.2%	$148	$1,200 - $2,500		8.1 - 16.9
C	**Domestic Hot Water Measures**						
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	**8.1%**	8.1%	$193		$2,200 - $3,000	11.4 - 15.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	**10.3%**	10.3%	$246		$3,200 - $4,000	13.0 - 16.3
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**5.0%**	5.0%	$119	$25 - $110		0.2 - 0.9
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**9.9%**	9.9%	$235	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	**29.1%**	29.1%	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**16.4%**	16.4%	$384	$50 - $215		3.3 - 5.7	5.5	3.5	2.3
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**21.5%**	21.5%	$501	$25 - $110		4.2 - 7.4	7.2	4.5	3.0
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)				$1,200 - $2,500					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	**18.7%**	18.7%	$436	$1,000 - $7,000		9.6 - 25.2	6.3	3.9	2.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)					$3,200 - $4,000				

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Energy Cost: Electricity = $0.11/kWh
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

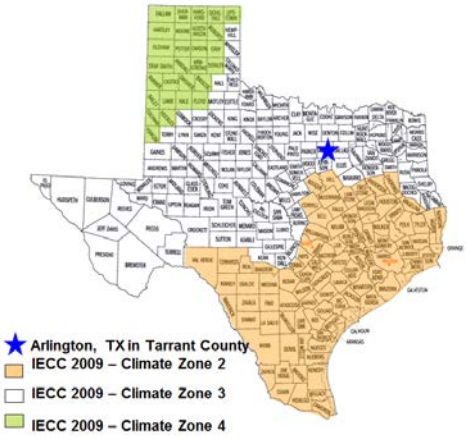
[2003 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 18% (Window-to-wall ratio: 27.1%)
* Lighting: 50% Energy Star permanent CFL or fluorescent lamps
* HVAC system: SEER 13 AC and 7.7 HSPF heat pump
* DHW: 0.90 EF Electric heater
* Duct Location: Unconditioned, vented attic
* Duct Leakage to Outdoor: 14.5 cfm/100 sq-ft CFA

Figure 2. Individual and Combined Energy Efficiency Measures for 2003 IECC Code-Compliant House with Heat Pump Heating for CoA

[Electric Cooling & Natural Gas Heating]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	1.8%	**2.0%**	$46		$300 - $880	6.6 - 19.2
2	Sealed (Unvented) Attic	7.6%	**5.7%**	$109	$2,000 - $3,500		18.3 - 32.0
3	Window Shading (None to 2 ft. Eaves on All Sides)	0.6%	**2.0%**	$56		$800 - $1,000	14.2 - 17.8
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)	1.9%	**3.0%**	$73		$800 - $1,000	11.0 - 13.7
5	Decreased Window SHGC (from .3 to .2)	-0.6%	**1.5%**	$50	$200 - $400		4.0 - 8.0
6	Decreased Window U Value (from .5 to .3)	4.2%	**4.2%**	$93	$600 - $900		6.4 - 9.6
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)	3.3%	**5.6%**	$142	$900 - $1,100		6.3 - 7.8
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	9.2%	**8.2%**	$172	$1,000 - $7,000		5.8 - 40.7
9	Improved Air Conditioner SEER (from 13 to 15 SEER)	3.8%	**6.0%**	$150	$900 - $2,500		6.0 - 16.6
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)	4.7%	**2.3%**	$33	$800 - $1,300		24.5 - 39.8
C	**Domestic Hot Water Measures**						
11	Tankless Gas Water Heater (without a Standing Pilot Light)	3.3%	**1.7%**	$23	$900 - $1,400		39.1 - 60.8
12	Removal of Pilot Light from Domestic Hot Water System	1.6%	**0.8%**	$11	$100 - $500		9.2 - 46.0
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	9.9%	**3.7%**	$32		$2,200 - $3,000	67.7 - 92.4
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	12.6%	**5.0%**	$51		$3,200 - $4,000	63.2 - 79.0
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	2.0%	**4.3%**	$112	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	4.2%	**8.7%**	$228	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	19.9%	**28.4%**	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Combined Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NO_x Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	8.6%	**15.8%**	$403	$50 - $215		3.1 - 5.4	5.8	3.9	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	13.1%	**17.0%**	$405	$50 - $215		4.3 - 9.9	5.8	3.6	2.5
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	16.0%	**15.0%**	$317	$1,000 - $7,000		8.5 - 29.7	4.6	2.3	2.1
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					

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 = $0.11/kWh
     Natural gas = $0.64/therm
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

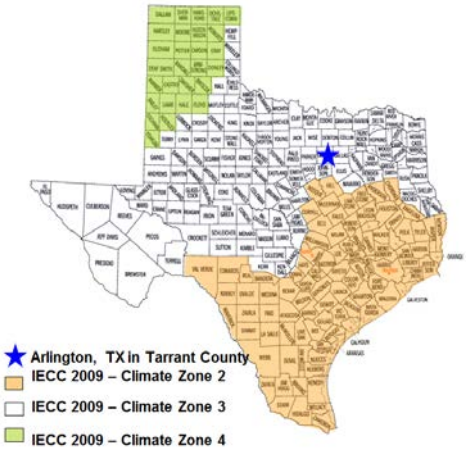
[2009 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 15% (Window-to-wall ratio: 22.6%)
* Lighting: 50% Energy Star permanent CFL 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

Figure 3. Individual and Combined Energy Efficiency Measures for 2009 IECC Code-Compliant House with Natural Gas Heating for CoA

[Electric Cooling & Heat Pump Heating]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	1.8%	**1.8%**	$45		$300 - $880	6.6 - 19.5
2	Sealed (Unvented) Attic	4.0%	**4.0%**	$103	$2,000 - $3,500		19.4 - 33.9
3	Window Shading (None to 2 ft. Eaves on All Sides)	2.1%	**2.1%**	$55		$800 - $1,000	14.6 - 18.2
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)	2.9%	**2.9%**	$74		$800 - $1,000	10.8 - 13.5
5	Decreased Window SHGC (from .3 to .2)	2.0%	**2.0%**	$52	$200 - $400		3.9 - 7.8
6	Decreased Window U Value (from .5 to .3)	3.8%	**3.8%**	$97	$600 - $900		6.2 - 9.3
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)	5.6%	**5.6%**	$142	$900 - $1,100		6.3 - 7.8
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	6.3%	**6.3%**	$161	$1,000 - $7,000		6.2 - 43.4
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)	6.7%	**6.7%**	$171	$1,200 - $2,500		7.0 - 14.6
C	**Domestic Hot Water Measures**						
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	7.6%	**7.6%**	$193		$2,200 - $3,000	11.4 - 15.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	9.7%	**9.7%**	$246		$3,200 - $4,000	13.0 - 16.3
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	4.3%	**4.3%**	$110	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	8.8%	**8.8%**	$226	$50 - $215		0.2 - 1.0
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	27.1%	**27.1%**	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	15.8%	**15.8%**	$403	$50 - $215		3.1 - 5.4	5.8	3.6	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	15.4%	**15.4%**	$393	$25 - $110		5.4 - 9.4	5.7	3.6	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)				$1,200 - $2,500					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	16.0%	**16.0%**	$407	$1,000 - $7,000		10.3 - 27.0	5.9	3.7	2.5
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)					$3,200 - $4,000				

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Energy Cost: Electricity = $0.11/kWh
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

[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 7.7 HSPF heat pump
* DHW: 0.90 EF Electric heater
* Duct Location: Unconditioned, vented attic
* Duct Leakage to Outdoor: 8 cfm/100 sq-ft CFA

Figure 4. Individual and Combined Energy Efficiency Measures for 2009 IECC Code-Compliant House with Heat Pump Heating for CoA

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1 INTRODUCTION

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

For more realistic recommendations, the CoA provided two years of residential building energy compliance reports from 2008 to 2010 which exceeded the energy efficiency requirements of the CoA (i.e., 2003 International Energy Conservation Code (IECC)). Based ona statistical analysis of energy compliance reports provided for 21 residential, the above-code approaches that had been made in the CoA were summarized for residential applications. From this summary of above-code approaches, recommendations were developed to achieve above-code energy performance based on the 2003 and 2009 IECC standard reference buildings, for single-family residences in the CoA.

The deliverables for the CoA consist of three parts:

- A review of two years of building energy compliance reports from 2008 to 2010 for 21 residential projects in the CoA;
- A summary of above-code approaches that have been made in the CoA during the 2008-2010; and
- Recommendations of 17 energy efficiency measures (EEMs) to maximize energy savings for residential buildings in the CoA with estimated cost of the improvement, simple payback calculations, and emissions savings.

1.1 Organization of the Report

The report is organized in the following order:

- Section 1 presents the introduction and purpose of the report.
- Section 2 presents the methodology that was used.
- Section 3 provides a review of the 21 residential buildings' energy compliance reports, including the results from statistical analysis and above-code approaches that have been made for the past two years from 2008 to 2010.
- Section 4 presents the proposed energy efficiency measures for single-family residences in the CoA, including savings from 17 individual measures along with the simple payback calculations.
- Section 5 is a summary which is followed by references.

2 METHODOLOGY

This section describes the methodology and assumptions that were used in to analyze information on energy certification for 21 residential buildings, and to develop the cost-effective recommendations for achieving energy performance better than 2003 and 2009 IECC code-compliant buildings for single-family residences in the CoA. 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**

To define important building parameters used to achieve above-code performance, a review of the building energy compliance reports for the past two years (2008-2010) was performed for 21 residential projects in the CoA. The buildings' envelope, fenestration, and system characteristics were summarized, and then statistically compared with the 2003 IECC Chapter 4 requirements for residential building. From this, a summary table of energy efficiency measures used for the residential buildings in the CoA during 2008-2010 was developed.

Based on the summary of residential above-code approaches, recommendations were developed to achieve above-code energy performance based on the 2003 and 2009 IECC standard reference house for single-family residences in the CoA. The analysis was performed using an ESL simulation tool based on the DOE-2.1e simulation of 2003 and 2009 IECC code-compliant, single family residence for Tarrant County where the CoA is located and the Fort Worth TMY2 weather file (Figure 5). Two options based on the choice of heating fuel type were considered: (a) natural gas (gas-fired furnace for space heating, and gas water heater for domestic water heating), and (b) electricity (heat pump for space heating, and electric water heater for domestic water heating)[1]. A total of 17 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.

The measures were then combined to achieve the total energy savings of the group is 15% above the base-case 2003 and 2009 IECC code-compliant house. The results from individual measures and cost analysis were used to guide the selection of measures. As a result, three combinations were proposed for each base case ((a) electric/gas house and (b) all-electric house). Each combination was formed to have a different payback period. Finally, the corresponding emissions savings of each combination were calculated based on the eGrid for Texas.

[1] For the rest of this report, these houses will be referred to as (a) electric/gas house and (b) all-electric house, respectively.

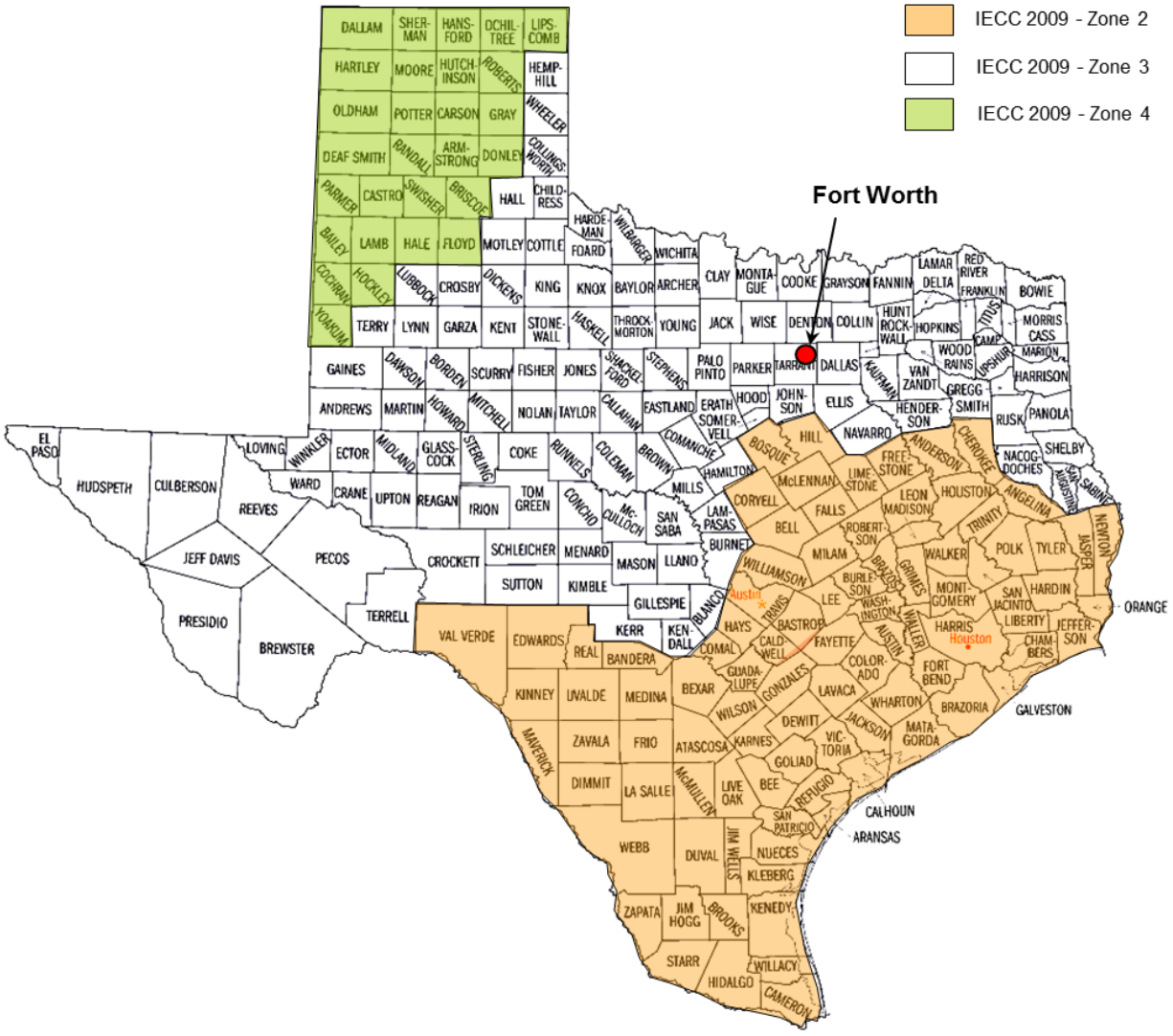


Figure 5. Tarrant County and Fort Worth TMY2 Weather File Used in the Analysis

2.2 Base-Case Building Description

The base-case building simulation model in this analysis is based on the *standard* design as defined in Chapter 4 of the 2003 and 2009 IECC, as well as certain assumptions which are described throughout this document. The base-case building is a 2,325 sq. ft., square-shape, one story, single-family, detached house oriented N, S, E, W, with a floor-to-ceiling height of 8 feet. Fifty percent of lamps in the house are assumed to be Energy Star permanent CFL or fluorescent lamps. The house has an attic with a roof pitched at 23 degrees, which contains the HVAC systems and ductwork. The base-case building envelope and system characteristics were determined from the general characteristics and the climate-specific characteristics as specified in the 2003 and 2009 IECC. Table 1 summarizes the base-case, 2003 and 2009 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 $0.11/kWh for electricity and $0.64/therm for natural gas. The electric rate was determined based on the information compiled by the Public Utility Commission of Texas[2]. The annual average rates calculated for Dallas were used for the natural gas rates[3].

[2] PUCT. 2010. *Average Annual Rate Comparison for Residential Electric Service: July 2010*. Austin, TX: Public Utility Commission of Texas. Retrieved September 30, 2010, from http://www.puc.state.tx.us/electric/rates/RESrate.cfm

[3] Atmos Energy. 2010a. *Atmos Energy Tariffs for Mid-Tex: September 2010 Mid-Tex GCR Rates*. Dallas, TX: Atmos Energy. Retrieved September 30, 2010, from http://www.atmosenergy.com/about/tariffs.html?st=mtx&pass=1

Table 1. Base Case Building Description

Characteristics	Assumptions		Comments
	2003 IECC for COA	2009 IECC for COA	
Building			
Building Type	Single family, detached house		
Gross Area	2,325 sq. ft. (48.21 ft. x 48.21 ft.)		
Number of Floors	1		
Floor to Floor Height (ft.)	8		
Orientation	South facing		
Construction			
Construction	Light-weight wood frame with 2x4 studs spaced at 16" on center		
Floor	Slab-on-grade floor		
Roof Configuration	Unconditioned, vented attic		
Roof Absorptance	0.75		Solar reflectance SR= 0.25
Ceiling Insulation (hr-sq.ft.-°F/Btu)	R-38	R-30	
Wall Absorptance	0.75		Assuming brick facia exterior
Wall Insulation (hr-sq.ft.-°F/Btu)	R-11	R-13	
Slab Perimeter Insulation	None		
Ground Reflectance	0.24		Assuming grass
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	0.47	0.5	
Solar Heat Gain Coefficient (SHGC)	0.4	0.3	
Window Area	18% of conditioned floor area	15% of conditioned floor area	This corresponds to 27.13% and 22.61% window-to-wall area ratio for the assumed 2003 and 2009 base case building configuration, respectively.
Exterior Shading	None		
Roof Radiant Barrier	No		Roof radiant barrier emissivity=0.05
Slope of Roof	5:12		Steep slope (5:12 Slope of roof =23 degrees)
Space Conditions			
Space Temperature Set point	68°F Heating, 78°F Cooling, 5°F setback/setup	72°F Heating, 75°F Cooling, no set-back	
Internal Heat Gains	1.095 kW (modeled as 0.547 kW for lighting and 0.547 kW for equipment)		This assumes heat gains from lighting, equipment and occupants.
Number of Occupants	None		Assuming internal gains include heat gain from occupants
Mechanical Systems			
HVAC System Type	Gas & Electric Type: Electric cooling (air conditioner) and natural gas heating (gas fired furnace)		
	All Electric Type: Electric cooling and heating (air conditioner with heat pump)		
HVAC System Efficiency	Gas & Electric Type: SEER 13 AC, 0.78 AFUE furnace		
	All Electric Type: SEER 13 AC, 7.7 HSPF heat pump		
Cooling Capacity (Btu/hr)	55,800		500 sq. ft./ton
Heating Capacity (Btu/hr)	55,800		1.0 x cooling capacity
DHW System Type	Gas & Electric Type: 40-gallon tank type gas water heater with a standing pilot light		
	All Electric Type: 50-gallon tank type electric water heater (without a pilot light)		
DHW Heater Energy Factor	Gas & Electric Type: 0.594		Gas: 0.67-0.0019 V EF Electric: <=12 KW: 0.97-0.00132 V EF >12kW: 1.73V+155SL Btu/h Where V=storage volume (gal.)
	All Electric Type: 0.904		
Duct Location	Unconditioned, vented attic		
Duct Leakage (%)	10.0% (supply) and 10.0% (return)	5.6% (supply) and 5.6% (return)	14.5 (2003 IECC) and 8.0 (2009 IECC) CFM/100 ft^2 of CFA to outdoors
Duct Insulation (hr-sq.ft.-°F/Btu)	R-8 (supply) and R-4 (return)	R-8 (supply) and R-6 (return)	
HVAC Duct Static Pressure	1		
Supply Air Flow (CFM/ton)	360		
Infiltration Rate (SG)	SLA= 0.00057	SLA= 0.00036	

3 REVIEW OF RESIDENTIAL BUILDING ENERGY COMPLIANCE REPORTS

This section provides a review of the 21 residential buildings' energy compliance reports, including the results from statistical analysis and above-code approaches made during the past two years (2008-2010) in the CoA. A statistical analysis was performed based on the 2003 IECC Chapter 4 performance path requirements. A summary table of the energy efficiency measures (EEMs) that had been used in the 21 houses was developed.

Section 3.1 presents a master table that summarizes important building characteristics of the 21 sample buildings, including a brief description of energy certification, general building information, envelope and fenestration characteristics, and mechanical system characteristics. Section 3.2 provides a statistical analysis of summarized results with the 2003 IECC performance path requirements. Section 3.3 gives a summary of the EEMs used in the 21 sample houses.

3.1 **Master Summary Table**

A master summary table was developed to describe and summarize important building characteristics of the 21 sample houses for the following four categories:

- Identification;
- Building;
- Envelope; and
- System.

The identification section presents information associated with the sample houses' certifications, as shown in Table 2. This includes the RSN number, building type, new or addition construction, single-family or multi-family, compliant option, certification date, energy code used for a certification, UA compliance option (UA is calculated by multiplying the U-Value by the area of the surface or surfaces), above-code percentages, Home Energy Rating System (HERS) index, and emission reductions. All 21 houses are new construction complied with the 2003 IECC. Five houses used the ESL's International Code Compliance Calculator (IC3) tool, while others generated their compliance reports using REM/Rate software.

Next, the building section presents information associated with general building characteristics, as shown in Table 3. This includes orientation, number of floors and bedrooms, floor area, ceiling height, conditioned space volume, and insulated shell area. Twelve houses are single-story buildings, and nine houses are two-story buildings. The number of bedrooms varies from three to six. More than half of the houses have a total floor area between 2,000 ft^2 and 4,000 ft^2. The average ceiling height of the 21 houses is 9.6 ft.

The envelope section presents information associated with construction properties, including window, wall, roof/ceiling, floors, and infiltration, as shown in Table 4. All sample houses have less than 18% of window-to-floor ratio and have less than 0.4 of window Solar Heat Gain Coefficient (SHGC). All sample houses have wall insulation higher than R-13. Ten houses have radiant barrier while the other eleven houses do not. Eight houses provide their infiltration test results.

Finally, the system section presents information associated with mechanical systems, as shown in Table 5. This includes duct insulation and leakage, system location, type and efficiency of air conditioning, heating, domestic water heater systems, and thermostat programmability. A seasonal energy efficiency ratio (SEER)14/R-6 trade-off was used for 19 houses. Six houses have heat pump systems with electric

water heaters while other 15 houses have gas furnaces for their heating with gas water heaters. 16 houses have programmable thermostats, and for the other five houses no information was provided.

Table 2. Identification Information of 21 Residential Buildings

No.	Certification Info.								UA Compliance Option[1]			% Above Code (Performance Path)			HERS Index	Emissions Reductions[2]		
	RSN #	Bldg. Type	SF/ MF	New/ Addition	Compliant Option		Certificate Date	Code	2001 IECC	2003 IECC	2006 IECC	2001 IECC	2003 IECC	2006 IECC		NOx (lbs/yr)	SOx (lbs/yr)	CO2 (lbs/yr)
1	208717	Res	SF	New	IC3	v3.6.2	07/12/10	IECC 2000/2001	-	-	-	8.8%	-	-	-	2.9	1.6	2,265
2	185029	Res	SF	New	IC3	v3.6.1	03/01/10	IECC 2000/2001	-	-	-	4.1%	-	-	-	1.2	0.6	974
3	183073	Res	SF	New	IC3	v3.6.1	02/10/10	IECC 2000/2001	-	-	-	4.2%	-	-	-	1.5	0.8	1,191
4	208723	Res	SF	New	IC3	v3.6.2	07/12/10	IECC 2000/2001	-	-	-	11.7%	-	-	-	3.9	2.2	3,096
5	195751	Res	SF	New	IC3	v3.6.2	04/30/10	IECC 2000/2001	-	-	-	6.9%	-	-	-	1.9	1.1	1,510
6	202251	Res	SF	New	Energy Star	v2.0[3]	06/30/10	IECC 2003	-	NC	-	-	12.5%	-	77	2.4	7.3	3,200
7	187098	Res	SF	New	Energy Star	v2.0	03/23/10	IECC 2003	-	C	-	-	10.5%	-	82	1.9	5.9	2,600
8	202253	Res	SF	New	Energy Star	v2.0	06/02/10	IECC 2003/2006	-	-	C	-	10.1%	10.9%	69	3.2	9.8	4,400
9	179339	Res	SF	New	Energy Star	v2.0	12/16/09	IECC 2001	C	-	-	-	-	-	79	4.3	4.6	4,200
10	186508	Res	SF	New	Energy Star	v2.0	03/05/10	IECC 2001/2003	C	-	-	-	10.2%	-	81	6.0	7.2	6,200
11	186506	Res	SF	New	Energy Star	v2.0	03/05/10	IECC 2000/2001/2003	C	-	-	8.6%	8.6%	-	82	4.5	5.1	4,600
12	188739	Res	SF	New	Energy Star	v2.0	03/22/10	IECC 2001	C	-	-	-	-	-	75	6.5	5.6	6,200
13	120408	Res	SF	New	Energy Star	v2.0	02/24/09	IECC 2001	C	-	-	-	-	-	76	6.5	6.7	6,431
14	182939	Res	SF	New	Energy Star	v2.0	02/15/10	IECC 2000/2001/2003	C	-	-	7.4%	7.4%	-	83	4.8	6.1	5,000
15	169076	Res	SF	New	Energy Star	v2.0	02/27/09	IECC 2001	C	-	-	16.9%	-	-	77	4.9	4.6	4,726
16	117170	Res	SF	New	Energy Star	v2.0	01/09/09	IECC 2001	C	-	-	-	-	-	85	5.9	4.3	3,362
17	116979	Res	SF	New	Energy Star	v2.0	12/10/08	IECC 2001	C	-	-	-	-	-	80	3.9	4.6	3,947
18	175714	Res	SF	New	Energy Star	v2.0	01/06/10	IECC 2000/2001/2003	C	-	-	8.1%	8.1%	-	83	2.8	3.1	2,800
19	115560	Res	SF	New	Energy Star	v2.0	11/20/08	IECC 2001	C	-	-	14.6%	-	-	78	11.9	9.6	6,513
20	184612	Res	SF	New	Energy Star	v2.0	02/18/10	IECC 2000/2001/2003	C	-	-	6.1%	6.1%	-	84	3.9	4.8	4,000
21	117146	Res	SF	New	Energy Star	v2.0	01/12/09	IECC 2001	C	-	-	17.7%	-	-	78	4.4	4.1	4,267

Note:

1. C=Complied; NC=Not Complied
2. The emissions reductions (lbs/yr) estimated for NOx, SOx, and CO2 were extracted from IC3 or ENERGY STAR compliant reports.
3. ENERGY STAR version 2.0 was active from 7/1/2006 to 4/1/2011 (Source from http://www.energystar.gov/index.cfm?c=new_homes.nh_history).

Table 3. Basic Building Information of 21 Residential Buildings

No.	Building Info.											
	Orientation	No. of Floors	No. of Bedroom	Conditioned Floor Area (sq ft)[1]						Avg. Ceiling Height (ft)	Cond. Volume (cubic ft)	Insulated Shell Area (sq ft)
				Total	1st Floor[2]	2nd Floor[2]	CFA from Master Table					
							Total	1st Floor	2nd Floor			
1	Northeast	2	-	2,565	2,095	470				9.0	23,085	-
2	West	1	-	1,824	1,824	-				9.0	16,416	-
3	Southwest	1	-	1,971	1,971	-				9.0	17,739	-
4	Northwest	2	-	2,745	1,609	1,136				9.0	24,705	-
5	Southwest	1	-	1,824	1,824	-				9.0	16,416	-
6	-	1	3	1,500	1,500	-				8.0	12,000	4,498
7	-	1	3	1,153	1,153	-				8.0	9,224	3,468
8	-	1	3	1,557	1,557	-				8.0	12,456	4,535
9	-	1	4	2,584	2,584	-	2,438	2,438	-	10.4	26,809	7,585
10	-	2	6	4,597	2,351	2,246				10.7	49,400	9,733
11	-	2	5	3,032	1,974	1,058				10.0	30,216	8,193
12	-	2	4	3,318	2,013	1,305	3,408	2,068	1,340	9.7	32,161	7,966
13	-	2	4	3,289	1,897	1,392	3,235	1,866	1,369	9.5	31,197	8,362
14	-	2	5	3,886	2,037	1,849				10.8	41,784	8,922
15	-	1	3	2,530	2,530	-	1,827	1,827	-	10.0	25,310	7,283
16	-	1	4	2,303	2,303	-				9.5	21,878	7,184
17	-	1	3	2,424	2,424	-				10.0	24,216	7,081
18	-	1	3	2,101	2,101	-				9.9	20,748	6,097
19	-	2	4	3,301	1,944	1,357				9.4	30,899	7,255
20	-	2	4	3,247	1,917	1,330				10.6	34,543	8,420
21	-	1	4	2,219	2,219	-	2,583	2,583	-	11.2	24,888	7,178

Note: Numbers in blue stand for the calculated values. Numbers in red stand for mismatched information (See note 1).

1. There is a discrepancy in information between individual compliance reports and the master table provided by the CoA for the following five houses: No.9, 12, 13, 15, and 21. This summary table is based on CFA from individual compliance reports.
2. The 1st and 2nd floor areas of five houses (No.9, 12, 13, 15, and 21) were calculated proportionally to the 1st and 2nd floor areas from the master table provided by the CoA.

Table 4. Envelope Information of 21 Residential Buildings

No.	Envelope																		
	Window					Wall			Roof/Ceiling						Floors			Infiltration	
	Area (sq ft)	WWR %	WFR %	U-value	SHGC	R-value	U-value	Ext. Finish Material	R-value	U-value	Radiant Barrier	Vaulted Ceiling R-value	Vaulted Ceiling U-value	Material	Slab Floors	Frame Floors R-value	Frame Floors U-value	CFM50	ACH50[1]
1	321	17.6%	12.5%	0.52	0.25	R-13	-	Brick Face	R-28	-	No	-	-	Comp Shingle	-	-	-	Untested	-
2	209	13.6%	11.5%	0.53	0.39	R-13	-	Brick Face	R-26	-	No	-	-	Comp Shingle	-	-	-	Untested	-
3	218	13.6%	11.1%	0.53	0.37	R-13	-	Brick Face	R-27	-	No	-	-	Comp Shingle	-	-	-	Untested	-
4	296	15.7%	10.8%	0.52	0.25	R-13	-	Brick Face	R-34	-	No	-	-	Comp Shingle	-	-	-	Untested	-
5	209	13.6%	11.5%	0.53	0.39	R-13	-	Brick Face	R-32	-	No	-	-	Comp Shingle	-	-	-	Untested	-
6	152	10.0%	10.1%	0.34	0.30	R-13	0.082	-	R-38	0.026	Yes	-	-	-	Uninsulated U=0.365	-	-	1,200	6.0
7	122	11.0%	10.6%	0.32	0.29	R-13+0.63 c.i.	0.080	-	R-30	0.033	No	-	-	-	Uninsulated U=0.365	-	-	922	6.0
8	149	11.0%	9.6%	0.34	0.30	R-13	0.085	-	R-30	0.026	Yes	-	-	-	Uninsulated U=0.365	-	-	1,245	6.0
9	331	15.0%	12.8%	0.35	0.31	R-13+1.1 c.i.	0.080	-	R-38	0.026	Yes	R-22	0.055	-	Uninsulated U=0.365	-	-	2,893	6.5
10	586	15.0%	12.7%	0.54	0.24	R-13+0.3 c.i.	0.080	-	R-30	0.033	No	R-19	0.052	-	Uninsulated U=0.365	R-19	0.050	Untested	-
11	389	12.0%	12.8%	0.54	0.24	R-13+0.3 c.i.	0.080	-	R-30	0.033	No	R-19	0.052	-	Uninsulated U=0.365	R-19	0.050	Untested	-
12	471	13.0%	14.2%	0.35	0.31	R-13+1.1 c.i.	0.080	-	R-38	0.026	Yes	R-22	0.055	-	Uninsulated U=0.365	R-22	0.050	2,777	5.2
13	443	12.0%	13.5%	0.35	0.31	R-13+1.1 c.i.	0.080	-	R-30	0.035	Yes	R-22	0.055	-	Uninsulated U=0.365	R-22	0.049	Untested	-
14	627	17.0%	16.1%	0.54	0.24	R-13+0.3 c.i.	0.080	-	R-30	0.033	No	R-19	0.052	-	Uninsulated U=0.365	R-19	0.050	Untested	-
15	339	15.0%	13.4%	0.35	0.27	R-13	0.085	-	R-30	0.026	Yes	R-19	0.053	-	Uninsulated U=0.365	-	-	2,466	5.8
16	294	12.0%	12.8%	0.54	0.24	R-13+1.1 c.i.	0.077	-	R-30	0.034	Yes	R-22	0.047	-	Uninsulated U=0.365	-	-	Untested	-
17	405	19.0%	16.7%	0.35	0.31	R-13+1.1 c.i.	0.080	-	R-30	0.035	Yes	R-22	0.055	-	Uninsulated U=0.365	-	-	Untested	-
18	264	14.0%	12.6%	0.54	0.24	R-13	0.082	-	R-30	0.034	No	R-19	0.052	-	Uninsulated U=0.365	-	-	Untested	-
19	431	15.0%	13.1%	0.37	0.27	R-13	0.085	-	R-30	0.033	Yes	R-22	0.048	-	Uninsulated U=0.285	R-22	0.042	3,089	6.0
20	553	16.0%	17.0%	0.54	0.24	R-13+0.3 c.i.	0.080	-	R-30	0.033	No	R-19	0.052	-	Uninsulated U=0.365	R-19	0.050	Untested	-
21	331	16.0%	14.9%	0.35	0.27	R-13+3.6 c.i.	0.063	-	R-38	0.026	Yes	R-19	0.052	-	Uninsulated U=0.365	-	-	2,488	6.0

Note: Numbers in blue stand for the calculated values.

1. Infiltration (ACH50) was calculated using ACH50 = CFM50*60 (min/hr)/ Cond. Volume (ft^3)

Table 5. System Information of 21 Residential Buildings

No.	System												
	Duct				Mech. Location	A/C		Heating System			Water Heater		Programmable Thermostat
	Supply R-value	Return R-value	Leakage (CFM25)	Leakage[1] (CFM/100ft^2)		SEER	Tons	Type	HSPF	AFUE	Type	EF	
1	R-6	R-6	Untested	-	Uncond.	14	5.0	HP	7.7	-	Elec	0.91	-
2	R-6	R-6	Untested	-	Uncond.	13	3.5	Gas	-	0.8	Gas	0.70	-
3	R-6	R-6	Untested	-	Uncond.	13	4.0	Gas	-	0.8	Gas	0.70	-
4	R-6	R-6	Untested	-	Uncond.	14	5.5	HP	7.7	-	Elec	0.91	-
5	R-6	R-6	Untested	-	Uncond.	14	3.5	HP	7.7	-	Elec	0.91	-
6	R-6	R-6	90	6.0	-	14	-	HP	7.7	-	Elec	0.90	Yes
7	R-8	R-8	69	6.0	-	13	-	HP	7.9	-	Elec	0.90	Yes
8	-	-	93	6.0	-	14	-	HP	7.7	-	Elec	0.90	Yes
9	R-6	R-6	155	6.0	-	14	-	Gas	-	0.8	Gas	0.58	Yes
10	R-6	R-6	274	6.0	-	14	-	Gas	-	0.8	Gas	0.58	Yes
11	R-6	R-6	180	5.9	-	14	-	Gas	-	0.8	Gas	0.58	Yes
12	R-6	R-6	198	6.0	-	14	-	Gas	-	0.8	Gas	0.58	Yes
13	R-6	R-6	196	6.0	-	14	-	Gas	-	0.8	Gas	0.58	Yes
14	R-6	R-6	232	6.0	-	14	-	Gas	-	0.8	Gas	0.58	Yes
15	R-6	R-6	151	6.0	-	14	-	Gas	-	0.8	Gas	0.62	Yes
16	R-6	R-6	138	6.0	-	14	-	Gas	-	0.8	Gas	0.62	Yes
17	R-6	R-6	145	6.0	-	14	-	Gas	-	0.8	Gas	0.58	Yes
18	R-6	R-6	126	6.0	-	14	-	Gas	-	0.8	Gas	0.62	Yes
19	R-6	R-6	195	5.9	-	14	-	Gas	-	0.8	Gas	0.59	Yes
20	R-6	R-6	194	6.0	-	14	-	Gas	-	0.8	Gas	0.58	Yes
21	R-6	R-6	133	6.0	-	14	-	Gas	-	0.8	Gas	0.62	Yes

Note: Numbers in blue stand for the calculated values.

1. Duct Leakage (CFM/100ft^2) was calculated using CFM/100ft^2 = Total leakage (CFM25) *100 ft^2 / Cond. Fl. Area (ft^2). Based on the ENERGY STAR compliance report and REM/Rate v12.9.3. These numbers are measured leakage via a duct blaster test.

3.2 **Analysis of Energy Certificate Information**

A statistical analysis was performed to identify the energy efficiency measures that applied in the 21 sample houses in the CoA. For the selected building parameters, a comparison was conducted with the 2003 IECC Chapter 4 performance path requirements using frequency and percentage bar graphs. In the graphs, a color coding was used to help readers easily understand the compassion.

- : Above-code (Better than 2003 IECC performance path)
- : Below code (Worse than 2003 IECC performance path)
- : Just code (Same as 2003 IECC performance path)
- : Not required (A code house is same as proposed.)

This section presents major comparison results for the four categories: identification, building, envelope, and system. Additional results are presented in Appendix A.

3.2.1 Identification

1) Above-Code Percentage (Performance Path)

Figure 6 shows the frequency and percentage distribution of 16 houses by their above-code percentage calculated from performance path analysis[4]. All 16 houses have energy performance better than the 2001, 2003, and/or 2006 IECC requirements. Eight houses (50%) have above-code percentage higher than 10%, and the above-code percentages of other eight houses were less than 10%: 0 to 5% for two houses and 5 to 10% for six houses.

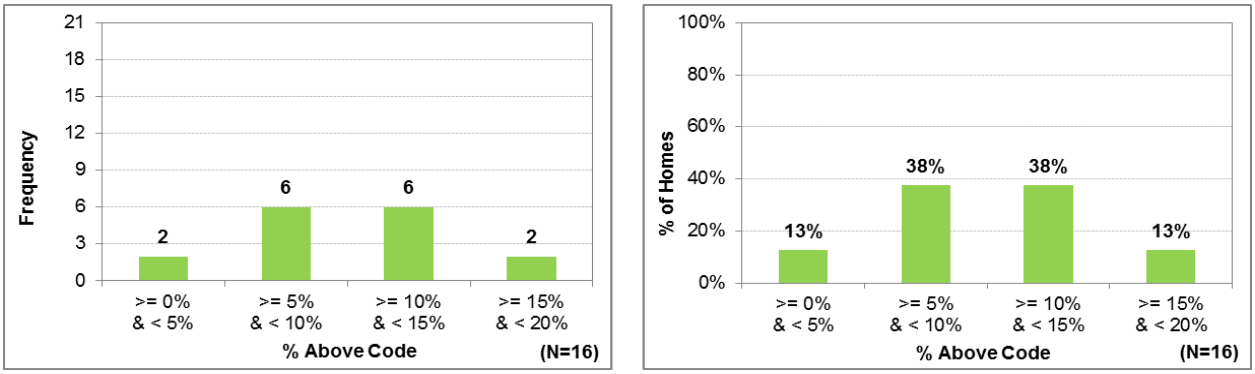


Figure 6. Frequency and Percentage Distribution of 16 Houses by Above-Code Percentage

[4] Five houses (building number of 9, 12, 13, 16 and 17) do not have the performance path certification.

3.2.2 Building

1) Number of Floors

Figure 7 shows the frequency and percentage distribution of the 21 houses by number of floors of the house. Twelve houses (57%) are one-story buildings, and nine houses (43%) are two-story buildings.

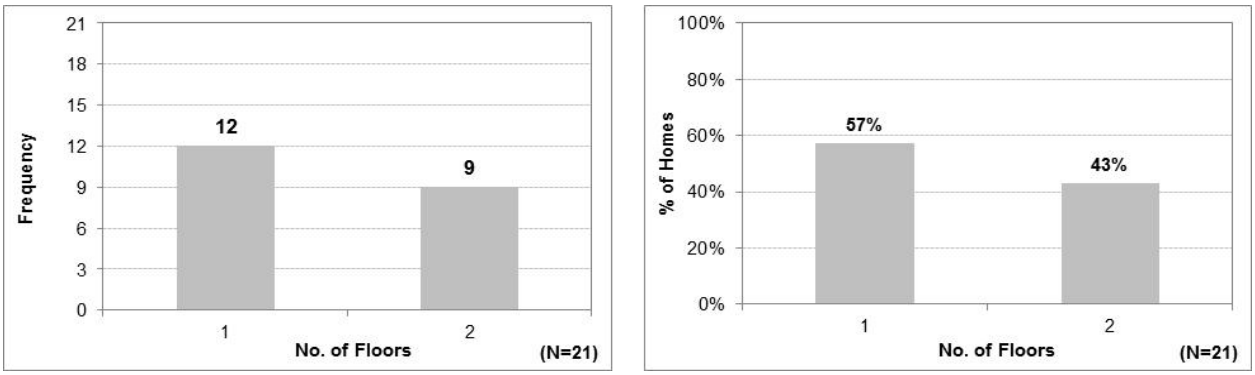


Figure 7. Frequency and Percentage Distribution of 21 Houses by Number of Floors

2) Total Floor Area

Figure 8 shows the frequency and percentage distribution of the 21 houses by total floor area of the house. A total floor area varies from 1,000 ft^2 to 5,000 ft^2. Six houses (29%) have a total floor area between 1,000 ft^2 and 2,000 ft^2. Eight houses (38%) have a total floor area between 2,000 ft^2 and 3,000 ft^2. The floor areas of other seven houses (34%) are larger than 3,000 ft^2: 3,000-4,000 ft^2 for six houses and 4,000-5,000 ft^2 for one house.

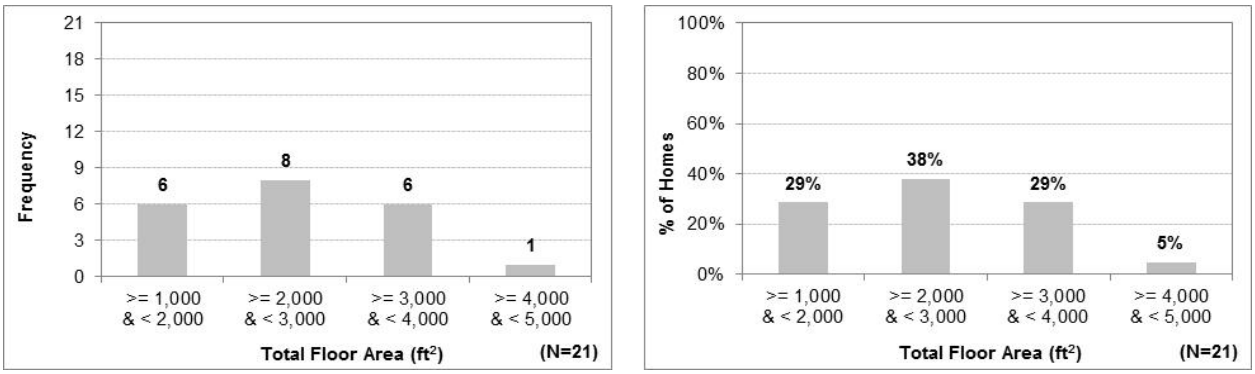


Figure 8. Frequency and Percentage Distribution of 21 Houses by Total Floor Area

3.2.3 Envelope

1) Floor

Figures 9 and 10 show the frequency and percentage distribution of seven 2-story houses by frame floor insulation R-value and of the 21 houses by slab floor insulation, respectively. All seven two-story houses have floor insulations better than code for their frame floor. All twenty-one houses do not have any slab insulations, which meets the 2003 IECC code requirements for slab floor.

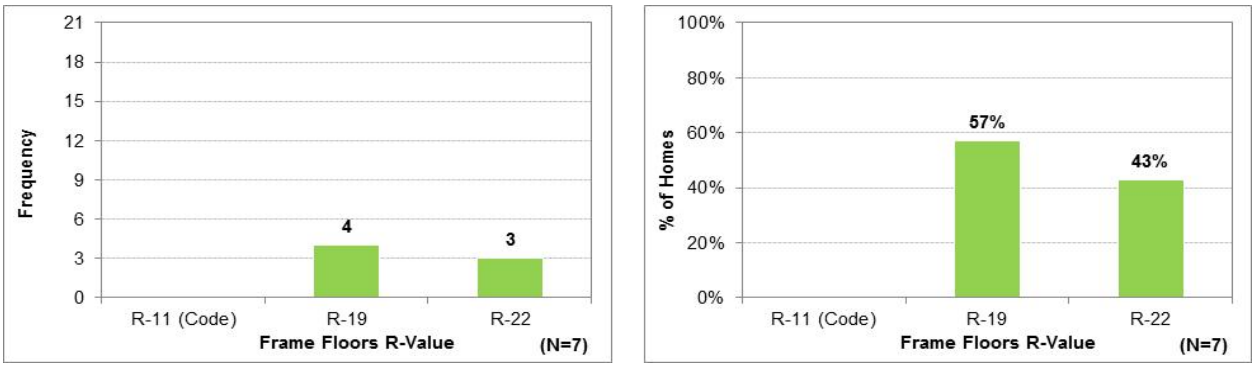


Figure 9. Frequency and Percentage Distribution of Seven Two-Story Houses by Frame Floors R-Value

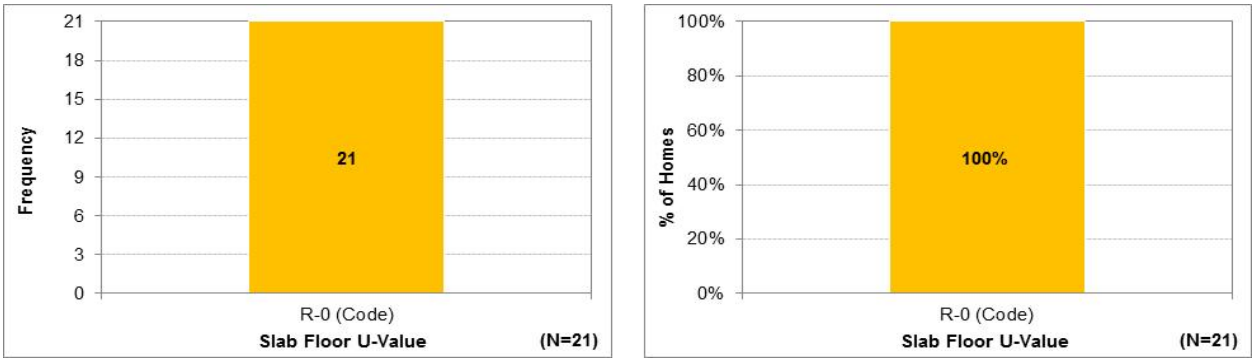


Figure 10. Frequency and Percentage Distribution of 21 Houses by Slab Floors R-Value

2) Average Ceiling Height

Figure 11 shows the frequency and percentage distribution of the 21 houses by average ceiling height per house. The average ceiling height of all twenty-one houses is 9.6 feet. Twelve houses (57%) have an average ceiling height between 9 and 10 feet.

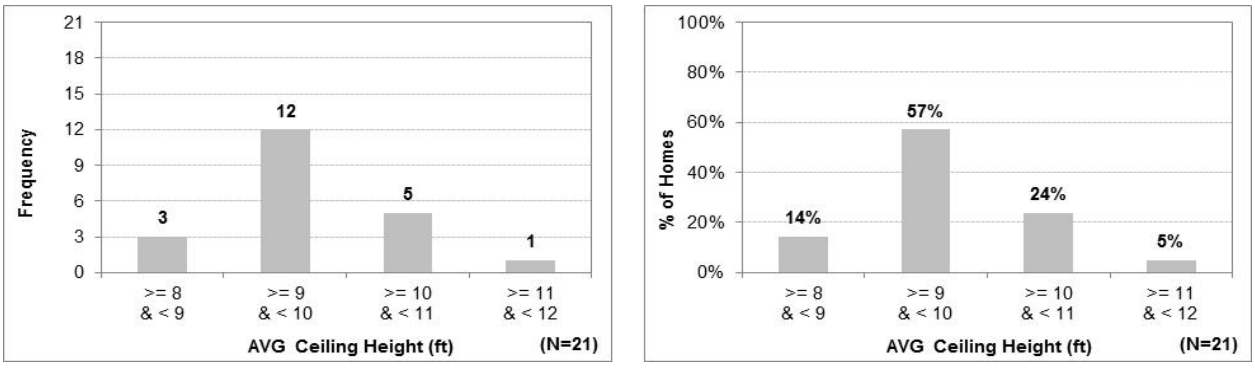


Figure 11. Frequency and Percentage Distribution of 21 Houses by Average Ceiling Height

3) Window

Figures 12 to 14 show the frequency and percentage distribution of the 21 houses by window-to-floor ratio (WFR), window U-value, and Solar Heat Gain Coefficient (SHGC). All twenty-one houses have window areas less than a 2003 IECC code house. Three houses (14%) have a WFR between 15% and 17.5%. Eleven houses (52%) have a WFR between 12.5% and 15%. The WFRs of other seven houses (34%) are less than 12.5%: 7.5-10% for one house and 10-12.5% for six houses. Ten houses (48%) have window U-values better than the 2003 IECC code house U-value, which is 0.47 Btu/hr-sq.ft.-F. All twenty-one houses have SHGC better than the 2003 IECC requirement, which is 0.40.

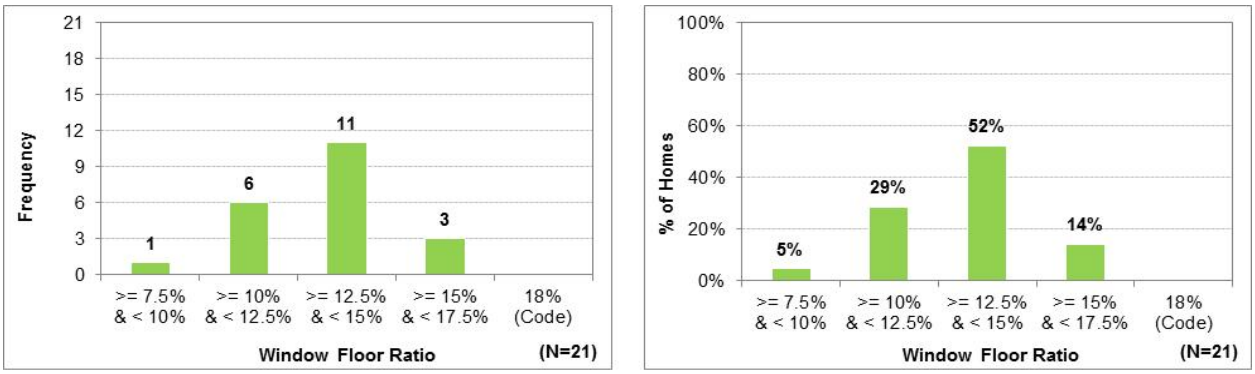


Figure 12. Frequency and Percentage Distribution of 21 Houses by Window-to-Floor Ratio

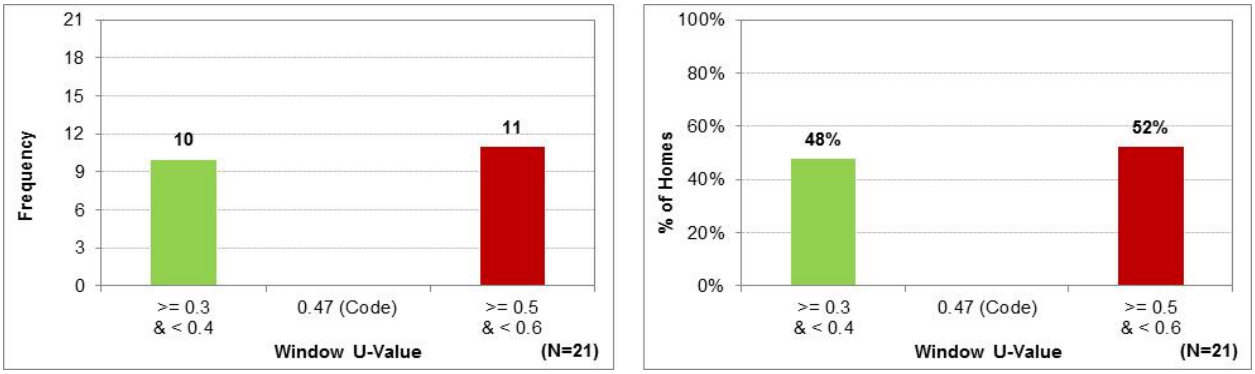


Figure 13. Frequency and Percentage Distribution of 21 Houses by Window U-Value

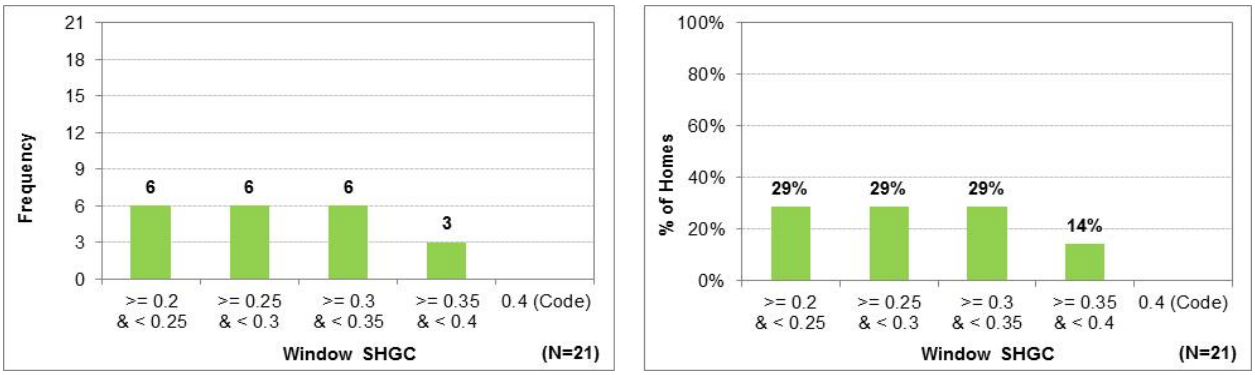


Figure 14. Frequency and Percentage Distribution of 21 Houses by Window SHGC

4) Wall R-Value

Figure 15 shows the frequency and percentage distribution of the 21 houses by wall insulation R-value. Ten houses (48%) meet the 2003 IECC code requirement, which is R-13. The other eleven houses (52%) have wall insulation better than the code.

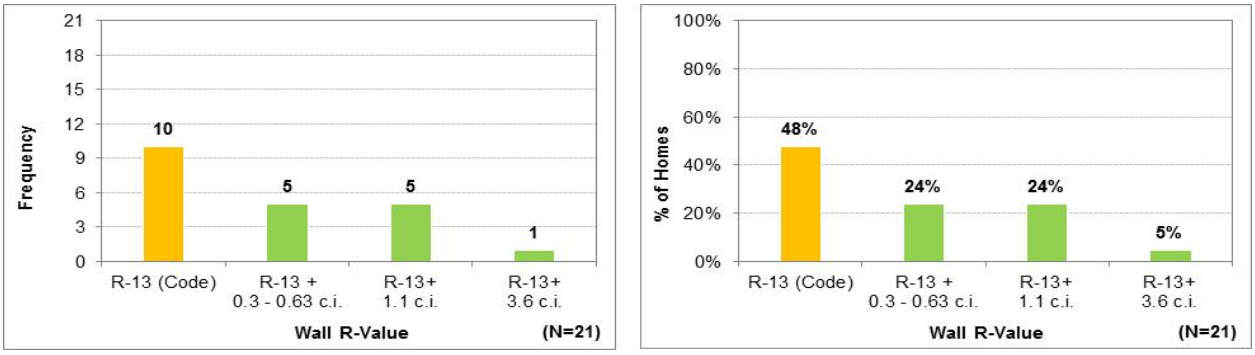


Figure 15. Frequency and Percentage Distribution of 21 Houses by Wall R-Value

5) Roof

Figures 16 and 17 show the frequency and percentage distribution of the 21 houses by attic radiant barrier and roof insulation R-value, respectively. Ten houses (48%) have radiant barrier. Six houses (29%) just meet the code requirements for roof insulation, and eleven houses (52%) have insulation values better than the code requirements[5]. Appendix A presents more details for this section.

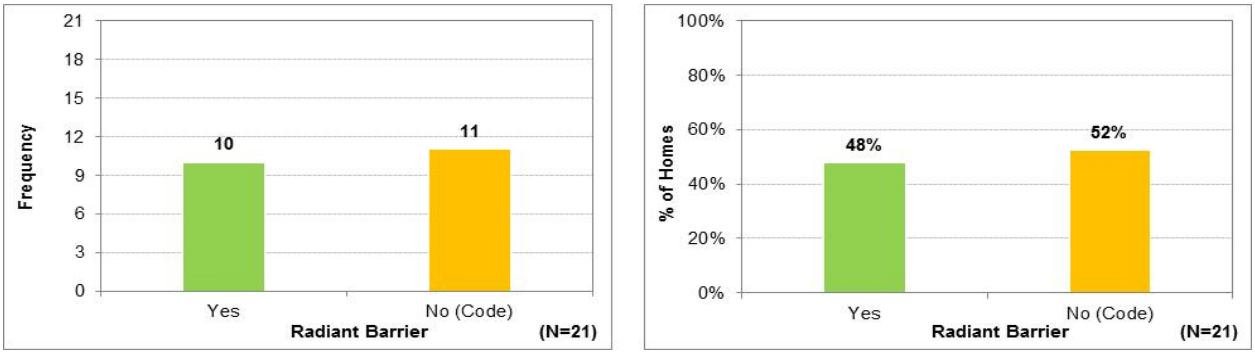


Figure 16. Frequency and Percentage Distribution of 21 Houses by Attic Radiant Barrier

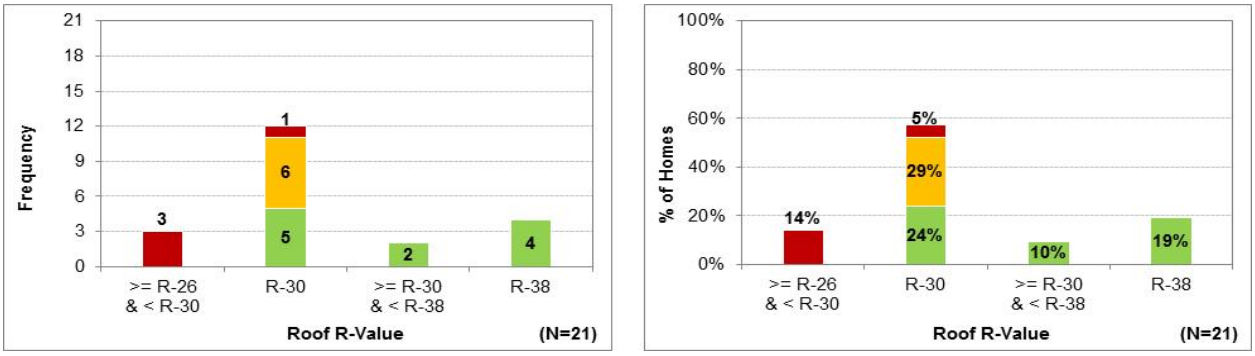


Figure 17. Frequency and Percentage Distribution of 21 Houses by Roof Insulation R-Value

[5] The 2003 IECC roof insulation requirements vary according to window-to-wall ratio.

6) Tested Air Leakage (ACH50)

Figure 18 shows the frequency and percentage distribution of eight houses by tested air leakage in air changes per house(ACH) using a blower door at a pressure of 50 Pa. All eight houses that were tested for their whole-house infiltration meet the code requirements[6]. Five houses (63% of them) have a 6.0 ACH50. More details for this section are presented in Appendix A.

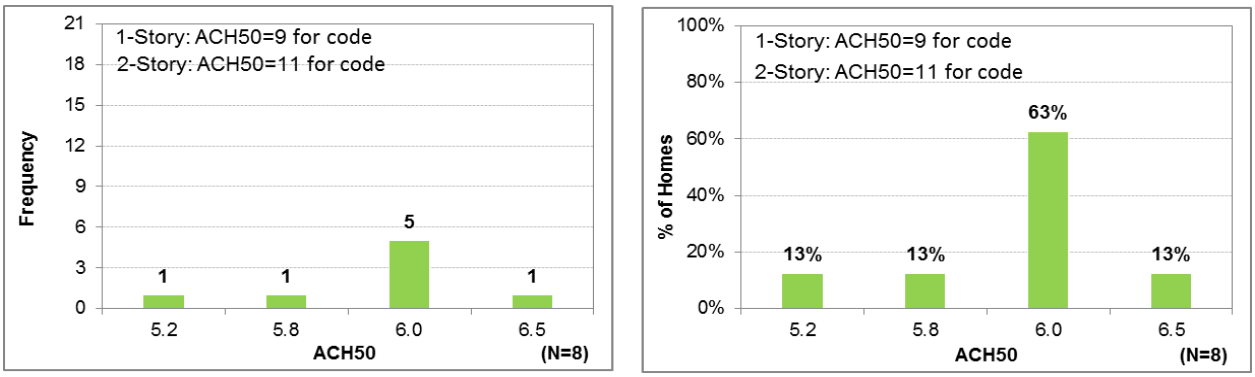


Figure 18. Frequency and Percentage Distribution of Eight Houses by Tested Air Leakage

[6] ACH50 for code house was calculated using: ACH = Normalized Leakage (0.57) x Weather Factor (0.89 for Tarrant County) = 0.50. 0.50 ACH=11 ACH50 for a 1-story house in Tarrant County and 9 ACH50 for a 2-story house in Tarrant County.

3.2.4 System

1) Duct

Figures 19 and 20 show the frequency and percentage distribution of -20 houses by duct insulation R-value and of 16 houses by tested duct leakage, respectively. Of the 20 houses that have information on their duct insulation[7], a SEER14/R-6 trade-off was used for 19 houses (95% of them). All 16 houses that were tested for their duct leakage meet the code requirements[8].

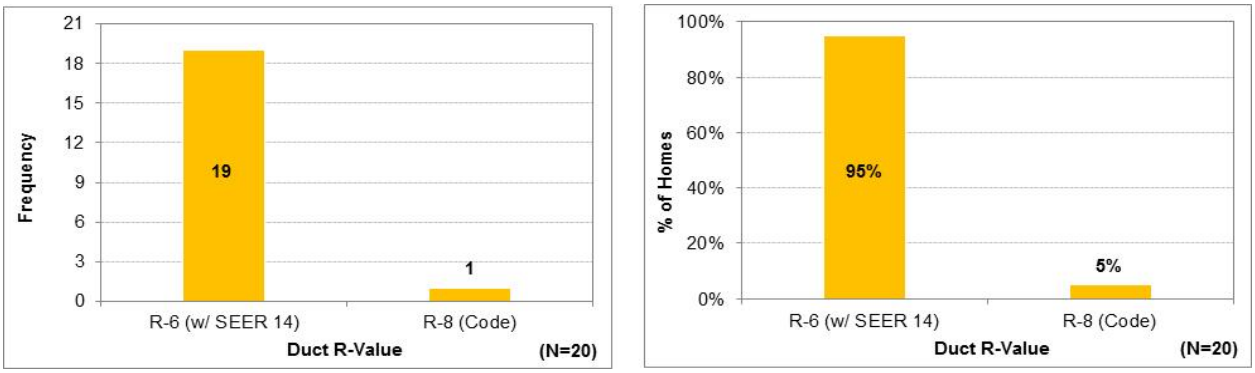


Figure 19. Frequency and Percentage Distribution of 20 Houses by Duct Insulation R-Value

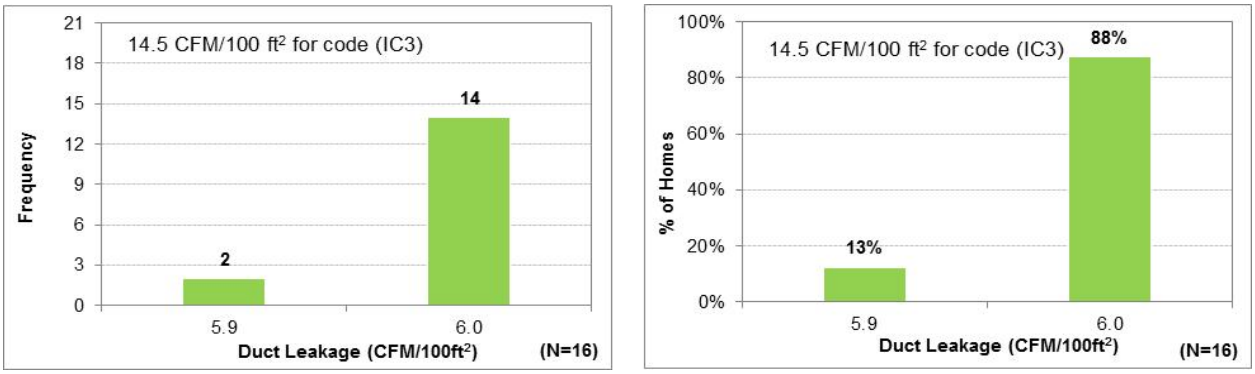


Figure 20. Frequency and Percentage Distribution of 16 Houses by Tested Duct Leakage

[7] House No. 8 did not provide information on duct insulation.

[8] For the 2003 IECC code house, a 20% total duct leakage (14.5 CFM/100ft^2) was assumed, which corresponds to a 0.80 duct distribution system efficiency (DSE) using the ESL's International Code Compliance Calculator (IC3) tool.

2) A/C System Efficiency

Figure 21 shows the frequency and percentage distribution of the 21 houses by A/C system efficiency. Three houses (14%) meet the 2003 IECC code requirement, which is SEER 13. Eighteen houses (86%) have a SEER higher than 13, but used with a SEER14/R-6 trade-off.

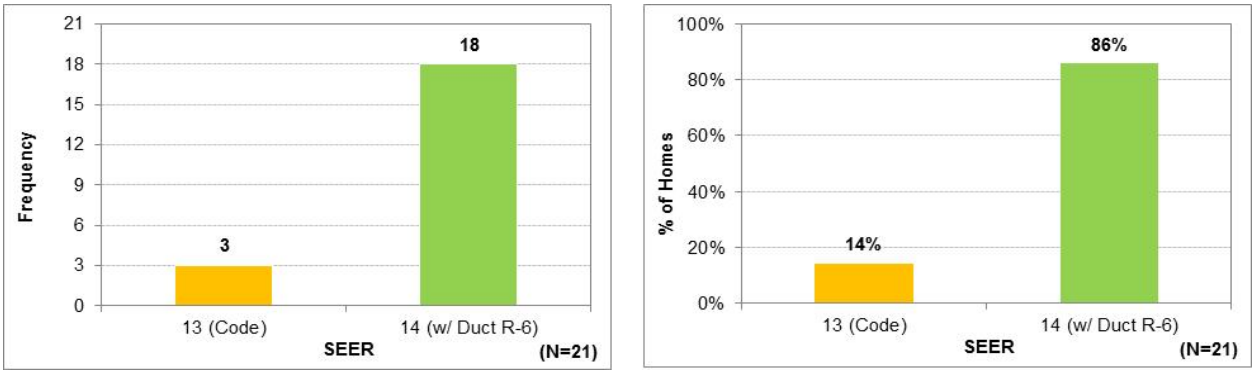


Figure 21. Frequency and Percentage Distribution of 21 Houses by A/C System Efficiency

3) Heating System

Figures 22 -24 show the frequency and percentage distribution of the 21 houses by type of heating system and the corresponding system efficiency. Six houses (29%) use heat pump for their heating, and other 15 houses (71%) have natural gas furnaces. Of six heat pump houses, five (83% of six houses) meet the 2003 IECC code requirement, and one house (17% of six houses) has system efficiency better than code. All 15 natural gas houses slightly exceed the code requirement.

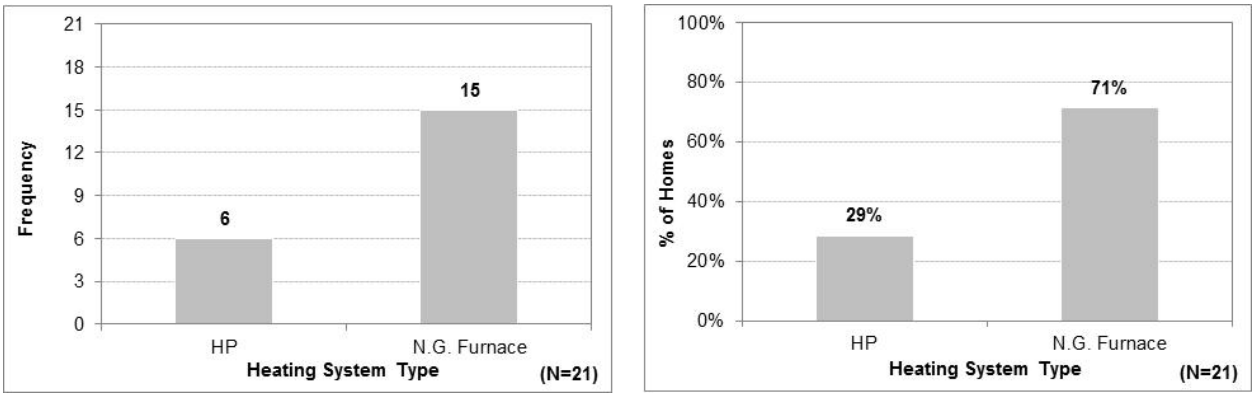


Figure 22. Frequency and Percentage Distribution of 21 Houses by Heating System Type

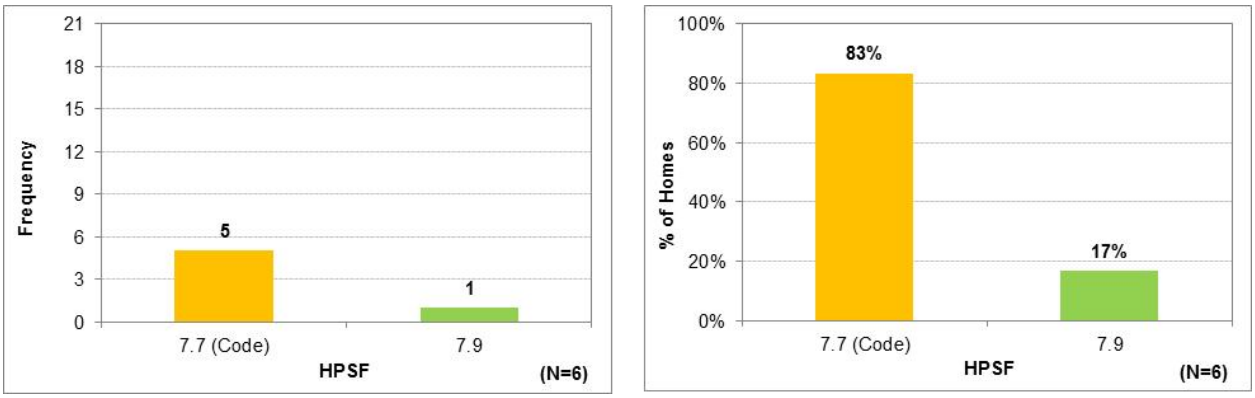


Figure 23. Frequency and Percentage Distribution of Six Houses by Heat Pump System Efficiency

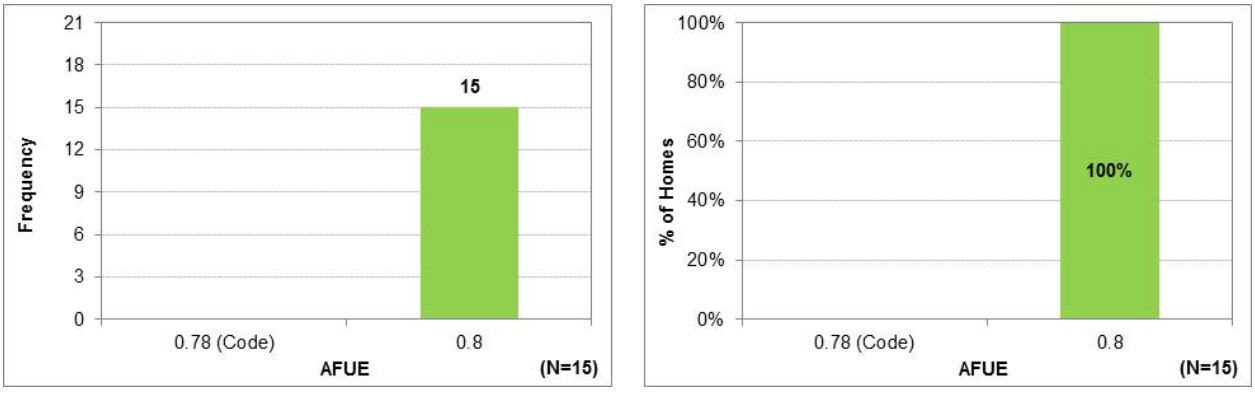


Figure 24. Frequency and Percentage Distribution of 15 Houses by N.G. Furnace System Efficiency

4) Water Heater

Figures 25- 27 show the frequency and percentage distribution of the 21 houses by type of water heater and the corresponding system efficiency. Six houses (29%) use electric water heaters, and the other 15 houses (71%) have natural gas water heaters. Of six electric water heater houses, three (50%) meet the code requirement, and the other three (50%) have an energy factor (EF) better than code. Of 15 natural gas water heater houses, six (40%) exceed the code requirement.

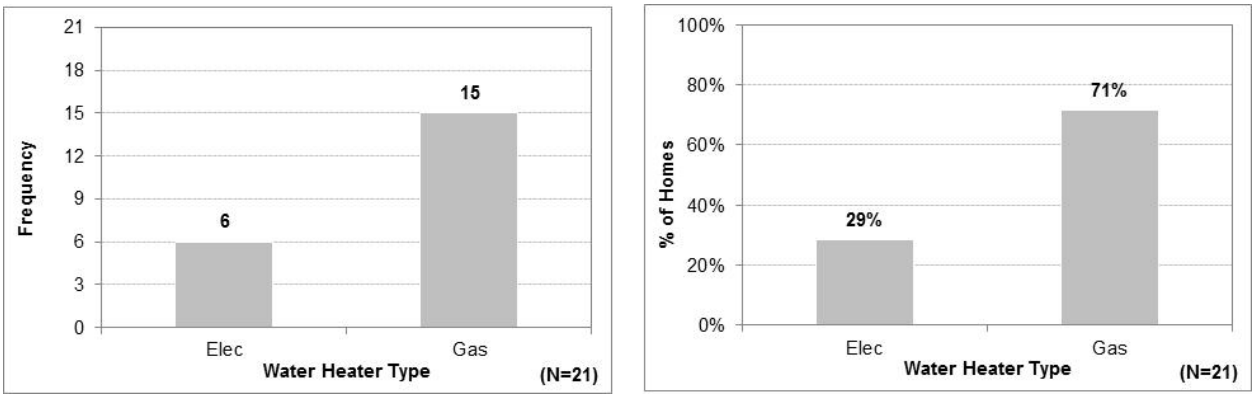


Figure 25. Frequency and Percentage Distribution of 21 Houses by Water Heater Type

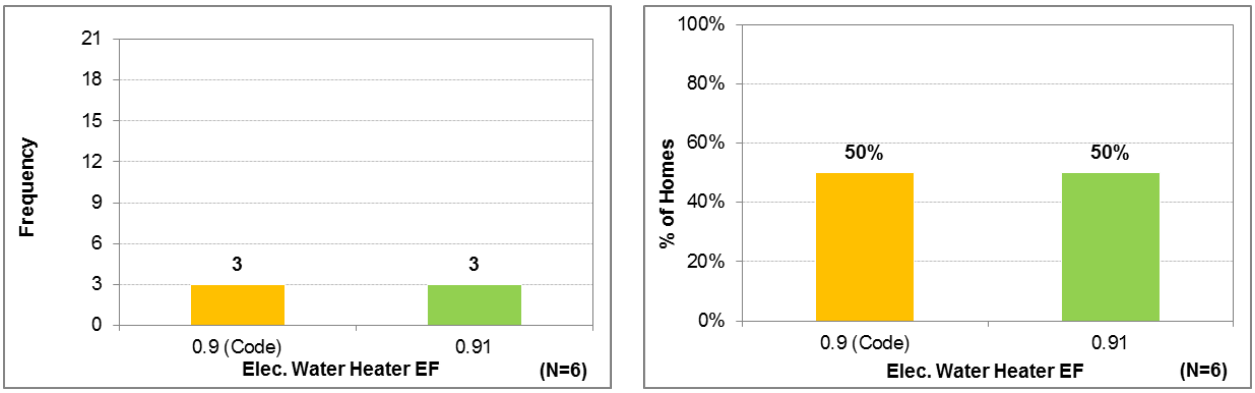


Figure 26. Frequency and Percentage Distribution of Six Houses by Electric Water Heater EF

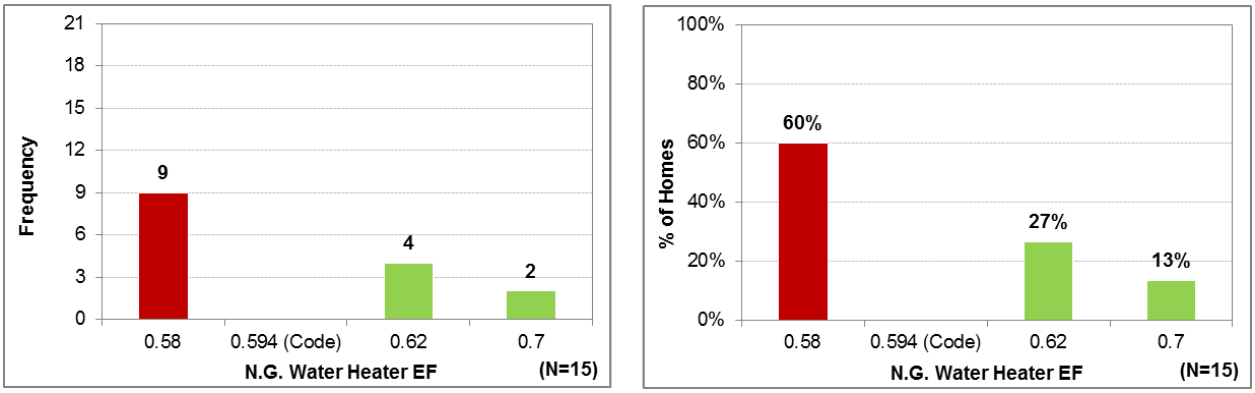


Figure 27. Frequency and Percentage Distribution of 15 Houses by N.G. Water Heater EF

3.3 **Energy Efficiency Measures**

Table 6 lists twelve energy efficiency measures (EEMs) used in the 21 residential buildings to achieve above-code energy performance based on the 2003 IECC Chapter 4 performance path. This includes envelope and fenestration, HVAC system, and domestic hot water system (DHW) measures. For envelope and fenestration measures, eleven houses (52%) installed radiant barriers in their attics as one of the above-code measures. Eleven houses (52%) have roof insulation R-value higher than the code requirement. Eleven houses (52%) have wall insulation better than code. Seven two-story houses have floor insulation better than code. Eight houses (38%) are tighter than the code house. All 21 houses have window areas less than the code house with a SHGC lower than the code requirement. Ten houses (48%) have window U-values better than code.

For HVAC system measures, 16 houses (76%) have reduced duct leakage than the code. 18 houses (86%) have A/C system with a SEER higher than 14, but used with a SEER14/R-6 trade-off. –Sixteen houses (76%) have higher efficient heating systems. For DHW system measures, nine houses (43%) have electric or natural gas water heaters with an EF higher than the code requirements.

Table 6. Summary on Energy Efficiency Measures Applied for Residential Buildings in CoA (2008-2010)

EEM #	Energy Efficiency Measure (EEM)	Description of EEM			Number of Houses	% of Houses
		Unit/Condition	Base Case (2003 IECC Code House)	EEM (Proposed House)		
Envelope and Fenestration Measures						
1	Roof/Ceiling Radiant Barrier	Radiant Barrier	No	Yes	11 / 21	52%
2	Increased Roof Insulation	R-Value, WWR 8-12%	R-19	R-30 R-38	5 1 / 21	52%
		R-Value, WWR 12-18%	R-30	R-32/R-34 R-38	2 3	
3	Increased Wall Insulation	R-Value	R-13	R-13 + c.i.	11 / 21	52%
4	Increased Floor Insulation (For 2-story houses)	R-Value	R-11	R-19 R-22	4 3 / 7	100%
5	Decreased Infiltration	ACH50[1], 1-story	11 ACH50	5.8/6.0/6.5	6 / 21	38%
		ACH50[1], 2-story	9 ACH50	5.2/6.0	2	
6	Decreased Window SHGC	SHGC	0.4	>= 0.2 & < 0.25 >= 0.25 & < 0.3 >= 0.3 & < 0.35 >= 0.35 & < 0.4	6 6 6 3 / 21	100%
7	Decreased Window U-Value	U-Value	0.47	>= 0.3 & < 0.35 >= 0.35 & < 0.4	3 7 / 21	48%
8	Decreased Window Area	WFR%	18%	>= 7.5% & < 10% >= 10% & < 12.5% >= 12.5% & < 15% >= 15% & < 17.5%	1 6 11 3 / 21	100%
HVAC System Measures						
9	Reduced Duct Leakage[2]	CFM/100ft^2	14.5	6	16 / 21	76%
10	Improved AC Efficiency[3]	SEER	13	14	18 / 21	86%
11	Imporved Heating System Efficiency	Efficiency, NG AFUE	0.78	0.8	15 / 21	76%
		Efficiency, HP HSPF	7.7	7.9	1	
Domestic Hot Water Measures						
12	Improved DHW Heater Efficiency[4]	EF, NG	0.594	0.62 0.7	4 2 / 21	43%
		EF, Elec.	0.904	0.9/0.91	3	

Note:

1 ACH = Normalized Leakage (0.57) x Weather Factor (0.89 for Tarrant County) = 0.57 x 0.89 = 0.50
0.50 ACH =11 ACH50 for a 1-story house in Tarrant County & 9 ACH50 for a 2-story house in Tarrant County

2 14.5 cfm/100ft^2 corresponds to 20% total duct leakage to outdoors, which is the leakage % for the 2001 IECC code house of the IC3

3 This EEM was used with R-6 duct insulation as a part of system efficiency trade-off.

4 (N.G.) EF = 0.67- 0.0019 x V; V=40 gal
(Elec.) EF = 0.97 - 0.00132 x V; V=50 gal

4 PROPOSED RESIDENTIAL ENERGY EFFICIENCY MEASURES

This section documents 17 energy efficiency measures (EEMs) for single-family residential buildings to achieve above-code energy performance based on the 2003 and 2009 IECC code-compliant house in Tarrant County, Texas, where the CoA is located. Section 4.1 gives a brief description of 17 individual EEMs and provides input parameters used in the simulation of each EEM. Section 4.2 presents the results of simulation and cost analysis.

4.1 **Individual EEMs**

Table 13 lists 17 energy efficiency measures considered in this analysis. These include measures for the building envelope and fenestration, HVAC system, domestic hot water (DHW) system, lighting and renewable options. Two different options were considered: (a) an electric/gas house and (b) an all-electric house. These measures were simulated by modifying the selected parameters used for the DOE-2 simulation tool. Tables 14 and 15 show the details on the simulation input parameters.

Table 7. Energy Efficiency Measures

	EEM No.	Electric/Gas House	All-Electric House
Envelope and Fenestration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	
	2	Sealed (Unvented) Attic	
	3	Window Shading (None to 2 ft. Eaves on All Sides)	
	4	Window Shading and Redistribution (2003 IECC: 27% Equal Windows w/o Shading to S=49%, N=27%, E/W = 16% with 2ft. Eaves on All Sides; 2009 IECC: 23% Equal Windows w/o Shading to S=41%, N=23%, E/W = 14% with 2ft. Eaves on All Sides)	
	5	Decreased Window SHGC (2003 IECC: from .4 to .2; 2009 IECC: from .3 to .2)	
	6	Decreased Window U Value (2003 IECC: from .47 to .3; 2009 IECC: from .5 to .3)	
	7	Decreased Window SHGC & U Value (2003 IECC: from .4 to .2 SHGC & from .47 to .3 U-Value; 2009 IECC: from .3 to .2 SHGC & from .5 to .3 U-Value)	
HVAC System Measures	8	Relocate Mechanical Systems within Conditioned Space	
	9	Improved Air Conditioner SEER (from 13 to 15 SEER)	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)
	10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)	-
Domestic Hot Water Measures	11	Tankless Gas Water Heater (without a Standing Pilot Light)	-
	12	Removal of Pilot Light from Domestic Hot Water System	-
	13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	
	14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	
Renewable Power Measures	17	4 kW Photovoltaic Array	

Table 8. Simulation Input Parameters of Individual EEMs for a 2003 IECC Code-Compliant House in CoA

	EEM #	Energy Efficiency Measure (EEM)	Radiant Barrier	Supply Duct Leakage (%)	Return Duct Leakage (%)	Insulation on Roof	Fractional Leakage Area for House	Fractional Leakage Area for Attic	Shading				WWR% forSide Wall				SHGC	U-Value	R-Value supply	R-Value return	Ducts in Conditioned Space	Improved SEER	Improved AFUE	Energy Factor	Lighting (kW)	Improved HSPF
									Front	Right	Back	Left	Front	Back	Right	Left										
		(a) Electric/Gas House Base Case	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
Envelope and Fenetration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	**Y**	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
	2	Sealed (Unvented) Attic	N	**5.00%**	**5.00%**	**R**	**0.00043**	**0**	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
	3	Window Shading (2ft overhang on all sides)	N	10.00%	10.00%	C	0.00057	0.0033	**2**	**2**	**2**	**2**	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
	4	Window Shading and Redistribution (2ft overhang on all sides, S=48.83%, N=27.13%, E/W = 16.28%)	N	10.00%	10.00%	C	0.00057	0.0033	**2**	**2**	**2**	**2**	**48.83**	**27.13**	**16.28**	**16.28**	0.4	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
	5	Decreased SHGC (CZ 3: from .4 to .2)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	**0.2**	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
	6	Decreased U Value (CZ3: from 0.47 to 0.3)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	**0.3**	8	4	ATTIC	13	0.78	0.594	0.547	7.70
	7	Decreased SHGC (CZ 3: from .4 to .2) & U Value (CZ3: from 0.47 to 0.3)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	**0.2**	**0.3**	8	4	ATTIC	13	0.78	0.594	0.547	7.70
HVAC System Measures	8	Mechanical Systems Within Conditioned Spaces	N	**0.00%**	**0.00%**	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	**1000**	**1000**	**ROOM**	13	0.78	0.594	0.547	7.70
	9	Improved SEER (from 13 to 15)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	**15**	0.78	0.594	0.547	7.70
	10	Improved Furnace Efficiency (from .78 to .93 AFUE)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	**0.93**	0.594	0.547	7.70
Domestic Hot Water Measures	11	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	**0.748**	0.547	7.70
	12	Removal of Pilot Light from DHW	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	**0.660**	0.547	7.70
	13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
	14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	**0.445**	7.70
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	**0.342**	7.70
Renewable Power Options	17	4 kW PV Array	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.594	0.547	7.70
		(b) All-Electric House[1] Base Case	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70
Envelope and Fenetration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	**Y**	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70
	2	Sealed (Unvented) Attic	N	**5.00%**	**5.00%**	**R**	**0.00043**	**0**	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70
	3	Window Shading (2ft overhang on all sides)	N	10.00%	10.00%	C	0.00057	0.0033	**2**	**2**	**2**	**2**	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70
	4	Window Shading and Redistribution (2ft overhang on all sides, S=48.83%, N=27.13%, E/W = 16.28%)	N	10.00%	10.00%	C	0.00057	0.0033	**2**	**2**	**2**	**2**	**48.83**	**27.13**	**16.28**	**16.28**	0.4	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70
	5	Decreased SHGC (CZ 3: from .4 to .2)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	**0.2**	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70
	6	Decreased U Value (CZ3: from 0.47 to 0.3)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	**0.3**	8	4	ATTIC	13	0.78	0.904	0.547	7.70
	7	Decreased SHGC (CZ 3: from .4 to .2) & U Value (CZ3: from 0.47 to 0.3)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	**0.2**	**0.3**	8	4	ATTIC	13	0.78	0.904	0.547	7.70
HVAC System Measures	8	Mechanical Systems Within Conditioned Spaces	N	**0.00%**	**0.00%**	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	**1000**	**1000**	**ROOM**	13	0.78	0.904	0.547	7.70
	9	Improved SEER (from 13 to 15) and Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	**15**	0.78	0.904	0.547	**8.50**
Domestic Hot Water Measures	13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70
	14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	**0.445**	7.70
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	**0.342**	7.70
Renewable Power Options	17	4 kW PV Array	N	10.00%	10.00%	C	0.00057	0.0033	0	0	0	0	27.13	27.13	27.13	27.13	0.4	0.47	8	4	ATTIC	13	0.78	0.904	0.547	7.70

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

Table 9. Simulation Input Parameters of Individual EEMs for a 2009 IECC Code-Compliant House in CoA

	EEM #	Energy Efficiency Measure (EEM)	Radiant Barrier	Supply Duct Leakage (%)	Return Duct Leakage (%)	Insulation on Roof	Fractional Leakage Area for House	Fractional Leakage Area for Attic	Shading				WWR% forSide Wall				SHGC	U-Value	R-Value supply	R-Value return	Ducts in Conditioned Space	Improved SEER	Improved AFUE	Energy Factor	Lighting (kW)	Improved HSPF
									Front	Right	Back	Left	Front	Back	Right	Left										
		(a) Electric/Gas House Base Case	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.5	8	6	ATTIC	13	0.78	0.594	0.547	7.70
Envelope and Fenetration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	**Y**	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.594	0.547	7.70
	2	Sealed (Unvented) Attic	N	**2.78%**	**2.78%**	**R**	**0.00027**	**0**	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.594	0.547	7.70
	3	Window Shading (2ft overhang on all sides)	N	5.56%	5.56%	C	0.00036	0.0033	**2**	**2**	**2**	**2**	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.594	0.547	7.70
	4	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	N	5.56%	5.56%	C	0.00036	0.0033	**2**	**2**	**2**	**2**	**40.70**	**22.61**	**13.57**	**13.57**	0.3	0.65	8	6	ATTIC	13	0.78	0.594	0.547	7.70
	5	Decreased SHGC (CZ 3: from .3 to .2)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	**0.2**	0.65	8	6	ATTIC	13	0.78	0.594	0.547	7.70
	6	Decreased U Value (CZ3: from 0.5 to 0.3)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	**0.3**	8	6	ATTIC	13	0.78	0.594	0.547	7.70
	7	Decreased SHGC (CZ 3: from .3 to .2) & U Value (CZ3: from 0.5 to 0.3)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	**0.2**	**0.3**	8	6	ATTIC	13	0.78	0.594	0.547	7.70
HVAC System Measures	8	Mechanical Systems Within Conditioned Spaces	N	**0.00%**	**0.00%**	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	**1000**	**1000**	**ROOM**	13	0.78	0.594	0.547	7.70
	9	Improved SEER (from 13 to 15)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	**15**	0.78	0.594	0.547	7.70
	10	Improved Furnace Efficiency (from .78 to .93 AFUE)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	**0.93**	0.594	0.547	7.70
Domestic Hot Water Measures	11	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	**0.748**	0.547	7.70
	12	Removal of Pilot Light from DHW	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	**0.660**	0.547	7.70
	13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.594	0.547	7.70
	14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.594	0.547	7.70
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.594	**0.445**	7.70
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.594	**0.342**	7.70
Renewable Power Options	17	4 kW PV Array	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.594	0.547	7.70
		(b) All-Electric House[1] Base Case	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.5	8	6	ATTIC	13	0.78	0.904	0.547	7.70
Envelope and Fenetration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	**Y**	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.904	0.547	7.70
	2	Sealed (Unvented) Attic	N	**2.78%**	**2.78%**	**R**	**0.00027**	**0**	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.904	0.547	7.70
	3	Window Shading (2ft overhang on all sides)	N	5.56%	5.56%	C	0.00036	0.0033	**2**	**2**	**2**	**2**	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.904	0.547	7.70
	4	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	N	5.56%	5.56%	C	0.00036	0.0033	**2**	**2**	**2**	**2**	**40.70**	**22.61**	**13.57**	**13.57**	0.3	0.65	8	6	ATTIC	13	0.78	0.904	0.547	7.70
	5	Decreased SHGC (CZ 3: from .3 to .2)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	**0.2**	0.65	8	6	ATTIC	13	0.78	0.904	0.547	7.70
	6	Decreased U Value (CZ3: from 0.5 to 0.3)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	**0.3**	8	6	ATTIC	13	0.78	0.904	0.547	7.70
	7	Decreased SHGC (CZ 3: from .3 to .2) & U Value (CZ3: from 0.5 to 0.3)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	**0.2**	**0.3**	8	6	ATTIC	13	0.78	0.904	0.547	7.70
HVAC System Measures	8	Mechanical Systems Within Conditioned Spaces	N	**0.00%**	**0.00%**	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	**1000**	**1000**	**ROOM**	13	0.78	0.904	0.547	7.70
	9	Improved SEER (from 13 to 15) and Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	**15**	0.78	0.904	0.547	**8.50**
Domestic Hot Water Measures	13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.904	0.547	7.70
	14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.904	0.547	7.70
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.904	**0.445**	7.70
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.904	**0.342**	7.70
Renewable Power Options	17	4 kW PV Array	N	5.56%	5.56%	C	0.00036	0.0033	0	0	0	0	22.61	22.61	22.61	22.61	0.3	0.65	8	6	ATTIC	13	0.78	0.904	0.547	7.70

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

4.2 **Results of Simulation and Cost Analysis**

4.2.1 Base-Case Energy Use

The annual total energy consumption of the 2003 IECC base case:

a) Site energy use by end-uses for an electric/gas house: 92.5 MMBtu/yr, including
- 15.9% for cooling;
- 21.0% for heating;
- 35.5% for lighting and equipment;
- 8.9% for fans and pumps; and
- 18.8% for domestic water heating.

b) Source energy use by fuel type for an electric/gas house: 216.5 MMBtu/yr, including
- 81.3% for electricity; and
- 18.7% for natural gas.

c) Site energy use by end-uses for an all-electric house: 73.8 MMBtu/yr, including
- 19.9% for cooling;
- 9.1% for heating;
- 44.4% for lighting and equipment;
- 11.0% for fans and pumps; and
- 15.6% for domestic water heating.

d) Source energy use by fuel type for an all-electric house: 233.2 MMBtu/yr, including
- 100% for electricity.

The annual total energy consumption of the 2009 IECC base case:

a) Site energy use by end-uses for an electric/gas house: 107.8 MMBtu/yr, including
- 14.3% for cooling;
- 29.7% for heating;
- 30.4% for lighting and equipment;
- 9.5% for fans and pumps; and
- 16.1% for domestic water heating.

b) Source energy use by fuel type for an electric/gas house: 238.9 MMBtu/yr, including
- 77.3% for electricity; and
- 22.7% for natural gas.

c) Site energy use by end-uses for an all-electric house: 79.1 MMBtu/yr, including
- 19.5% for cooling;
- 11.9% for heating;
- 41.5% for lighting and equipment;
- 12.6% for fans and pumps; and
- 14.5% for domestic water heating.

d) Source energy use by fuel type for an all-electric house: 250.0 MMBtu/yr, including
- 100% for electricity.

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 single-family houses in the CoA. It should be noted that the 2003 IECC code compliance results using the performance path analysis are determined based on site energy consumption, while 2009 IECC is based on source energy consumption. Based on the 2009 IECC, the measures reducing electricity consumption will yield higher savings percentage than the measures decreasing natural gas consumption for an electric/gas house.

4.2.2 Energy Savings from Various Individual EEMs

Tables 16 and 17 summarize the savings achieved from proposed EEMs and cost analysis for the 2003 and 2009 IECC code-compliant houses, including:

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

The annual site energy use was obtained from the BEPS report of the DOE-2 output and then converted to source energy[9]. Figure 52 to Figure 59 provide a graphical representation of the site/source energy consumption of the individual EEMs for the 2003 and 2009 IECC code-compliant base-case houses.

The savings results for the 2003 IECC code-compliant base case are:

a) Radiant barrier in attics:
   - Electric/gas house: 1.8% (site energy savings) and 2.1% (source energy savings) and
   - All-electric house: 2.0% (site -and source energy savings).

b) Sealed Attic:
   - Electric/gas house: 9.4% (site energy savings) and 7.6% (source energy savings) and
   - All-electric house: 6.4% (site -and source energy savings).

c) Window Shading:
   - Electric/gas house: 1.3% (site energy savings) and 3.1% (source energy savings) and
   - All-electric house: 3.3% (site -and source energy savings).

d) Window Shading and Redistribution:
   - Electric/gas house: 3.7% (site energy savings) and 4.9% (source energy savings) and
   - All-electric house: 4.7% (siteand source energy savings).

e) Decreased Window SHGC:
   - Electric/gas house: -1.0% (site energy savings) and 3.8% (source energy savings) and
   - All-electric house: 4.5% (site and source energy savings).

f) Decreased Window U-Value:
   - Electric/gas house: 3.4% (site energy savings) and 4.0% (source energy savings) and
   - All-electric house: 3.7% (site and source energy savings).

[9] 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.

g) Decreased Window SHGC and U-Value:
- Electric/gas house: 1.6% (site energy savings) and 7.1% (source energy savings) and
- All-electric house: 7.6% (site and source energy savings).

h) Relocate Mechanical Systems within Conditioned Space:
- Electric/gas house: 11.1% (site energy savings) and 10.4% (source energy savings) and
- All-electric house: 8.5% (site and source energy savings).

i) Improved Air Conditioner SEER:
- Electric/gas house: 4.1% (site energy savings) and 5.9% (source energy savings).

j) Improved Heat Pump Efficiency:
- All-electric house: 6.2% (site & source energy savings).

k) Improved Furnace Efficiency:
- Electric/gas house: 3.5% (site energy savings) and 1.6% (source energy savings).

l) Tankless Gas Water Heater:
- Electric/gas house: 3.9% (site energy savings) and 1.8% (source energy savings).

m) Removal of Pilot Light from DHW System:
- Electric/gas house: 1.8% (site energy savings) and 0.9% (source energy savings).

n) Solar DHW System (32 sq. ft. collector, 65 gal tank):
- Electric/gas house: 11.6% (site energy savings) and 4.1% (source energy savings) and
- All-electric house: 8.1% (site and source energy savings).

o) Solar DHW System (64 sq. ft. collector, 80 gal tank):
- Electric/gas house: 14.6% (site energy savings) and 5.6% (source energy savings) and
- All-electric house: 10.3% (site and source energy savings).

p) 75% Energy Star Permanent CFL or Fluorescent Indoor Lamps:
- Electric/gas house: 2.9% (site energy savings) and 5.0% (source energy savings) and
- All-electric house: 5.0% (site and source energy savings).

q) 100% Energy Star Permanent CFL or Fluorescent Indoor Lamps:
- Electric/gas house: 5.8% (site energy savings) and 10.1% (source energy savings) and
- All-electric house: 9.9% (site and source energy savings).

r) 4 kW Photovoltaic Array:
- Electric/gas house: 23.2% (site energy savings) and 31.3% (source energy savings) and
- All-electric house: 29.1% (site and source energy savings).

The savings results for the 2009 IECC code-compliant base case are:

a) Radiant barrier in attics:
- Electric/gas house: 1.8% (site energy savings) and 2.0% (source energy savings) and
- All-electric house: 1.8% (site and source energy savings).

b) Sealed Attic:
- Electric/gas house: 7.6% (site energy savings) and 5.7% (source energy savings) and
- All-electric house: 4.0% (site and source energy savings).

c) Window Shading:
- Electric/gas house: 0.6% (site energy savings) and 2.0% (source energy savings) and
- All-electric house: 2.1% (site and source energy savings).

d) Window Shading and Redistribution:
- Electric/gas house: 1.9% (site energy savings) and 3.0% (source energy savings) and
- All-electric house: 2.9% (site and source energy savings).

e) Decreased Window SHGC:
- Electric/gas house: -0.6% (site energy savings) and 1.5% (source energy savings) and
- All-electric house: 2.0% (site and source energy savings).

f) Decreased Window U-Value:
- Electric/gas house: 4.2% (site energy savings) and 4.2% (source energy savings) and
- All-electric house: 3.8% (site and source energy savings).

g) Decreased Window SHGC and U-Value:
- Electric/gas house: 3.3% (site energy savings) and 5.6% (source energy savings) and
- All-electric house: 5.6% (site and source energy savings).

h) Relocate Mechanical Systems within Conditioned Space:
- Electric/gas house: 9.2% (site energy savings) and 8.2% (source energy savings) and
- All-electric house: 6.3% (site and source energy savings).

i) Improved Air Conditioner SEER:
- Electric/gas house: 3.8% (site energy savings) and 6.0% (source energy savings).

j) Improved Heat Pump Efficiency:
- All-electric house: 6.7% (site and source energy savings).

k) Improved Furnace Efficiency:
- Electric/gas house: 4.7% (site energy savings) and 2.3% (source energy savings).

l) Tankless Gas Water Heater:
- Electric/gas house: 3.3% (site energy savings) and 1.7% (source energy savings).

m) Removal of Pilot Light from DHW System:
- Electric/gas house: 1.6% (site energy savings) and 0.8% (source energy savings).

n) Solar DHW System (32 sq. ft. collector, 65 gal tank):
- Electric/gas house: 9.9% (site energy savings) and 3.7% (source energy savings) and
- All-electric house: 7.6% (site and source energy savings).

o) Solar DHW System (64 sq. ft. collector, 80 gal tank):
- Electric/gas house: 12.6% (site energy savings) and 5.0% (source energy savings) and
- All-electric house: 9.7% (site and source energy savings).

p) 75% Energy Star Permanent CFL or Fluorescent Indoor Lamps:
- Electric/gas house: 2.0% (site energy savings) and 4.3% (source energy savings) and
- All-electric house: 4.3% (site and source energy savings).

q) 100% Energy Star Permanent CFL or Fluorescent Indoor Lamps:
- Electric/gas house: 4.2% (site energy savings) and 8.7% (source energy savings) and
- All-electric house: 8.8% (site and source energy savings).

r) 4 kW Photovoltaic Array:
- Electric/gas house: 19.9% (site energy savings) and 28.4% (source energy savings) and
- All-electric house: 27.1% (site and source energy savings).

Of 17 measures for both 2003 and 2009 code-compliant houses, a renewable energy option such as a solar PV measure presents the most savings for both electric/gas and all-electric houses. Among the envelope and fenestration measures, the sealed attic measure results in the highest savings for an electric/gas house, while the decreased window SHGC and U-Value measures resulted in the highest savings for an all-electric house. Among the HVAC system measures, locating the HVAC unit and ducts in the conditioned space results in the highest savings for both electric/gas and all-electric houses. In domestic hot water measures, the solar DHW system measure with 64 ft^2 collector and 80 gallon tank was found to be the most effective for both electric/gas and all-electric houses. The replacements of existing incandescent lighting fixtures with 100% Energy Star permanent CFL or fluorescent lamps also shows high savings for both electric/gas and all-electric types of houses.

4.2.3 Cost Effectiveness of Various Individual EEMs

It should be noted that due to the difference in the unit cost of electricity and gas, the energy cost savings for a measure will not always coincide with the energy savings. These savings depend on the fuel type associated with the end use affected from that measure. Because of this, measures that reduce electricity use for space cooling or lighting and equipment in both types of houses and heating in the all-electric house resulted in significant energy cost savings compared to the measures that reduce only gas use. For example, the solar DHW measure with a 64 sq. ft. collector yields a similar or higher savings (%) than the lighting measure that replaces 75% of existing incandescent lamps with Energy Star permanent CFL or fluorescent lamps in an electric/gas house, but the cost savings are much smaller because the cost savings from the significant reduction in gas use was offset by the increased cost of electricity use for operating the pump.

For both types of houses, 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 sealed attic, improved windows, locating mechanical systems in the conditioned spaces, and improved AC efficiency. Solar DHW measures are cost-effective only for the all-electric house.

To estimate the cost-effectiveness of measures, the implementation costs of each measure (obtained from various resources listed in Appendix B), were surveyed along with simple payback calculations. The cost-effectiveness of a measure depends upon the energy cost savings versus the cost of implementation.

Most of the measures have nearly equal payback periods for both type of houses, except for the solar DHW system. The solar DHW system is a cost-effective measure only for an all-electric house with a payback period of 11.4 to 16.3 years (both code-compliant houses).

For both types of houses, the most cost-effective measures are lighting measures (EEM 15 to 16) with the shortest payback periods of 0.2 to 1.0 years (both code-compliant houses). Improved window performance measures (EEM 5 to 7) yield the second shortest payback periods of 1.8 to 10.7 years (2003 IECC code-compliant house) and 3.9 to 9.6 years (2009 IECC code-compliant house). Installing radiant barrier in attics and improving the AC efficiency also yields relatively short payback periods. The results of the cost analysis are also graphically represented in Figures 60 to 67.

4.2.4 Combined EEMs

Grouped measures are the combination of individual measures. The results from individual measures and cost analysis were used to guide the selection of measures for this group analysis. The measures were combined to achieve the total source energy savings[10] of the group is 15% above the base-case simulation of each 2003 and 2009 IECC code-compliant house. 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 68 to 71, three group measures were proposed for each base case except the 2003 IECC code-compliant electric/gas house. For the 2003 IECC code-compliant electric/gas type house, two more combinations were proposed. In each figure, the first table summarizes the results obtained from individual measures in terms of annual site energy savings, annual source energy 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 energy savings, and includes: energy savings, energy cost savings, estimated costs, payback period for each combination, and annual NOx, SO_2, and CO_2 emission savings.

The combinations 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. For the 2003 IECC code-compliant house, the most cost-effective combination (Combination 1 for both types of houses) has a payback period of:

a) Electric/gas house: 3.3 to 5.8 years and
b) All-electric house: 3.3 to 5.7 years.

A payback period of the least cost-effective combination (Combination 3 for both types of houses) is:

a) Electric/gas house: 8.8 to 30.5 years and
b) All-electric house: 9.6 to 25.2 years.

For the 2009 IECC code-compliant house, the most cost-effective combination (Combination 1 for both types of houses) has a payback period of:

a) Electric/gas house: 3.1 to 5.4 years and
b) All-electric house: 3.1 to 5.4 years.

A payback period of the least cost-effective combination (Combination 3 for both types of houses) is:

a) Electric/gas house: 8.5 to 29.7 years and

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

b) All-electric house: 10.3 to 27.0 years.

Table 10. Simulation Results of Individual EEMs for a 2003 IECC Code-Compliant House in CoA

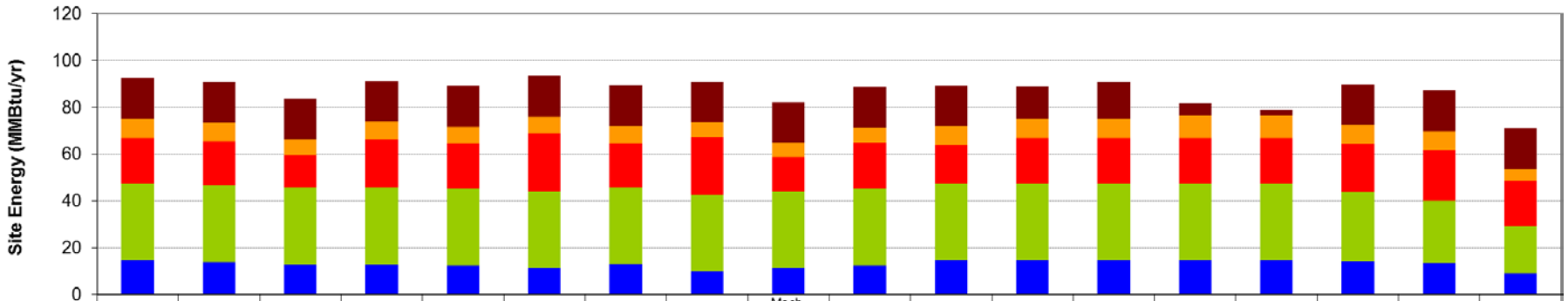
	EEM #	Energy Efficiency Measure (EEM)	Site Energy Use by End-Uses (MMBtu/yr)						Source Energy Use by Fuel Type (MMBut/yr)		Savings Above Base Case (%)		$ Savings ($/yr)	Increased Marginal Cost ($)	Increased New System Cost ($)	Payback (yrs)
			Cooling	Heating	Ltg & Equip	Fans &Pumps	DHW	Total	Elec.	Gas	Site	Source				
		(a) Electric/Gas House Base Case	14.7	19.4	32.8	8.2	17.4	92.5	176.0	40.5						
Envelope and Fenetration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	13.7	19.0	32.8	7.9	17.4	90.8	171.9	40.0	1.8%	2.1%	$44		$300 - $880	6.7 - 19.8
	2	Sealed (Unvented) Attic	12.8	14.0	32.8	6.8	17.4	83.8	165.6	34.5	9.4%	7.6%	$141	$2,000 - $3,500		14.2 - 24.8
	3	Window Shading (2ft overhang on all sides)	12.8	20.8	32.8	7.5	17.4	91.3	167.8	42.0	1.3%	3.1%	$75		$800 - $1,000	10.7 - 13.4
	4	Window Shading and Redistribution (2ft overhang on all sides, S=48.83%, N=27.13%, E/W = 16.28%)	12.4	19.3	32.8	7.2	17.4	89.1	165.6	40.4	3.7%	4.9%	$107		$800 - $1,000	7.5 - 9.3
	5	Decreased SHGC (CZ 3: from .4 to .2)	11.3	24.8	32.8	7.1	17.4	93.4	161.8	46.4	-1.0%	3.8%	$111	$200 - $400		1.8 - 3.6
	6	Decreased U Value (CZ3: from 0.47 to 0.3)	13.0	18.8	32.8	7.4	17.4	89.4	168.1	39.8	3.4%	4.0%	$84	$600 - $900		7.1 - 10.7
	7	Decreased SHGC (CZ 3: from .4 to .2) & U Value (CZ3: from 0.47 to 0.3)	9.8	24.6	32.8	6.4	17.4	91.0	154.8	46.2	1.6%	7.1%	$183	$900 - $1,100		4.9 - 6.0
HVAC System Measures	8	Mechanical Systems Within Conditioned Spaces	11.3	14.5	32.8	6.2	17.4	82.2	158.9	35.1	11.1%	10.4%	$205	$1,000 - $7,000		4.9 - 34.1
	9	Improved SEER (from 13 to 15)	12.4	19.8	32.8	6.3	17.4	88.7	162.7	40.9	4.1%	5.9%	$133	$900 - $2,500		6.8 - 18.8
	10	Improved Furnace Efficiency (from .78 to .93 AFUE)	14.7	16.2	32.8	8.2	17.4	89.3	176.0	37.0	3.5%	1.6%	$20	$800 - $1,300		39.1 - 63.5
Domestic Hot Water Measures	11	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	14.7	19.4	32.8	8.2	13.8	88.9	176.0	36.5	3.9%	1.8%	$23	$900 - $1,400		39.1 - 60.8
	12	Removal of Pilot Light from DHW	14.7	19.4	32.8	8.2	15.7	90.8	176.0	38.6	1.8%	0.9%	$11	$100 - $500		9.2 - 46.0
	13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	14.7	19.4	32.8	9.6	5.3	81.8	180.4	27.2	11.6%	4.1%	$32		$2,200 - $3,000	67.7 - 92.4
	14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	14.7	19.4	32.8	9.6	2.5	79.0	180.4	24.1	14.6%	5.6%	$51		$3,200 - $4,000	63.2 - 79.0
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	14.1	20.5	29.7	8.1	17.4	89.8	164.0	41.7	2.9%	5.0%	$115	$25 - $110		0.2 - 1.0
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	13.5	21.7	26.6	7.9	17.4	87.1	151.7	43.0	5.8%	10.1%	$234	$50 - $215		0.2 - 0.9
Renewable Power Options	17	4 kW PV Array	9.0	19.4	20.2	5.0	17.4	71.0	108.2	40.5	23.2%	31.3%	$692		$20,000 - $30,000	28.9 - 43.3
		(b) All-Electric House[1] Base Case	14.7	6.7	32.8	8.1	11.5	73.8	233.2	–						
Envelope and Fenetration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	13.7	6.6	32.8	7.7	11.5	72.3	228.5	–	2.0%	2.0%	$48		$300 - $880	6.2 - 18.2
	2	Sealed (Unvented) Attic	12.8	5.1	32.8	6.9	11.5	69.1	218.4	–	6.4%	6.4%	$152	$2,000 - $3,500		13.2 - 23.1
	3	Window Shading (2ft overhang on all sides)	12.8	7.0	32.8	7.3	11.5	71.4	225.6	–	3.3%	3.3%	$77		$800 - $1,000	10.3 - 12.9
	4	Window Shading and Redistribution (2ft overhang on all sides, S=48.83%, N=27.13%, E/W = 16.28%)	12.4	6.6	32.8	7.0	11.5	70.3	222.1	–	4.7%	4.7%	$113		$800 - $1,000	7.1 - 8.9
	5	Decreased SHGC (CZ 3: from .4 to .2)	11.3	8.0	32.8	6.9	11.5	70.5	222.8	–	4.5%	4.5%	$106	$200 - $400		1.9 - 3.8
	6	Decreased U Value (CZ3: from 0.47 to 0.3)	13.0	6.5	32.8	7.3	11.5	71.1	224.7	–	3.7%	3.7%	$87	$600 - $900		6.9 - 10.3
	7	Decreased SHGC (CZ 3: from .4 to .2) & U Value (CZ3: from 0.47 to 0.3)	9.8	7.9	32.8	6.2	11.5	68.2	215.5	–	7.6%	7.6%	$181	$900 - $1,100		5.0 - 6.1
HVAC System Measures	8	Mechanical Systems Within Conditioned Spaces	11.3	5.4	32.8	6.5	11.5	67.5	213.3	–	8.5%	8.5%	$203	$1,000 - $7,000		4.9 - 34.5
	9	Improved SEER (from 13 to 15) and Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	12.4	6.3	32.8	6.2	11.5	69.2	218.7	–	6.2%	6.2%	$148	$1,200 - $2,500		8.1 - 16.9
Domestic Hot Water Measures	13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	14.7	6.7	32.8	9.5	4.1	67.8	214.3	–	8.1%	8.1%	$193		$2,200 - $3,000	11.4 - 15.6
	14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	14.7	6.7	32.8	9.5	2.5	66.2	209.1	–	10.3%	10.3%	$246		$3,200 - $4,000	13.0 - 16.3
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	14.1	6.9	29.7	7.9	11.5	70.1	221.5	–	5.0%	5.0%	$119	$25 - $110		0.2 - 0.9
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	13.5	7.2	26.6	7.7	11.5	66.5	210.1	–	9.9%	9.9%	$235	$50 - $215		0.2 - 0.9
Renewable Power Options	17	4 kW PV Array	10.4	4.7	23.2	5.7	8.1	52.3	165.3	–	29.1%	29.1%	$692		$20,000 - $30,000	28.9 - 43.3

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

Table 11. Simulation Results of Individual EEMs for a 2009 IECC Code-Compliant House in CoA

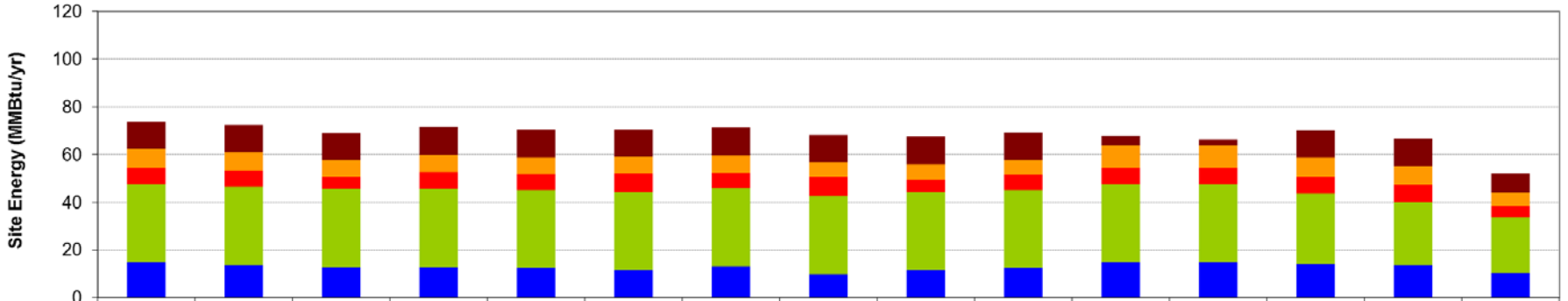
	EEM #	Energy Efficiency Measure (EEM)	Site Energy Use by End-Uses (MMBtu/yr)						Source Energy Use by Fuel Type (MMBut/yr)		Savings Above Base Case (%)		$ Savings ($/yr)	Increased Marginal Cost ($)	Increased New System Cost ($)	Payback (yrs)
			Cooling	Heating	Ltg & Equip	Fans &Pumps	DHW	Total	Elec.	Gas	Site	Source				
		(a) Electric/Gas House Base Case	15.4	32.0	32.8	10.2	17.4	107.8	184.5	54.3						
Envelope and Fenetration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	14.6	31.4	32.8	9.7	17.4	105.9	180.4	53.7	1.8%	2.0%	$46		$300 - $880	6.6 - 19.2
	2	Sealed (Unvented) Attic	14.2	26.0	32.8	9.2	17.4	99.6	177.6	47.7	7.6%	5.7%	$109	$2,000 - $3,500		18.3 - 32.0
	3	Window Shading (2ft overhang on all sides)	14.1	33.3	32.8	9.5	17.4	107.1	178.2	55.8	0.6%	2.0%	$56		$800 - $1,000	14.2 - 17.8
	4	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	13.9	32.2	32.8	9.4	17.4	105.7	177.3	54.6	1.9%	3.0%	$73		$800 - $1,000	11.0 - 13.7
	5	Decreased SHGC (CZ 3: from .3 to .2)	13.9	34.8	32.8	9.6	17.4	108.5	177.9	57.4	-0.6%	1.5%	$50	$200 - $400		4.0 - 8.0
	6	Decreased U Value (CZ3: from 0.5 to 0.3)	13.9	30.0	32.8	9.2	17.4	103.3	176.6	52.1	4.2%	4.2%	$93	$600 - $900		6.4 - 9.6
	7	Decreased SHGC (CZ 3: from .3 to .2) & U Value (CZ3: from 0.5 to 0.3)	12.4	33.0	32.8	8.6	17.4	104.2	170.0	55.4	3.3%	5.6%	$142	$900 - $1,100		6.3 - 7.8
HVAC System Measures	8	Mechanical Systems Within Conditioned Spaces	13.0	26.3	32.8	8.4	17.4	97.9	171.3	48.1	9.2%	8.2%	$172	$1,000 - $7,000		5.8 - 40.7
	9	Improved SEER (from 13 to 15)	13.0	32.7	32.8	7.8	17.4	103.7	169.4	55.1	3.8%	6.0%	$150	$900 - $2,500		6.0 - 16.6
	10	Improved Furnace Efficiency (from .78 to .93 AFUE)	15.4	26.9	32.8	10.2	17.4	102.7	184.5	48.7	4.7%	2.3%	$33	$800 - $1,300		24.5 - 39.8
Domestic Hot Water Measures	11	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	15.4	32.0	32.8	10.2	13.8	104.2	184.5	50.4	3.3%	1.7%	$23	$900 - $1,400		39.1 - 60.8
	12	Removal of Pilot Light from DHW	15.4	32.0	32.8	10.2	15.7	106.1	184.5	52.5	1.6%	0.8%	$11	$100 - $500		9.2 - 46.0
	13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	15.4	32.0	32.8	11.6	5.3	97.1	188.9	41.6	9.9%	3.5%	$32		$2,200 - $3,000	67.7 - 92.4
	14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	15.4	32.0	32.8	11.6	2.5	94.3	188.9	37.9	12.6%	5.0%	$51		$3,200 - $4,000	63.2 - 79.0
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	14.9	33.6	29.7	10.0	17.4	105.6	172.5	56.1	2.0%	4.3%	$112	$25 - $110		0.2 - 1.0
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	14.3	35.2	26.6	9.8	17.4	103.3	160.2	57.9	4.2%	8.7%	$228	$50 - $215		0.2 - 0.9
Renewable Power Options	17	4 kW PV Array	9.7	32.0	20.7	6.5	17.4	86.3	116.7	54.3	19.9%	28.4%	$692		$20,000 - $30,000	28.9 - 43.3
		(b) All-Electric House[1] Base Case	15.4	9.4	32.8	10.0	11.5	79.1	250.0	–						
Envelope and Fenetration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	14.6	9.3	32.8	9.5	11.5	77.7	245.5	–	1.8%	1.8%	$45		$300 - $880	6.6 - 19.5
	2	Sealed (Unvented) Attic	14.2	8.0	32.8	9.4	11.5	75.9	239.8	–	4.0%	4.0%	$103	$2,000 - $3,500		19.4 - 33.9
	3	Window Shading (2ft overhang on all sides)	14.1	9.7	32.8	9.3	11.5	77.4	244.6	–	2.1%	2.1%	$55		$800 - $1,000	14.6 - 18.2
	4	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	13.9	9.4	32.8	9.2	11.5	76.8	242.7	–	2.9%	2.9%	$74		$800 - $1,000	10.8 - 13.5
	5	Decreased SHGC (CZ 3: from .3 to .2)	13.9	10.0	32.8	9.3	11.5	77.5	244.9	–	2.0%	2.0%	$52	$200 - $400		3.9 - 7.8
	6	Decreased U Value (CZ3: from 0.5 to 0.3)	13.9	8.9	32.8	9.0	11.5	76.1	240.5	–	3.8%	3.8%	$97	$600 - $900		6.2 - 9.3
	7	Decreased SHGC (CZ 3: from .3 to .2) & U Value (CZ3: from 0.5 to 0.3)	12.4	9.6	32.8	8.4	11.5	74.7	236.1	–	5.6%	5.6%	$142	$900 - $1,100		6.3 - 7.8
HVAC System Measures	8	Mechanical Systems Within Conditioned Spaces	13.0	8.0	32.8	8.8	11.5	74.1	234.2	–	6.3%	6.3%	$161	$1,000 - $7,000		6.2 - 43.4
	9	Improved SEER (from 13 to 15) and Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	13.0	8.9	32.8	7.6	11.5	73.8	233.2	–	6.7%	6.7%	$171	$1,200 - $2,500		7.0 - 14.6
Domestic Hot Water Measures	13	Solar DHW System (32 sq. ft. collector, 65 gal tank)	15.4	9.4	32.8	11.4	4.1	73.1	232.1	–	7.6%	7.1%	$193		$2,200 - $3,000	11.4 - 15.6
	14	Solar DHW System (64 sq. ft. collector, 65 gal tank)	15.4	9.4	32.8	11.4	2.5	71.5	225.8	–	9.7%	9.7%	$246		$3,200 - $4,000	13.0 - 16.2
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	14.9	9.8	29.7	9.8	11.5	75.7	239.2	–	4.3%	4.3%	$110	$25 - $110		0.2 - 1.0
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	14.3	10.1	26.6	9.6	11.5	72.1	227.8	–	8.8%	8.8%	$226	$50 - $215		0.2 - 1.0
Renewable Power Options	17	4 kW PV Array	11.2	6.8	23.9	7.3	8.4	57.6	182.1	–	27.2%	27.1%	$692		$20,000 - $30,000	28.9 - 43.3

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



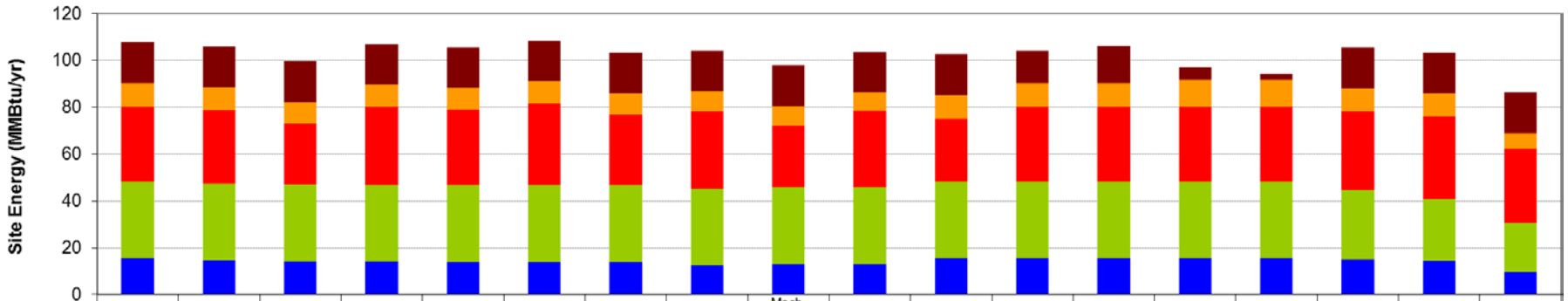
	Base Case	Radiant Barrier	Sealed Attic	Window Shading	Window Shading & Redistribution	Decreased SHGC	Decreased U Value	Decreased SHGC & U Value	Mech. Systems within Conditioned Space	Improved SEER	Improved Furnace Efficiency	Tankless Gas Water Heater	Removal of Pilot Light	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Total	92.5	90.8	83.8	91.3	89.1	93.4	89.4	91.0	82.2	88.7	89.3	88.9	90.8	81.8	79.0	89.8	87.1	71.0
DHW	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	13.8	15.7	5.3	2.5	17.4	17.4	17.4
Fans+Pumps	8.2	7.9	6.8	7.5	7.2	7.1	7.4	6.4	6.2	6.3	8.2	8.2	8.2	9.6	9.6	8.1	7.9	5.0
Heating	19.4	19.0	14.0	20.8	19.3	24.8	18.8	24.6	14.5	19.8	16.2	19.4	19.4	19.4	19.4	20.5	21.7	19.4
Lgt+Appl	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	29.7	26.6	20.2
Cooling	14.7	13.7	12.8	12.8	12.4	11.3	13.0	9.8	11.3	12.4	14.7	14.7	14.7	14.7	14.7	14.1	13.5	9.0

Figure 28. Site Energy Use of Various EEMs for a 2003 IECC Code-Compliant Electric/Gas House in CoA



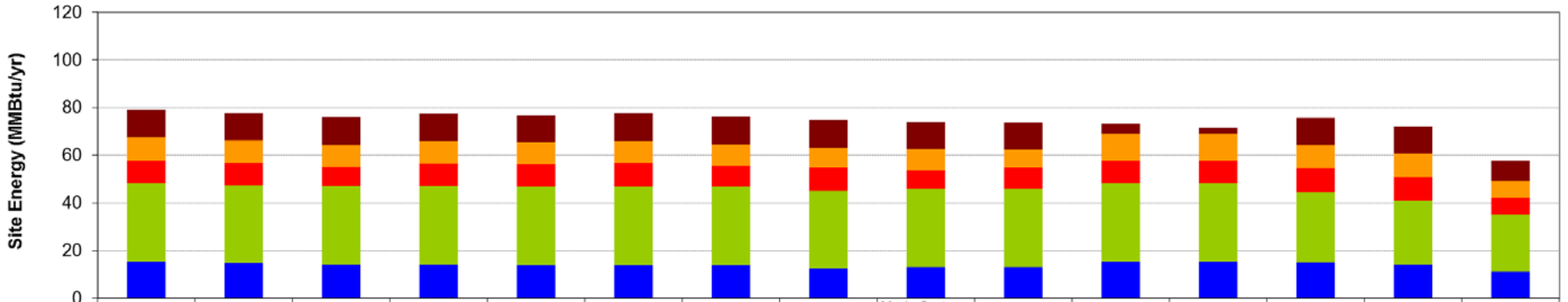
	Base Case	Radiant Barrier	Sealed Attic	Window Shading	Window Shading and Redistribution	Decreased SHGC	Decreased U Value	Decreased Window SHGC & U Value	Mech. Systems within Conditioned Space	Improved Heat Pump Efficiency	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Total	73.8	72.3	69.1	71.4	70.3	70.5	71.1	68.2	67.5	69.2	67.8	66.2	70.1	66.5	52.3
DHW	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	4.1	2.5	11.5	11.5	8.1
Fans+Pumps	8.1	7.7	6.9	7.3	7.0	6.9	7.3	6.2	6.5	6.2	9.5	9.5	7.9	7.7	5.7
Heating	6.7	6.6	5.1	7.0	6.6	8.0	6.5	7.9	5.4	6.3	6.7	6.7	6.9	7.2	4.7
Lgt+Appl	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	29.7	26.6	23.2
Cooling	14.7	13.7	12.8	12.8	12.4	11.3	13.0	9.8	11.3	12.4	14.7	14.7	14.1	13.5	10.4

Figure 29. Site Energy Use of Various EEMs for a 2003 IECC Code-Compliant All-Electric House in CoA



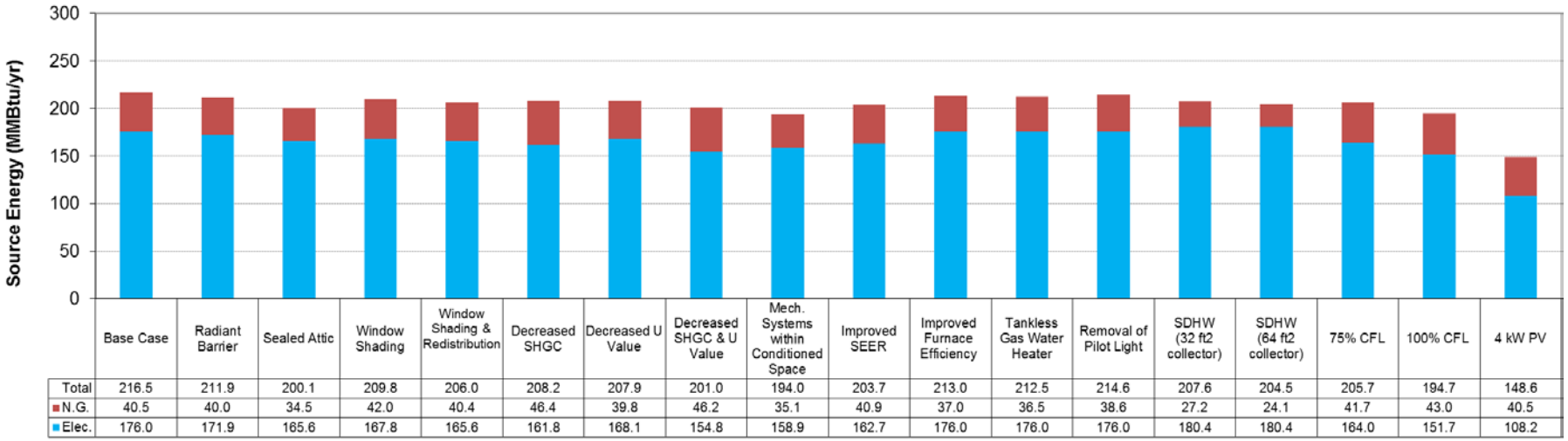
	Base Case	Radiant Barrier	Sealed Attic	Window Shading	Window Shading & Redistribution	Decreased SHGC	Decreased U Value	Decreased SHGC & U Value	Mech. Systems within Conditioned Space	Improved SEER	Improved Furnace Efficiency	Tankless Gas Water Heater	Removal of Pilot Light	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Total	107.8	105.9	99.6	107.1	105.7	108.5	103.3	104.2	97.9	103.7	102.7	104.2	106.1	97.1	94.3	105.6	103.3	86.3
DHW	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	13.8	15.7	5.3	2.5	17.4	17.4	17.4
Fans+Pumps	10.2	9.7	9.2	9.5	9.4	9.6	9.2	8.6	8.4	7.8	10.2	10.2	10.2	11.6	11.6	10.0	9.8	6.5
Heating	32.0	31.4	26.0	33.3	32.2	34.8	30.0	33.0	26.3	32.7	26.9	32.0	32.0	32.0	32.0	33.6	35.2	32.0
Lgt+Appl	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	29.7	26.6	20.7
Cooling	15.4	14.6	14.2	14.1	13.9	13.9	13.9	12.4	13.0	13.0	15.4	15.4	15.4	15.4	15.4	14.9	14.3	9.7

Figure 30. Site Energy Use of Various EEMs for a 2009 IECC Code-Compliant Electric/Gas House in CoA



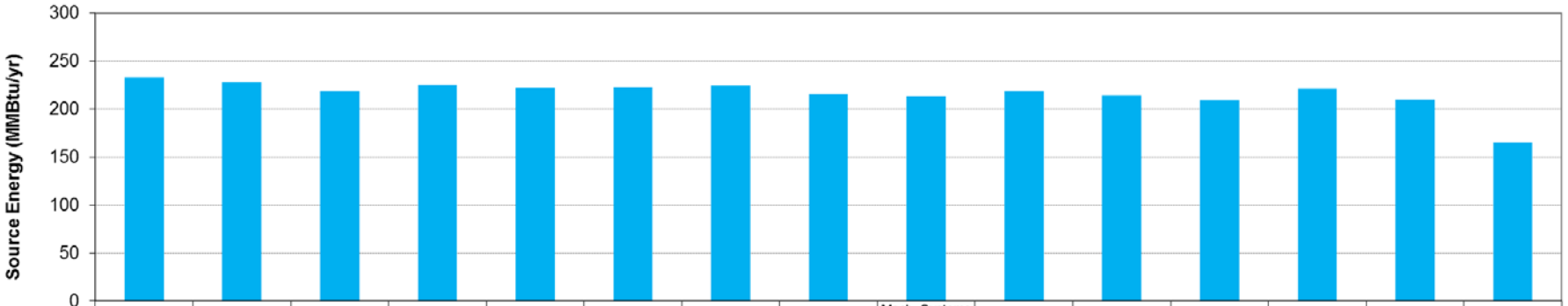
	Base Case	Radiant Barrier	Sealed Attic	Window Shading	Window Shading and Redistribution	Decreased SHGC	Decreased U Value	Decreased Window SHGC & U Value	Mech. Systems within Conditioned Space	Improved Heat Pump Efficiency	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Total	79.1	77.7	75.9	77.4	76.8	77.5	76.1	74.7	74.1	73.8	73.1	71.5	75.7	72.1	57.6
DHW	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	4.1	2.5	11.5	11.5	8.4
Fans+Pumps	10.0	9.5	9.4	9.3	9.2	9.3	9.0	8.4	8.8	7.6	11.4	11.4	9.8	9.6	7.3
Heating	9.4	9.3	8.0	9.7	9.4	10.0	8.9	9.6	8.0	8.9	9.4	9.4	9.8	10.1	6.8
Lgt+Appl	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	29.7	26.6	23.9
Cooling	15.4	14.6	14.2	14.1	13.9	13.9	13.9	12.4	13.0	13.0	15.4	15.4	14.9	14.3	11.2

Figure 31. Site Energy Use of Various EEMs for a 2009 IECC Code-Compliant All-Electric House in CoA



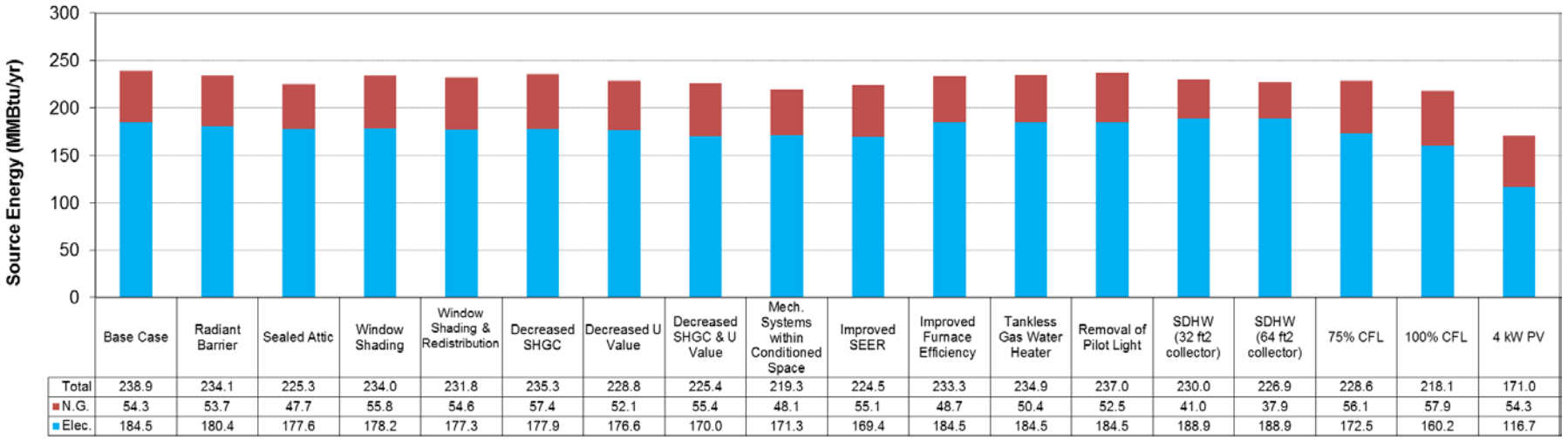
	Base Case	Radiant Barrier	Sealed Attic	Window Shading	Window Shading & Redistribution	Decreased SHGC	Decreased U Value	Decreased SHGC & U Value	Mech. Systems within Conditioned Space	Improved SEER	Improved Furnace Efficiency	Tankless Gas Water Heater	Removal of Pilot Light	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Total	216.5	211.9	200.1	209.8	206.0	208.2	207.9	201.0	194.0	203.7	213.0	212.5	214.6	207.6	204.5	205.7	194.7	148.6
N.G.	40.5	40.0	34.5	42.0	40.4	46.4	39.8	46.2	35.1	40.9	37.0	36.5	38.6	27.2	24.1	41.7	43.0	40.5
Elec.	176.0	171.9	165.6	167.8	165.6	161.8	168.1	154.8	158.9	162.7	176.0	176.0	176.0	180.4	180.4	164.0	151.7	108.2

Figure 32. Source Energy Use of Various EEMs for a 2003 IECC Code-Compliant Electric/Gas House in CoA



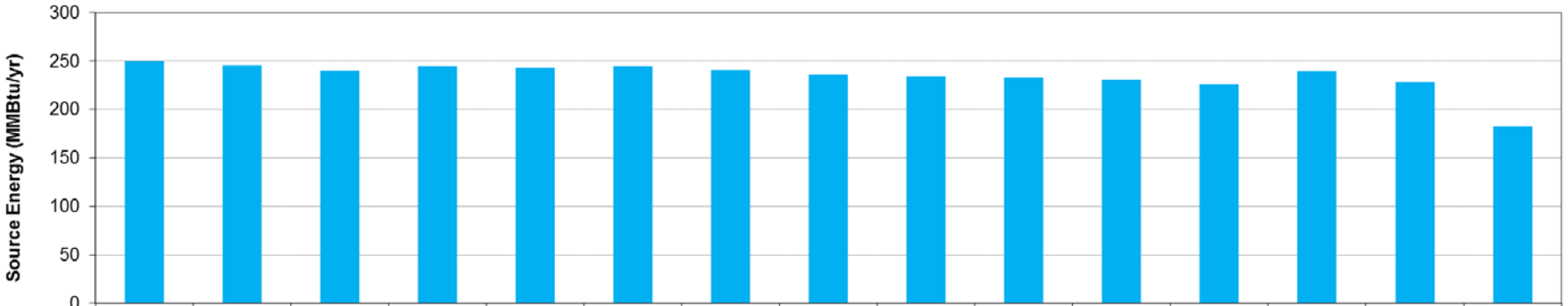
	Base Case	Radiant Barrier	Sealed Attic	Window Shading	Window Shading and Redistribution	Decreased SHGC	Decreased U Value	Decreased Window SHGC & U Value	Mech. Systems within Conditioned Space	Improved Heat Pump Efficiency	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Total	233.2	228.5	218.4	225.6	222.1	222.8	224.7	215.5	213.3	218.7	214.3	209.1	221.5	210.1	165.4
N.G.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elec.	233.2	228.5	218.4	225.6	222.1	222.8	224.7	215.5	213.3	218.7	214.3	209.1	221.5	210.1	165.4

Figure 33. Source Energy Use of Various EEMs for a 2003 IECC Code-Compliant All-Electric House in CoA



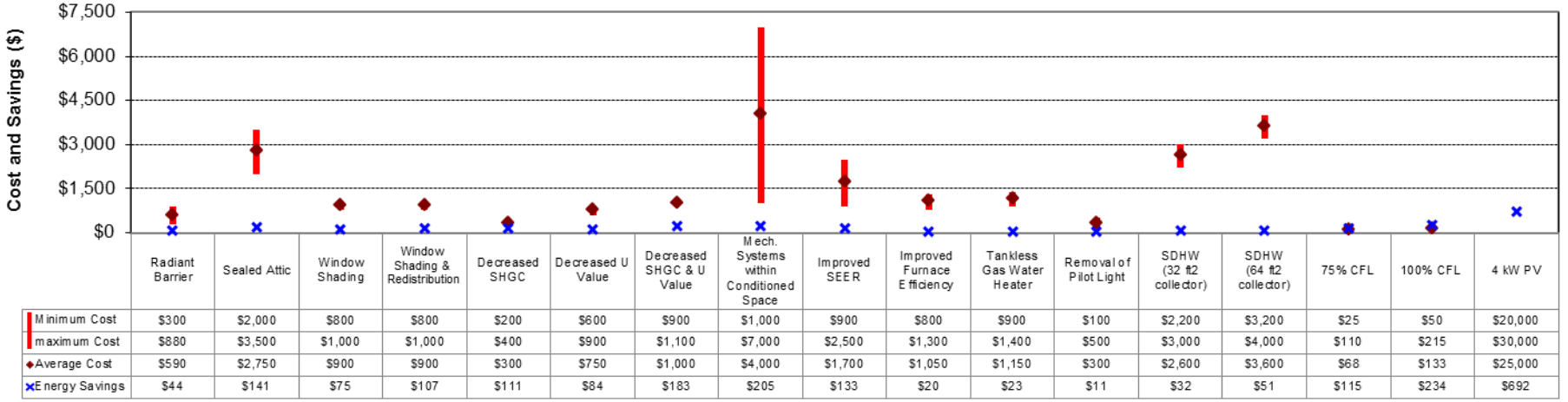
	Base Case	Radiant Barrier	Sealed Attic	Window Shading	Window Shading & Redistribution	Decreased SHGC	Decreased U Value	Decreased SHGC & U Value	Mech. Systems within Conditioned Space	Improved SEER	Improved Furnace Efficiency	Tankless Gas Water Heater	Removal of Pilot Light	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Total	238.9	234.1	225.3	234.0	231.8	235.3	228.8	225.4	219.3	224.5	233.3	234.9	237.0	230.0	226.9	228.6	218.1	171.0
N.G.	54.3	53.7	47.7	55.8	54.6	57.4	52.1	55.4	48.1	55.1	48.7	50.4	52.5	41.0	37.9	56.1	57.9	54.3
Elec.	184.5	180.4	177.6	178.2	177.3	177.9	176.6	170.0	171.3	169.4	184.5	184.5	184.5	188.9	188.9	172.5	160.2	116.7

Figure 34. Source Energy Use of Various EEMs for a 2009 IECC Code-Compliant Electric/Gas House in CoA



	Base Case	Radiant Barrier	Sealed Attic	Window Shading	Window Shading and Redistribution	Decreased SHGC	Decreased U Value	Decreased Window SHGC & U Value	Mech. Systems within Conditioned Space	Improved Heat Pump Efficiency	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Total	250.0	245.5	239.8	244.6	242.7	244.9	240.5	236.1	234.2	233.2	231.1	225.8	239.2	227.8	182.1
N.G.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elec.	250.0	245.5	239.8	244.6	242.7	244.9	240.5	236.1	234.2	233.2	231.1	225.8	239.2	227.8	182.1

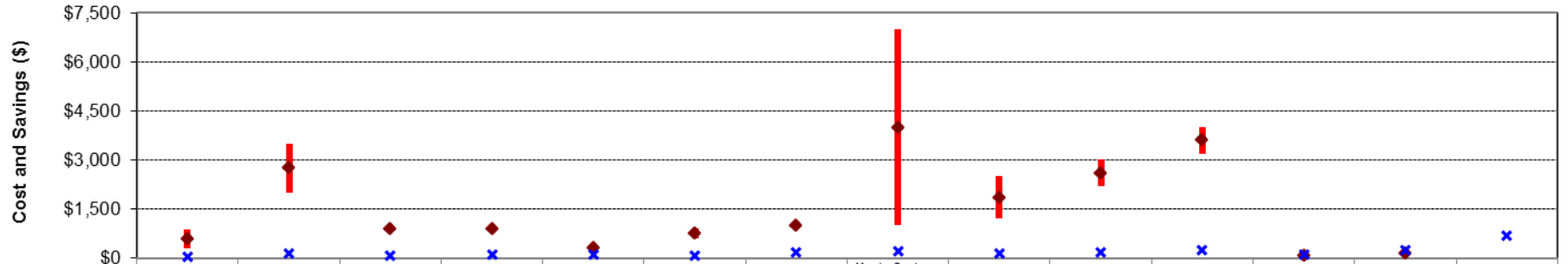
Figure 35. Source Energy Use of Various EEMs for a 2009 IECC Code-Compliant All-Electric House in CoA



	Radiant Barrier	Sealed Attic	Window Shading	Window Shading & Redistribution	Decreased SHGC	Decreased U Value	Decreased SHGC & U Value	Mech. Systems within Conditioned Space	Improved SEER	Improved Furnace Efficiency	Tankless Gas Water Heater	Removal of Pilot Light	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Minimum Cost	$300	$2,000	$800	$800	$200	$600	$900	$1,000	$900	$800	$900	$100	$2,200	$3,200	$25	$50	$20,000
maximum Cost	$880	$3,500	$1,000	$1,000	$400	$900	$1,100	$7,000	$2,500	$1,300	$1,400	$500	$3,000	$4,000	$110	$215	$30,000
Average Cost	$590	$2,750	$900	$900	$300	$750	$1,000	$4,000	$1,700	$1,050	$1,150	$300	$2,600	$3,600	$68	$133	$25,000
Energy Savings	$44	$141	$75	$107	$111	$84	$183	$205	$133	$20	$23	$11	$32	$51	$115	$234	$692

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

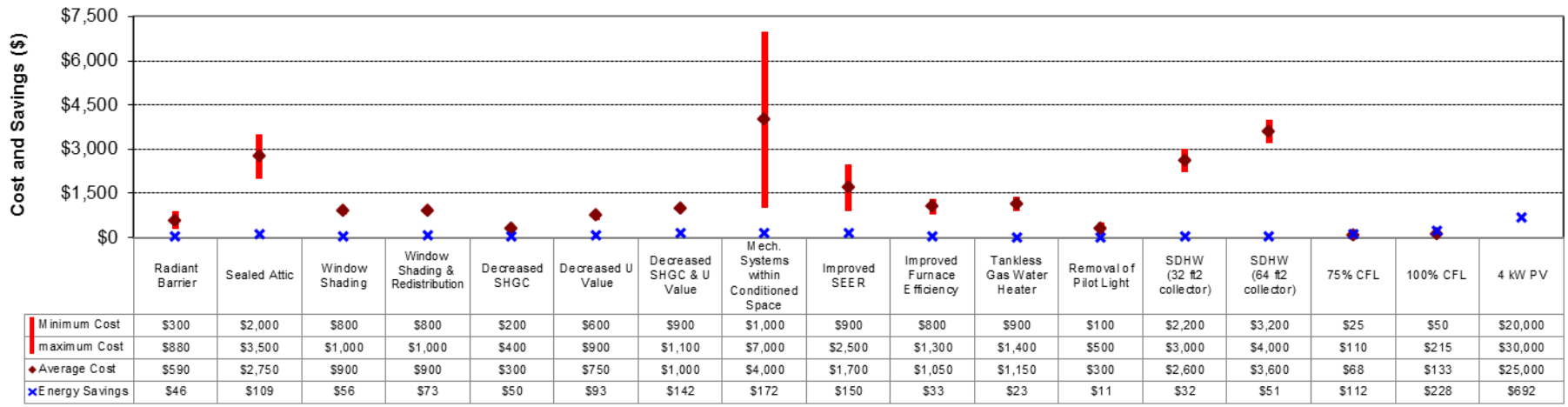
Figure 36. First Costs and Annual Energy Cost Savings for Various EEMs for a 2003 IECC Code-Compliant Electric/Gas House in CoA



	Radiant Barrier	Sealed Attic	Window Shading	Window Shading and Redistribution	Decreased SHGC	Decreased U Value	Decreased Window SHGC & U Value	Mech. Systems within Conditioned Space	Improved Heat Pump Efficiency	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Minimum Cost	$300	$2,000	$800	$800	$200	$600	$900	$1,000	$1,200	$2,200	$3,200	$25	$50	$20,000
Maximum Cost	$880	$3,500	$1,000	$1,000	$400	$900	$1,100	$7,000	$2,500	$3,000	$4,000	$110	$215	$30,000
Average Cost	$590	$2,750	$900	$900	$300	$750	$1,000	$4,000	$1,850	$2,600	$3,600	$68	$133	$25,000
Energy Savings	$48	$152	$77	$113	$106	$87	$181	$203	$148	$193	$246	$119	$235	$692

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

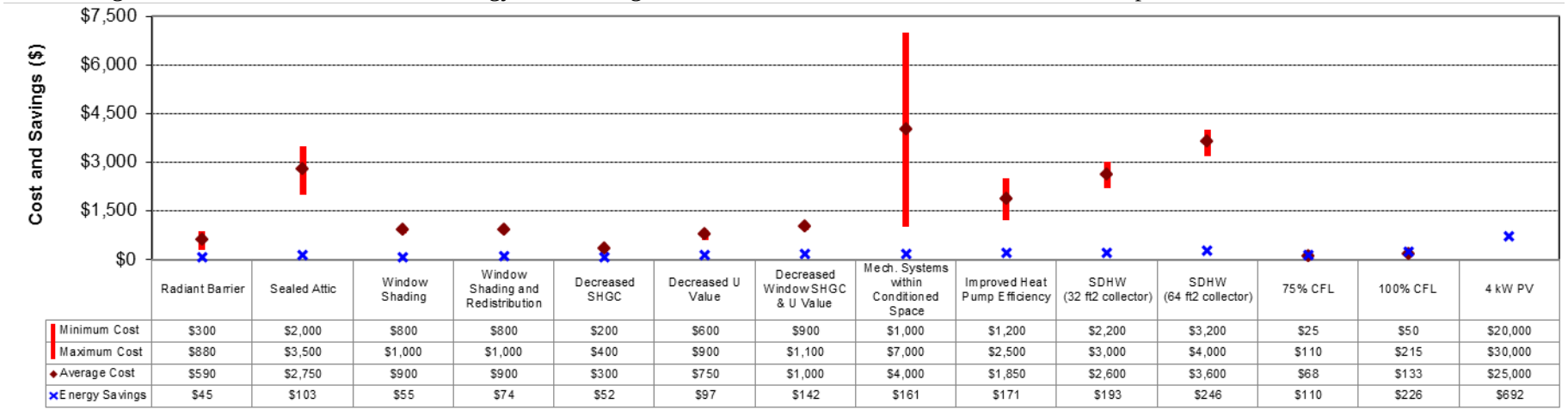
Figure 37. First Costs and Annual Energy Cost Savings for Various EEMs for a 2003 IECC Code-Compliant All-Electric House in CoA



	Radiant Barrier	Sealed Attic	Window Shading	Window Shading & Redistribution	Decreased SHGC	Decreased U Value	Decreased SHGC & U Value	Mech. Systems within Conditioned Space	Improved SEER	Improved Furnace Efficiency	Tankless Gas Water Heater	Removal of Pilot Light	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Minimum Cost	$300	$2,000	$800	$800	$200	$600	$900	$1,000	$900	$800	$900	$100	$2,200	$3,200	$25	$50	$20,000
maximum Cost	$880	$3,500	$1,000	$1,000	$400	$900	$1,100	$7,000	$2,500	$1,300	$1,400	$500	$3,000	$4,000	$110	$215	$30,000
Average Cost	$590	$2,750	$900	$900	$300	$750	$1,000	$4,000	$1,700	$1,050	$1,150	$300	$2,600	$3,600	$68	$133	$25,000
Energy Savings	$46	$109	$56	$73	$50	$93	$142	$172	$150	$33	$23	$11	$32	$51	$112	$228	$692

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

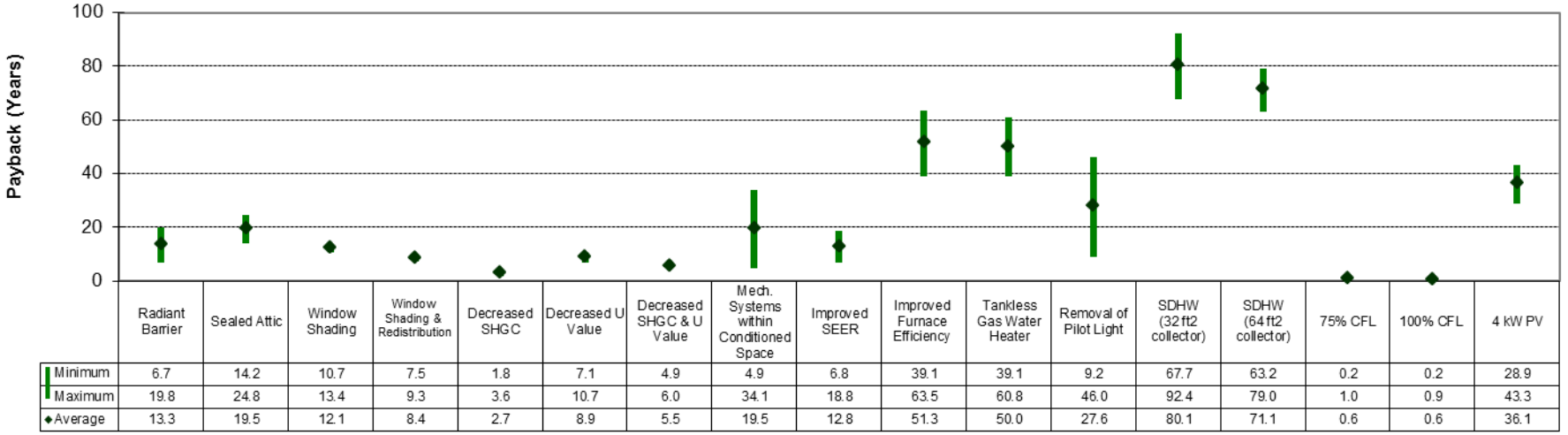
Figure 38. First Costs and Annual Energy Cost Savings for Various EEMs for a 2009 IECC Code-Compliant Electric/Gas House in CoA



	Radiant Barrier	Sealed Attic	Window Shading	Window Shading and Redistribution	Decreased SHGC	Decreased U Value	Decreased Window SHGC & U Value	Mech. Systems within Conditioned Space	Improved Heat Pump Efficiency	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Minimum Cost	$300	$2,000	$800	$800	$200	$600	$900	$1,000	$1,200	$2,200	$3,200	$25	$50	$20,000
Maximum Cost	$880	$3,500	$1,000	$1,000	$400	$900	$1,100	$7,000	$2,500	$3,000	$4,000	$110	$215	$30,000
Average Cost	$590	$2,750	$900	$900	$300	$750	$1,000	$4,000	$1,850	$2,600	$3,600	$68	$133	$25,000
Energy Savings	$45	$103	$55	$74	$52	$97	$142	$161	$171	$193	$246	$110	$226	$692

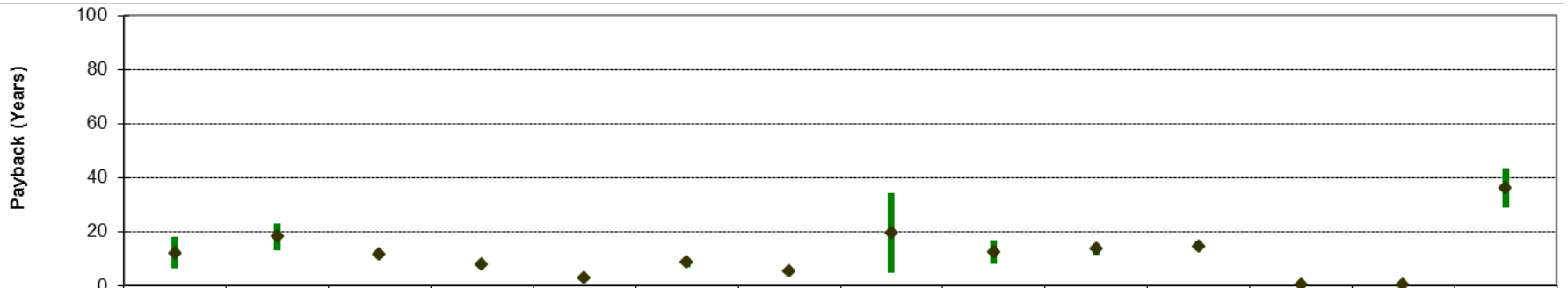
Note. Minimum to maximum cost for the EEM "4kW PV" which is not displayed in the plot is $20,000 to $30,000.

Figure 39. First Costs and Annual Energy Cost Savings for Various EEMs for a 2009 IECC Code-Compliant All-Electric House in CoA



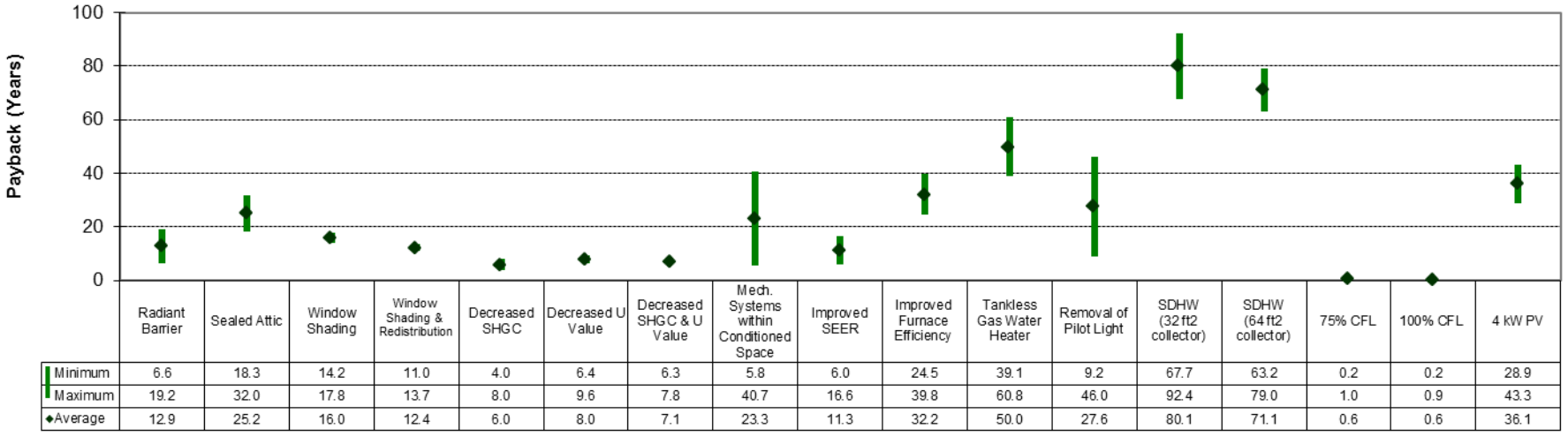
	Radiant Barrier	Sealed Attic	Window Shading	Window Shading & Redistribution	Decreased SHGC	Decreased U Value	Decreased SHGC & U Value	Mech. Systems within Conditioned Space	Improved SEER	Improved Furnace Efficiency	Tankless Gas Water Heater	Removal of Pilot Light	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Minimum	6.7	14.2	10.7	7.5	1.8	7.1	4.9	4.9	6.8	39.1	39.1	9.2	67.7	63.2	0.2	0.2	28.9
Maximum	19.8	24.8	13.4	9.3	3.6	10.7	6.0	34.1	18.8	63.5	60.8	46.0	92.4	79.0	1.0	0.9	43.3
Average	13.3	19.5	12.1	8.4	2.7	8.9	5.5	19.5	12.8	51.3	50.0	27.6	80.1	71.1	0.6	0.6	36.1

Figure 40. Payback Period for Various EEMs for a 2003 IECC Code-Compliant Electric/Gas House in CoA



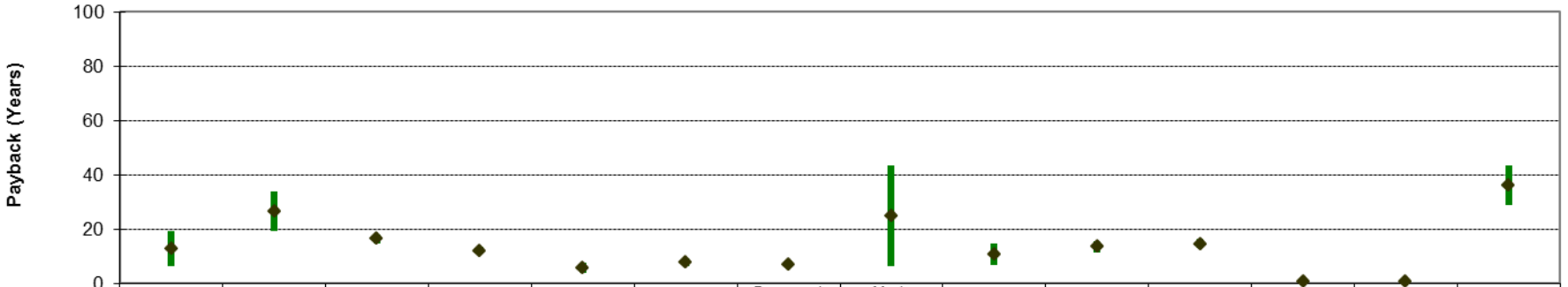
	Radiant Barrier	Sealed Attic	Window Shading	Window Shading and Redistribution	Decreased SHGC	Decreased U Value	Decreased Window SHGC & U Value	Mech. Systems within Conditioned Space	Improved Heat Pump Efficiency	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Minimum	6.2	13.2	10.3	7.1	1.9	6.9	5.0	4.9	8.1	11.4	13.0	0.2	0.2	28.9
Maximum	18.2	23.1	12.9	8.9	3.8	10.3	6.1	34.5	16.9	15.6	16.3	0.9	0.9	43.3
Average	12.2	18.2	11.6	8.0	2.9	8.6	5.6	19.7	12.5	13.5	14.7	0.6	0.6	36.1

Figure 41. Payback Period for Various EEMs for a 2003 IECC Code-Compliant All-Electric House in CoA



	Radiant Barrier	Sealed Attic	Window Shading	Window Shading & Redistribution	Decreased SHGC	Decreased U Value	Decreased SHGC & U Value	Mech. Systems within Conditioned Space	Improved SEER	Improved Furnace Efficiency	Tankless Gas Water Heater	Removal of Pilot Light	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Minimum	6.6	18.3	14.2	11.0	4.0	6.4	6.3	5.8	6.0	24.5	39.1	9.2	67.7	63.2	0.2	0.2	28.9
Maximum	19.2	32.0	17.8	13.7	8.0	9.6	7.8	40.7	16.6	39.8	60.8	46.0	92.4	79.0	1.0	0.9	43.3
◆Average	12.9	25.2	16.0	12.4	6.0	8.0	7.1	23.3	11.3	32.2	50.0	27.6	80.1	71.1	0.6	0.6	36.1

Figure 42. Payback Period for Various EEMs for a 2009 IECC Code-Compliant Electric/Gas House in CoA



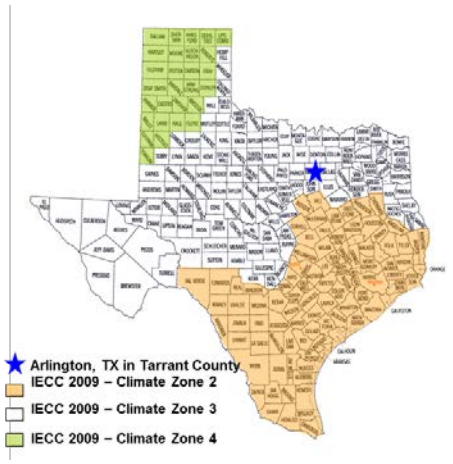
	Radiant Barrier	Sealed Attic	Window Shading	Window Shading and Redistribution	Decreased SHGC	Decreased U Value	Decreased Window SHGC & U Value	Mech. Systems within Conditioned Space	Improved Heat Pump Efficiency	SDHW (32 ft2 collector)	SDHW (64 ft2 collector)	75% CFL	100% CFL	4 kW PV
Minimum	6.6	19.4	14.6	10.8	3.9	6.2	6.3	6.2	7.0	11.4	13.0	0.2	0.2	28.9
Maximum	19.5	33.9	18.2	13.5	7.8	9.3	7.8	43.4	14.6	15.6	16.3	1.0	1.0	43.3
◆Average	13.1	26.7	16.4	12.2	5.9	7.8	7.1	24.8	10.8	13.5	14.7	0.6	0.6	36.1

Figure 43. Payback Period for Various EEMs for a 2009 IECC Code-Compliant All-Electric House in CoA

[Electric Cooling & Natural Gas Heating]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	**1.8%**	2.1%	$44		$300 - $880	6.7 - 19.8
2	Sealed (Unvented) Attic	**9.4%**	7.6%	$141	$2,000 - $3,500		14.2 - 24.8
3	Window Shading (None to 2 ft. Eaves on All Sides)	**1.3%**	3.1%	$75		$800 - $1,000	10.7 - 13.4
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)	**3.7%**	4.9%	$107		$800 - $1,000	7.5 - 9.3
5	Decreased Window SHGC (from .4 to .2)	**-1.0%**	3.8%	$111	$200 - $400		1.8 - 3.6
6	Decreased Window U Value (from .47 to .3)	**3.4%**	4.0%	$84	$600 - $900		7.1 - 10.7
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)	**1.6%**	7.1%	$183	$900 - $1,100		4.9 - 6.0
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	**11.1%**	10.4%	$205	$1,000 - $7,000		4.9 - 34.1
9	Improved Air Conditioner SEER (from 13 to 15 SEER)	**4.1%**	5.9%	$133	$900 - $2,500		6.8 - 18.8
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)	**3.5%**	1.6%	$20	$800 - $1,300		39.1 - 63.5
C	**Domestic Hot Water Measures**						
11	Tankless Gas Water Heater (without a Standing Pilot Light)	**3.9%**	1.8%	$23	$900 - $1,400		39.1 - 60.8
12	Removal of Pilot Light from Domestic Hot Water System	**1.8%**	0.9%	$11	$100 - $500		9.2 - 46.0
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	**11.6%**	4.1%	$32		$2,200 - $3,000	67.7 - 92.4
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	**14.6%**	5.6%	$51		$3,200 - $4,000	63.2 - 79.0
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**2.9%**	5.0%	$115	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**5.8%**	10.1%	$234	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	**23.2%**	31.3%	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**9.1%**	16.5%	$378	$50 - $215		3.3 - 5.8	5.4	3.6	2.2
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**12.9%**	16.9%	$362	$50 - $215		4.8 - 11.1	5.2	3.2	2.2
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	**16.8%**	15.9%	$308	$1,000 - $7,000		8.8 - 30.5	4.4	2.3	2.0
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
	Combination 4									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**15.0%**	18.0%	$380	$50 - $215		4.6 - 7.9	5.5	3.3	2.4
6	Decreased Window U Value (from .47 to .3)				$600 - $900					
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)					$800 - $1,000				
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 5									
15	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**17.2%**	19.0%	$389	$50 - $215		6.0 - 12.6	5.6	3.2	2.5
6	Decreased Window U Value (from .47 to .3)				$600 - $900					
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					

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 = $0.11/kWh
     Natural gas = $0.64/therm
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

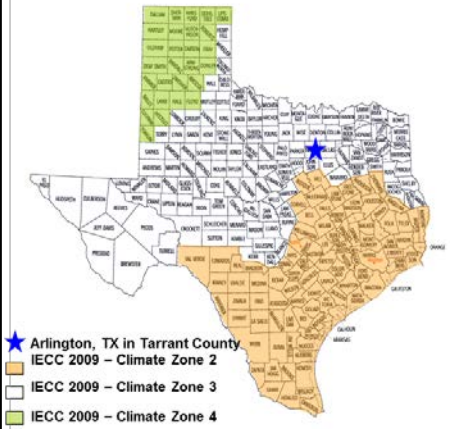
[2003 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 18% (Window-to-wall ratio: 27.1%)
* Lighting: 50% Energy Star permanent CFL 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: 14.5 cfm/100 sq-ft CFA

Figure 44. Individual and Combined Energy Efficiency Measures for 2003 IECC Code-Compliant House with Natural Gas Heating for CoA

[Electric Cooling & Heat Pump Heating]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	**2.0%**	2.0%	$48		$300 - $880	6.2 - 18.2
2	Sealed (Unvented) Attic	**6.4%**	6.4%	$152	$2,000 - $3,500		13.2 - 23.1
3	Window Shading (None to 2 ft. Eaves on All Sides)	**3.3%**	3.3%	$77		$800 - $1,000	10.3 - 12.9
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)	**4.7%**	4.7%	$113		$800 - $1,000	7.1 - 8.9
5	Decreased Window SHGC (from .4 to .2)	**4.5%**	4.5%	$106	$200 - $400		1.9 - 3.8
6	Decreased Window U Value (from .47 to .3)	**3.7%**	3.7%	$87	$600 - $900		6.9 - 10.3
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)	**7.6%**	7.6%	$181	$900 - $1,100		5.0 - 6.1
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	**8.5%**	8.5%	$203	$1,000 - $7,000		4.9 - 34.5
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)	**6.2%**	6.2%	$148	$1,200 - $2,500		8.1 - 16.9
C	**Domestic Hot Water Measures**						
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	**8.1%**	8.1%	$193		$2,200 - $3,000	11.4 - 15.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	**10.3%**	10.3%	$246		$3,200 - $4,000	13.0 - 16.3
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**5.0%**	5.0%	$119	$25 - $110		0.2 - 0.9
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**9.9%**	9.9%	$235	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	**29.1%**	29.1%	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**16.4%**	16.4%	$384	$50 - $215		3.3 - 5.7	5.5	3.5	2.3
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**21.5%**	21.5%	$501	$25 - $110		4.2 - 7.4	7.2	4.5	3.0
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)				$1,200 - $2,500					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	**18.7%**	18.7%	$436	$1,000 - $7,000		9.6 - 25.2	6.3	3.9	2.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)					$3,200 - $4,000				

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Energy Cost: Electricity = $0.11/kWh
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

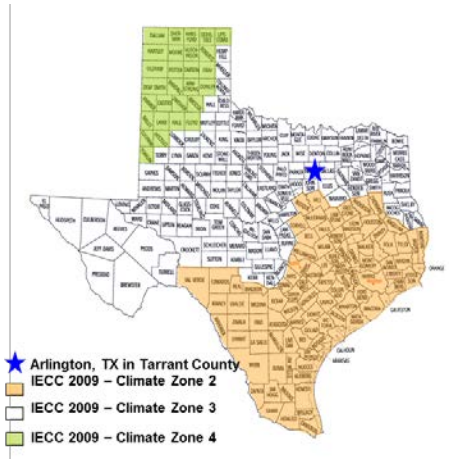
[2003 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 18% (Window-to-wall ratio: 27.1%)
* Lighting: 50% Energy Star permanent CFL or fluorescent lamps
* HVAC system: SEER 13 AC and 7.7 HSPF heat pump
* DHW: 0.90 EF Electric heater
* Duct Location: Unconditioned, vented attic
* Duct Leakage to Outdoor: 14.5 cfm/100 sq-ft CFA

Figure 45. Individual and Combined Energy Efficiency Measures for 2003 IECC Code-Compliant House with Heat Pump Heating for CoA

[Electric Cooling & Natural Gas Heating]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	1.8%	**2.0%**	$46		$300 - $880	6.6 - 19.2
2	Sealed (Unvented) Attic	7.6%	**5.7%**	$109	$2,000 - $3,500		18.3 - 32.0
3	Window Shading (None to 2 ft. Eaves on All Sides)	0.6%	**2.0%**	$56		$800 - $1,000	14.2 - 17.8
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)	1.9%	**3.0%**	$73		$800 - $1,000	11.0 - 13.7
5	Decreased Window SHGC (from .3 to .2)	-0.6%	**1.5%**	$50	$200 - $400		4.0 - 8.0
6	Decreased Window U Value (from .5 to .3)	4.2%	**4.2%**	$93	$600 - $900		6.4 - 9.6
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)	3.3%	**5.6%**	$142	$900 - $1,100		6.3 - 7.8
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	9.2%	**8.2%**	$172	$1,000 - $7,000		5.8 - 40.7
9	Improved Air Conditioner SEER (from 13 to 15 SEER)	3.8%	**6.0%**	$150	$900 - $2,500		6.0 - 16.6
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)	4.7%	**2.3%**	$33	$800 - $1,300		24.5 - 39.8
C	**Domestic Hot Water Measures**						
11	Tankless Gas Water Heater (without a Standing Pilot Light)	3.3%	**1.7%**	$23	$900 - $1,400		39.1 - 60.8
12	Removal of Pilot Light from Domestic Hot Water System	1.6%	**0.8%**	$11	$100 - $500		9.2 - 46.0
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	9.9%	**3.7%**	$32		$2,200 - $3,000	67.7 - 92.4
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	12.6%	**5.0%**	$51		$3,200 - $4,000	63.2 - 79.0
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	2.0%	**4.3%**	$112	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	4.2%	**8.7%**	$228	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	19.9%	**28.4%**	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Combined Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	8.6%	**15.8%**	$403	$50 - $215		3.1 - 5.4	5.8	3.9	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	13.1%	**17.0%**	$405	$50 - $215		4.3 - 9.9	5.8	3.6	2.5
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	16.0%	**15.0%**	$317	$1,000 - $7,000		8.5 - 29.7	4.6	2.3	2.1
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					

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 = $0.11/kWh
     Natural gas = $0.64/therm
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

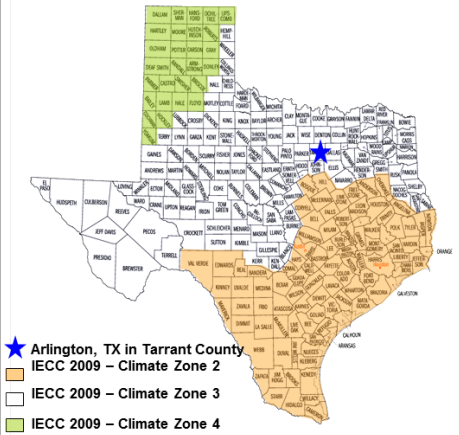
[2009 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 15% (Window-to-wall ratio: 22.6%)
* Lighting: 50% Energy Star permanent CFL 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

Figure 46. Individual and Combined Energy Efficiency Measures for 2009 IECC Code-Compliant House with Natural Gas Heating for CoA

[Electric Cooling & Heat Pump Heating]

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	1.8%	**1.8%**	$45		$300 - $880	6.6 - 19.5
2	Sealed (Unvented) Attic	4.0%	**4.0%**	$103	$2,000 - $3,500		19.4 - 33.9
3	Window Shading (None to 2 ft. Eaves on All Sides)	2.1%	**2.1%**	$55		$800 - $1,000	14.6 - 18.2
4	Window Shading and Redistribution (22.6% Equal Window s on All Sides with No Shading to S=40.7%, N=22.6%, E/W = 13.6% with 2ft. Eaves on All Sides)	2.9%	**2.9%**	$74		$800 - $1,000	10.8 - 13.5
5	Decreased Window SHGC (from .3 to .2)	2.0%	**2.0%**	$52	$200 - $400		3.9 - 7.8
6	Decreased Window U Value (from .5 to .3)	3.8%	**3.8%**	$97	$600 - $900		6.2 - 9.3
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)	5.6%	**5.6%**	$142	$900 - $1,100		6.3 - 7.8
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	6.3%	**6.3%**	$161	$1,000 - $7,000		6.2 - 43.4
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)	6.7%	**6.7%**	$171	$1,200 - $2,500		7.0 - 14.6
C	**Domestic Hot Water Measures**						
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	7.6%	**7.6%**	$193		$2,200 - $3,000	11.4 - 15.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	9.7%	**9.7%**	$246		$3,200 - $4,000	13.0 - 16.3
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	4.3%	**4.3%**	$110	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	8.8%	**8.8%**	$226	$50 - $215		0.2 - 1.0
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	27.1%	**27.1%**	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	15.8%	**15.8%**	$403	$50 - $215		3.1 - 5.4	5.8	3.6	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	15.4%	**15.4%**	$393	$25 - $110		5.4 - 9.4	5.7	3.6	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)				$1,200 - $2,500					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	16.0%	**16.0%**	$407	$1,000 - $7,000		10.3 - 27.0	5.9	3.7	2.5
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)					$3,200 - $4,000				

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Energy Cost: Electricity = $0.11/kWh
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

[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 7.7 HSPF heat pump
* DHW: 0.90 EF Electric heater
* Duct Location: Unconditioned, vented attic
* Duct Leakage to Outdoor: 8 cfm/100 sq-ft CFA

Figure 47. Individual and Combined Energy Efficiency Measures for 2009 IECC Code-Compliant House with Heat Pump Heating for CoA

5 SUMMARY

This report presents cost-effective recommendations to maximize energy savings for residential buildings in the City of Arlington (CoA). For more realistic recommendations, the CoA provided two years of residential building energy compliance reports from 2008 to 2010 which exceeded the energy efficiency requirements of the CoA (i.e., 2003 International Energy Conservation Code (IECC)). The buildings' envelope, fenestration, and system characteristics were summarized and then statistically compared with the 2003 IECC Chapter 4 requirements for residential buildings, and a summary table of energy efficiency measures used in the CoA during the past two years (2008-2010) was developed. Based on a summary of above-code approaches, recommendations were developed to achieve above-code energy performance based on the 2003 and 2009 IECC standard reference buildings, for single-family residences buildings in the CoA.

A total of 17 recommendations based on the energy savings above the base-case house were selected. These measures include building envelope and fenestration, HVAC system, domestic hot water (DHW) 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 site or source energy savings of the group is 15% above the base-case, 2003 or 2009 IECC code-compliant houses. As a result, three combinations were proposed for each base case ((a) electric/gas house and (b) all-electric house) in CoA. Each combination was formed to have a different payback period. Finally, the corresponding emissions savings (NOx, SO_2, and CO_2) of each combination were calculated based on the eGrid for Texas.

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APPENDIX A

Appendix A includes details on the statistical analysis of the 21 residential sample buildings compared with the 2003 IECC requirements. The "Frequency" plot presents a number of residential sample buildings complied with each condition. The "% of Homes" plot presents the percentage of the "Frequency" plot.

: Above-code (Better than 2003 IECC performance path)
: Below code (Worse than 2003 IECC performance path)
: Just code (Same as 2003 IECC performance path)
: Not required (Code house is same as proposed)

1) Compliant Option

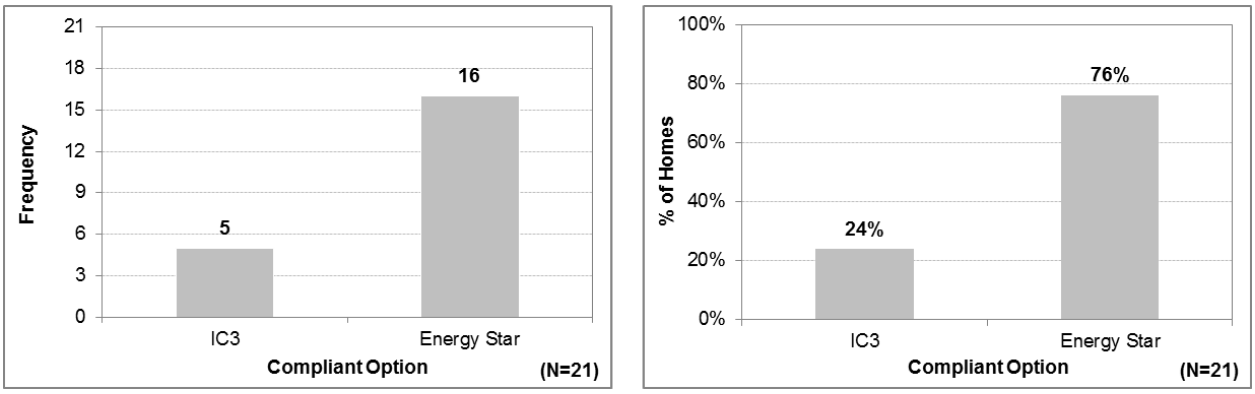


Figure A-1. Frequency and Percentage Distribution of 21 Houses by Compliant Option

2) UA Compliant Option (Energy Star)

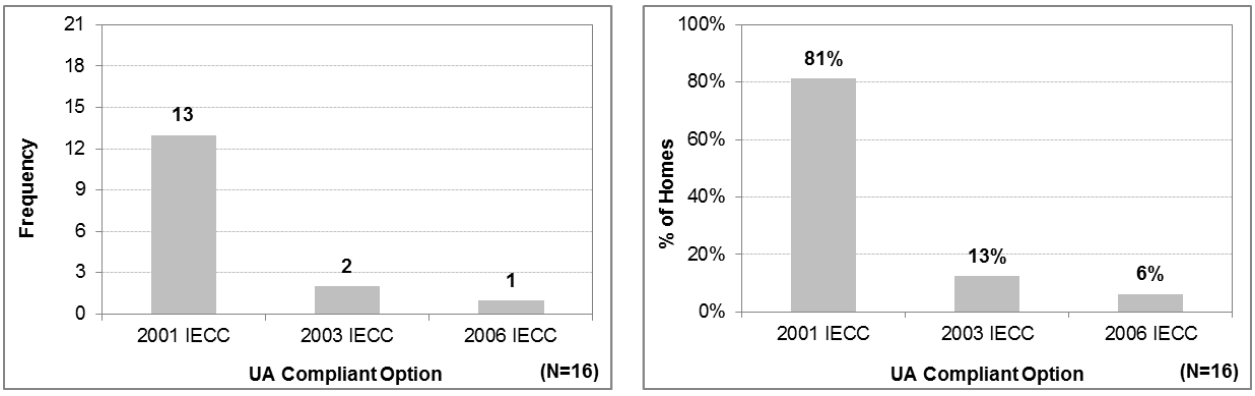


Figure A-2. Frequency and Percentage Distribution of 16 Houses by UA Complaint Option

3) Performance Path Option

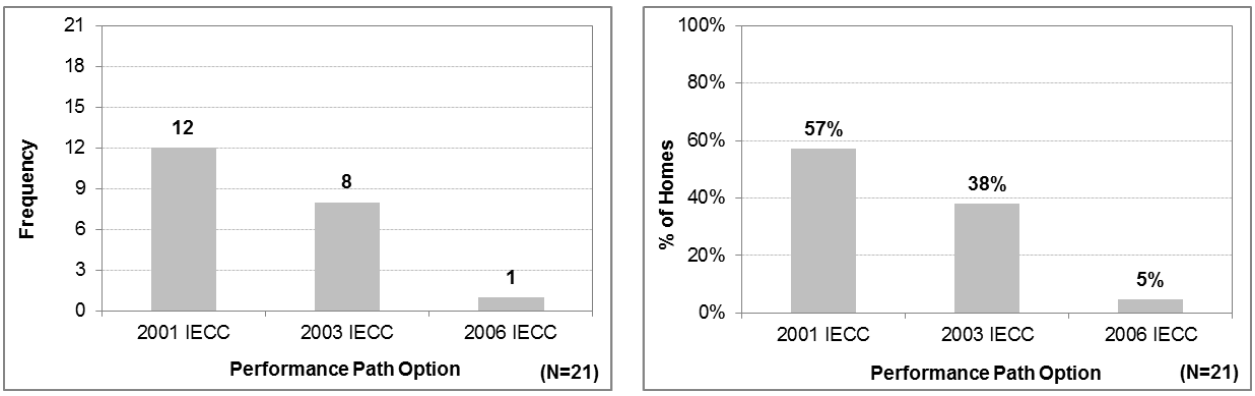


Figure A-3. Frequency and Percentage Distribution of 21 Houses by Performance Path Option

4) Window
   a. Window to Wall Ratio

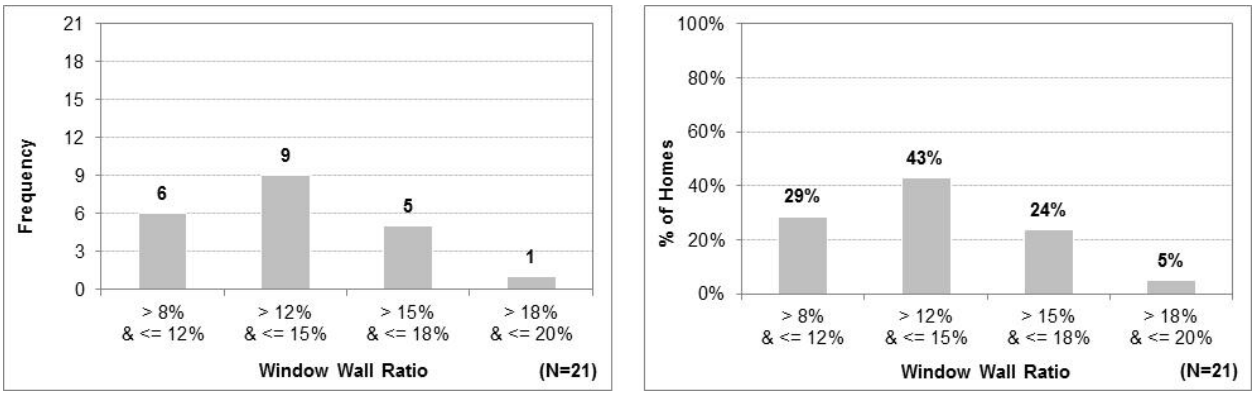


Figure A-4. Frequency and Percentage Distribution of 21 Houses by Window-to-Wall Ratio

5) Roof
   a. Radiant Barrier

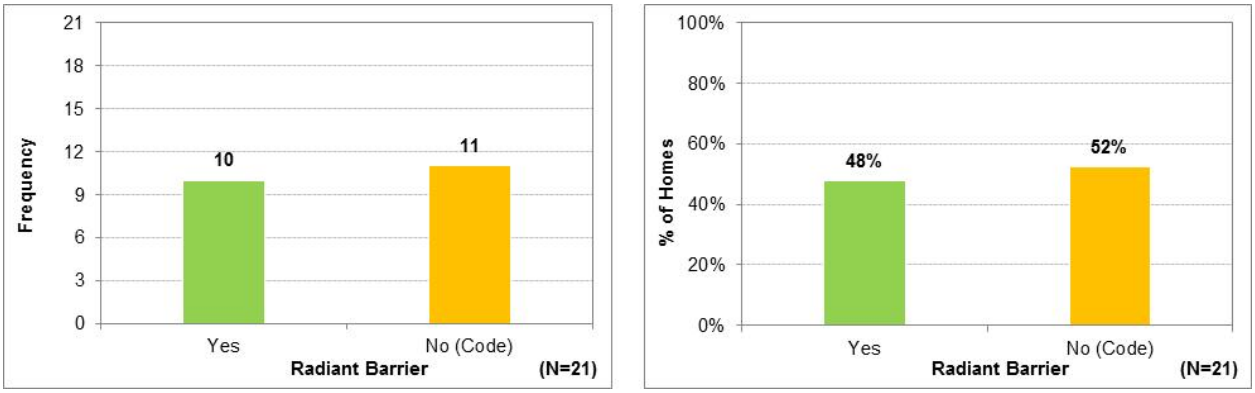


Figure A-5. Frequency and Percentage Distribution of 21 Houses by Radiant Barrier

b. Roof R-Value

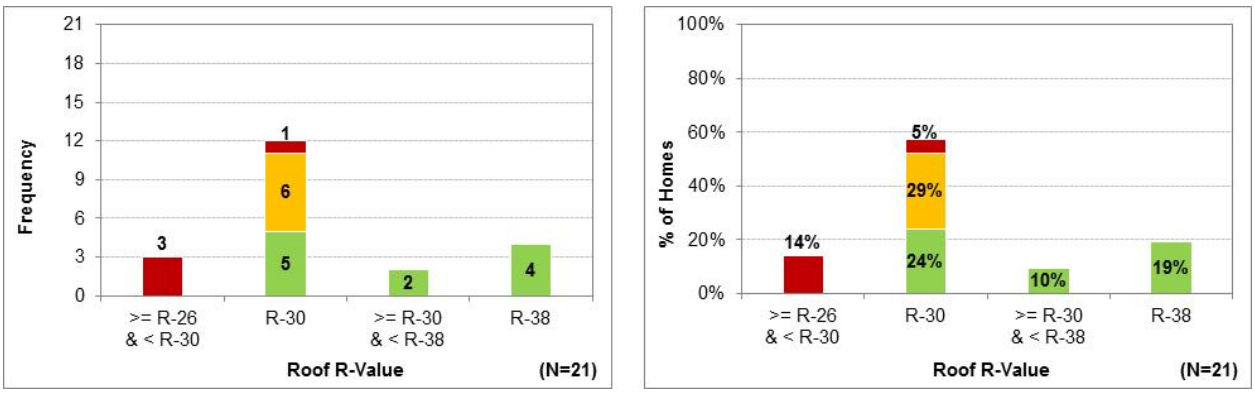


Figure A-6. Frequency and Percentage Distribution of 21 Houses by Roof R-Value

c. Roof R-Value, WWR (8-12%)

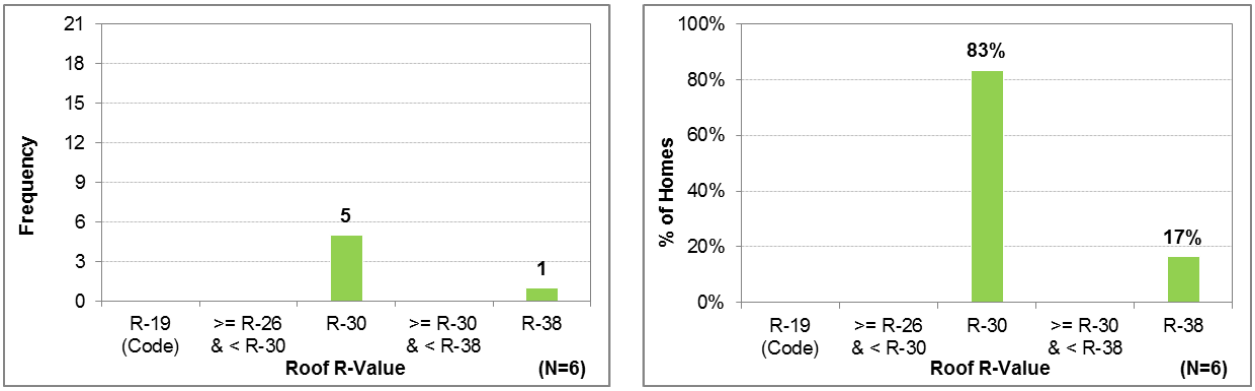


Figure A-7. Frequency and Percentage Distribution of Six Houses by Roof R-Value, WWR (8-12%)

d. Roof R-Value, WWR (12-15%)

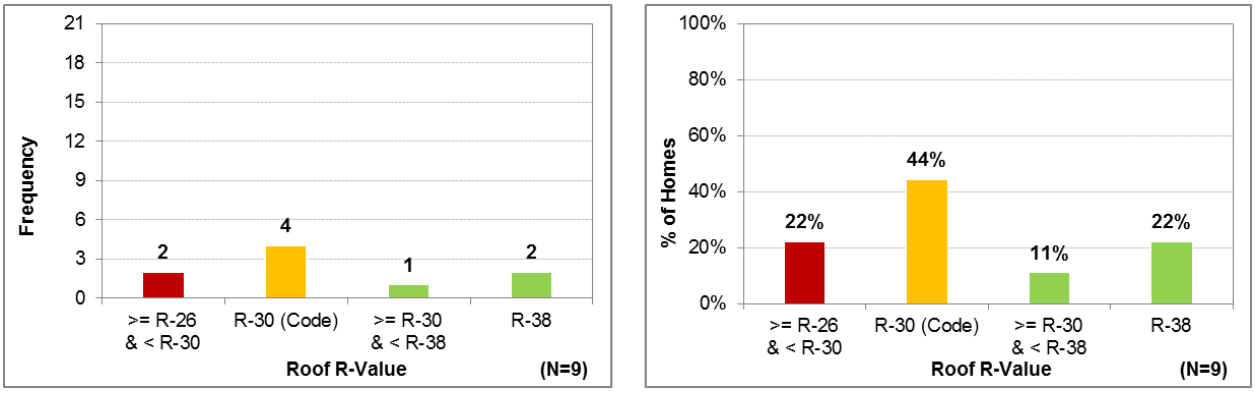


Figure A-8. Frequency and Percentage Distribution of Nine Houses by Roof R-Value, WWR (12-15%)

e. Roof R-Value, WWR (15-18%)

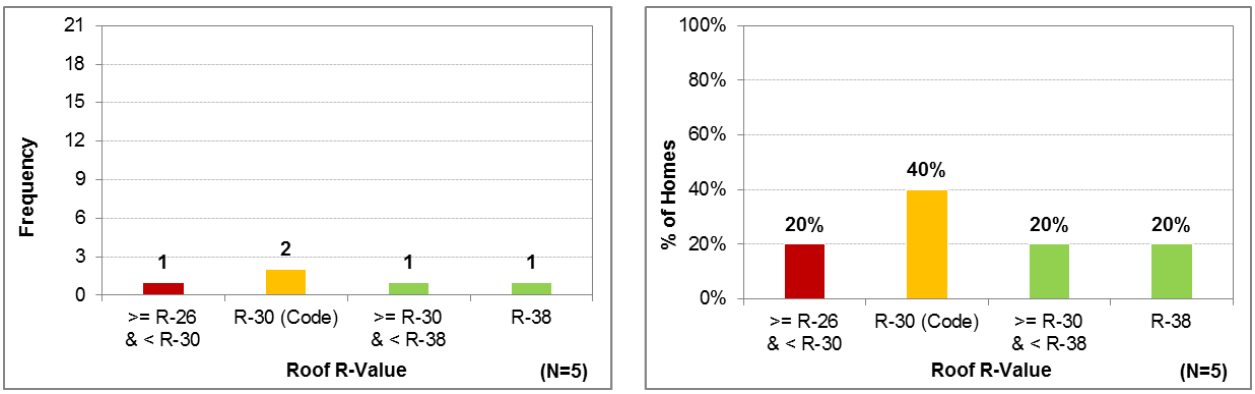


Figure A-9. Frequency and Percentage Distribution of Five Houses by Roof R-Value, WWR (15-18%)

f. Roof R-Value, WWR (18-20%)

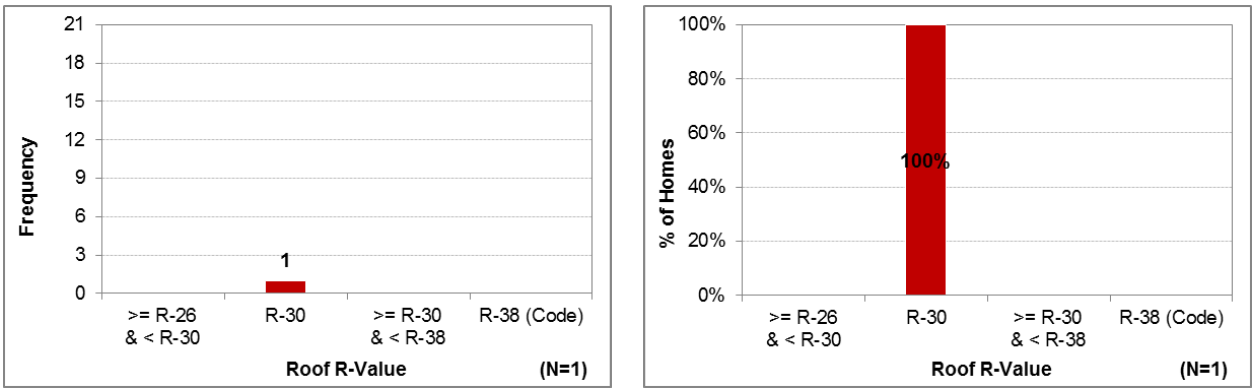


Figure A-10. Frequency and Percentage Distribution of One House by Roof R-Value, WWR (18-20%)

6) Vaulted Ceiling R-Value

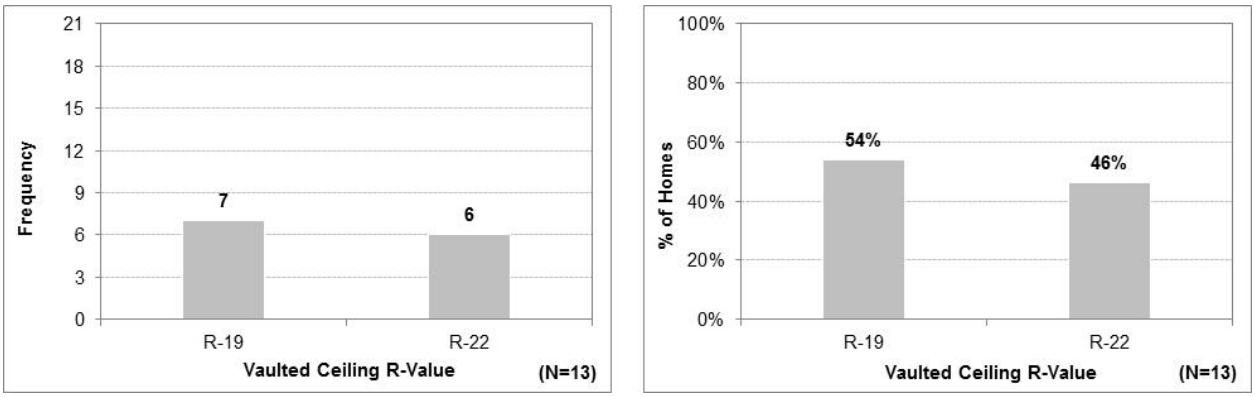


Figure A- 11. Frequency and Percentage Distribution of 13 Houses by Vaulted Ceiling R-Value

7) Infiltration

a. Infiltration (ACH50)

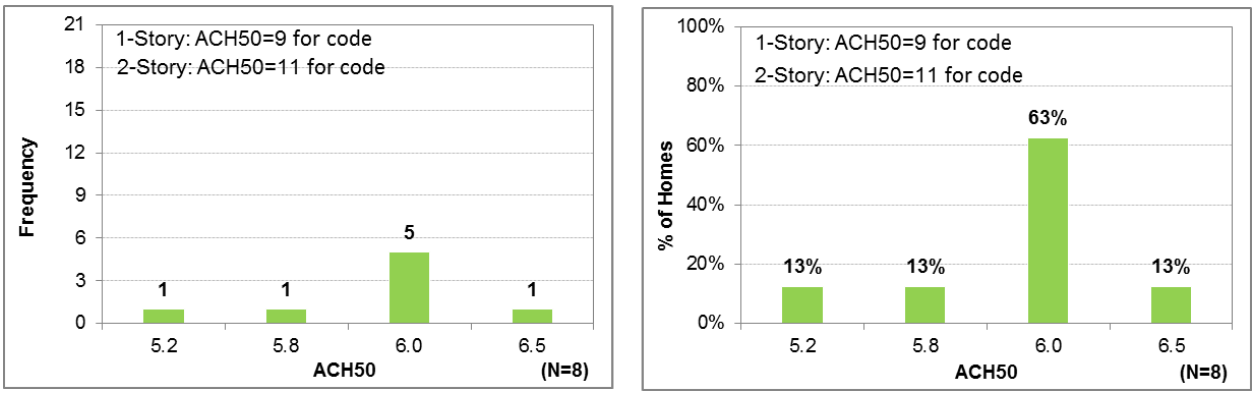


Figure A-12. Frequency and Percentage Distribution of Eight Houses by Infiltration

b. Infiltration (ACH50) for a 1-Story Building

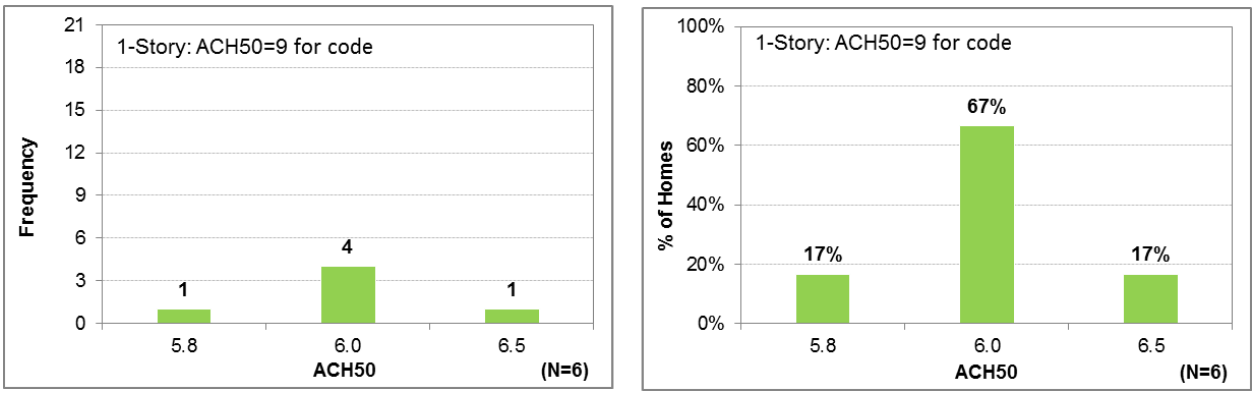


Figure A-13. Frequency and Percentage Distribution of Six Houses by Infiltration of a 1-Story Building

c. Infiltration (ACH50) for a 2-Story Building

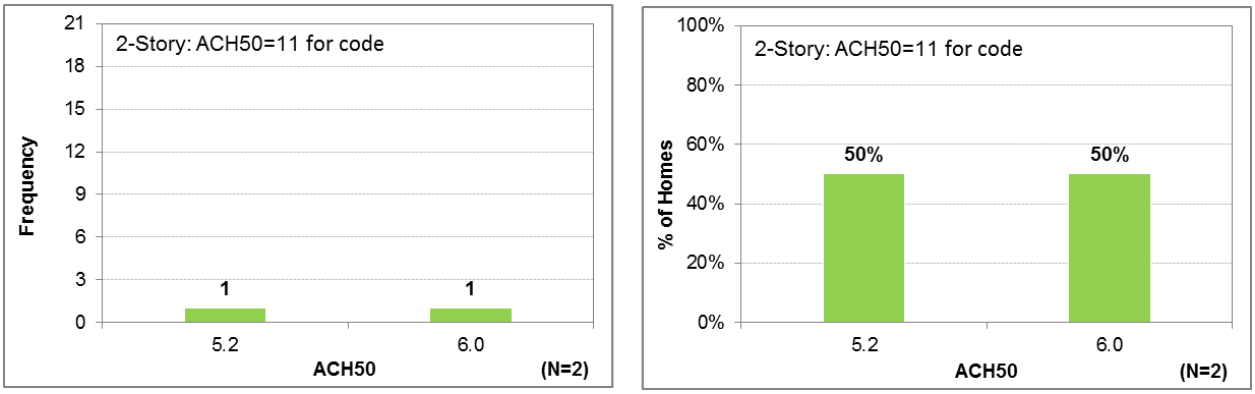


Figure A- 14. Frequency and Percentage Distribution of Two Houses by Infiltration of a 2-Story Building

APPENDIX B

Appendix B provides the implementation cost of each EEM obtained from various resources. Table B-1 summarizes the cost information for all measures, and the detailed product information and resources are listed in Table B-2 to Table B-7.

Table B-1. Summary of the Cost Information

Envelope and Fenestration Measures		Dimensions /Quantity	Unit Cost ($)	Total Increased Cost ($)	Reference Table (Table A-2)
Base Case	No Radiant Barrier	2,526 sq. ft. roof area	$0/sqft		
EEM 1	Radiant Barrier		$0.12-$0.35/sqft	$300-$880	Table Radiant Barrier - No. 1,2,3,4,5,6
Base Case	Attic Not Sealed	2,325 sq. ft. conditioned floor area			Table Duct-2 - No. 1,2,3,4
EEM2	Attic Sealed		$1.0-$1.5/sqft	$2,000-$3,500	
Base Case	No Window Shading	193 ft. perimeter	$4-$20/linear foot		Table Shading-1 - No. 4; Table Shading-2 - No. 1
EEM 3	2' Eaves		$8-$25/linear foot	$800-$1,000	Table Shading-1 - No. 4; Table Shading-2 - No. 2
Base Case	No Window Shading	193 ft. perimeter	$4-$20/linear foot		Table Shading-1 - No. 4; Table Shading-2 - No. 1
EEM 4	2' Eaves		$8-$25/linear foot	$800-$1,000	Table Shading-1 - No. 4; Table Shading-2 - No. 2
Base Case	0.3 SHGC	No. of (36"x60") windows: 23	$146-$153/Unit		Table Windows-1 -No 5,33
EEM 5	0.2 SHGC		$162/Unit	$200-$400	Table Windows-1 -No 9
Base Case	CZ2: 0.65 U-Value	No. of (36"x60") windows: 23	-		Table Windows-1 -No1, 2
	CZ3: 0.5 U-Value		CZ3:$112/Unit		Table Windows-1 -No 12,13; Table Windows-3-No 2
	CZ4: 0.35 U-Value		CZ4(0.35 SHGC):$105~$130/Unit CZ4(0.3 SHGC):$110~$137/Unit		Table Windows-1 -No 31 Table Windows-2 -No 2; Table Windows-3 -No 3
EEM 6	0.3 U-Value		CZ2: $137~$153/Unit	$600-$900	Table Windows-1 -No 5,18,19,20,21,22,23; Table Windows-3-No 3
			CZ3: $137~$153/Unit		
			CZ4(0.35 SHGC):$146/Unit CZ4(0.3 SHGC):$153/Unit	$350-$900	Table Windows-1 -No 32,33,34,35 Table Windows-1 -No 5
Base Case	CZ2: 0.3 SHGC and 0.65 U-Value	No. of (36"x60") windows: 23	-		Table Windows-1 -No1, 2
	CZ3:0.3 SHGC and 0.5 U-Value		CZ3: $112/Unit		Table Windows-1 -No 12,13; Table Windows-3-No 2
EEM7	CZ2 and CZ3: 0.2 SHGC and 0.3 U-Value		CZ2 and CZ3: $162/Unit	$900-$1,100	Table Windows-1 -No 7,8,9,10,11
					Table Windows-1 -No 24,25,26,27,28

Table B-2. Summary of the Cost Information (Continued)

HVAC System Measures		Capacity	Increased Cost/ Equipment Cost ($)	Labor Cost ($)	Total Increased Cost ($)	Reference Table (Table A-3)
ELECTRIC/GAS HOUSE						
Base Case	Duct in Unconditioned Space	2,325 conditioned floor area		n/a		Table Duct-1 - No. 1,2,3
EEM 8	Duct in Conditioned Space		$0.20/ft.		$1,000-$7,000	
Base Case	SEER 13 Air Conditioning System	5 ton	$3,300-$4,550 (Avg. $3,925)	n/a		Table Air Conditioning with Gas Heat - No. 1,2,5,9
EEM 9	SEER 15 Air Conditioning System		$4,800-$6,560		$900-$2,500	Table Air Conditioning with Gas Heat - No. 3,4,6,10
Base Case	0.78 AFUE Furnace (w/o pilot light)	55,800Btuh	$800-$2,700	n/a		Table Furnace - No. 3,8
EEM 10	0.93 AFUE Furnace (w/o pilot light)		$2,100-$3,500		$800-$1,300	Table Furnace- No. 2,9
ALL-ELECTRIC HOUSE						
Base Case	Duct in Unconditioned Space	2,325 conditioned floor area		n/a		Table Duct-1 - No. 1,2,3
EEM 8	Duct in Conditioned Space		$0.20/ft.		$1,000-$7,000	
Base Case	7.7 HSPF/SEER 13 Heat Pump	5 ton	$1,500-$3,500	n/a		Table Heat Pump- No. 3,5,10,12,14,16,23
EEM9	8.5 HSPF/SEER 15 Heat Pump		$3,500-$6,000		$1,200-$2,500	Table Heat Pump- No. 1,11,13,20,21

DHW System Measures		Capacity	Equipment Cost ($)	Installation Cost ($)	Total Increased Cost ($)	Reference Table (Table A-4)
ELECTRIC/GAS HOUSE						
Base Case	Tanktype Gas Water Heater w/ pilot light	40/50 Gallon	$260-$360	$340-$530		Table Water Heater-1 - No. 9,10,11,12
EEM11	Tankless Gas Water Heater w/o pilot light	7.4 GPM	$830-$1,400	$640-$830	$900-$1400	Table Water Heater-1 - No. 1,2,3,4,5,6,7,8
EEM12	Tanktype Gas Water Heater w/o pilot light	40/50 Gallon	$350-$800	$340-$530	$100-$500	Table Water Heater-1 - No. 15,19,20
Base Case	No Solar Water Heater		$0	$0		
EEM 13	Solar Water Heater(32 sq.ft collector)	65/80 Gallon	$2,200-$3,000	n/a	$2,200-$3,000	Table Solar Water Heater-1 No. 1,2,4
EEM 14	Solar Water Heater(64 sq.ft collector)	80 Gallon	$3,200-$4,000	n/a	$3,200-$4,000	Table Solar Water Heater-1 No. 2,4,5,6 Table Solar Collector-1 No. 1,2,3,4,5,6,7,8
ALL-ELECTRIC HOUSE						
Base Case	No Solar Water Heater		$0	$0		
EEM 13	Solar Water Heater(32 sq.ft collector)	65/80 Gallon	$2,200-$3,000	n/a	$2,200-$3,000	Table Solar Water Heater-1 No. 1,2,4
EEM 14	Solar Water Heater(64 sq.ft collector)	80 Gallon	$3,200-$4,000	n/a	$3,200-$4,000	Table Solar Water Heater-1 No. 2,4,5,6 Table Solar Collector-1 No. 1,2,3,4,5,6,7,8

Lighting Measures		Quantity		Unit Cost ($)		Total Increased Cost ($)	Reference Table (Table A-5)
		Incandescent	CFL	Incandescent	CFL		
Base Case	50% EnergyStar Permanent CFL or Fluorescent Lamps	14 ~ 28	14 ~ 28	$0.6-$1.3	$4.0-$8.9		Table Incandescent Lamps No. 1,2,3,4 Table CFL-Pin Type (w/ Lampholder) No. 1, 2,3,4,5
EEM15	75% EnergyStar Permanent CFL or Fluorescent Lamps	7 ~ 14	21 ~ 42			$25-$110	
EEM16	100% EnergyStar Permanent CFL or Fluorescent Lamps	28 ~ 56	0			$50-$215	

Renewable Power Meausres		Capacity	Equipment Cost ($)	Installation Cost ($)	Total Increased Cost ($)	Reference Table (Table A-6)
Base Case	No PV Array		$0	$0		
EEM17	4kW PV	4kW	$10,000-$20,000	$10,000	$20,000-$30,000	Table Solar PV-1 No. 1, 2,3,4,5

Table B-3. Cost Information for Envelope and Fenestration Measures

Radiant Barrier

	Manufacturer	Description	Material ($/500 sqft)	Material ($/sqft)	Pictures	Source
1		Perforated Radiant Barrier is the latest discovery in supreme attic insulation. It consists of a single layer of poly, sandwiched between two sheets of perforated reflective foil.	$73.99	$0.15		http://www.buyfoilinsulation.com/Radiant-Barrier-Perforated-4-x-125-500-sq-ft-?sc=8&category=38
2		"REFLECTIX" RADIANT BARRIER 48" x 125'; Covers 500 sq. ft.; Scrim reinforced perforated.; Use on attic rafters; Reflects 97% radiant energy; Reduces heat during summer and retains heat during winter; Non-toxic & non-carcinogenic.; Not affected by moisture or humidity.; Does not promote growth of mold or mildew .; No special clothing or tools for installation.	$80.99	$0.16		http://www.acehardwareoutlet.com/(dv23awuekfph0v55abyxa245)/productdetails.aspx?sku=5269238&source=GoogleBase
3	Ra-flet	Ra-flect Radiant Barrier (Premium)	$67.00	$0.13		http://www.raflect.com/
4	EcoFoil	Radiant Barrier - Solid	$73.99	$0.15		http://www.buyfoilinsulation.com/Radiant-Barrier-Solid-4x125-500-sq-ft-?sc=11&category=66
5	Innovative insulation	RADIANT BARRIER. Super R Diamond	$59.50	$0.12		http://www.radiantbarrier.com/index.htm?src=adwords&?adg=radiantbarrier&gclid=CLPjndP74KACFRQdswodTlNQLw
6	Innovative insulation	RADIANT BARRIER, Super R Plus (Heavy Duty)	$74.50	$0.15		

Duct-2

No.	Description	Area (ft2)	Material	Roof Venting	Air Sealing at the Top Floor Ceiling	Downsizing Cooling Equipment	Total Increased Construction Cost ($)	Sources
1	Vented Attic	4500	$1,500.00	$750.00	$750.00	$0.00	$ 4500 ($1.0 per ft2)	http://jobsite.buildig.com/articles/greener-building/unvented-attic.aspx
	Unvented Attic		$ 9000 ($2 per ft2)	$0.00	$0.00	-$1,500.00		
2	Unvented Attic	-					$600.00	http://www.ornl.gov/info/ornlreview/v40_2_07/36960-v1.pdf
3	Vented Attic	2325	$.5-$.7 per ft2	n/a	n/a	n/a	$2000-$4000	http://www.toolbase.org/pdf/techinv/insulationalternatives_techspec.pdf
	Unvented Attic	2526	$1.25-$2.25 per ft2	n/a	n/a	n/a		
4	Sealed attics (sometimes referred to as "unvented cathedralized attics") have their insulation and air pressure boundary at the plane of the roof (and gable ends) instead of at the ceiling plane.	2325	$1.0-$1.5 per ft2				$2300-$3500	http://www.toolbase.org/pdf/techinv/ductsinconditionedspace_techspec.pdf

Shading-1

No.	Eave Construction	2007 Unit cost ($/linear foot)	2010 Unit cost ($/linear foot)	Perimeter (ft)	Total Cost ($/house)	Increased Cost	2007 Source	2010 Source
1	Wood Eave with open Soffit including blocking, screened 2" holes for ventilation with paint	$15.28		193	$2,949.04		http://osfm.fire.ca.gov/pdf/regulations/UWIC-BRpt091004.pdf	http://www.osfm.fire.ca.gov/strucfireengineer/pdf/bml/wuiproducts.pdf http://osfm.fire.ca.gov/strucfireengineer/pdf/CBC/EaveVentPolicy0901Final4Feb09.pdf
2	Wood Eave with enclosed Soffit including blocking, screened 2" holes for ventilation with paint	$19.37		193	$3,738.41			
3	Wood-framed eave with enclosed, stucco-covered Soffit incl. blocking, screened 2" holes for ventilation with paint.	$33.26		193	$6,419.18			
4	Average width of eave: 16 inch	$23.00	$4.00	193	$772.00			dale@jeffersonchristian.net (this will send a message to his phone and he will call back)
	2 ft eave	$39.00	$8.00	193	$1,544.00	$800.00	Paige, Jefferson Christian Custom Homes, August 2006.	

Shading-2 (2 ft Eave, Estimated based on 2007 Survey)

No.	Eave Construction	Procedure	UNIT	Quantity	Unit Cost (Material)	Total Cost (Material)	Unit Cost (Labor)	Total Cost (Labor)	Total Cost ($/LF)	Source
1	Eave with enclosed soffit $ per LF (Assuming eave length as 16 inch)	Install 2"x4" side supports at wall and fascia	LF	3	0.38	1.14	1.73	5.19	6.33	http://osfm.fire.ca.gov/pdf/regulations/UWIC-BRpt091004.pdf#search=%22Cost-Benefit%20Evaluation%20of%20Proposed%20California%22
		Install 3/8" plywood soffit	SF	1.5	1.36	2.04	1.48	2.22	4.26	
		Install vent screen, 3"	LF	1	0.44	0.44	1.99	1.99	2.43	
		Drill 2" 0 hole	EA	2			2.8	5.6	5.6	
		Paint, primer with 2 finish coats	SF	2	0.34	0.68	0.38	0.76	1.44	
		Total Cost				**4.3**		**15.76**	**20.06**	
2	Increasing Eave Length to 2ft	Install 2"x4" side supports at wall and fascia	LF	4	0.38	1.52	1.73	6.92	8.44	
		Install 3/8" plywood soffit	SF	2	1.36	2.72	1.48	2.96	5.68	
		Install vent screen, 3"	LF	1	0.44	0.44	1.99	1.99	2.43	
		Drill 2" 0 hole	EA	2			2.8	5.6	5.6	
		Paint, primer with 2 finish coats	SF	2	0.34	0.68	0.38	0.76	1.44	
		Increased Roof Area	SF	1.5	1	1.5			**1.5**	
		Total Cost				**6.86**		**18.23**	**25.09**	
	Increased cost per house:		**Total perimeter**	**193**					**970.79**	

Windows-1 (2010 Survey)

Item	No.	U-Value	SHGC	Total Unit Cost ($/Unit)	Description	Window Type	Frame	Glazing Type	Remark
Climate Zone 2 Base Case	1	0.59	0.29		MI Windows and Doors, Series TX165 Non-Thermal	Single-Hung	Aluminum	Duraseal Spaces, 1/8 RLE7138, Air, 1/8 RLE7138; with flat grids	MI Windows; Probuild Co LLC - 23518 Coons Rd Tomball, TX 77375 (281 351-9883) Dave Weir (Aggie) 832-928-0519
	2	0.56	0.32		MI Windows and Doors, Series TX165 Non-Thermal	Single-Hung	Aluminum	Duraseal Spaces, 1/8 RLE7138, Air, 1/8 RLE7138; without grids	
Climate Zone 2 EEM	3	0.6	0.2		MI Windows and Doors, Series TX165 Non-Thermal	Single-Hung	Aluminum	Duraseal Spacer, 1/8" Clear (Inside), Air, 1/8 Tinted Low E (Outside); with	
	4	0.57	0.24		MI Windows and Doors, Series TX165 Non-Thermal	Single-Hung	Aluminum	Duraseal Spacer, 1/8" Clear (Inside), Air, 1/8 Tinted Low E (Outside);	
	5	0.3	0.27	$153	Tech View 270	Single-Hung	Vinyl	no grids, Low-E 270, Argon	Enercon Windows & Hardware 1312 W Villa Maria Rd Bryan, TX 77801 979-823-3639 (Brad Beard 3-31-2010)
	6	0.3	0.25	$208	CertainTeed Bryn Mawr	Single-Hung	Vinyl	no grids, Low-E, Argon	
	7	0.31	0.19		200 Series Tilt-Wash Double-Hung	Double-Hung	Wood	Tempered, Low-E SmartSun™ Tempered with Finelight™	Anderson Windows; Probuild Co LLC - 23518 Coons Rd Tomball, TX 77375 (281 351-9883) Dave Weir (Aggie) 832-928-0519
	8	0.29	0.18		400 Series Woodwright® Full- Frame Double-Hung Window	Double-Hung	Wood	HP Low-E4® Sun with Finelight™ Grilles	
	9	0.28	0.2	$162	Tech View (CertainTeed Generic) 366	Single-Hung	Vinyl	no grids, Low-E 366, Argon	Enercon Windows & Hardware 1312 W Villa Maria Rd Bryan, TX 77801 979-
	10	0.27	0.23		Simonton ProFinish Contractor	Casement		no grids; Low-E 270/Lami (.060); Argon	Simonton Windows 1-800-SIMONTON or A&A Home Craftsman 361-289-0058 (arthur-mills1@hotmail.com)
	11	0.27	0.17		Simonton ProFinish Contractor	Casement		no grids; Low-E366/Lami (.060); Argon	
Climate Zone 3 Base Case	12	0.5	0.28	$423	RAM S900 W/SOLAR BAN 60 CSMT 1LT	Casement	Alum., painted,	Interior Glaze, Low-E, No Argon, Insulated Glass	Ram Windows (Barbara 281-495-9056, ext 14; 3/25-26/2010)
	13	0.49	0.36		MI Windows and Doors, Series 3540	Single-Hung	Vinyl	3/16" clear insulated glass (outside), 3/16" gray tint (inside) with flat	MI Windows; Probuild Co LLC - 23518 Coons Rd Tomball, TX 77375 (281 351-9883) Dave Weir (Aggie) 832-928-0519
	14	0.5	0.25		MI Windows and Doors, Series TX165 Non-Thermal	Single-Hung	Aluminum	Duraseal Spacer, 1/8" Clear (Inside), Argon, 1/8 LOE366 (Outside); without	
	15	0.53	0.25		MI Windows and Doors, Series TX165 Non-Thermal	Single-Hung	Aluminum	Duraseal Spacer, 3/32" Clear (Inside), Argon, 3/32 LOE366 (Outside);	
Climate Zone 3 EEM	16	0.53	0.22		MI Windows and Doors, Series TX165 Non-Thermal	Single-Hung	Aluminum	Duraseal Spacer, 1/8" Clear (Inside), Argon, 1/8 LOE366 (Outside); with flat	
	17	0.55	0.23		MI Windows and Doors, Series TX165 Non-Thermal	Single-Hung	Aluminum	Duraseal Spacer, 3/32" Clear (Inside), Argon, 3/32 LOE366 (Outside); with	
	18	0.3	0.27	$153	Tech View 270	Single-Hung	Vinyl	no grids, Low-E 270, Argon	Enercon Windows & Hardware 1312 W Villa Maria Rd Bryan, TX 77801 979-
	19	0.3	0.28		Simonton ProFinish Contractor	Single-Hung		no grids, Low-E 270/Lami (.060); Krypton; intercept spacer	Simonton Windows 1-800-SIMONTON or A&A Home Craftsman 361-289-0058 (arthur-mills1@hotmail.com)
	20	0.29	0.27		Simonton ProFinish Contractor	Single-Hung		no grids, TiAC36/Lami (.060); Krypton; intercept spacer	
	21	0.29	0.27		Simonton ProFinish Contractor	Double-Hung		no grids, TiAC36/Clear; Krypton; intercept spacer	
	22	0.31	0.28		Simonton ProFinish Contractor	Double-Hung		no grids, TiAC36/Lami (.060); Krypton; Super spacer	
	23	0.3	0.31		MI Windows and Doors, Series 3540	Single-Hung	Vinyl	1/8|030PVB|1/8 Clear, Argon, 1/8" Low E; without grids	MI Windows; Probuild Co LLC - 23518 Coons Rd Tomball, TX 77375 (281 351-
	24	0.31	0.19		200 Series Tilt-Wash Double-Hung	Double-Hung	Wood	Tempered, Low-E SmartSun™ Tempered with Finelight™	Anderson Windows; Probuild Co LLC - 23518 Coons Rd Tomball, TX 77375 (281 351-9883) Dave Weir (Aggie) 832-928-0519
	25	0.29	0.18		400 Series Woodwright® Full- Frame Double-Hung Window	Double-Hung	Wood	HP Low-E4® Sun with Finelight™ Grilles	
	26	0.28	0.2	$162	Tech View (CertainTeed Generic) 366	Single-Hung	Vinyl	no grids, Low-E 366, Argon	Enercon Windows & Hardware 1312 W Villa Maria Rd Bryan, TX 77801 979-
	27	0.27	0.23		Simonton ProFinish Contractor	Casement		no grids; Low-E 270/Lami (.060); Argon	Simonton Windows 1-800-SIMONTON or A&A Home Craftsman 361-289-0058 (arthur-mills1@hotmail.com)
	28	0.27	0.17		Simonton ProFinish Contractor	Casement		no grids; Low-E366/Lami (.060); Argon	

Windows-1 (2010 Survey) *(Continued)*

Item	No.	U-Value	SHGC	Total Unit Cost ($/Unit)	Description	Window Type	Frame	Glazing Type	Remark
Climate Zone 4 Base Case	29	0.46	0.53		200 Series Tilt-Wash Double- Hung Window	Double-Hung	Wood	Tempered, Clear Dual Pane, with Finelight™Grilles	Anderson Windows; Probuild Co LLC - 23518 Coons Rd Tomball, TX 77375 (281 351-9883) Dave Weir (Aggie) 832-928-0519
	30	0.44	0.53		Anderson 200 Series Casement	Casement	Wood	Clear Dual Pane Tempered with Finelight™ Grilles	
	31	0.35	0.37		MI Windows and Doors, Series 3540	Single-Hung	Vinyl	1/8 Tinted Lo-E, Airspace, 1/8|030PVB|1/8 Clear; without grids	MI Windows; Probuild Co LLC - 23518 Coons Rd Tomball, TX 77375 (281 351-9883) Dave Weir (Aggie) 832-928-0519
Climate Zone 4 EEM	32	0.31	0.38		MI Windows and Doors, Series 3540	Single-Hung	Vinyl	1/8 Tinted Lo-E, Argon, 1/8|030PVB|1/8 Clear; without grids	
	33	0.31	0.34	$146	American Craftsman Single Hung Vinyl Windows	Single-Hung	Vinyl	5/8", insulated, Low-E, Argon, Screen	Home Depot (Charles, 3/31/2010)
	34	0.33	0.42		Simonton ProFinish Contractor	Casement		Clear/Clear; Air fill, Intercept spacer	Simonton Windows 1-800-SIMONTON or A&A Home Craftsman 361-289-0058 (arthur-mills1@hotmail.com)
	35	0.32	0.42		Simonton ProFinish Contractor	Casement		Clear/Clear; Air fill, Super spacer	

Windows-2 (2007 Survey)

No.	Glazing Type	Frame	Window Style	Window Size	Total Unit U Value	Center of Glass U-Value	SHGC	Daylight Transmittance	2007 Price ($)	Manufacturer /Distributor	Contact Person
1	Thermflect/Argon, Low-Conductance Spacer, Double Pane	Vinyl	Single-Hung w/o Grid	36" X 60"	0.31	0.25	0.29	0.71	Builder's Cost: $170	CertainTeed http://www.certainteed.com	Enercon Windows & Hardware 1312 W Villa Maria, Bryan, Texas 77801 (979) 823-3639 Communication with Oscar Beard on 05/17/2006.
2	Air-filled, Low-e, Double Pane	Aluminum	Single-Hung w/o Grid	36" X 60"	0.37		0.29	0.67	Builder's Cost: $110	Atrium Companies, Inc, HR Windows®	
3	Air-filled, Double Pane	Aluminum	Single-Hung w/o Grid	36" X 60"	0.52		0.6	0.81	Builder's Cost: $82	Atrium Companies, Inc, HR Windows®	

Note: Tested in accordance with NFRC 100-97. Data applicable for double-pane insulating units using either double-strength double pane glass with a 1/2" air space or single-strength glass with 9/16" air space.

Windows-3 (2007 Survey)

No.	Glazing Type	Frame	Window Style	Window Size	Total Unit U Value	Center of Glass U-Value	SHGC	Daylight Transmittance	2007 Price ($)	Manufacturer/Distributor	Contact Person
1	Air-filled	Aluminum	Single-Hung w/ Grid	36" X 60"	0.67		0.68	0.7	$88.00	MI Windows and Doors- BetterBilt	LOWE'S OF BRYAN, TX #0103 3225 FREEDOM BLVD. BRYAN, TX 77802 (979) 774-4141 Visiting Date: 5/25/2006
2	Air-filled low-e	Aluminum	Single-Hung w/ Grid	36" X 60"	0.55		0.33	0.55	$112.00	MI Windows and Doors- BetterBilt	
3	Air filled low-e	Vinyl	Single-Hung w/o Grid	36" X 60"	0.35		0.32	0.58	$137.00	Pella - ThermaStar	
4	Argon-filled low-e	Vinyl	Single-Hung w/o Grid	36" X 60"	0.33		0.31	0.58	$210.40	Pella - ThermaStar	
5	Air-filled low-e	Wood	Double-Hung w/o Grid	36" X 60"					$243.00	Pella	

Note: All windows listed above are insulated window unit.

Windows-4 (2010 Survey)

No.	Glazing Type	Frame	Window Style	Window Size	Total Unit U Value	Center of Glass U-Value	SHGC	Visible Trans-mittance	Item #	2010 Price ($)	Manufacturer/Distributor	Contact Person
1	Air-filled low-e	Aluminum	Single-Hung w/ Grid	36" X 60"	0.55		0.33	0.55	6963	$106.00	MI Windows and Doors- BetterBilt	LOWE'S OF BRYAN, TX #0103 3225 FREEDOM BLVD. BRYAN, TX 77802 (979) 774-4141 Visiting Date: 4/14/2010
2	Air-filled	Aluminum	Single-Hung w/ No Grid	36" X 60"	0.66		0.68	0.7	109933	$81.00	MI Windows and Doors- BetterBilt	
3	Air-filled	Aluminum	Single-Hung w/ Grid	36" X 60"	0.68		0.61	0.63	108482	$106.00	MI Windows and Doors- BetterBilt	
4	Air-filled low-e	Vinyl	Single-Hung w/o Grid	36" X 60"	0.34		0.28	0.51	194900	$148.00	Pella - ThermaStar	

Windows-5 (2010 Survey)

No.	Glazing Type	Frame	Window Style	Window Size	Total Unit U Value	Center of Glass U-Value	SHGC	Visible Trans-mittance	2010 Price ($)	Manufacturer/Distributor	Contact Person
1	Low-e glass	Aluminum	Single-Hung w/ Grid	36" X 60"	0.35		0.34		$105.00	H-R	Home Depot 1615 University Drive East,College Station,TX,(979)595-1188 Visiting Date: 4/14/2010
2	Low-e glass	Aluminum	Single-Hung w/ Grid	36" X 60"	0.35		0.34		$130.00	H-R	
3	Low-e glass	Vinyl	Single-Hung w/ Grid	36" X 60"	0.35		0.34		$177.00	H-R	

Note: The information above was provided by service assistant in Home Depot and there are no product samples

Windows-6 (2010 Survey)

No.	Glazing Type	Frame	Window Style	Window Size	Total Unit U Value	Center of Glass U-Value	SHGC	Visible Trans-mittance	2010 Price ($)	Manufacturer/Distributor	Contact Person
1	LOE 366/Argon	Vinyl	Single-Hung w/ Grid	36" X 60"	0.28		0.2	0.47		BURRIS WINDOW	Enercon Windows & Hardware 1312 W Villa Maria, Bryan, Texas 77801 (979) 823-3639 Communication with Tom Ferguson on 4/14/2010.
2	Argon	Vinyl	Double-Hung w/o Grid	36" X 60"	0.3		0.25	0.46		Certain Teed	

Note: The prices were not provided by Tom Ferguson and he said only the owner who might be available on Friday (4/16/2010) would give the price.

Table B-4. Cost Information for HVAC Measures

Duct-1

No.	Description	Conditioned Floor Area (ft2)	HVAC Material*	HVAC Labor	Incremental Framing Cost ($)	Incremental Drywall Cost ($)	Total Increased Construction Cost ($)	Sources
1	Side-by-side comparison of two identical single-story homes where ductwork was installed after drywall was complete using a bulkhead dropped down from the ceiling,which ran along the long axis of the house; Supply branches, perpendicular to the supply line, were fitted with high-throw diffusers placed at room interior walls						**$230.00**	http://www.toolbase.org/pdf/techinv/ductsinconditionedspace_techspec.pdf
2	Duct in Unconditioned Space		$252.00	$103.00	n/a	n/a	**$355.00**	http://www.toolbase.org/pdf/techinv/ductsinconditionedspace_techspec.pdf
	Duct in Conditioned Space		$201.00	$100.00	$50.00	$282.00	**$633.00**	
3	In the affordable home with simple floor plan, ducts were created with trunk line spanning length of home in constructed bulkhead along first-floor ceiling; Registers off the trunk line serve both floors. A central return was provided at the landing of an open stairway	2325	Increased cost: $0.2 per ft2				**$465.00**	http://www.toolbase.org/pdf/techinv/ductsinconditionedspace_techspec.pdf

*Material cost savings include shorter duct runs and smaller diameter duct line.

Air Conditioning with Gas Heat

Item	No.	2007 Price	2010 Price	Brand	Type of Fuel	Model	Efficiency	Capacity	Description	Pictures	2007 Source and Contact Info		2010 Information/Contact
Air Conditioning with Gas Heat (Carrier)	1	$4,550	approx $5100	Carrier	Electric for cooling, gas for heating	Condenser: 24ABR360 Coil: CNRHP6024 Furnace: 58STA110-1-22	13 SEER/ 80%AFUE	5 ton	R-22 phase out refrigerant; Pilot-free PowerHeat™ ignition		http://www.residential.carrier.com (Date: 05/12/2006)	Central Texas Air Conditioning Service Inc (979) 846-4660 Communication with Jerry Anthony on 05/12/2005.	Central Texas Air ctheadgill@centraltexasair.com (Chris Threadgill))
	2	$5,424	approx $5100	Carrier	Electric for cooling, gas for heating	Condenser: 24ABa360 Coil: CNRHP6024 Furnace: 58STA110-1-22	13 SEER/ 80%AFUE	5 ton	R-410A EPA compliant refrigerant; Pilot-free PowerHeat™ ignition		http://www.residential.carrier.com (Date: 05/12/2006)		
	3	$6,276	approx $6400	Carrier	Electric for cooling, gas for heating	Out of stock, no longer available	15 SEER/ 80% AFUE	5 ton	R-22 phase out refrigerant; Pilot-free PowerHeat™ ignition		http://www.residential.carrier.com (Date: 05/12/2006)		
	4	$6,561	approx $6400	Carrier	Electric for cooling, gas for heating	Condenser: 24ACA560 Coil: CNRHP6024 Furnace: 58STA110-1-22	15 SEER/ 80%AFUE	5 ton	R-410A EPA compliant refrigerant; Pilot-free PowerHeat™ ignition		http://www.residential.carrier.com (Date: 05/12/2006)		
Air Conditioning with Gas Heat (Lennox)	5	$3,933	$3,987	Lennox	Electric for cooling, gas for heating		13 SEER/ 80%AFUE	5 ton	Ref. Type: R-22, Gas Furnace: 135000 Btu/hr		http://www.smarterwayinc.com/res_systems/gas_furnaces/lennox.asp	Barker's Htg & Cooling Inc 400 Graham Rd College Station, TX 77840 (979-690-2278)	Barker's Htg & Cooling Inc 400 Graham Rd College Station, TX 77840 (979-690-2278) Contacted Phillip on 3-15-2010
	6	$5,786	$6,295	Lennox	Electric for cooling, gas for heating	XE 16 series	15 SEER/ 80%AFUE	5 ton	Ref. Type: R-410A, Gas Furnace: 135000 Btu/hr		http://www.smarterwayinc.com/res_systems/gas_furnaces/lennox.asp		
Air Conditioning with Gas Heat (All Makers)	7	$4,500	will call back, but figure 10% increase	All Makers	Electric for cooling, gas for heating	n/a	13 SEER/ 80%AFUE	5 ton	$1,300 / Ton including duct work $6,500 for 5-ton unit with duct work $4,500 for 5-5on unit without duct work		Aggieland A/C & Heating	979-696-1333 (Tommy)	979-696-1333 (Tommy) 3-16-2010
	8	$6,200		All Makers	Electric for cooling, gas for heating	n/a	15 SEER/ 80%AFUE	5 ton	$1,615 / Ton including duct work $8,075 for 5-ton unit with work $6,200 for 5-ton unit without duct work		Aggieland A/C & Heating	979-696-1333 (Tommy)	979-696-1333 (Tommy) 3-16-2010
	9	$12,000	4500 + $12/sqft+misc equip (300)	All Makers	Electric for cooling, gas for heating	n/a	13 SEER/ 80%AFUE	5 ton	$12,000 includes duct work.		ACC-Aggieland Climate Control	979-450-2653 (Jose Rodrigueg)	ACC-Aggieland Climate Control 3-16-2010 Talked to Clay.
	10	$13,000	5500 +12/ft for duct +300	All Makers	Electric for cooling, gas for heating	n/a	15 SEER/ 80%AFUE	5 ton	$13,000 includes duct work.		ACC-Aggieland Climate Control	979-450-2653 (Jose Rodrigueg)	ACC-Aggieland Climate Control 3-16-2010 Talked to Clay.
	11	$3,300	10-15% increase	All Makers	Electric for cooling, gas for heating	n/a	13 SEER/ 80%AFUE	5 ton	$1,500 / Ton including duct work $7,500 for 5-ton unit with duct work $3,300 for 5-ton unit (No Duct Work & No Labor)		IntelAir Heating & Cooling LLC	979-219-2767 (Eric Burch)	Intelair Heating & Cooling LLC (979) 219-2767 no website
	12	$4,800		All Makers	Electric for cooling, gas for heating	n/a	15 SEER/ 80%AFUE	5 ton	$1,800 / Ton including duct work $9,000 for 5-ton unit with duct work $4,800 for 5-ton unit (No Duct Work & No Labor)		IntelAir Heating & Cooling LLC	979-219-2767 (Eric Burch)	Intelair Heating & Cooling LLC (979) 219-2767 no website

NOTE: New code for CS:if 13, you have to use R-8 insulation on duct. So most people just use SEER 14 and that way they can stick with R-6. This is for new systems. Old systems with old duct work can be grandfathered.

Furnace

Item	No.	20007 Price	2010 Price	Brand	Type of Fuel	Model	Efficiency	Capacity	Description	Pictures	2007 Source and Contact Info		2010 Information/Contact
Gas Furnace (Carrier- up to 96.6% AFUE)	1	-	$3700 - 4800	Carrier	Natural Gas	58MVB	96.6% AFUE	40,000 - 120,000 BTUH	Infinity 96 Gas Furnace; Multipoise, condensing, direct vent/non direct vent gas furnace; Variable speed blower; Pilot-free PowerHeat™ ignition.		http://www.residential.carrier.com/products/furnaces/gas/index.shtml (Date: 5/11/2006)		**Central Texas Air Conditioning Service Inc (979) 846-4660 threadgill@centraltexasair.com (Chris Threadgill)**
	2	About $1000 increase in cost	**$3,460.00**	**Carrier**	**Natural Gas**	**58MTB**	**93% AFUE**	38,000 - 128,000 BTUH	Performance 93 Gas Furnace; Multipoise, condensing, direct vent/non direct vent; 4-5 speed blower; Pilot-free PowerHeat™ ignition.		http://www.residential.carrier.com/products/furnaces/gas/index.shtml (Date: 5/11/2006)		Malek Service - 10464 State Highway 30 College Station, TX 77845 Phone:979-776-2222 Fax:979-776-2282 Contact: Robin (3-24-2010)
	3		**$2,700.00**	**Carrier**	**Natural Gas**	**58CTA, 58CTX**	**80% AFUE**	40,000 - 154,000 BTUH	Performance 80 Gas Furnace; Induced-combustion; Enhanced comfort control with dual stages of heating; 4-5 speed blower; Pilot-free PowerHeat™ ignition.		http://www.residential.carrier.com/products/furnaces/gas/index.shtml (Date: 5/11/2006)		
Gas Furnace (Goodman- 80% to 93% AFUE)	4	$1063/$768	-	**Goodman**	Natural Gas	GMV81155CXA/GMS81155CNA	80% AFUE	115,000 BTUH	GMV8 Series 80% AFUE Two-Stage, Variable-Speed/GMS8/GDS8 Series 80% AFUE Single-Stage, Multi-Speed; Upflow /Horiz.		http://www.smarterwayinc.com/res_components/gas_furnace/lennox.asp		does not seem to be available anymore
	5	$1,658.00	-	**Goodman**	Natural Gas	GMV91155DXA	93% AFUE	115,000 BTUH	GMV9/GCV9 Series 93% AFUE Two-Stage, Variable-Speed, Upflow /Horiz.		http://www.smarterwayinc.com/res_components/gas_furnace/lennox.asp		does not seem to be available anymore
Gas Furnace (Rheem- 80% to 93% AFUE)	6	$1,200.00	~10% increase	**Rheem**	**Natural Gas**	**RGFN15EARJR**	**80% AFUE**	**125,000BTUH**	**Rheem® Natural / Propane Gas Furnaces**			**A Top Tech, (979) 696-1333**	**979-696-1333 (Tommy) 3-16-2010**
	7	$2100/$2300		**Rheem**	**Natural Gas**	**RGRA12ERA-JS/RGFD12ERCMS**	**93% AFUE**	**120,000 BTUH**	**Rheem® 1-Stage Multi-Speed / Rheem® Modulating Variable Speed**				
Gas Furnace (Lennox- 80% to 93% AFUE)	8	$1,314.00	**$827.00**	**Lennox**	**Natural Gas**	**G40UH60D135**	**80% AFUE**	**132,000 BTUH**	**Up/Horiz**		**Barkers Heating and Cooling, http://www.smarterwayinc.com/res_components/gas_furnace/lennox.asp**	**(979) 690-2278 (Charlie)**	**Barker's Htg & Cooling Inc (979) 690-2278 (Philip 3-15-2010)**
	9	$2492/$2043	**2753 / 2042**	**Lennox**	**Natural Gas**	**G61MPV60D135/G61MP60D135**	**94% AFUE**	**132,000 BTUH**	**Lennox Signature® Collection G61V 94+% AFUE Two-Stage, Variable-Speed Furnaces/Lennox Signature® Collection G61 94.1% AFUE Two-Stage, Multi-Speed Furnaces. Up/Horiz./Down**				
AC/Furnace (Goodman)	10	-	$2,502.00	Goodman		GSC130601/CAPF4860C6/GMS80905CN	13 SEER, 80% AFUE	5 ton (90,000 Btu/h)	**Air Conditioning/Gas Furnace System**		https://www.expresshvac.com		Express HVAC
	11	-	$3,075.00	Goodman		GSC140601/CAPF4860D6/GKS91155DX	14 SEER, 92.1% AFUE	5 ton (115,000 Btu/hr)	**Air Conditioning/Gas Furnace System**		http://acdirect.com/ (Date: 05/11/2006)		Express HVAC
	12	-	$15,560.00	Goodman		GMVC80704BX	14 SEER, 92.1% AFUE	5 ton (115,000 Btu/hr)	**Goodman GPG13601401A - 13 Seer- 5 TON Cooling / 138,000 BTU Heating**		http://acdirect.com/ (Date: 05/11/2006)		http://www.alpinehomeair.com

Heat Pump

Item	No.	2007 Price	2010 Price	Brand	Type of Fuel	Model	Efficiency	Capacity	Description	Pictures	2007 Source and Contact Info		2010 Information/Contact
Heat Pump (Carrier - Up to 19 SEER and 9.5 HSPF)	1	-	4890 (including labor)	Carrier	Electric	25HPA3	15 SEER/8.5 HSPF	Heating Capacity: 18,000 - 60,000 Btu/h Cooling Capacity: 1.5 - 5 tons	Carrier Performance Series Heat Pump; Versatile heating and cooling heat pump for maximum home comfort; Up to 15 SEER and 9.0 HSPF; Models include 25HPA5, 25HPA4, 25HPA3, 25HPR3, 38YXA, 38YZA, 38YSP.		http://www.residential.carrier.com/products/acheatpumps/heatpumps/index.shtml (Date: 5/12/2006)		http://www.champion-hvac.com/hp-carrier.htm
	2	-	4200 (including labor)	Carrier	Electric	25HCA3	13 SEER/8 HSPF	Heating Capacity: 18,000 - 60,000 Btu/h Cooling Capacity: 1.5 - 5 tons	Carrier Comfort Series Heat Pump Economical heating and cooling heat pump for optimal home comfort; Up to 14 SEER and 8.5 HSPF; Models include 25HCA4, 25HCA3, 25HCR3, 38YRA, 38YSA.		http://www.residential.carrier.com/products/acheatpumps/heatpumps/index.shtml (Date: 5/12/2006)		http://www.champion-hvac.com/hp-carrier.htm
Heat Pump (Goodman)	3	$3,189.00	1500-2800	Goodman	Electric	GSH130601A ARUF061	13 SEER/8.5 HSPF	Heating Capacity: 55000 Btu/h Cooling Capacity: 5 ton	Goodman 5 Ton 13 Seer Air Conditioning System with Heat Pump; One Goodman fully charged outdoor heat pump air conditioning condensing unit; One matched indoor air handling unit; One supplemental heating element.		Price: http://acdirect.com/ (Date: 05/11/2006) Product: http://www.goodmanmfg.com/		Google Products
	4	$3,492.00	not found	Goodman	Electric	GSH140601A AEPF4260	14.5 SEER/8.5 HSPF	Heating Capacity: 55000 Btu/h Cooling Capacity: 5 ton	Goodman 5.0 Ton 14.5 Seer Air Conditioning System with Heat Pump: One Goodman fully charged outdoor heat pump air conditioning condensing unit ; One matched indoor air handling unit, multi-position including evaporator cooling coil ; One supplemental heating element up to 15 Kw (10Kw up to 3 Ton)		http://acdirect.com/heat_pump_goodman_heat_pump_rudd_heat_pump_.php (Date: 07/31/06)		
Heat Pump (Ruud)	5	$3,591.00	~10% increase	Ruud	Electric	UPNE-060JAZ UHLA-HM6024JA	13 SEER/8.5 HSPF	Heating Capacity: 57000 Btu/h Cooling Capacity: 5 ton	Achiever by Ruud 5 Ton 13 Seer Variable Speed Air Conditioning System with Heat Pump; One Ruud UPNE series 13 SEER heat pump condenser; One matched indoor air handling unit; One Ruud supplemental electric heating kit.		Price: http://acdirect.com/ (Date: 05/11/2006) Product: http://www.ruudac.com		979-696-1333 (Tommy) 3-16-2010
	6	$4,366.00		Ruud	Electric		14 SEER/8.5 HSPF		One Ruud UPNE series 14 SEER heat pump condenser One Ruud factory-matched indoor air handler One Ruud supplemental electric heating kit (with electric heat and heat pumps)		http://acdirect.com/x.cat/product.php?productid=290 (Date: 07/31/06)		
Heat Pump (Rheem)	7	$4,400.00	~10% increase	Rheem	Electric		13 SEER	5 ton	Price includes labor but not duct work			A Top Tech (979) 696-1333	979-696-1333 (Tommy) 3-16-2010
	8	$5,100.00	~10% increase	Rheem	Electric		14 SEER	5 ton	Price includes labor but not duct work				
	9	$6,100.00	~10% increase	Rheem	Electric		16 SEER	5 ton	Price includes labor but not duct work				
Heat Pump (All Makers)	10	$5,000.00	~10% increase	All Makers	Electric	n/a	13 SEER/8.5 HSPF	5 ton	$1400 / Ton including duct work $7000 for 5-ton unit with duct work $5000 for 5-ton unit without duct work		Aggieland A/C & Heating	979-696-1333 (Tommy)	left 979-696-1333 (Tommy) 3-16-2010
	11	$7,000.00		All Makers	Electric	n/a	15 SEER/8.5 HSPF	5 ton	$1800 / Ton including duct work $9000 for 5-5on unit with duct work $7000 for 5-ton unit without duct work		Aggieland A/C & Heating	979-696-1333 (Tommy)	le979-696-1333 (Tommy) 3-16-2010
	12	$3,600.00	~1200 increase	All Makers	Electric	n/a	13 SEER/ 8.5 HSPF	5 ton	$1,800 / Ton including duct work $9000 for 5-ton unit with duct work $3600 for 5-ton unit (No Duct Work & No Labor)		InteliAir Heating & Cooling LLC	979-219-2767 (Eric Burch)	Talked to Clay.
	13	$5,800.00		All Makers	Electric	n/a	15 SEER/ 8.5 HSPF	5 ton	$2,000 / Ton including duct work $10000 for 5-ton unit with duct work $5800 for 5-ton unit (No Duct Work & No Labor)		InteliAir Heating & Cooling LLC	979-219-2767 (Eric Burch)	Talked to Clay.

Heat Pump *(Continued)*

Item	No.	2007 Price	2010 Price	Brand	Type of Fuel	Model	Efficiency	Capacity	Description	Pictures	2007 Source and Contact Info		2010 Information/Contact
Heat Pump (Trane)	14	$4,050.00	$1,955.00	Trane	Electric	2TWR3060A1	13 SEER/ 8.5 HSPF	5 ton	$2700 for installation		JC Innovative Services	979-778-9990 (John Gipson)	JG Innovative Services 222 Manno Road Bryan, TX 77808 979-778-9990 (David) 3-16-2010
	15	$4,950.00	no longer made	Trane	Electric	2TWZ9060B1	15 SEER/ 8.75HSPF	5 ton	$3300 for installation		JC Innovative Services	979-778-9990 (John Gipson)	JG Innovative Services 222 Manno Road Bryan, TX 77808 979-778-9990 (David) 3-16-2010
Heat Pump (Lennox)	16	$3,584.00	$3,383.00	Lennox	Electric	XP13 series	13 SEER/ 8.5 HSPF	5 ton	installation = ~$8,250		http://www.smartenwayinc.com/res_systems/heat_pump/heatpump1.asp#Lennox		Baker's Htg & Cooling Inc 400 Graham Rd College Station, TX 77840 (979-690-2278) Contacted Phillip on 3-15 and 3-16 2010
	17	$5,872.00	$4,059.00	Lennox	Electric	XP 16 series	16 SEER/ 8.75HSPF	5 ton	R-410 xp16-060 installationpn = ~$11,250		http://www.smartenwayinc.com/res_systems/heat_pump/heatpump1.asp#Lennox		
Heat Pump - Carrier	18	-	$11,000.00	Carrier	Electric	25HPA6	16.5 SEER/9.5 HSPF	Heating Capacity: 24,000 - 60,000Btu/h Cooling Capacity: 2 - 5 tons	Carrier Performance Series Heat Pump; Versatile heating and cooling heat pump for maximum home comfort; Up to 15 SEER and 9.0 HSPF; Models include 25HPA5 (15SEER/8.5HSPF)and 25HPA6		http://www.residential.carrier.com/products/acheatpumps/heatpumps/performance.shtml	Central Texas AC Service - 1910 Greenfield Plaza, Bryan, TX 77802 (979) 846-4660	Central Texas Air Conditioning Service Inc (979) 846-4660 threadgill@centraltexasair.com (Chris Threadgill)) 3-18-2010
	19	-	$16,247.00	Carrier	Electric	25HNA9	19 SEER/9.5 HSPF	Heating Capacity: 24,000 - 60,000Btu/h Cooling Capacity: 2 - 5 tons	Carrier's exclusive Infinity® Series heat pump has two stages, operating with less power longer. And we engineered it to team with an Infinity Series furnace to create an economical HYBRID HEAT® dual fuel system, which saves you year-round. 25 HNA6 has 16.6 SEER/9.3 HSPF		http://www.residential.carrier.com/products/acheatpumps/heatpumps/infinity.shtml	Central Texas AC Service - 1910 Greenfield Plaza, Bryan, TX 77802 (979) 846-4660	
	20	-	$7,159.00	Carrier	Electric	25HBB5	15 SEER/8.8 HSPF	Heating Capacity: 18,000 - 60,000Btu/h Cooling Capacity: 1.5 - 5 tons	The Base heat pump is our most economical way to provide year-round home comfort. Its efficient cooling system, with up to 15.0 SEER, reverses during cooler weather for low-cost electric heat.		http://www.residential.carrier.com/products/acheatpumps/heatpumps/infinity.shtml	Central Texas AC Service - 1910 Greenfield Plaza, Bryan, TX 77802 (979) 846-4660	
Heat Pump TRANE	21	-	3500-5000	Trane	Electric	4TWB4060E	up to 15 SEER/ up to 8.5 HSPF	Cooling Capacity: 60,000 Btu/h (Nomial 5 tons)	price depends on inside unit, square footage, plans, windows, orientation (most installers will ask you for all this information before you buuy a unit. Check the J-book specifications.		http://www.trane.com/Residential/Products/Heat-Pumps		Climate Masters of BCS 979-985-5839 spoke with Richard
	22	-	8000-10000	Trane	Electric	4TWZ0060A	up to 19 SEER/ up to 9 HSPF	Nominal Capacity: 5 tons	2 stage compressor "Cadillac." must be used with communicator. Price does not include duct work		http://www.trane.com/Residential/Products/Heat-Pumps		
Rheem® Heat Pump Self-Contained Package Units	23		$3,520.00	Rheem	Electric	Rheem RQNJA060JK000	13 SEER	5 ton					HVAC\ExpressHVAC.pdf OR http://www.expresshvac.com/res_systems/package/HVAC_package.asp
	24		$3,779.00	Rheem	Electric	Rheem RQFMA060JK000	14 SEER	5 ton					

Table B-5. Cost Information for DHW Measures

Water Heater -1

Item	No.	2007 Price	2010 Price	Brand	Type of Fuel	Model	Energy Factor	Capacity	Description	Pictures	Source	Contact Person	2010 Contact Info
Tankless Gas Water Heater	1	$999.00	$865.00	Paloma	Natural Gas	Model PTG-74PVN	0.82	7.4 GPM	Whole Home 7.4 GPM Natural Gas Tankless Water Heater With Remote Control; Electronic ignition; Supplies hot water for 2 to 3 applications; 199,900 BTU burner.		http://www.homedepot.com/ (Date: 05/09/2006)		Home Depot no longer carries HG Paloma Brand. Try http://www.heater-store.com
	2		$1050, with tax credit	Paloma	Natural Gas	PH-28RIFS	0.82	8.5 GPM	Paloma 7.4 Series Residential Indoor Gas Tankless Water Heater. Remote controller included. Optional remote controllers available. Model for indoor installations only.		http://www.palomawaterheaters.com/products.html#residential		http://www.besthotwaterheaters.com/catalogue_product.php?id=327
	3	$949.00	$1,294.00	Bosch AquaStar	Natural Gas	Model 250SX-NG	0.85	6.4 GPM	Whole House Gas Tankless Water Heater; Electronic ignition; Supplies hot water for 2 applications.		http://www.homedepot.com/ (Date: 05/09/2006)	Internet Price	Amazon.com
	4		$835.00	Bosch AquaStar	Natural Gas	Model 125FX	0.78	4.6GPM			http://www.boschhotwater.com/Portals/7/Marketing/125FX.pdf		Click here to see brochure; see also http://www.amazon.com/Bosch-AquaStar-Natural-Tankless-NG/dp/B0006GVNT0
	5	$929.00	$1,149.00	Rheem	Natural Gas	RTG-74PVN	0.82	7.4 GPM	Rheem Tankless 7.4 GPM- Indoor Tankless Water Heater- 7.4 Gallon; 19000-199,900 btuh.		http://www.hmwallace.com/index.asp?PageAction=VIEWPROD&ProdID=2016 (Date: 05/15/2006)		http://www.amazon.com/RHEEM-199KBTU-Tankless-Heater-RTG74PVN/dp/B0015B4J50/ref=sr_1_1?ie=UTF8&s=hi&qid=1268338131&sr=1-1
	6	$1,397.00	$1,397.00	Takagi	Natural Gas	T-KD20	0.84 (85% thermal efficiency)	6.9 GPM	First hour rating: 240 GPH. Min 20,000 Btu Max 185,000 Btu. Outlet Temp: 95-180°F. No pilot light. (Qualify for $300 TAX credit)		http://www.tanklesswaterheaters.com/takagitk1.html; http://www.designerplumbing.com		http://blujay.com/?page=ad&adid=1536668&cat=11060000
	7	$1457/$1401	$899.00	Takagi	Natural Gas	T-K1S/T-K2	85% thermal efficiency	6.9 GPM	First hour rating: 240 GPH. Min 20,000 Btu Max 190,000 Btu. Outlet Temp: 95-180°F. Electronic ignition. No pilot light. (Qualify for $300 TAX credit)		http://www.tanklesswaterheaters.com/takagitk1.html; http://www.designerplumbing.com		http://blujay.com/?page=ad&adid=1536658&cat=11060000
	8	$2,297.00	$1,460.00	Takagi	Natural Gas	T-M1	0.81 (82.4% thermal efficiency)	9.6 GPM	First hour rating: 300 GPH. Min 25,000 Btu Max 235,000 Btu. Outlet Temp: 95-180°F. Electronic ignition. No pilot light. (Qualify for $300 TAX credit)		http://www.tanklesswaterheaters.com/takagitk1.html; http://www.designerplumbing.com		http://www.tanklesswaterheatersdirect.com/shop/tanklesswaterheaters/takagi/takagitm1buy.asp
Tank-type Gas Water Heater with Pilot light	9	$377.99($409.99)	$520.00	Kenmore	Natural Gas	#33926(#33916)		40(50) Gallon	Kenmore Power Miser 9, 40(50) gal. Gas Water Heater; Hourly input -40,000 BTU.		http://www.sears.com/ (Date: 05/09/2006)		http://instant-water-heaters.devhub.com
	10	$215.95($232.50)	$269.90	State	Natural Gas	GS6 40YBRT	0.60 (0.59)	38	Select® Standard Vent Gas Water Heaters; Feature C3 Technology™ that protects against accidental ignition of flammable vapors like those from gasoline; Green Choice™ gas burner produces 33% lower NOx emissions than standard burners		http://www.statewaterheaters.com/Spec/res-gas.html#codemod	CITY SUPPLY COMPANY, INC. HOUSTON, TX 77003 B: 713-224-1643 This company no longer sells this product line.	CITY SUPPLY COMPANY, INC. http://www.citysupplyplumbing.com 1800-CITY SUPP spoke with Ken
	11	$325.00	$260.00	Rheem	Natural Gas	2ZV40F1	0.6	40 Gallon	Guardian Fury® Gas Water Heaters.		http://www.rheem.com/commercial/catalog/Res_detail.asp?id=76 (Date: 05/15/2006) 2010 Price from Amazon	HUGHES 541 GRAHAM ROAD COLLEGE STATION, TX 77845 Phone: (979) 690-7636 Fax: (979) 690-7821 Communication with Barney on	Amazon
	12	$310.00	$356.97	A.O. Smith	Natural Gas	GCV50	0.58	50 Gallon	ProMax gas water heaters. Hourly input: 40000Btu/h.		http://www.hotwater.com/lit/spec/media/res_gas/ARG-SS002-0405H.pdf (Date: 5/17/2006)	Valley Supply, College Station, TX (979) 779-7042 (979) 823-5522 (FAX) Communication with John on 5/17/2006	Valley Supply, College Station, TX (979) 779-7042 (979) 823-5522 (FAX) Communication with John on 3-15-2010

Water Heater -1 *(Continued)*

Item	No.	2007 Price	2010 Price	Brand	Type of Fuel	Model	Energy Factor	Capacity	Description	Pictures	Source	Contact Person	2010 Contact Info
Tank-type Gas Water Heater with Electronic Ignition	13	$757.50	upgraded, see note for new product info.	State	Natural Gas	PR6 40 XCVIT	0.62	40 Gallon	Select® Power-Vent residenital gas water heater; hourly input-40000Btu; Equipped with nearly-indestructible silicon nitride hot surface igniter.		http://www.stateind.com/lit/media/spec/res-gas/SPVG6-1-4.pdf (Date: 05/10/2006)	STATE Water Heaters 1-800-365-0024 ACT PIPE & SUPPLY, INC. 6900 WEST SAM HOUSTON PARKWAY NORTH HOUSTON, TX 77041 B: 713-937-0600 713-933-0426 (Ecklund)	ACT Pipe & Supply (832-467-8900) Alex
	14	$817.50	not available	State	Natural Gas	PR6 40 XBPDT	0.59(0.58)	40 Gallon	Select® Power Direct-Vent residenital gas water heater; hourly input-40000Btu; Equipped with nearly-indestructible silicon nitride hot surface igniter.		http://www.stateind.com/lit/media/spec/res-gas/SPDVG5-1-4.pdf (Date: 5/10/2006)		
	15	$585.00	307.14+ tax	Rheem	Natural Gas	42VRP40 (ZZVR40 is not nat gas; 42 is for propane)	0.64	40 Gallon	PowerVent High Efficiency, Induced Draft Gas Water Heater, Electronic ignition system		http://www.rheem.com/consumer/catalog/Res_detail.asp?id=68 (Date: 5/15/2006)	HUGHES 541 GRAHAM ROAD COLLEGE STATION, TX 77845 Phone: (979) 690-7636 Fax: (979) 690-7821 Communication with Barney on 05/15/2006.	(HD Supply) HUGHES 541 GRAHAM ROAD COLLEGE STATION, TX 77845 Phone: (979) 690-7636 Spoke with Ernesto; left a message for Barney about #14.
	16	$565.00	special order only	Reud	Natural Gas	PVP40FW	0.62	40 Gallon	PowerVent Induced Draft Gas Water Heater with the Guardian System™, Electronic ignition system		http://www.rheem.com/consumer/catalog/Res_detail.asp?id=68&brand=Reud (Date: 5/15/2006)		
	17	$985.00	price pending	A.O. Smith	Natural Gas	GPDH-50/GPDT-50	0.58	50 Gallon	Power House® Sealed Shot Power Direct-Vent Gas Water Heaters; horizontal and vertical venting options up to 45 feet; Advanced Intelli-Vent gas control valve with rugged silicon nitride hot surface igniter; Closed-combustion, two-pipe system draws clean combustion air from outside, vents outside the home; Environmentally friendly Green Choice™ gas burner reduces NOx emissions by 33% compared to standard burners; Hourly input: 40000/50000Btu/h		http://www.hotwater.com/lit/spec/media/res_gas/A7521.pdf (Date: 5/17/2006)	Valley Supply, College Station, TX (979) 779-7042 (979) 823-5522 (FAX) Communication with John on 5/17/2006	Valley Supply, College Station, TX (979) 779-7042 (979) 823-5522 (FAX) Communication with John on 3-15-2010
	18	$1,200.00	1464.71 +Plus tax	A.O. Smith	Natural Gas	GPHE-50	90% Thermal Efficiency	50 Gallon	Vertex™ Power-Vent Gas Water Heaters; Money-saving 90% thermal efficiency; Endless hot water means homeowners will always get "one more hot shower", Hot water output similar to larger, less efficient 75-gallon unit; Equipped with nearly indestructible silicon nitride hot surface ignitor – no standing pilot; Hourly input: 76000 Btu/h.		http://www.hotwater.com/lit/spec/media/res_gas/ARGSS01306.pdf (Date: 5/17/2006)	David Cunningham High M. Cunningham 137555 Beachmark Dallas , TX 75234 B/ 972-888-3808 F/ 972-888-3838	Cunningham does NOT give price information directly. Referred to local Bryan vendor: Ferguson 979 774 1389 (Mail)
	19	-	$800.00	Reliance	Natural Gas	SKU: 671147 Model 6-50-YBVIT UPC	0.65	50 Gallon	50 Gallon, Natural Gas, Power Vent Water Heater, Electronic Ignition, Vents With 3" PVC, CPVC Or ABS Schedule 40 Piping, 40,000 BTUs Energy Factor .65, Dimensions: 69-3/4" Tall x 20" Diameter, 6 Year Tank & Parts Warranty, FVIR Approved.				True Value Hardware Store
	20	-	$800.00	Kenmore	Natural Gas	153.33205	0.65	50 Gallon	Kenmore 50 Gallon Tall Natural Gas Water Heater ENERGY STAR qualified appliance. The electronics on this Kenmore natural gas hot water heater make it easy to operate, and the electric ignition of the gas burner will increase your overall savings, energy-w				Sears.com
	21	-	this product no longer made	Maytag	Natural Gas	MR6 50 XCVIT	0.61	50 Gallon					
Tank-type Electric Water Heater	22	$269.99($299.99)		Kenmore	Electric	#32946(#32154)		40(50) Gallon	Kenmore Power Miser 9(12), 40(50) gallon Electric Water Heater; Kilowatt Hrs. per Year-4721(4622).		http://www.sears.com/ (Date: 05/09/2006)		
	23	$188.00			Electric			55 Gallon			http://www.toolbase.org/Toolbase Resources/level4TechInv.aspx?ContentDetailID=599&BucketID=6&CategoryID=9	TOOLBASE Techspecs, by the NAHB Research Center for the Partnership for Advancing Technology in Housing (PATH).	
Tankless Electric Water Heater	24	$585.00			Electric			Whole House			http://www.toolbase.org/Toolbase Resources/level4TechInv.aspx?ContentDetailID=599&BucketID=6&CategoryID=9	TOOLBASE Techspecs, by the NAHB Research Center for the Partnership for Advancing Technology in Housing (PATH).	
	25	$750/$775		Stiebel Eltron	Electric	Tempra 29/36		4.5 GPM	Single phase 150 amp residential electric water heater.		http://www.tanklesswaterheaters.com/stiebeleltron.html	Retail Price	
	26	$749.00		EEMAX	Electric	Series Three	99% Efficiency	4.0 GPM	EEMAX Series Three Residential Heater Single phase 150 amp residential electric water heater.		http://www.tanklesswaterheaters.com/eemaxheaters.html	Retail Price	
	27	$596.00		PowerStar	Electric	AE125	0.95	3.5 GPM	PowerStar AE125 Electric Whole House Tankless; Provides up to 3.5 gallons per minute(50 degree temp rise) for water usage at 105° F: 2 sinks or 1 shower.		http://www.tanklesswater.com/ (Date: 05/09/2006)		

Solar Water Heater -1

Item	No.	2010 Price	Brand	Model	Type of Fuel	Capacity	Energy Factor	Description	Pictures	2007 Source and Contact Info		2010 Information/Contact
Solar Water Heater	1	$2,154.00	SunEarth	EP6632	-	66 gallon		SunEarth Active Solar Water Heater For temperate climate zones Open Loop System: 66 gal w / 4x8 Solar Panel		**Solar Direct**	http://shop.solardirect.com/product_info.php?products_id=190	
	2	**$2,345.00**	**SunEarth**	**EP8040**	-	**80 gallon**		**SunEarth Active Solar Water Heater For temperate climate zones Open Loop System: 80 gal w 4x10 Solar Panel**		**Solar Direct**	http://shop.solardirect.com/product_info.php?products_id=191	
	3	$3,536.00	SunEarth	EP12064		120 gallon		SunEarth Active Solar Water Heater For temperate climate zones Open Loop System: 120 gal w 4x8 Solar Panel		**Solar Direct**	http://shop.solardirect.com/product_info.php?products_id=192	
	4	$2,728.38	Alternate Energy Technologies LLC	**IPV-80-40**	-	80 gallon		40 Sqft Collector		**Alternative Energy Store**	http://www.altestore.com/store/Solar-Water-Heaters/Climate-freezes-Closed-Loop-Systems/Closed-Loop-Systems-for-1-4-People/Closed-Loop-PV-Powered-w-Tank/AET-PV-w-	http://www.altestore.com/store/Solar-Water-Heaters/Climate-freezes-Closed-Loop-Systems/Closed-Loop-Systems-for-1-4-People/Closed-Loop-PV-Powered-w-Tank/AET-PV-w-
	5	$3,493.00	Alternate Energy Technologies LLC	**IPV-80-64**		80 gallon		64 sqft Sqft Collector		**Alternative Energy Store**		http://www.altestore.com/store/Solar-Water-Heaters/Climate-freezes-Closed-Loop-Systems/Closed-Loop-Systems-for-1-4-People/Closed-Loop-PV-Powered-w-Tank/AET-PV-w-
	6	$6,000 with installtion	American Solar Works; Rheem (tank)	**ASW 58A-20/25/30**		**80 gallon**		48 Sqft Collector, 1000 per collector. Tank with heat exchanger = 1300 . Controller 250, misc		**Texas Green Energy**		TEXAS GREEN ENERGY, INC. 5930 Piper Lane College Station, TX 77845 Contact: Adam Burke Phone: 979-209-0010 Fax: 866-365-1965
	7	$7,300.00	American Solar Works; Rheem (tank)	**ASW 58A-20/25/31**		120 gallon		80 Sqft Collector		**Texas Green Energy**		TEXAS GREEN ENERGY, INC. 5930 Piper Lane College Station, TX 77845 Contact: Adam Burke Phone: 979-209-0010 Fax: 866-365-1965

Solar Collector -1

Item	No.	2010 Price	Brand	Model	Type	Dim.	Capacity	Description	Sources
Solar Collector	1	$858	Alternate Energy Technologies	AE-32	AET 4 X 8 Ae-Series, Crystal Clear Collector	4x8	32 sqft	Alternate Energy Technologies AE- Series Solar Collectors: Glazing: 1 sheet of solite glass, 1/8" or 5/32" thick with 0.01% iron oxide content. Transmittance: 91.0%, Flow Rate: 0.5 to 1.8 GPM recommended	http://www.altestore.com/store/Solar-Water-Heaters/Collectors-Mounts-and-System-Components/AET-Collectors-Rack-Mounts/AET-4-X-8-Ae-Series-Crystal-Clear-Collector/p103/
	2	$915	Alternate Energy Technologies	MSC-32	AET 4X8 Msc-Series, Crystal Clear Collector	4x8	32 sqft	Alternate Energy Technologies Morning Star™ (MSC) Series Solar Water Heating Collectors: Glazing: 1 sheet of low iron tempered glass, 1/8" thick with 0.01% iron oxide content. (5/32" on MSC-40) Transmittance: 91.0%, Flow Rate: 0.5 to 1.8 GPM recommended	http://www.altestore.com/store/Solar-Water-Heaters/Collectors-Mounts-and-System-Components/AET-Collectors-Rack-Mounts/AET-4X8-Msc-Series-Crystal-Clear-Collector/p177/
	3	$1,716	Alternate Energy Technologies	AE-32	AET 4 X 8 Ae-Series, Crystal Clear Collector	(4x8) *2	64 sqft	Alternate Energy Technologies AE- Series Solar Collectors: Glazing: 1 sheet of solite glass, 1/8" or 5/32" thick with 0.01% iron oxide content. Transmittance: 91.0%, Flow Rate: 0.5 to 1.8 GPM recommended	http://www.altestore.com/store/Solar-Water-Heaters/Collectors-Mounts-and-System-Components/AET-Collectors-Rack-Mounts/AET-4-X-8-Ae-Series-Crystal-Clear-Collector/p103/
	4	$1,830	Alternate Energy Technologies	MSC-32	AET 4X8 Msc-Series, Crystal Clear Collector	(4x8) *2	64 sqft	Alternate Energy Technologies Morning Star™ (MSC) Series Solar Water Heating Collectors: Glazing: 1 sheet of low iron tempered glass, 1/8" thick with 0.01% iron oxide content. (5/32" on MSC-40) Transmittance: 91.0%, Flow Rate: 0.5 to 1.8 GPM recommended	http://www.altestore.com/store/Solar-Water-Heaters/Collectors-Mounts-and-System-Components/AET-Collectors-Rack-Mounts/AET-4X8-Msc-Series-Crystal-Clear-Collector/p177/
	5	$998	Chromagen	CR-130	Chromagen Collector Active Solar Water Heater Panel w /Mounting Hardw are One 4 x 8 Collector	4x8	32 sqft	Product Applications: Solar Domestic Hot Water Heater System, Work alongside your conventional w ater heater, Designed for all climates, System collectors designed to mount on roof, Installs on all roof types: shingle, w ood shake, metal and title	http://shop.solardirect.com/product_info.php?cPath=69_71_84_72_87&products_id=657
	6	$1,040	Heliodyne	Gobi 408	GOBI 408 Solar Water Collector, Set of tw o 4 x 8 collectors	4x8	32 sqft	Model 408-002 Black paint coating: Adequate heat absorption in ideal climate regions, Best for w arm climates w ith ample solar radiation, The black paint collectors should only be used in ideal climates (such as Haw aii.) Model 408-001 Blue sputtered coating: Optimal heat absorption w ith minimal emission, Suitable for all types of installations, and regions, Recommended for cool climates (add $140)	http://shop.solardirect.com/product_info.php?products_id=530
	7	$1,996	Chromagen	CR-130	Chromagen Collector Active Solar Water Heater Panel w /Mounting Hardw are One 4 x 8 Collector	(4x8) *2	64 sqft	Product Applications: Solar Domestic Hot Water Heater System, Work alongside your conventional w ater heater, Designed for all climates, System collectors designed to mount on roof, Installs on all roof types: shingle, w ood shake, metal and title	http://shop.solardirect.com/product_info.php?cPath=69_71_84_72_87&products_id=657
	8	$2,080	Heliodyne	Gobi 408	GOBI 408 Solar Water Collector, Set of tw o 4 x 8 collectors	(4x8) *2	64 sqft	Model 408-002 Black paint coating: Adequate heat absorption in ideal climate regions, Best for w arm climates w ith ample solar radiation, The black paint collectors should only be used in ideal climates (such as Haw aii.) Model 408-001 Blue sputtered coating: Optimal heat absorption w ith minimal emission, Suitable for all types of installations, and regions, Recommended for cool climates (add $140)	http://shop.solardirect.com/product_info.php?products_id=530

Table B-6. Cost Information for Lighting Measures

Incandescent Lamps

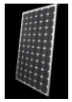
No.	Brand	Model	Description	Unit Wattage (W/unit)	Unit Price ($/unit)	Pictures	Source
1	GE LIGHTING	60A15/CF	Incandescent Lamp, Lamp Designation 60A15/CF CD2, Watts 60, Voltage 120, Lamp Shape A15, Ceiling Fan, Medium Base, Rated Average Life Hours 1500, Lumens 650, Maximum Overall Length 3 1/2 In, Diameter 1 7/8 In	60	$1.31		http://www.idealtruevalue.com/servlet/the-49352/Detail
2	Philips	374694	Incandescent - Lamps/Light Bulbs Lamp Code: A19 BulbStyle: Arbitrary Standard Wattage: 60 Voltage: 120 Base Type: Med. Base Style: Medium Lumens: 890 Color: Frost	60	$0.60		http://www1.mscdirect.com/CGI/NNSRIT?PMPXNO=5510638&PMT4NO=82145666
3	Halco	6321	60 Watt - A19 Light Bulb - Frosted - 5,000 Life Hours - 130 Volt - Brass Base - Halco Lighting 6321	60	$0.55-$0.65		http://www.1000bulbs.com/60-Watt-Incandescents/837/
4	Westinghouse	WB33321	This Westinghouse incandescent light bulb has a type A 15 lamp size, which measures 1-7/8" diameter. Standard E-26 base makes this incandescent light fit in most light bulb sockets. C-9 incandescent filament offers efficient lighting. Provides an average life of up to 2500 hours.	60	$0.74		http://www.globalindustrial.com/p/electrical/bulbs/incandescent/a-15-60w-frosted-sb-130v-2pk-box?utm_source=nextag&utm_medium=cpc&utm_campaign=Incandescent-Bulbs-nextag&infoParam.campaignId=W

CFL-Pin Type (w/ Lampholder)

No.	Brand	Model	Description	Unit Wattage (W/unit)	Unit Price ($/unit)	Total Unit Price ($/unit)	Pictures	Source
1	Sylvania	FC13-GX2335S	13W 3500 Kelvin 2 Pin GX23 Base Compact Fluorescent Light Bulb	13	$1.77-$1.98	$3.99-$4.20		http://www.1000bulbs.com/333/
	Maris	FMP13H-BASE_(10_X_2.22)	13W 2PIN FLUORESCENT BIAX LAMP HOLDER (GX23 BASE) - CASE PACK QTY 10		$2.22			http://marisusa.com/zen-cart/index.php?main_page=product_info&cPath=135_138_139&products_id=4124
2	LITETRONICS	LT 59520	13 watt T4 2-Pin (GX23-2) Base 5,000K Double Tube Compact Fluorescent Litetronics Light Bulb	13	$2.73	$5.02		http://www.elightbulbs.com/Litetronics-59520-L-12164-13W-T4-D-GX23-2-5000K-Double-Tube-2-Pin-Base-Compact-Fluorescent-Light-Bulb
	Satco	80-1506	13 Watt 2-Pin Lampholder w/Uno Thread and Ring, Height: 1-1/2", Push-In Terminals, Solid Wire w/U-Channel 1/8IP Hickey, GX23 Twin, GX23-2 Quad, 75W-600V Socket		$2.29			http://www.lightbulbemporium.com/satco_80_1506_13w_2_pin_fluorescent_lampholder.asp
3	Howard Industries	QT18/27	18W Double Tube 2 pin CF lamp, G24d-2 base, 827 color by Howard Lighting CF18D/827	18	$3.15	$6.15		http://www.needabulb.com/18W-Double-Tube-2-pin-CF-lamp-G24d-2-base-827-color-by-Howard-Lighting-CF18D827-P56535/7C20.aspx
	Leviton	26725-202	G24d-2 Base, 18W 2-Pin, 10mm Compact Fluorescent Lampholder, Vertical, Bottom Snap-In, Green Color Code, Quick-Connect 18AWG Solid or Str. Tinned - White Body		$3.00			http://www.google.com/products/catalog?hl=en&q=2+pin+G24d-2+base+lampholder+18W&cid=10417353620847550492&ei=3nbDS6_cOD2ASagSsAg&sa=title&ved=0CAcQ8wIwADgA#p
4	Global Consumer	FC13-GX2350OD	13W 5000 Kelvin 2 Pin GX23 Base Compact Fluorescent Light Bulb	13	$1.34-$1.91	$6.34-$6.91		http://www.1000bulbs.com/37899/
	GAYNOR	1185-13-HSC	13Watt,for base GX23 or GX23-2		$5.00			http://equaynor.com/_get_item.php?style=1185-HSC
5	Silver	FLD13/E/SP27K	Silver Compact Fluorescent G24Q-1, 4 Pin, 13W 2700k Bulb 25pcs	13	$3.24-$3.90	$8.19-$8.85		http://www.compactfluorescentusa.com/Silver-Compact-Fluorescent-G24Q-1-4-Pin-13W-2700k-Bulb-25pcs-7280-prod.htm
	Leviton	26725-411	Leviton Compact Fluorescent Lamp Holder CFL Light Socket G24q-1 GX24q-1 Base Bottom Screw Mount 10W 13W 4-Pin 26725-411		$4.95			http://www.fruitridgetools.com/storefrontprofiles/processfeed.aspx?sfid=136763&i=230786786&mpid=41171&dfid=1

Table B-7. Cost Information for Renewable Power Measures

Solar PV -1

Item	No.	2010 Price ($/panel)	# of Panels for 4 kW	Price ($/4kW)	Brand	Model	Module Efficiency	Capacity (W)	Area (sqft)	Description	Pictures	Sources
Solar PV	1	$565.00	20	**$11,300.00**	**KYOCERA**	KD210GX-LP	16.0%	210	16	Multi-crystalline silicon cells		http://www.innovativesolar.com/solar-modules-196/kyocera-201/kd210gx-lpu-337.html
	2	$455.00	23	**$10,465.00**	YINGU SOLAR	**YL175**	13.5% (Cell: 15.0%)	175	13.9	High efficiency crystalline solar cell		http://www.innovativesolar.com/solar-modules-196/yingli-solar-241/175-watt-964.html
	3	$880.00	22	**$19,360.00**	SANYO	**190**	18.8% (Cell: 16.4%)	190	12.5	Hybrids of single crystalline silicon surrounded by ultra-thin amorphous silicon layers		http://www.gogreensolar.com/products/sanyo-hit-190-watt-solar-panel-hip-190ba19?utm_source=google-product-search
	4	$550.00	25	**$13,750.00**	Suntech	**STP160S 24/A**	14.1%	160	13.7	Monocrystalline silicon solar cells		http://www.innovativesolar.com/solar-modules-196/suntech-206/160-watt-aluminum-931.html
	5	$732.95	18	**$13,193.10**	SHARP	**ND-U230C1**	14.1%	230	17.5	Polycrystalline silicon		http://www.ecodirect.com/Sharp-ND-U230C1-230-Watt-24-Volt-p/sharp-nd-u230c1.htm