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SEEC Southern Energy Efficiency Center

ANALYSIS OF ABOVE-CODE (2009 IECC) RESIDENTIAL ENERGY EFFICIENCY MEASURES IN ONCOR SERVICE AREA

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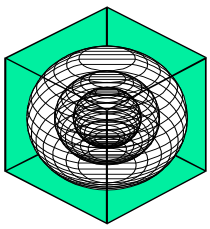

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EXECUTIVE SUMMARY

The purpose of this report is to provide an analysis of residential energy efficiency and renewable measures that would exceed the 2009 edition of the International Energy Conservation Code (IECC) in the ONCOR service territory. This information is useful to homebuilders, utility demand side energy managers, homeowners and others who wish to construct buildings that exceed the minimum national energy code requirements.

A total of 17 measures based on the energy savings above the base-case house were selected. These measures include Renewable Power Options, Heating Ventilation and Air Conditioning (HVAC), Fenestration, Envelope, Lighting and Domestic Hot Water (DHW) options. Individual measures were then categorized into four groups: 0 to 5%, 5 to 10%, and 10 to 15% and above 15% source energy savings above the base-case house. After categorizing, three example groups were formed combining the individual measures so that the combined source energy savings of the group is 15% above the base-case 2009 code-compliant house (Table 1). The savings achieved by each group ranged from 15 to 28%. The photovoltaic options presented the most savings in the range of 12-42% for all base-case houses.

The analysis was performed using an ESL simulation model based on the DOE-2.1e simulation of a 2009 IECC code-compliant, single-family residence. Two sets of simulations based on the choice of heating fuel type were considered: (a) an air-conditioned house with natural-gas heating/domestic water heating (i.e., gas-fired furnace for space heating and gas water heater for domestic water heating), and (b) an air-conditioned house with electric heating/domestic water heating (i.e., heat pump for space heating and electric water heater for domestic water heating). Version 3.03.02 of the Energy Systems Laboratory's International Code Compliance Calculator (IC3) was used with the appropriate TMY2 weather files. Different counties in the ONCOR territory were grouped according to 2009 IECC Climate Zone; and finally, two zones—Climate Zone 2 and 3—were identified and analyzed.

Table 1. Three Groups of 15% Above 2009 IECC Code

Groups 15% Above 2009 IECC Code	Base Case with Natural Gas				Base Case with Heat Pump			
	EEM #	Measures	Savings Above Base case (Source %)		EEM #	Measures	Savings Above Base case (Source %)	
			Travis (Climate Zone: 2A)	Dallas (Climate Zone: 3A)			Travis (Climate Zone: 2A)	Dallas (Climate Zone: 3A)
Group 1	**3**	4 kW PV Array	26.8%	27.8%	**3**	4 kW PV Array	25.5%	26.4%
Group 2	**6**	Mechanical Systems Within Conditioned Spaces	18.3%	17.6%	**18**	Solar DHW System (80 gal tank)	19.3%	19.4%
	15	50% Energy Star CFL Indoor Lamps			**15**	50% Energy Star CFL Indoor Lamps		
Group 3	**7**	Improved SEER (from 13 to 15)	15.3%	15.1%	**6**	Mechanical Systems Within Conditioned Spaces	17.9%	15.3%
	10	Decreased SHGC (from .3 to .2) & U Value (Travis: from .65 to .35 / Dallas: from .5 to .35)			**10**	Decreased SHGC (from .3 to .2) & U Value (Travis: from .65 to .35 / Dallas: from .5 to .35)		
	13	Radiant Barrier			**7**	Improved SEER (from 13 to 15)		
	14	25% Energy Star CFL Indoor Lamps[1)]						

1) Only applied to Dallas County

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1 INTRODUCTION

The purpose of this report is to provide an analysis of residential energy efficiency and renewable measures that would exceed the 2009 edition of the International Energy Conservation Code (IECC) the ONCOR service territory (Figure 1). This information is useful to homebuilders, utility demand side energy managers, homeowners and others who wish to construct buildings that exceed the minimum national energy code requirements.

The analysis was performed using an ESL simulation model based on the DOE-2.1e simulation of a 2009 IECC code-compliant, single family residence. Two sets of simulations based on the choice of heating fuel type were considered: (a) an air-conditioned house with natural-gas heating/domestic water heating and (b) an air-conditioned house with electric heating/domestic water heating. The simulation was conducted using version 3.03.02 of the Laboratory's International Code Compliance Calculator (IC3) and the appropriateTMY2 weather files. In this analysis, the different counties in the ONCOR territory were grouped according to 2009 IECC Climate Zone; and finally, two zones ─ Climate Zone 2 and 3 ─ were identified and analyzed. The grouping of counties is provided in Table 2.

2 BASE-CASE MODEL DESCRIPTION

The base-case, single-family residential house assumptions were based on the "standard design" as defined by 2009 IECC, Section 405 and selected assumptions described in this document. Two sets of simulations based on the choice of heating fuel type were considered: (a) an air-conditioned house with natural-gas heating/domestic water heating and (b) an air-conditioned house with electric heating/domestic water heating.

The base-case residence is a 2,325 sq. ft., square-shaped, single-story, single-family, detached house aligned north, south, east, and west, with a floor-to-ceiling height of 8 feet. The house has a vented attic with a 23 degrees pitched roof, which contains the HVAC system and ductwork. The wall construction is light-weight wood frame with 2x4 studs at 16" on center with a slab-on-grade-floor, which is typical construction according to the National Association of Home Builders - survey (NAHB 2003). The building envelope properties and the space conditions used the definitions from the 2009 IECC. Table 3 summarizes the base-case building characteristics used in the DOE-2 simulation model. The simulation results are based on the TMY2 hourly weather data: Austin TMY2 data for Travis County and Dallas/Fort Worth TMY2 data for Dallas County.

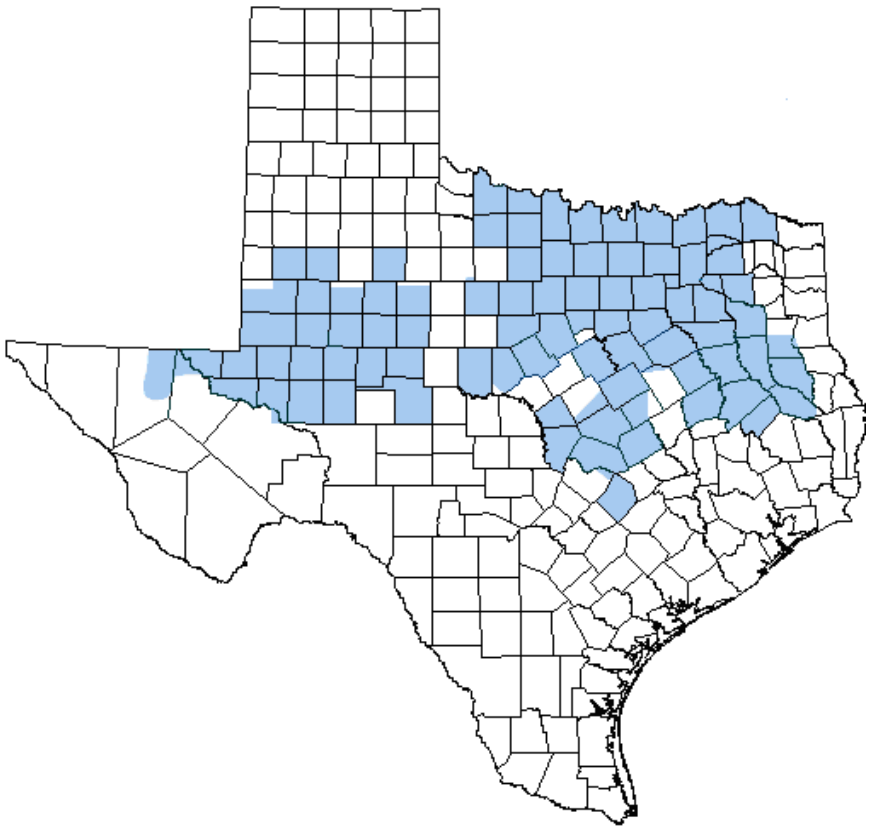

Figure 1. ONCOR Service Territory
(Ref: http://www.oncor.com/electricity/territory/).

Table 2. Counties Served by ONCOR and Corresponding 2009 IECC Climate Zone

COUNTY	2009 IECC Climate Zone	COUNTY	2009 IECC Climate Zone	COUNTY	2009 IECC Climate Zone	COUNTY	2009 IECC Climate Zone	COUNTY	2009 IECC Climate Zone
HENDERSON	3A	WISE	3A	FISHER	3B	LIMESTONE	2A	WINKLER	3B
SMITH	3A	WOOD	3A	JACK	3A	MCLENNAN	2A	COKE	3B
DALLAS	3A	ANDERSON	2A	MITCHELL	3B	NAVARRO	3A	PECOS	3B
ELLIS	3A	ANGELINA	2A	NOLAN	3B	BASTROP	2A	STERLING	3B
HOOD	3A	CHEROKEE	2A	PALO PINTO	3A	BURNET	3A	TOM GREEN	3B
JOHNSON	3A	HOUSTON	2A	SHACKELFORD	3B	TRAVIS	2A	BAYLOR	3B
TARRANT	3A	NACOGDOCHES	3A	STEPHENS	3A	WILLIAMSON	2A	CLAY	3A
LAMAR	3A	RUSK	3A	YOUNG	3A	MILAM	2A	COOKE	3A
RED RIVER	3A	TRINITY	2A	BELL	2A	ANDREWS	3B	FANNIN	3A
COLLIN	3A	BORDEN	3B	BOSQUE	2A	CRANE	3B	GRAYSON	3A
DELTA	3A	DAWSON	3B	BROWN	3A	ECTOR	3B	HUNT	3A
DENTON	3A	GAINES	3B	COMANCHE	3A	GLASSCOCK	3B	MONTAGUE	3A
HOPKINS	3A	KENT	3B	CORYELL	2A	MARTIN	3B	WICHITA	3A
KAUFMAN	3A	LYNN	3B	FALLS	2A	MIDLAND	3B	WILBARGER	3B
PARKER	3A	SCURRY	3B	FREESTONE	2A	REAGAN	3B	CULBERSON	3B
RAINS	3A	COLEMAN	3B	HILL	2A	REEVES	3B		
ROCKWALL	3A	EASTLAND	3A	LAMPASAS	3A	UPTON	3B		
VAN ZANDT	3A	ERATH	3A	LEON	2A	WARD	3B		

Table 3. Characteristics of the Base-Case Model

Characteristics	Information Source	Assumptions		Comments
		Travis (2009 IECC Climate Zone: 2A)	Dallas (2009 IECC Climate Zone: 3A)	
Building				
Building Type		Single family, detached house		
Gross Area	NAHB (2003)	2,325 sq. ft. (48.21 ft. x 48.21 ft.)		
Number of Floors	NAHB (2003)	1		
Floor to Floor Height (ft.)	NAHB (2003)	8		
Orientation		South facing		
Construction				
Construction	NAHB (2003)	Light-weight wood frame with 2x4 studs spaced at 16" on center		
Floor	NAHB (2003)	Slab-on-grade floor		
Roof Configuration	NAHB (2003)	Unconditioned, vented attic		
Roof Absorptance	2009 IECC, Table 405.5.2(1)	0.75		Solar reflectance SR= 0.25
Ceiling Insulation (hr-sq.ft.-°F/Btu)	2009 IECC, Table 402.1.3 (402.1.1)	R-27.84		
Wall Absorptance	2009 IECC, Table 405.5.2(1)	0.75		Assuming brick facia exterior
Wall Insulation (hr-sq.ft.-°F/Btu)	2009 IECC, Table 402.1.3 (402.1.1)	R-11.8		
Slab Perimeter Insulation	2009 IECC, Table 402.1.3 (402.1.1)	None		
Ground Reflectance	DOE2.1e User Manual (LBL 1993)	0.24		Assuming grass
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	2009 IECC, Table 402.1.3	0.65	0.5	
Solar Heat Gain Coefficient (SHGC)	2009 IECC, Table 402.1.1	0.3		
Window Area	2009 IECC, Table 405.5.2 (1)	15% of conditioned floor area		This amounts to 348.75 sq. ft. window area and 22.61% window-to-wall area ratio for the assumed base case building configuration.
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	2009 IECC, Table 405.5.2 (1)	72°F Heating, 75°F Cooling, no set-back		
Internal Heat Gains	2009 IECC, Table 405.5.2 (1)	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	2009 IECC, Table 405.5.2 (1)	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	2009 IECC, Table 503.2.3 (2), 503.2.3 (4)	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)[1)]		55,800		1.0 x cooling capacity
DHW System Type	Tank size from ASHRAE HVAC Systems and Equipment Handbook	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	2009 IECC, Table 504.2	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	NAHB (2003)	Unconditioned, vented attic		20-30%
Duct Leakage (%)	2009 IECC, Sec. 403.2.2	5.555% (supply) and 5.555% (return)		Total: 8 CFM/100 ft^2 to outdoor
Duct Insulation (hr-sq.ft.-°F/Btu)	2009 IECC, Sec. 403.2.2 & 405.1	R-6 (supply) and R-6 (return)		
HVAC Duct Static Pressure		1		
Supply Air Flow (CFM/ton)		360		
Infiltration Rate (SG)	2009 IECC, Table 405.5.2 (1), ASHRAE 119 Section 5.1	SLA= 0.00036		

[1)] For all base-case houses, the number of unmet heating hours (hours reported as underheated) was zero. Appendix A presents the unmet heating hours for each base-case house.

3 ENERGY EFFICIENCY MEASURES (EEMs)

3.1 Individual Energy Efficiency Measures

For the analysis, 17 individual Energy Efficiency Measures (EEMs) were considered. These included renewable energy systems, efficient HVAC & air distribution systems, fenestration measures, building envelope measures, and efficient domestic hot water (DHW) systems. These measures were simulated by modifying the selected parameters used with the Laboratory's IC3 Calculator. Table 4 shows the EEMs that were simulated for the single-family, base-case house with natural gas heating and heat pump heating.

Table 4. Individual EEMs for a House with Natural Gas Heating and Heat Pump Heating

	EEM #	Energy Efficiency Measure	
Base case	1	Base Case with Natural Gas	Base Case with Heat Pump
Renewable Power Options	2	6 kW PV Array	6 kW PV Array
	3	4 kW PV Array	4 kW PV Array
	4	2 kW PV Array	2 kW PV Array
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)
	6	Mechanical Systems Within Conditioned Spaces	Mechanical Systems Within Conditioned Spaces
	7	Improved SEER (from 13 to 15)	Improved SEER (from 13 to 15)
	8	Improved Furnace Efficiency (from .78 to .93 AFUE)	Improved Heat Pump Efficiency (from 7.70 to 8.50 HSPF)
Fenestration	9	Decreased SHGC (from .3 to .2)	Decreased SHGC (from .3 to .2)
	10	Decreased SHGC (from .3 to .2) & U Value (Travis: from .65 to .35 / Dallas: from .5 to .35)	Decreased SHGC (from .3 to .2) & U Value (Travis: from .65 to .35 / Dallas: from .5 to .35)
	11	Window Shading (2ft overhang on all sides)	Window Shading (2ft overhang on all sides)
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)
Envelope	13	Radiant Barrier in Attics	Radiant Barrier in Attics
Lighting Options	14	25% Energy Star CFL Indoor Lamps	25% Energy Star CFL Indoor Lamps
	15	50% Energy Star CFL Indoor Lamps	50% Energy Star CFL Indoor Lamps
DHW Measures	16	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	Not Available
	17	Removal of Pilot Light from DHW	Not Available
	18	Solar DHW System (80 gal tank)	Solar DHW System (80 gal tank)

3.2 Description of Individual Measures

3.2.1 Renewable Power Options

EEM No.2-4: 6 kW, 4 kW, and 2 kW PV Array

- **Base case**: There are no PV panels installed for the base case.
- **Test case**: The test-case house is assumed to be grid-connected with a 6 kW, 4 kW or 2 kW PV array of Kyocera multi-crystalline solar cells (16% efficiency). The analysis of long-term performance was conducted using a PV F-CHART for the typical weather conditions of Dallas and using TMY2 weather data for the given mounting conditions. In this analysis, the array tilt was assumed to be the same as the latitude of the location: 30 degrees for Travis County and 32 degrees for Dallas County. For 6 kW system 30 panels were used with a total PV array area making 480 sq.ft, for 4 kW system 20 panels were used with a total PV array area making 320 sq.ft and for 2 kW system 10 panels were used with a total PV array area making 160 sq.ft respectively.

3.2.2 HVAC Options

EEM No.5: Static Pressure

- **Base case**: The static duct pressure for the HVAC duct system is set at 1" WC.
- **Test case**: For the test case, the static pressure for the HVAC duct system is set at 0.5"WC measured as per NCI (National Comfort Institute) standard and certified by third party.

EEM No.6: Mechanical Systems Within Conditioned Space

- **Base case**: The base-case air distribution system includes the HVAC unit and the ducts located in the unconditioned, vented attic. The attic was assumed to have an air infiltration rate of 1.5 ACH. The insulation for supply and return ducts are R-6 and R-6, respectively. A 5.6% duct leakage was assumed for both the supply and return duct.
- **Test case**: This measure analyzed the energy savings that would occur if the HVAC system including the supply and return ductwork was moved from the attic location assumed in the base-case house to a location within the thermal envelope of the conditioned space.

EEM No.7: Improved SEER

- **Base case**: For the base case with natural gas heating, the HVAC system comprises a SEER 13 air-conditioner and a gas-fired furnace with an Annual Fuel Utilization Efficiency (AFUE) of 0.78. For the base case with heat pump heating, the HVAC system comprises a SEER 13 air-conditioner and a heat pump with a Heating Seasonal Performance Factor (HSPF) of 7.7. The capacity of the cooling system is 55,800 Btu/hr, which assumes 500 sq. ft. per ton. The capacity of the heating system is 55,800 Btu/hr, which assumes 1.0 times of the cooling capacity. The heating and cooling set-points were 72°F for winter and 75°F for summer, with no setback.
- **Test case**: For the test case, the SEER 13 air conditioner in the base-case house was replaced with a similarly sized SEER 15 air conditioner and a higher efficiency fan.

EEM No.8: Improved Furnace/Heat Pump Efficiency

- **Base case**: This base case is same as the previous base case of EEM No.7.
- **Test case**: For the test case, the gas-fired furnace in the base-case house with natural gas heating (0.78 AFUE) was replaced with a similarly sized condensing furnace with an AFUE of 0.93. For the house with heat pump heating, the HSPF 7.7 heat pump system was replaced with a similarly sized HSPF 8.5 heat pump.

3.2.3 Fenestration Options

EEM No.9: Decreased SHGC

- **Base case**: The base-case SHGC value is 0.3.
- **Test case**: For the test case, the SHGC is taken as 0.2.

EEM No.10: Decreased SHGC and U-Value

- **Base case**: The base-case U-Factor is taken as 0.65 Btu/h-sq. ft.-F for Travis County and 0.5 Btu/h-sq. ft.-F for Dallas County and SHGC as 0.3 for both counties.
- **Test case**: For the test case, the U-Factor is taken as 0.35 Btu/h-sq. ft.-F and SHGC as 0.2.

EEM No.11: Window Shading

- **Base case**: The base case is simulated without any window shading for the windows.
- **Test case**: This measure was simulated by modeling 2 ft. roof overhangs on all four sides. The gross window area, orientation, and other characteristics were kept the same as the base-case house, which did not have overhangs.

EEM No.12: Window Shading and Redistribution

- **Base case**: The window-to-floor area ratio for the base-case house is 15%, equally distributed on all four sides. This translates to 22.61% window-to-wall area ratio equally distributed on all four sides. The base-case house is simulated without any window shading.
- **Test case**: For this measure, the house was simulated with the windows distributed 40.70% on the south, 22.61 % on the north, 13.57 % each on east and west orientations. A 2 ft. roof overhang was also included on all four sides.

3.2.4 Envelope Option

EEM No.13: Radiant Barrier in Attics

- **Base case**: The base case is simulated with radiant barrier option set to "No."
- **Test case**: In test case, the radiant barrier option is set to "Yes," and the emissivity of radiant barrier is taken as 0.05.

3.2.5 Lighting Options

EEM No.14-15: 25% and 50% Energy Star CFL Indoor Lamps

- **Base case**: 100% incandescent fixtures are assumed for the base-case house. Table 405.5.2 (1) of the IECC 2009 describes the internal heat gain to be 1.095 kW. It is assumed that 0.547 kW are allocated to heat gains from lighting and 0.547 kW are allocated to heat gains from miscellaneous equipment.
- **Test case**: For the test case, Energy Star CFL lamps were assumed using 75% less energy than an incandescent lamp. The resulting internal heat gain from lights of which 25% are CFL lamps is 0.445 kW. From lights of which 50% are CFL lamps, the resulting internal heat gain is 0.342 kW.

3.2.6 DHW Measures

EEM No.16: Tankless Gas Water Heater

- **Base case**: A storage tank type domestic hot water (DHW) heater is simulated for the base-case house. For the house with the natural gas heating, the DHW energy factor is set at 0.594. Energy factor ratings incorporate the energy usage of the pilot light in the gas DHW heater.

- **Test case**: This measure is applicable only for a house with natural gas heating that has a gas DHW heater. For a house with natural gas heating, the resultant change in the DHW energy factor from 0.594 to 0.748[1].

EEM No.17: Removal of Pilot Light from DHW

- **Base case**: For a house with natural gas heating, the base-case DHW system is a 40-gallon, storage type with a standing pilot light that consumes 500 Btu/hr and a calculated energy factor of 0.594.
- **Test case**: This measure is applicable only for a house with natural gas heating that has a gas DHW heater. In order to simulate the impact of removing the pilot light, a higher EF of 0.66 was chosen.

EEM No.18: Solar DWH System (80 gal tank)

- **Base case**: For a house with natural gas heating, the base-case DHW system is a 40-gallon, storage type with a standing pilot light that consumes 500 Btu/hr and a calculated energy factor of 0.594. For a house with heat pump heating, the base-case DHW system is a 50-gallon, storage type electric water heater. The energy factor of the system is 0.904. The daily hot water use was calculated as 70 gallons/day, which assumes that the house has four bedrooms. The hot water supply temperature is 120°F. The method to simulate DHW in DOE-2.1e using the energy factor is based on Building America House Performance Analysis Procedures (NREL 2001) that assumes a constant hourly DHW use and eliminates the efficiency dependence on part-loads.
- **Test case**: For this measure, a solar thermal DHW system, comprised of two 32.8 sq. ft. of flat plate solar collectors was simulated using the F-Chart program (Klein and Beckman 1983). In this analysis, the collector tilt was assumed to be 45 degrees for Travis County and 47 degrees for Dallas County, i.e. latitude plus 15 degrees which is expected to provide maximum output for the peaking winter domestic water heating loads. Any supplementary hot water heating was provided by the base-case water heating system. Also, additional electricity use was taken into account for operating the pump.

[1] The EF for the tankless water heater is based on a survey of manufacturers and recommendations of the 2008 California Building Energy Efficiency Standards.

3.3 Simulation Input Parameters for Individual Measures

Table 5 and Table 6 list the input parameters used for the base case and individual Energy Efficient Measures (EEMs) for Travis County (Climate Zone: 2A) and Dallas County (Climate Zone: 3A), respectively. Two different options were considered for the analysis: (a) a base-case residence with natural gas heating and (b) a base-case residence with heat pump heating. The two rows in which a whole row of cells are shaded present the parameters used in the base-case runs. The remaining rows show the parameters used in the simulation of the individual energy efficiency measures. The shaded cell in each row indicates the change in the value of the parameter used to simulate the measure.

Table 5. Simulation Input Parameters for Individual EEMs (Travis County, Climate Zone 2A)

	EEM #	Energy Efficiency Measure	Supply Fan Static Pressure	Supply Duct Leakage (%)	Return Duct Leakage (%)	R-Value supply	R-Value return	Ducts in Conditioned Space	Improved SEER	Improved AFUE	Improved HSPF	SHGC	U-Value	Shading				WWR% forSide Wall				Radiant Barrier	Lighting (kW)	Energy Factor
														Front	Right	Back	Left	Front	Back	Right	Left			
	1	Base case Natural Gas (2A)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
Renewable Power Options	2	6 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	3	4 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	4	2 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	**0.5**	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	6	Mechanical Systems Within Conditioned Spaces	1.0	**0.00%**	**0.00%**	**1000**	**1000**	**ROOM**	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	7	Improved SEER (from 13 to 15)	1.0	5.56%	5.56%	6	6	ATTIC	**15**	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	8	Improved Furnace Efficiency (from .78 to .93 AFUE)	1.0	5.56%	5.56%	6	6	ATTIC	13	**0.93**	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
Fenestration	9	Decreased SHGC (from .3 to .2)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	**0.2**	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	10	Decreased SHGC (from .3 to .2) & U Value (from .65 to .35)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	**0.2**	**0.35**	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	11	Window Shading (2ft overhang on all sides)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	**2**	**2**	**2**	**2**	22.61	22.61	22.61	22.61	N	0.547	0.594
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	**2**	**2**	**2**	**2**	**40.70**	**22.61**	**13.57**	**13.57**	N	0.547	0.594
Envelope	13	Radiant Barrier in Attics	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	**Y**	0.547	0.594
Lighting Options	14	25% Energy Star CFL Indoor Lamps	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	**0.445**	0.594
	15	50% Energy Star CFL Indoor Lamps	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	**0.342**	0.594
DHW Measures	16	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	**0.748**
	17	Removal of Pilot Light from DHW	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	**0.660**
	18	Solar DHW System (80 gal tank)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	1	Base case Heat Pump (2A)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
Renewable Power Options	2	6 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	3	4 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	4	2 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	**0.5**	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	6	Mechanical Systems Within Conditioned Spaces	1.0	**0.00%**	**0.00%**	**1000**	**1000**	**ROOM**	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	7	Improved SEER (from 13 to 15)	1.0	5.56%	5.56%	6	6	ATTIC	**15**	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	8	Improved Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	**8.50**	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
Fenestration	9	Decreased SHGC (from .3 to .2)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	**0.2**	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	10	Decreased SHGC (from .3 to .2) & U Value (from .65 to .35)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	**0.2**	**0.35**	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	11	Window Shading (2ft overhang on all sides)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	**2**	**2**	**2**	**2**	22.61	22.61	22.61	22.61	N	0.547	0.904
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	**2**	**2**	**2**	**2**	**40.70**	**22.61**	**13.57**	**13.57**	N	0.547	0.904
Envelope	13	Radiant Barrier in Attics	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	**Y**	0.547	0.904
Lighting Options	14	25% Energy Star CFL Indoor Lamps	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	**0.445**	0.904
	15	50% Energy Star CFL Indoor Lamps	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	**0.342**	0.904
DHW Measures	18	Solar DHW System (80 gal tank)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.65	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904

Table 6. Simulation Input Parameters for Individual EEMs (Dallas County, Climate Zone 3A)

	EEM #	Energy Efficiency Measure	Supply Fan Static Pressure	Supply Duct Leakage (%)	Return Duct Leakage (%)	R-Value supply	R-Value return	Ducts in Conditioned Space	Improved SEER	Improved AFUE	Improved HSPF	SHGC	U-Value	Shading				WWR% forSide Wall				Radiant Barrier	Lighting (kW)	Energy Factor
														Front	Right	Back	Left	Front	Back	Right	Left			
	1	Base case Natural Gas (3A)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
Renewable Power Options	2	6 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	3	4 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	4	2 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	**0.5**	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	6	Mechanical Systems Within Conditioned Spaces	1.0	**0.00%**	**0.00%**	**1000**	**1000**	**ROOM**	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	7	Improved SEER (from 13 to 15)	1.0	5.56%	5.56%	6	6	ATTIC	**15**	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	8	Improved Furnace Efficiency (from .78 to .93 AFUE)	1.0	5.56%	5.56%	6	6	ATTIC	13	**0.93**	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
Fenestration	9	Decreased SHGC (from .3 to .2)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	**0.2**	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	10	Decreased SHGC (from .3 to .2) & U Value (from .5 to .35)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	**0.2**	**0.35**	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	11	Window Shading (2ft overhang on all sides)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	**2**	**2**	**2**	**2**	22.61	22.61	22.61	22.61	N	0.547	0.594
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	**2**	**2**	**2**	**2**	**40.70**	**22.61**	**13.57**	**13.57**	N	0.547	0.594
Envelope	13	Radiant Barrier in Attics	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	**Y**	0.547	0.594
Lighting Options	14	25% Energy Star CFL Indoor Lamps	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	**0.445**	0.594
	15	50% Energy Star CFL Indoor Lamps	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	**0.342**	0.594
DHW Measures	16	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	**0.748**
	17	Removal of Pilot Light from DHW	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	**0.660**
	18	Solar DHW System (80 gal tank)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.594
	1	Base case Heat Pump (3A)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
Renewable Power Options	2	6 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	3	4 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	4	2 kW PV Array	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	**0.5**	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	6	Mechanical Systems Within Conditioned Spaces	1.0	**0.00%**	**0.00%**	**1000**	**1000**	**ROOM**	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	7	Improved SEER (from 13 to 15)	1.0	5.56%	5.56%	6	6	ATTIC	**15**	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	8	Improved Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	**8.50**	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
Fenestration	9	Decreased SHGC (from .3 to .2)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	**0.2**	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	10	Decreased SHGC (from .3 to .2) & U Value (from .5 to .35)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	**0.2**	**0.35**	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904
	11	Window Shading (2ft overhang on all sides)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	**2**	**2**	**2**	**2**	22.61	22.61	22.61	22.61	N	0.547	0.904
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	**2**	**2**	**2**	**2**	**40.70**	**22.61**	**13.57**	**13.57**	N	0.547	0.904
Envelope	13	Radiant Barrier in Attics	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	**Y**	0.547	0.904
Lighting Options	14	25% Energy Star CFL Indoor Lamps	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	**0.445**	0.904
	15	50% Energy Star CFL Indoor Lamps	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	**0.342**	0.904
DHW Measures	18	Solar DHW System (80 gal tank)	1.0	5.56%	5.56%	6	6	ATTIC	13	0.78	7.70	0.3	0.5	0	0	0	0	22.61	22.61	22.61	22.61	N	0.547	0.904

4 SIMULATION RESULTS FOR INDIVIDUAL MEASURES

Table 7 and Table 8 show the impact of individual EEMs on site and source energy consumption for different end-uses and fuel types and total for Travis County (Climate Zone: 2A) and Dallas County (Climate Zone: 3A), respectively. The annual site energy use presented in this table is obtained from the BEPS report of the DOE-2 output file for each option, natural gas heating and heat pump heating. The table also includes the calculated source energy savings (%) of the EEMs when compared to the base-case energy consumption for each fuel type which is presented in the last three columns.

Table 7. Simulation Results for Individual EEMs (Travis County, Climate Zone 2A)

	EEM #	Energy Efficiency Measure	Cooling Load (MMBtu)	Heating Load (MMBtu)	Others (MMBtu)	Fans &Pumps (MMBtu)	DHW (MMBtu)	Total Site Energy Consumed			Total Source Energy Consumed			Savings Above Base case (Source %)		
								Elec. (kWh)	Gas (MMBtu)	Total (MMBtu)	Elec. (kWh)	Gas (MMBtu)	Total (MMBtu)	Elec.	Gas	Total
	1	Base case Natural Gas (2A)	18.7	26.2	32.8	11.3	18.9	18405.6	45.1	107.9	58161.8	49.6	248.1	0.0%	0.0%	0.0%
Renewable Power Options	2	6 kW PV Array	18.7	26.2	32.8	11.3	18.9	9157.6	45.1	76.3	28938.1	49.6	148.3	50.2%	0.0%	40.2%
	3	4 kW PV Array	18.7	26.2	32.8	11.3	18.9	12240.6	45.1	86.9	38680.4	49.6	181.6	33.5%	0.0%	26.8%
	4	2 kW PV Array	18.7	26.2	32.8	11.3	18.9	15322.6	45.1	97.4	48419.5	49.6	214.8	16.8%	0.0%	13.4%
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	17.6	27.4	32.8	5.8	18.9	16471.3	46.3	102.5	52049.2	50.9	228.5	10.5%	-2.7%	7.9%
	6	Mechanical Systems Within Conditioned Spaces	15.5	20.8	32.8	9.1	18.9	16823.0	39.7	97.1	53160.6	43.7	225.1	8.6%	12.0%	9.3%
	7	Improved SEER (from 13 to 15)	15.7	26.8	32.8	8.5	18.9	16705.7	45.7	102.7	52790.2	50.3	230.4	9.2%	-1.3%	7.1%
	8	Improved Furnace Efficiency (from .78 to .93 AFUE)	18.7	22.0	32.8	11.3	18.9	18405.6	40.9	103.7	58161.8	45.0	243.4	0.0%	9.3%	1.9%
Fenestration	9	Decreased SHGC (from .3 to .2)	16.9	28.3	32.8	10.5	18.9	17643.6	47.2	107.4	55753.8	51.9	242.2	4.1%	-4.7%	2.4%
	10	Decreased SHGC (from .3 to .2) & U Value (from .65 to .35)	15.3	24.1	32.8	9.2	18.9	16793.7	43.0	100.3	53068.0	47.3	228.4	8.8%	4.7%	7.9%
	11	Window Shading (2ft overhang on all sides)	17.3	27.1	32.8	10.5	18.9	17760.8	46.0	106.6	56124.3	50.6	242.1	3.5%	-2.0%	2.4%
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	17.1	26.3	32.8	10.4	18.9	17672.9	45.2	105.5	55846.4	49.7	240.3	4.0%	-0.2%	3.1%
Envelope	13	Radiant Barrier in Attics	17.7	25.6	32.8	10.7	18.9	17936.7	44.5	105.7	56680.0	49.0	242.3	2.5%	1.3%	2.3%
Lighting Options	14	25% Energy Star CFL Indoor Lamps	18.0	27.4	29.7	11.0	18.9	17204.0	46.3	105.0	54364.6	50.9	236.4	6.5%	-2.7%	4.7%
	15	50% Energy Star CFL Indoor Lamps	17.4	28.7	26.6	10.8	18.9	16061.0	47.6	102.4	50752.6	52.4	225.5	12.7%	-5.5%	9.1%
DHW Measures	16	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	18.7	26.2	32.8	11.3	14.8	18405.6	41.0	103.8	58161.8	45.1	243.5	0.0%	9.1%	1.8%
	17	Removal of Pilot Light from DHW	18.7	26.2	32.8	11.3	16.9	18405.6	43.1	105.9	58161.8	47.4	245.9	0.0%	4.4%	0.9%
	18	Solar DHW System (80 gal tank)	18.7	26.2	32.8	12.7	2.6	18814.1	28.8	93.0	59452.4	31.7	234.6	-2.2%	36.1%	5.4%
	1	Base case Heat Pump (2A)	18.7	7.7	32.8	11.1	12.3	24208.7	–	82.6	76499.4	–	261.0	0.0%	–	0.0%
Renewable Power Options	2	6 kW PV Array	18.7	7.7	32.8	11.1	12.3	14960.7	–	51.0	47275.7	–	161.3	38.2%	–	38.2%
	3	4 kW PV Array	18.7	7.7	32.8	11.1	12.3	18043.7	–	61.6	57018.0	–	194.5	25.5%	–	25.5%
	4	2 kW PV Array	18.7	7.7	32.8	11.1	12.3	21125.7	–	72.1	66757.1	–	227.8	12.7%	–	12.7%
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	17.6	8.0	32.8	5.7	12.3	22391.6	–	76.4	70757.3	–	241.4	7.5%	–	7.5%
	6	Mechanical Systems Within Conditioned Spaces	15.5	6.4	32.8	9.3	12.3	22362.3	–	76.3	70664.7	–	241.1	7.6%	–	7.6%
	7	Improved SEER (from 13 to 15)	15.7	7.9	32.8	8.4	12.3	22596.7	–	77.1	71405.6	–	243.6	6.7%	–	6.7%
	8	Improved Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	18.7	7.1	32.8	11.1	12.3	24032.8	–	82.0	75943.7	–	259.1	0.7%	–	0.7%
Fenestration	9	Decreased SHGC (from .3 to .2)	16.9	8.2	32.8	10.3	12.3	23593.2	–	80.5	74554.5	–	254.4	2.5%	–	2.5%
	10	Decreased SHGC (from .3 to .2) & U Value (from .65 to .35)	15.3	7.2	32.8	9.1	12.3	22479.5	–	76.7	71035.2	–	242.4	7.1%	–	7.1%
	11	Window Shading (2ft overhang on all sides)	17.3	7.9	32.8	10.4	12.3	23651.8	–	80.7	74739.7	–	255.0	2.3%	–	2.3%
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	17.1	7.7	32.8	10.3	12.3	23505.3	–	80.2	74276.7	–	253.4	2.9%	–	2.9%
Envelope	13	Radiant Barrier in Attics	17.7	7.6	32.8	10.5	12.3	23710.4	–	80.9	74925.0	–	255.6	2.1%	–	2.1%
Lighting Options	14	25% Energy Star CFL Indoor Lamps	18.0	8.0	29.7	10.9	12.3	23124.3	–	78.9	73072.7	–	249.3	4.5%	–	4.5%
	15	50% Energy Star CFL Indoor Lamps	17.4	8.3	26.6	10.6	12.3	22039.9	–	75.2	69646.0	–	237.6	9.0%	–	9.0%
DHW Measures	18	Solar DHW System (80 gal tank)	18.7	7.7	32.8	12.5	2.4	21712.5	–	74.1	68611.4	–	234.1	10.3%	–	10.3%

Table 8. Simulation Results for Individual EEMs (Dallas County, Climate Zone 3A)

	EEM #	Energy Efficiency Measure	Cooling Load (MMBtu)	Heating Load (MMBtu)	Others (MMBtu)	Fans &Pumps (MMBtu)	DHW (MMBtu)	Total Site Energy Consumed			Total Source Energy Consumed			Savings Above Base case (Source %)		
								Elec. (kWh)	Gas (MMBtu)	Total (MMBtu)	Elec. (kWh)	Gas (MMBtu)	Total (MMBtu)	Elec.	Gas	Total
	1	Base case Natural Gas (3A)	15.7	33.0	32.8	10.4	19.6	17262.6	52.6	111.5	54549.8	57.9	244.0	0.0%	0.0%	0.0%
Renewable Power Options	2	6 kW PV Array	15.7	33.0	32.8	10.4	19.6	7816.6	52.6	79.3	24700.5	57.9	142.1	54.7%	0.0%	41.7%
	3	4 kW PV Array	15.7	33.0	32.8	10.4	19.6	10965.6	52.6	90.0	34651.3	57.9	176.1	36.5%	0.0%	27.8%
	4	2 kW PV Array	15.7	33.0	32.8	10.4	19.6	14113.6	52.6	100.8	44599.0	57.9	210.0	18.2%	0.0%	13.9%
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	14.8	34.5	32.8	5.4	19.6	15533.4	54.1	107.1	49085.6	59.5	227.0	10.0%	-2.9%	7.0%
	6	Mechanical Systems Within Conditioned Spaces	13.0	26.3	32.8	8.4	19.6	15885.1	45.9	100.1	50197.0	50.5	221.8	8.0%	12.7%	9.1%
	7	Improved SEER (from 13 to 15)	13.2	33.7	32.8	8.0	19.6	15826.5	53.3	107.3	50011.7	58.6	229.3	8.3%	-1.3%	6.0%
	8	Improved Furnace Efficiency (from .78 to .93 AFUE)	15.7	27.7	32.8	10.4	19.6	17262.6	47.3	106.2	54549.8	52.0	238.2	0.0%	10.1%	2.4%
Fenestration	9	Decreased SHGC (from .3 to .2)	14.2	35.9	32.8	9.8	19.6	16647.1	55.5	112.3	52604.9	61.1	240.5	3.6%	-5.5%	1.4%
	10	Decreased SHGC (from .3 to .2) & U Value (from .5 to .35)	12.6	35.7	32.8	8.9	19.6	15914.4	55.3	109.6	50289.6	60.8	232.4	7.8%	-5.1%	4.7%
	11	Window Shading (2ft overhang on all sides)	14.3	34.3	32.8	9.8	19.6	16676.4	53.9	110.8	52697.5	59.3	239.1	3.4%	-2.5%	2.0%
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	14.2	33.2	32.8	9.6	19.6	16588.5	52.8	109.4	52419.7	58.1	236.9	3.9%	-0.4%	2.9%
Envelope	13	Radiant Barrier in Attics	14.8	32.3	32.8	9.9	19.6	16852.3	51.9	109.4	53253.2	57.1	238.8	2.4%	1.3%	2.1%
Lighting Options	14	25% Energy Star CFL Indoor Lamps	15.1	34.6	29.7	10.3	19.6	16148.9	54.2	109.3	51030.5	59.6	233.7	6.5%	-3.0%	4.2%
	15	50% Energy Star CFL Indoor Lamps	14.6	36.2	26.6	10.1	19.6	15035.2	55.8	107.1	47511.1	61.4	223.5	12.9%	-6.1%	8.4%
DHW Measures	16	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	15.7	33.0	32.8	10.4	15.6	17262.6	48.6	107.5	54549.8	53.5	239.6	0.0%	7.6%	1.8%
	17	Removal of Pilot Light from DHW	15.7	33.0	32.8	10.4	17.7	17262.6	50.7	109.6	54549.8	55.8	241.9	0.0%	3.6%	0.9%
	18	Solar DHW System (80 gal tank)	15.7	33.0	32.8	11.8	3.1	17671.0	36.1	96.4	55840.5	39.8	230.3	-2.4%	31.3%	5.6%
	1	Base case Heat Pump (3A)	15.7	9.7	32.8	10.2	12.9	23827.7	–	81.3	75295.4	–	256.9	0.0%	–	0.0%
Renewable Power Options	2	6 kW PV Array	15.7	9.7	32.8	10.2	12.9	14381.7	–	49.1	45446.1	–	155.1	39.6%	–	39.6%
	3	4 kW PV Array	15.7	9.7	32.8	10.2	12.9	17530.7	–	59.8	55396.9	–	189.0	26.4%	–	26.4%
	4	2 kW PV Array	15.7	9.7	32.8	10.2	12.9	20678.7	–	70.6	65344.6	–	223.0	13.2%	–	13.2%
HVAC Options	5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	14.8	10.0	32.8	5.2	12.9	22186.4	–	75.7	70109.0	–	239.2	6.9%	–	6.9%
	6	Mechanical Systems Within Conditioned Spaces	13.0	8.0	32.8	8.8	12.9	22127.8	–	75.5	69923.8	–	238.6	7.1%	–	7.1%
	7	Improved SEER (from 13 to 15)	13.2	9.8	32.8	7.7	12.9	22391.6	–	76.4	70757.3	–	241.4	6.0%	–	6.0%
	8	Improved Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	15.7	8.9	32.8	10.2	12.9	23593.2	–	80.5	74554.5	–	254.4	1.0%	–	1.0%
Fenestration	9	Decreased SHGC (from .3 to .2)	14.2	10.3	32.8	9.5	12.9	23358.7	–	79.7	73813.6	–	251.9	2.0%	–	2.0%
	10	Decreased SHGC (from .3 to .2) & U Value (from .5 to .35)	12.6	10.2	32.8	8.6	12.9	22596.7	–	77.1	71405.6	–	243.6	5.2%	–	5.2%
	11	Window Shading (2ft overhang on all sides)	14.3	9.9	32.8	9.5	12.9	23270.8	–	79.4	73535.8	–	250.9	2.3%	–	2.3%
	12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	14.2	9.7	32.8	9.3	12.9	23124.3	–	78.9	73072.7	–	249.3	3.0%	–	3.0%
Envelope	13	Radiant Barrier in Attics	14.8	9.5	32.8	9.6	12.9	23329.4	–	79.6	73721.0	–	251.5	2.1%	–	2.1%
Lighting Options	14	25% Energy Star CFL Indoor Lamps	15.1	10.0	29.7	10.0	12.9	22772.6	–	77.7	71961.3	–	245.5	4.4%	–	4.4%
	15	50% Energy Star CFL Indoor Lamps	14.6	10.4	26.6	9.8	12.9	21776.1	–	74.3	68812.4	–	234.8	8.6%	–	8.6%
DHW Measures	18	Solar DHW System (80 gal tank)	15.7	9.7	32.8	11.6	2.7	21252.9	–	72.5	67159.1	–	229.1	10.8%	–	10.8%

5 GROUPED MEASURES

Grouped measures are the combination of individual measures. To accomplish this, individual measures were grouped into four different categories: 0-5%, 5-10%, 10-15% and above 15% savings above the base-case house. Groups with savings below 2% above the base-case house were not used in the group measure combinations. Table 9 shows the categorizing of the individual EEMs for each option, natural gas heating and heat pump heating. The amounts of savings achieved by each EEM were similar between Travis County (Climate Zone: 2A) and Dallas County (Climate Zone: 3A). After categorizing, three groups were formed combining the individual measures so that the combined source energy savings of the group is 15% above the base-case, 2009 code-compliant house. Table 10 presents the list of the grouped measures. For Group 3, the EEM #14, 25% Energy Star CFL Indoor Lamps, was applied only to Dallas County because for Travis County, 15% above savings was achieved without the EEM #14.

Table 9. Grouping of Results for a House with Natural Gas Heating and Heat Pump Heating

	2009 IECC Cimate Zone: 2A (Travis)				2009 IECC Cimate Zone: 3A (Dallas)			
	Range	EEM #	Individual Measures	Savings Above Base case (Source %)	Range	EEM #	Individual Measures	Savings Above Base case (Source %)
NATURAL GAS	Above 15%	2	6 kW PV Array	40.2%	Above 15%	2	6 kW PV Array	41.7%
		3	4 kW PV Array	26.8%		3	4 kW PV Array	27.8%
	10-15%	4	2 kW PV Array	13.4%	10-15%	4	2 kW PV Array	13.9%
	5-10%	6	Mechanical Systems Within Conditioned Spaces	9.3%	5-10%	6	Mechanical Systems Within Conditioned Spaces	9.1%
		15	50% Energy Star CFL Indoor Lamps	9.1%		15	50% Energy Star CFL Indoor Lamps	8.4%
		10	Decreased SHGC (from .3 to .2) & U Value (from .65 to .35)	7.9%		5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	7.0%
		5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	7.9%		7	Improved SEER (from 13 to 15)	6.0%
		7	Improved SEER (from 13 to 15)	7.1%		18	Solar DHW System (80 gal tank)	5.6%
		18	Solar DHW System (80 gal tank)	5.4%	0-5%	10	Decreased SHGC (from .3 to .2) & U Value (from .5 to .35)	4.7%
	0-5%	14	25% Energy Star CFL Indoor Lamps	4.7%		14	25% Energy Star CFL Indoor Lamps	4.2%
		12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	3.1%		12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	2.9%
		11	Window Shading (2ft overhang on all sides)	2.4%		8	Improved Furnace Efficiency (from .78 to .93 AFUE)	2.4%
		9	Decreased SHGC (from .3 to .2)	2.4%		13	Radiant Barrier in Attics	2.1%
		13	Radiant Barrier in Attics	2.3%		11	Window Shading (2ft overhang on all sides)	2.0%
		8	Improved Furnace Efficiency (from .78 to .93 AFUE)	1.9%		16	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	1.8%
		16	Tankless Gas Water Heater (from .594 to .748 Energy Factor)	1.8%		9	Decreased SHGC (from .3 to .2)	1.4%
		17	Removal of Pilot Light from DHW	0.9%		17	Removal of Pilot Light from DHW	0.9%
HEAT PUMP	Above 15%	2	6 kW PV Array	38.2%	Above 15%	2	6 kW PV Array	39.6%
		3	4 kW PV Array	25.5%		3	4 kW PV Array	26.4%
	10-15%	4	2 kW PV Array	12.7%	10-15%	4	2 kW PV Array	13.2%
		18	Solar DHW System (80 gal tank)	10.3%		18	Solar DHW System (80 gal tank)	10.8%
	5-10%	15	50% Energy Star CFL Indoor Lamps	9.0%	5-10%	15	50% Energy Star CFL Indoor Lamps	8.6%
		6	Mechanical Systems Within Conditioned Spaces	7.6%		6	Mechanical Systems Within Conditioned Spaces	7.1%
		5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	7.5%		5	Decreased Duct Static Pressure (from 1.0 inch to .5 inch)	6.9%
		10	Decreased SHGC (from .3 to .2) & U Value (from .65 to .35)	7.1%		7	Improved SEER (from 13 to 15)	6.0%
		7	Improved SEER (from 13 to 15)	6.7%		10	Decreased SHGC (from .3 to .2) & U Value (from .5 to .35)	5.2%
	0-5%	14	25% Energy Star CFL Indoor Lamps	4.5%	0-5%	14	25% Energy Star CFL Indoor Lamps	4.4%
		12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	2.9%		12	Window Shading and Redistribution (2ft overhang on all sides, S=40.70%, N=22.61%, E/W = 13.57%)	3.0%
		9	Decreased SHGC (from .3 to .2)	2.5%		11	Window Shading (2ft overhang on all sides)	2.3%
		11	Window Shading (2ft overhang on all sides)	2.3%		9	Decreased SHGC (from .3 to .2)	2.0%
		13	Radiant Barrier in Attics	2.1%		13	Radiant Barrier in Attics	2.1%
		8	Improved Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	0.7%		8	Improved Heat Pump Efficiency (from 7.70 to 8.50 HSPF)	1.0%

Table 10. Grouped Measures for a House with Natural Gas Heating and Heat Pump Heating

Groups 15% Above 2009 IECC Code	Base Case with Natural Gas		Base Case with Heat Pump	
	EEM #	Measures	EEM #	Measures
Group 1	**3**	4 kW PV Array	**3**	4 kW PV Array
Group 2	**6**	Mechanical Systems Within Conditioned Spaces	**18**	Solar DHW System (80 gal tank)
	15	50% Energy Star CFL Indoor Lamps	**15**	50% Energy Star CFL Indoor Lamps
Group 3	**7**	Improved SEER (from 13 to 15)	**6**	Mechanical Systems Within Conditioned Spaces
	10	Decreased SHGC (from .3 to .2) & U Value (Travis: from .65 to .35 / Dallas: from .5 to .35)	**10**	Decreased SHGC (from .3 to .2) & U Value (Travis: from .65 to .35 / Dallas: from .5 to .35)
	13	Radiant Barrier in Attics	**7**	Improved SEER (from 13 to 15)
	14	25% Energy Star CFL Indoor Lamps[1)]		

1) Only applied to Dallas County

6 SIMULATION RESULTS FOR GROUPED MEASURES

Table 11 and Table 12 show the impact of grouped EEMs on site and source energy consumption for different end-uses and fuel types and total for Travis County (Climate Zone: 2A) and Dallas County (Climate Zone: 3A), respectively. 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 and re-running the IC3 Calculator. The annual site energy use presented in this table is obtained from the BEPS report of the DOE-2 output file for each option, both natural gas heating and heat pump heating. The table also includes the calculated source energy savings (%) of each group when compared to the base-case energy consumption for each fuel type which is presented in the last three columns.

Table 11. Simulation Results for Grouped Measures (Travis County, Climate Zone 2A)

Group #	Energy Efficiency Measure	Cooling Load (MMBtu)	Heating Load (MMBtu)	Others (MMBtu)	Fans &Pumps (MMBtu)	DHW (MMBtu)	Total Site Energy Consumed			Total Source Energy Consumed			Savings Above Base case (Source %)		
							Elec. (kWh)	Gas (MMBtu)	Total (MMBtu)	Elec. (kWh)	Gas (MMBtu)	Total (MMBtu)	Elec.	Gas	Total
	Base case Natural Gas (2A)	18.7	26.2	32.8	11.3	18.9	18405.6	45.1	107.9	58161.8	49.6	248.1	0.0%	0.0%	0.0%
1	Group 1 -4 kW PV Array	18.7	26.2	32.8	11.3	18.9	12240.6	45.1	86.9	38680.4	49.6	181.6	33.5%	0.0%	26.8%
2	Group 2 - Mechanical Systems Within Conditioned Spaces - 50% Energy Star CFL Indoor Lamps	14.4	22.8	26.6	8.6	18.9	14536.9	41.7	91.3	45936.7	45.9	202.6	21.0%	7.5%	18.3%
3	Group 3 - Improved SEER (from 13 to 15) - Decreased SHGC (from .3 to .2) & U Value (from .65 to .35) - Radiant Barrier in Attics	12.1	24.1	32.8	6.6	18.9	15093.8	43.0	94.5	47696.4	47.3	210.0	18.0%	4.7%	15.3%
	Base case Heat Pump (2A)	18.7	7.7	32.8	11.1	12.3	24208.7	–	82.6	76499.4	–	261.0	0.0%	–	0.0%
1	Group 1 -4 kW PV Array	18.7	7.7	32.8	11.1	12.3	18043.7	_	61.6	57018.0	_	194.5	25.5%	_	25.5%
2	Group 2 - Solar DHW System (80 gal tank) - 50% Energy Star CFL Indoor Lamps	17.4	8.3	26.6	12.0	2.4	19543.7	_	66.7	61758.0	_	210.7	19.3%	_	19.3%
3	Group 3 - Mechanical Systems Within Conditioned Spaces - Improved SEER (from 13 to 15) - Decreased SHGC (from .3 to .2) & U Value (from .65 to .35)	10.7	6.2	32.8	5.8	12.3	19871.0	_	67.8	62792.5	_	214.2	17.9%	_	17.9%

Table 12. Simulation Results for Grouped Measures (Dallas County, Climate Zone 3A)

Group #	Energy Efficiency Measure	Cooling Load (MMBtu)	Heating Load (MMBtu)	Others (MMBtu)	Fans &Pumps (MMBtu)	DHW (MMBtu)	Total Site Energy Consumed			Total Source Energy Consumed			Savings Above Base case (Source %)		
							Elec. (kWh)	Gas (MMBtu)	Total (MMBtu)	Elec. (kWh)	Gas (MMBtu)	Total (MMBtu)	Elec.	Gas	Total
	Base case Natural Gas (3A)	15.7	33.0	32.8	10.4	19.6	17262.6	52.6	111.5	54549.8	57.9	244.0	0.0%	0.0%	0.0%
1	Group 1 -4 kW PV Array	15.7	33.0	32.8	10.4	19.6	10965.6	52.6	90.0	34651.3	57.9	176.1	36.5%	0.0%	27.8%
2	Group 2 - Mechanical Systems Within Conditioned Spaces - 50% Energy Star CFL Indoor Lamps	12.0	28.9	26.6	8.1	19.6	13687.0	48.5	95.2	43250.9	53.4	200.9	20.7%	7.8%	17.6%
3	Group 3 - Improved SEER (from 13 to 15) - Decreased SHGC (from .3 to .2) & U Value (from .5 to .35) - 25% Energy Star CFL Indoor Lamps - Radiant Barrier in Attics	9.5	37.8	29.7	6.4	19.6	13364.6	57.4	103.0	42232.1	63.1	207.2	22.6%	-9.1%	15.1%
	Base case Heat Pump (3A)	15.7	9.7	32.8	10.2	12.9	23827.7	–	81.3	75295.4	–	256.9	0.0%	–	0.0%
1	Group 1 -4 kW PV Array	15.7	9.7	32.8	10.2	12.9	17530.7	_	59.8	55396.9	_	189.0	26.4%	_	26.4%
2	Group 2 - Solar DHW System (80 gal tank) - 50% Energy Star CFL Indoor Lamps	14.6	10.4	26.6	11.2	2.7	19201.3	_	65.5	60676.1	_	207.0	19.4%	_	19.4%
3	Group 3 - Mechanical Systems Within Conditioned Spaces - Improved SEER (from 13 to 15) - Decreased SHGC (from .3 to .2) & U Value (from .5 to .35)	8.8	8.6	32.8	5.8	12.9	20193.4	_	68.9	63811.3	_	217.7	15.3%	_	15.3%

7 SUMMARY

This report presents an analysis of residential energy efficiency measures that would exceed the 2009 IECC code in the ONCOR service territory. The analysis was performed using an ESL simulation model based on the DOE-2.1e simulation of a 2009 IECC code-compliant, single family residence. Two sets of simulations based on the choice of heating fuel type were considered: (a) an air-conditioned house with natural-gas heating and (b) an air-conditioned house with electric heating. The different counties in the ONCOR territory were grouped according to 2009 IECC Climate Zone; and finally, two zones ─ Climate Zone 2 and 3 ─ were identified and analyzed. To conduct the simulation using version 3.03.02 of the Laboratory's International Code Compliance Calculator (IC3), the appropriateTMY2 weather files were selected for each Climate Zone: Austin TMY2 data for Travis County and Dallas/Fort Worth TMY2 data for Dallas County.

A total of 17 measures based on the energy savings above the base-case house were selected, including Renewable Power Options, Heating Ventilation and Air Conditioning (HVAC), Fenestration, Envelope, Lighting and Domestic Hot Water (DHW) options. Individual measures were then categorized into four groups: 0 to 5%, 5 to 10%, and 10 to 15% and above 15% source energy savings above the base-case house. After categorizing, three example groups were formed combining the individual measures so that the combined source energy savings of the group is 15% above the base-case 2009 code-compliant house. These example groups represent one way of grouping to achieve 15% above the code, and the savings achieved by each group ranged from 15 to 28%.

APPENDIX A. UNMET HEATING HOURS

Appendix A presents the number of unmet heating hours (hours reported as under heated) for each base-case houses. For all base-case houses, the number of unmet heating hours was zero, which means the HVAC system is adequately sized to meet the heating load.

Table A.1 Unmet Hours for a Base-Case House with Natural Gas Heating (Travis, Climate Zone 2A)

	- - - -D E M A N D S- - - - -		- -B A S E B O A R D S- - -		- -T E M P E R A T U R E S- -		- -L O A D S N O T M E T- -	
MONTH	HEAT EXTRACTION ENERGY (MBTU)	HEAT ADDITION ENERGY (MBTU)	BASEBOARD ENERGY (MBTU)	MAXIMUM BASEBOARD LOAD (KBTU/HR)	MAXIMUM ZONE TEMP (F)	MINIMUM ZONE TEMP (F)	HOURS UNDER HEATED	HOURS UNDER COOLED
JAN	0.22235	-4.398	0.00000	0.000	74.9	72.1	0	0
FEB	0.66518	-4.058	0.00000	0.000	74.9	72.1	0	0
MAR	1.21077	-2.486	0.00000	0.000	75.0	72.0	0	0
APR	2.27480	-0.321	0.00000	0.000	75.0	72.2	0	0
MAY	3.84008	-0.010	0.00000	0.000	75.0	72.2	0	0
JUN	6.30299	0.000	0.00000	0.000	75.0	72.6	0	0
JUL	8.21261	0.000	0.00000	0.000	75.0	74.8	0	0
AUG	8.45093	0.000	0.00000	0.000	75.1	74.8	0	0
SEP	6.14450	0.000	0.00000	0.000	75.0	72.3	0	0
OCT	4.18725	-0.064	0.00000	0.000	75.0	72.2	0	0
NOV	1.90087	-1.036	0.00000	0.000	75.0	72.2	0	0
DEC	0.45485	-3.971	0.00000	0.000	74.9	72.1	0	0

Table A.2 Unmet Hours for a Base-Case House with Heat Pump Heating (Travis, Climate Zone 2A)

	- - - -D E M A N D S- - - - -		- -B A S E B O A R D S- - -		- -T E M P E R A T U R E S- -		- -L O A D S N O T M E T- -	
MONTH	HEAT EXTRACTION ENERGY (MBTU)	HEAT ADDITION ENERGY (MBTU)	BASEBOARD ENERGY (MBTU)	MAXIMUM BASEBOARD LOAD (KBTU/HR)	MAXIMUM ZONE TEMP (F)	MINIMUM ZONE TEMP (F)	HOURS UNDER HEATED	HOURS UNDER COOLED
JAN	0.22227	-4.397	0.00000	0.000	74.9	72.1	0	0
FEB	0.66509	-4.057	0.00000	0.000	74.9	72.1	0	0
MAR	1.21069	-2.485	0.00000	0.000	75.0	72.0	0	0
APR	2.27477	-0.321	0.00000	0.000	75.0	72.2	0	0
MAY	3.84008	-0.010	0.00000	0.000	75.0	72.2	0	0
JUN	6.30299	0.000	0.00000	0.000	75.0	72.6	0	0
JUL	8.21261	0.000	0.00000	0.000	75.0	74.8	0	0
AUG	8.45093	0.000	0.00000	0.000	75.1	74.8	0	0
SEP	6.14450	0.000	0.00000	0.000	75.0	72.3	0	0
OCT	4.18724	-0.064	0.00000	0.000	75.0	72.2	0	0
NOV	1.90083	-1.035	0.00000	0.000	75.0	72.2	0	0
DEC	0.45476	-3.970	0.00000	0.000	74.9	72.1	0	0

Table A.3 Unmet Hours for a Base-Case House with Natural Gas Heating (Dallas, Climate Zone 3A)

	----DEMANDS-----		--BASEBOARDS---		--TEMPERATURES--		--LOADS NOT MET--	
MONTH	HEAT EXTRACTION ENERGY (MBTU)	HEAT ADDITION ENERGY (MBTU)	BASEBOARD ENERGY (MBTU)	MAXIMUM BASEBOARD LOAD (KBTU/HR)	MAXIMUM ZONE TEMP (F)	MINIMUM ZONE TEMP (F)	HOURS UNDER HEATED	HOURS UNDER COOLED
JAN	0.17420	-6.117	0.00000	0.000	74.9	72.1	0	0
FEB	0.10383	-4.559	0.00000	0.000	74.8	72.1	0	0
MAR	0.52254	-2.329	0.00000	0.000	74.9	72.1	0	0
APR	1.63284	-0.598	0.00000	0.000	74.9	72.2	0	0
MAY	2.66679	-0.142	0.00000	0.000	74.9	72.2	0	0
JUN	5.97406	0.000	0.00000	0.000	75.0	73.4	0	0
JUL	8.02417	0.000	0.00000	0.000	75.1	74.8	0	0
AUG	8.30346	0.000	0.00000	0.000	75.0	74.8	0	0
SEP	5.64159	0.000	0.00000	0.000	75.0	73.9	0	0
OCT	3.07817	-0.177	0.00000	0.000	75.0	72.2	0	0
NOV	0.78762	-1.878	0.00000	0.000	74.9	72.1	0	0
DEC	0.16663	-4.777	0.00000	0.000	74.9	72.1	0	0

Table A.4 Unmet Hours for a Base-Case House with Heat Pump Heating (Dallas, Climate Zone 3A)

	----DEMANDS-----		--BASEBOARDS---		--TEMPERATURES--		--LOADS NOT MET--	
MONTH	HEAT EXTRACTION ENERGY (MBTU)	HEAT ADDITION ENERGY (MBTU)	BASEBOARD ENERGY (MBTU)	MAXIMUM BASEBOARD LOAD (KBTU/HR)	MAXIMUM ZONE TEMP (F)	MINIMUM ZONE TEMP (F)	HOURS UNDER HEATED	HOURS UNDER COOLED
JAN	0.17413	-6.115	0.00000	0.000	74.9	72.1	0	0
FEB	0.10378	-4.558	0.00000	0.000	74.8	72.1	0	0
MAR	0.52243	-2.328	0.00000	0.000	74.9	72.1	0	0
APR	1.63276	-0.598	0.00000	0.000	74.9	72.2	0	0
MAY	2.66677	-0.142	0.00000	0.000	74.9	72.2	0	0
JUN	5.97406	0.000	0.00000	0.000	75.0	73.4	0	0
JUL	8.02417	0.000	0.00000	0.000	75.1	74.8	0	0
AUG	8.30346	0.000	0.00000	0.000	75.0	74.8	0	0
SEP	5.64159	0.000	0.00000	0.000	75.0	73.9	0	0
OCT	3.07814	-0.177	0.00000	0.000	75.0	72.2	0	0
NOV	0.78755	-1.877	0.00000	0.000	74.9	72.1	0	0
DEC	0.16656	-4.776	0.00000	0.000	74.9	72.1	0	0

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