RECOMMENDATIONS FOR 15% ABOVE-CODE ENERGY EFFICIENCY MEASURES ON IMPLEMENTING HOUSTON AMENDMENTS TO MULTIFAMILY RESIDENTIAL BUILDINGS IN HOUSTON, TEXAS

Jaya Mukhopadhyay[1], Zi Liu[1], Mini Malhotra[1], Sandeep Kota[1]
Sheila Blake[2], Jeff Haberl[1], Charles Culp[1], Bahman Yazdani[1]

[1] Energy Systems Laboratory, Texas A&M University System
College Station, TX
[2]City of Houston Code Enforcement
Houston, TX

ABSTRACT

This paper presents results from an analysis of the energy saving potential for multifamily residential buildings in Houston. In this analysis, the energy efficient measures were proposed by the building officials with the City of Houston and analyzed by the Energy Systems Laboratory using a code-compliant calculator. Along with the options proposed by the officials, additional measures were selected from the 15% above code energy analysis conducted by the Energy Systems Laboratory for residential houses across the State of Texas. A total of 16 measures based on their energy savings above a code-compliant residence were selected. These measures were categorized into five groups: renewable power options, heating ventilation and air conditioning (HVAC), fenestration, envelope, lighting and domestic hot water (DHW) options. The analysis was performed using a simulation model of an International Energy Conservation Code (IECC 2000 with 2001 supplement)-compliant, single-family residence in Houston, Texas. Two sets of simulations based on the choice of heating fuel type were considered.

Individual measures were then categorized into 3 groups: 2 to 5%, 5 to 10%, and above 10% energy savings above base case. Individual measures from the three categories were then chosen to form group measures whose combined energy savings is above 15%. Six group measures were simulated for the electric/gas base case building and five group measures for the all-electric base case building. The cost of implementing the individual measures was also calculated along with simple payback period.

INTRODUCTION

The papers addresses the requests put forth by the City of Houston building officials. The officials have requested that the Energy Systems Laboratory test the energy reduction potential of the measures proposed by the officials for the multifamily residential buildings in the city of Houston. Along with the measures proposed by the officials, additional measures were selected from the 15% above code energy analysis conducted by the Energy Systems Laboratory for residential houses across the state of Texas (Malhotra 2007). A single-family residence complying with the 2000 International Energy Conservation Code, as modified by the 2001 Supplement[1] (ICC 1999; 2001), is modified to suit the requirements of multifamily residential building and taken up as the base case.

Two sets of simulations, based on the choice of heating fuel type, were considered: a) natural gas (i.e., gas-fired furnace for space heating, and gas water heater for domestic water heating) without thermostat setback, and b) electricity (i.e., heat pump for space heating, and electric water heater for domestic water heating) without thermostat setback.

This paper presents the test results of measures for these two cases. The simulation was conducted using version 2.50.08 of the DOE-2 input file and the TMY2 weather file for the city of Houston, Texas.

BASE CASE BUILDING DESCRIPTION

The base case building simulation model in this analysis is based on information provided by the city of Houston building officials, National Association of Home Builders (NAHB) and specifications for the "Standard Design" building as defined in Chapter 4 of the 2001 IECC. Table 1 summarizes the base case building characteristics used in the DOE-2 simulation model.

Figure 1 presents a schematic layout of the units. The base case is a two-storied building consisting of 8 units, with a floor-to-ceiling height of 8 feet. 4 units

[1] In the remainder of this paper, this will be denoted as the 2001 IECC.

are arranged on the first floor in sets of 2 units, which share a common wall. A breezeway is situated between the two sets of units. Four more units are arranged on the second floor in a similar configuration.

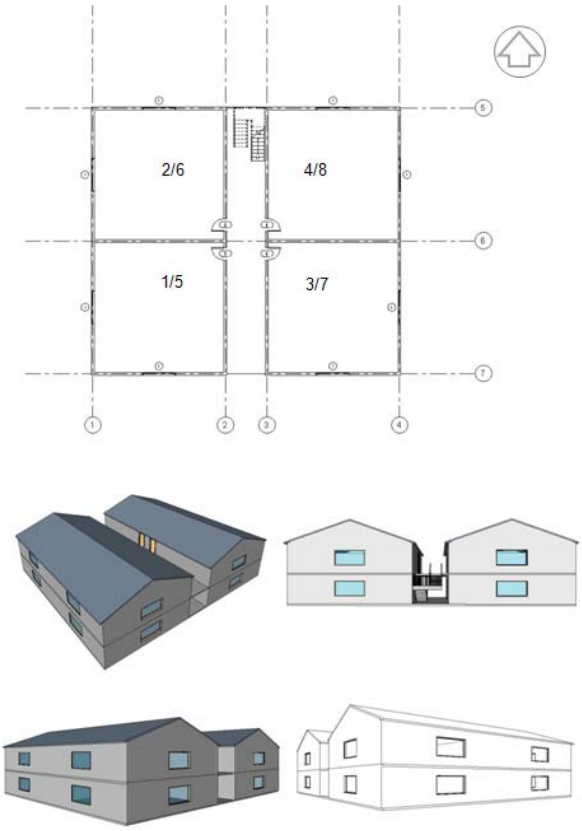


Figure 1: Schematic Layout of the Eight Units

Building Envelope, Space and Interior/Exterior Lighting and Equipment Power Characteristics

The base case units are square-shaped, one storied, 1009 sq. ft. (each unit), with a floor-to-ceiling height of 8 feet. The units on the second floor have a vented attic with a roof pitched at 23 degrees. The units have fascia brick exterior and asphalt shingle roofing. The wall construction is out of light-weight wood frame with 2X4 studs at 16" centre-to-centre with slab-on-grade-floor as per the information obtained from the National Association of Home Builders (NAHB 2003). The wall insulation is R-11[2] and ceiling insulation is R-19[3] as recommended by the 2001 IECC. The building has wall and roof absorptance of 0.75. The window area is 8% of the total conditioned space area, as per NAHB (2003)[4], distributed equally on two of the exterior walls of each unit. As described in chapter 4 of the IECC 2001, the windows have no exterior shading; the window glazing has a U-value of 0.47 Btu/hr-sq.ft.°F[5] and solar heat gain coefficient as 0.4[6]. One 20 sq. ft. door, of 0.2 Btu/h-sq. ft.-°F U-value[7], is assumed for each unit. The air infiltration rate was 0.47 ACH, which is based on the weather factor specified in ASHRAE Standard 136 (ASHRAE 1993)[8].

The total internal heat gain is assumed to be 0.22 kW[9] (modeled as 0.11 kW for lighting and 0.11 kW for equipment). All the space conditions are taken as per the 2001 IECC. 100% incandescent interior fixtures are assumed for the base case house. As per the code requirements, no occupants are assumed in the simulated building.

HVAC System Characteristics

The base case HVAC system for each unit includes a central air-conditioning system and a heating system. Two options for the heating fuel type were considered: a) natural gas (i.e., gas-fired furnace for space heating, and gas water heater for domestic water heating), and b) electricity (i.e., heat pump for space heating, and electric water heater for domestic water heating)[10]. For electric/gas set of units, the base case HVAC system is comprised of a SEER 13 air-conditioner and a gas-fired, forced-air furnace of 0.78 Annual Fuel Utilization Efficiency (AFUE)[11]. For the all-electric set of units, the base case HVAC system is comprised of a SEER 13 air conditioner with a heat pump of 7.7 Heating Season Performance Factor (HSPF)[12]. For both types of arrangements, the capacity of the cooling system is 24,216 Btu/hr, and the capacity of the heating system is -19527.78 Btu/hr, which assumes 500 sq. ft. per ton. This is based on the information provided by the Houston officials.

Air Distribution System Characteristics

[2] Refer Table 402.1.1(1) 2001IECC.
[3] Refer Table 502.2.4(6) 2001 IECC.
[4] This amounts to 80.72 sq. ft. window area and 10.6% window-to-wall area ratio for the base case building size and configuration.
[5] Refer Table 402.1.1(2) 2001 IECC.
[6] Refer Section 402.1.3.1.4 , 2001 IECC.
[7] This is specified in Section 402.1.3.4.3, p.64, of the 2001 IECC.
[8] This requirement can be found in Section 402.1.3.10, p.65, ASHRAE Standard 136.
[9] Refer Section 402.1.3.6, 2001 IECC.
[10] In the remainder of this paper, these units will be referred to as (a) electric/gas unit, and (b) all-electric unit, respectively.
[11] The efficiency of HVAC system is determined by NAECA 2006.

The base case air distribution system, which includes the HVAC unit and the ducts, is located in a conditioned space for the set of units on the lower floor. The HVAC unit and ducts are located in the unconditioned, vented attic for the set of units on the upper floor. The attic was assumed to have an air infiltration rate of 15 ACH[12]. The insulations for supply and return ducts are R-8 and R-4, respectively[13]. A 10% and 20% duct leakage, for the return and supply duct respectively, was assumed for the base case units[14] on the second floor.

Domestic Hot Water System Characteristics

For an electric/gas building, the base case domestic hot water (DHW) system is a 30-gallon[15], storage-type, natural gas water heater with a standing pilot light that consumes 500 Btu/hr[16], with a calculated energy factor (EF) of the system totaling 0.563[17]. For an all-electric building, the base case DHW system is a 40-gallon[16], storage-type, electric water heater. The energy factor (EF) of the system is 0.8772[18]. The daily hot water use was calculated as 50 gallons/day[18], which assumes that each unit has two bedrooms. The hot water supply temperature is 120°F[19].

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.

COST ANALYSIS

The cost analysis for different measures was carried out using three different utility cost rates. The cost of energy for each case is 30% more than the previous case. The reason to use the three cases is to calculate the pay backs in the event of an increase in fuel prices over a period of time. For the first case, the cost of electricity and natural gas is taken as 0.15/kWh for electricity and $1.00/CCF for natural gas. For the second case, the cost of electricity and natural gas is taken as $0.2/kWh for electricity and $1.5/CCF for natural gas and for the third case, they are 0.25/kWh for electricity and $2.00/CCF for natural gas, respectively.

SUMMARY OF INDIVIDUAL ENERGY EFFICIENCY MEASURES

For analysis 16 individual measures were considered, some were proposed by Houston city officials, while others taken from the 15% above code analysis report. These include measures for the renewable power options, options related to HVAC system/air distribution system, fenestration, building envelope, and domestic hot water (DHW) system. The measures were simulated by modifying the selected parameters used for the DOE-2 simulation model. Table 2 shows the EEMs which were simulated for the electric/gas base case building and all-electric base case building.

Renewable power options

The test case building is assumed to be grid-connected with a 6W, 4 kW or 2 kW PV array of Kyocera multi-crystalline solar cells (16% efficiency). The analysis of long-term performance was calculated using a PV F-CHART for the typical weather conditions of Houston, using TMY2 weather data, and, for the given mounting conditions, i.e. array tilt depending on the roof tilt (for the summer peak cooling loads, an array is tilted at about 15 degrees, i.e. latitude minus 15 degree, is expected to provide maximum output). The cost of a 6 kW system is around $41,000. 4 kW and 2 kW systems cost $29,000 and $17,000 respectively for the entire multifamily building.

HVAC Options

Decreasing the Supply Airflow: In this energy efficiency measure, the supply air flow is decreased to a reduced value of 250cfm/ton as requested by the Houston officials.

Decreased Duct Static Pressure: In this test case, the static pressure for the HVAC duct system is reset from 1" WC to 0.5"WC measured as per NCI (National Comfort Institute) standard and certified by a third party.

[12] This infiltration rate was chosen to match measured data by Kim (2006).

[13] This requirement can be found in Table 503.3.3.3 , 2001 IECC.

[14] This is based on the field measurements from Houston Officials.

[15] The size of the DHW tank are adopted from minimum water heater capacities for a four bedroom 2.5 bath single family living unit (Table 4, p.49.9, ASHRAE 2003)

[16] This value is consistent with information provided by DHW manufacturers.

[17] The EF of the DHW system was calculated from the minimum performance requirement using Table 504.2, 2001 IECC.

[18] This is specified in Section 402.1.3.7, 2001 IECC.

[19] This is specified in Section 402.1.3.7, 2001 IECC.

Decreased Duct Leakage: As requested by the city of Houston, the energy efficiency measure is re-set from 20% to 6.7% for supply and from 10% to 3.3% for return ducts on second floor units. Since the ducts are in conditioned space on the first floor, the duct leakage is set at zero in the base case and no changes have been made. The cost of implantation for decreasing the duct leakages is between $200 and $450 for each unit.

Mechanical Systems within Conditioned Spaces: 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 in the base case building to a location within the thermal envelope of the conditioned space. This measure is applicable to second floor units only. In the first floor units the mechanical systems are in a conditioned space. Locating the duct in the conditioned space will increase the cost by $1,000 to $7,000 for each unit.

Improved SEER and Furnace Efficiency: For the test case, the SEER 13 air conditioner in the base case building was replaced with a similarly sized SEER 15 air conditioner. The gas-fired furnace in the electric/gas base case building (0.78 AFUE) was replaced with a similarly sized condensing furnace with an AFUE of 0.93. Replacing a SEER 13 air conditioner with a SEER 15 air conditioner would increase the cost by $900 to $2,500. Replacing a 0.78 AFUE furnace with a 0.93 AFUE furnace would increase the cost by $600 to $1,500 for each unit.

Fenestration Options

Decreased SHGC and U-value: The Houston building officials recommended a SHGC value of 0.35 for the test case but, as per the 15% above code report, an SHGC of 0.3 is implemented for test case as it is more stringent than the one recommended by Houston building officials. The U-Factor is taken as 0.35 Btu/h-sq. ft.-°F. The cost of improving the SHGC and U-value of the fenestration system will be between $900 and $1,100 for each unit.

Envelope Options

Decreased Infiltration: A test cases for changed infiltration was simulated, a decrease to an air change of 0.35 ACH, as requested by the city of Houston officials. The cost of decreasing infiltration is between $350 and $1,500 for each unit.

Lighting options

Energy Star Indoor Lamps: Two options for high efficiency lamps were simulated. In the first case, 25% Energy Star fluorescent lamps were used, assuming that a fluorescent lamp uses 75% less energy than an incandescent lamp. The resulting internal heat gain from lights, of which 25% are fluorescent lamps, was 0.36 kW. In the second case, 50% Energy Star fluorescent lamps were used. Assuming that a fluorescent lamp uses 75% less energy than an incandescent lamp, the resulting internal heat gain from lights was 50% less, which is 0.275 kW. The cost of implementing the 25% Energy Star indoor lighting is $100 and the cost of implementing the 25% Energy Star indoor lighting is $500 to $800 for each unit.

Domestic Hot Water System Options

Use of a Tankless Water Heater: For the electric/gas base case building, the DHW Energy Factor (EF) was changed from 0.563 to 0.748[20] [21]. For the all-electric base-case building, this measure was simulated by increasing the DHW energy factor from 0.8772 to 0.95. Installing a tankless electric water heater in an all-electric house would only increase the cost by $700 to $1,400 for each unit.

Solar DHW System: For this measure a solar thermal DHW system, comprised of two 32 sq. ft. 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 the same as the latitude for that location, considering a hot water use of 50 gallons/day, year round. Table 3 lists the characteristics of the solar thermal system for Houston. In this analysis, 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. Installing a solar DHW system would increase the cost by $2,900 to $5,200 for each unit.

[20] A degradation factor of 8.8% (Davis Energy Group, Inc. 2006) is used when calculating EF for tankless water heaters.

[21] The EF for the tankless water heater is based on a survey of manufacturers and recommendations of the 2008 California Building Energy Efficiency Standards (Davis Energy Group, Inc. 2006).

SIMULATION INPUTS AND RESULTS FOR INDIVIDUAL MEASURES

Table 4 lists the parameters used for the Energy Efficient Measures (EEMs) for the electric/gas building located in Houston (Harris County), Texas. The DOE-2 Desktop Processor (DDP) is used to simulate the measures. Each unit in the simulation model is simulated as a single row. Eight rows of input to the DDP are required to simulate one multifamily building. The first 8 rows of values in all the tables present information used in the base case runs. The remaining rows, in sets of eight, present information used in the simulation of the individual energy efficiency measures. The shaded cell in each row indicates the change in the value used to simulate the measure.

Table 5 and Table 6 show the impact of individual EEMs on energy consumption for different end-uses for the electric/gas building consisting of eight units. Figure 2 and Figure 3 provide a graphical representation of the resultant energy consumption of the EEMs. The annual energy use presented in these tables is obtained from the BEPS report of the DOE-2 output file[22]. The tables also include the calculated energy savings of the EEMs when compared to the base case energy consumption which is presented in the last column.

For the electric/gas option, all of the renewable options provide energy savings in the range of 23% to 69%. In the HVAC options, putting mechanical systems in a conditioned space provides a savings of 6.18% and decreases the duct leakage results in an energy savings of 4.16%. When considering options for fenestration, decreasing the SHGC and the U-value of windows provides an energy savings of 1.5%. For envelope options, decreasing the infiltration saves up to 3.28% of energy consumption. Changing out 25% and 50% conventional incandescent lighting fixtures for Energy Star CFLs saves 1.44% to 3.64% of energy consumption, respectively. Using tankless gas water heaters provides an energy savings of 8.51%. Using a solar DHW system provides a savings of 23.5%.

For the all-electric option, all of the renewable options provide an energy savings in the range of 30% to 87%. In the HVAC options, putting mechanical systems in a conditioned space provides a savings of 5.27% and improves SEER results with an energy savings of 4.42%, followed by decreasing duct pressure, which results in a savings of 3.99%. When considering options for fenestration, decreasing the SHGC and the U-value of windows provides an energy savings of 1.63%. For envelope options, decreasing the infiltration saves up to 1.98% of energy consumption. Changing out 25% and 50% of conventional incandescent lighting fixtures for Energy Star CFLs saves 2.32% to 5.69% of energy consumption, respectively. Using solar DHW system provides a savings of 16.98%.

[22] For the complete analysis refer to Liu et al. (2008).

SIMULATION INPUTS AND RESULTS FOR GROUP MEASURES

Individual measures are grouped into three different categories: 0-5%, 5-10%, and above 10%, based on their savings above base case. Table 7 and Table 8 present the grouping of measures for the electric/gas base case building and the all-electric base case building. After categorizing, six group measures for the electric/gas base case building and five group measures for the all-electric base case building have been formed by combining the individual measures so that the combined savings of each measure in the group is more than 15% above the base case. Typically, groups consist of 1-4 individual measures. After categorizing them into different groups, each individual measure that falls under the above 10% category is taken as a separate group. The groups that have two measures are the combination of one measure from the 5-10% category and the other from the 0-5% group—their combined savings make up to 15% or above. The groups that have three or more measures are formed by taking one or two measures from the 5-10% category and the rest from the 0-5% category or vice versa. Table 9 provides group measures for the electric/gas base case building and a base case all-electric building.

Table 10 presents the parameters used in the simulation of the group measures. The first eight rows of values in the table present information used for base case runs. The remaining rows present information used for simulating the group measures. The shaded cells in each row indicate the change in the values of parameters of individual measures selected to simulate the group measure.

Table 11 and Table 12 show the energy savings for different group measures for the electric/gas base case building and the all-electric base case building. For the electric/gas base case building, the first 2 groups consist of renewable power options. Both achieved a savings of more than 20%. Group 3, which is a combination of tankless DHW, decreased duct leakage, and improved SEER, provided the next

maximum savings of 15.6%. It is followed by group 5 (i.e., mechanical in conditioned space, improved SEER, 50% Energy Star indoor lamps, decreased SHGC and U-value), then group 4 (reduced static pressure, mechanical in conditioned space, then group 6 (i.e., 50% Energy Star indoor lamps, tankless water heater, decreased infiltration), decreased infiltration, improved SEER, improved AFUE and 25% Energy Star indoor lamps) with 16. 3%, 16.2 % and 15.5%, respectively, over the base case.

For the all-electric-gas base case building, the first two groups consist of renewable power options: the first group, solar PV, provided a savings of 29.1% and the second group, solar DHW system, provided a savings of 16.98% above the base case. Group 3, which is a combination of 50% Energy Star CFL Indoor lamps, mechanical in a conditioned space, improved SEER, and decreased static pressure provided the maximum savings of 17.1% followed by group 4 and group 5 with 15.7% and 16.8 % over the base case.

CONCLUSIONS / SUMMARY

This paper presents information about the energy saving potential for residential buildings in Houston, Texas that are designed to be 15% above code. The energy efficient measures discussed in this paper were proposed by the building officials with the city of Houston. Along with the options proposed by the officials, additional measures were selected from the 15% above code energy analysis previously conducted by the Energy Systems Laboratory for residential buildings across the state of Texas. A total of sixteen measures, based on the energy savings above a base case code-compliant building, were selected. These measures were categorized into five groups: renewable energy options, heating ventilation and air conditioning (HVAC), fenestration, envelope, lighting and, finally, domestic hot water (DHW) options. The analysis was performed using a simulation of an International Energy Conservation Code (IECC)-compliant, single-family residence in Houston, Texas. Two sets of simulations were performed based on the choice of heating fuel type. No thermostat setback was considered.

Individual measures were then categorized into three groups: 2 to 5%, 5 to 10%, and above 10% energy savings above base case. Individual measures from the three categories were then chosen to form group measures whose combined energy savings is above 10%. Six group measures were simulated for the electric/gas base case building and five group measures for the all-electric base case building. Costs of implementation of individual measures were also calculated along with simple payback period.

Renewable energy options provided the best results with energy savings over 20% for both the electric/gas house as well as the all-electric base case. Implementing the solar DHW system in the electric/gas base case house reduced the energy consumption by 23.46%. Implementing the solar DHW system in the all-electric base case house reduced energy consumption by 16.98%. Locating the mechanical systems in a conditioned space resulted in the highest savings for implementing an individual measure for both the base case buildings. For the electric/gas base case the savings was 6.18% while in the all-electric base case, the savings was 5.27%.

REFERENCES

ASHRAE. 1993. ANSI/ASHRAE Standard 136-1993 (RA 2006) - A Method of Determining Air Change Rates in Detached Dwellings. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASHRAE. 2001. ANSI/ASHRAE Standard 62-2001 Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASHRAE. 2003. ASHRAE Handbook - HVAC Applications. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

Davis Energy Group, Inc. 2006. Measure Information Template: Tankless Gas Water Heaters. 2008 California Building Energy Efficiency Standards.

ICC. 1999. 2000 International Energy Conservation Code. Falls Church, VA: International Code Council, Inc.

ICC. 2001. 2001 Supplement to the International Energy Conservation Code. Falls Church, VA: International Code Council, Inc.

Kim, S. 2006. An Analysis of International Energy Conservation Code (IECC)-Compliant Single-Family Residential Energy Use. Ph.D. Dissertation, College Station, TX: Texas A&M University.

Klein, S.A., W.A. Beckman. 1983. F-Chart Solar Energy System Analysis: DOS Version 5.6. F-Chart Software. Middleton, WI. www.fchart.com.

LBL. 1993. DOE-2 BDL Summary Version 2.1E. LBL Report No. 349346. Berkley, CA: Lawrence Berkeley Laboratory.

Liu, Z., J. Mukhopadhyay, M. Malhotra, S. Kota, J. Haberl, C. Culp, B. Yazdani. 2008. Recommendations for 15% Above-Code Energy Efficiency Measures on Implementing Houston Amendments to Single Family Buildings in Houston Texas, ESL- ESL-TR-08-10-01.

Malhotra, M., J. Mukhopadhyay, B. Liu, J. Haberl, C. Culp, B. Yazdani. 2007. Recommendations for 15%. Above-Code Energy Efficiency Measures for Single-Family Residences. 15.5 Symposium on Improving Building Systems in Hot & Humid Climates. San Antonio, TX.

NAECA. 2006. National Appliance Energy Conservation Act.

NAHB. 2003. The Builders Practices Survey Reports. National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NREL. 2001. Building America House Performance Analysis Procedures (NREL/TP-550-27754). Golden, CO: National Renewable Energy Laboratory. pg. 34.

Table 1: Assumptions for the Multifamily Base Case Dwelling Unit for an 8-Unit Building

CHARACTERISTIC	BASECASE ASSUMPTIONS		COMMENTS	SOURCES
Building				
Building type	Multifamily residential building			
Gross area per unit	1,009 sq. ft. (31.76 ft. x 31.76 ft.)			NAHB (2003)
Number of floors for building, units per floors	2 floors, 4 units per floor			NAHB (2003)
Floor to floor height (ft.) per unit	8			NAHB (2003)
No. of exposed walls per unit	3 exposed walls			
Construction				
Construction	Light-weight wood frame with 2x4 studs spaced at 16" on center			NAHB (2003)
Floor of 1st floor units	Slab-on-grade floor			NAHB (2003)
Roof configuration of 2nd floor units	Unconditioned, vented attic			NAHB (2003)
Roof absorptance	0.75		Assuming asphalt shingle roofing	
Ceiling insulation (hr-sq.ft.-°F/Btu) per	R-19		Based on HDD65 and 10.6% window-to-wall area ratio	2001 IECC, Table 502.2.4(7), (p.83)
Wall absorptance	0.75		Assuming brick facia exterior	
Wall insulation (hr-sq.ft.-°F/Btu)	R-11		Based on HDD65 and 10.6% window-to-wall area ratio	2001 IECC, Table 502.2.4(7), (p.83)
Slab Perimeter Insulation for 1st floor units	None		Based on HDD65 and 10.6% window-to-wall area ratio	2001 IECC, Table 502.2.4(7), (p.83)
Ground reflectance	0.24		Assuming grass	DOE2.1e User Manual (LBL 1993)
U-Factor of glazing (Btu/hr-sq.ft.°F)	0.47		Based on HDD65 and 10.6% window-to-wall area ratio	2001 IECC, Table 502.2.4(7), (p.83)
Door U-Value (Btu/hr-sq.ft.°F)	0.2			
Solar Heat Gain Coefficient (SHGC)	0.4		0.4 for HDD < 3500, and 0.68 for HDD ≥ 3500	2001 IECC, Section 402.1.3.1.4, (p.64)
Window area and distribution per unit	8% of conditioned floor area, distributed equally on 2 orientations		This amounts to 80.72 sq. ft. window area and 10.6% window-to-wall area ratio per unit.	NAHB (2003)
Exterior shading	None			2001 IECC, Section 402.1.3.1.3, (p.64)
Slope of Roof (2nd Floor Units)	5:12 Slope = 23 Degree Slope			
Space Conditions				
Space temperature setpoint per unit	68°F Heating, 78°F Cooling, 5°F set-back/ set-up for winter and summer, respectively, for 6 hours per day			2001 IECC, Table 402.1.3.5, (p.64)
Internal heat gains per unit	0.44 W (modeled as 0.22 W for lighting and 0.22 W for equipment)		This assumes heat gains from lighting, equipment and occupants.	2001 IECC, Section 402.1.3.6, (p.65)
Number of bedrooms per unit	2		Calculated from the area assigned to each unit.	
Number of occupants per unit	None		Assuming internal gains include heat gain from occupants	2001 IECC, Section 402.1.3.6, (p.65)
Mechanical Systems	Electric/Gas	All-electric		
HVAC system type	Electric cooling (air conditioner) and natural gas heating (gas fired furmace)	Electric cooling and heating (air conditioner with heat pump)		
HVAC system efficiency	SEER 13 AC, 0.78 AFUE furnace	SEER 13 AC, 7.7 HSPF heat pump		NAECA (2006)
Cooling capacity (Btu/hr) per unit	24,216		500 sq. ft./ton	
Heating capacity (Btu/hr) per unit	19,528		500 sq. ft./ton	
DHW system type per unit	30-gallon tanktype gas water heater with a standing pilot light	40-gallon tanktype electric water heater (without a pilot light)		Tank size from ASHRAE HVAC Systems and Equipment Handbook
DHW heater energy factor	0.563	0.8772	(a) 0.62-0.0019V, (b) 0.93-0.00132V, Where V=storage volume (gal.)	2001 IECC, Table 504.2, (p.91)
Duct location for 1st floor units	In conditioned space			NAHB (2003)
Duct location for 2nd floor units	Unconditioned, vented attic			NAHB (2003)
Duct leakage (%) for 1st floor units	0%			
Duct leakage (%) for 2nd floor units	Supply - 20% Return - 10%			Field Measurement Report from City of Houston Officials
Duct insulation (hr-sq.ft.-°F/Btu)	R-8 (supply) and R-4 (return)			2001 IECC
Air Infiltration	0.47 ACH			
Attic Infiltration	15 ACH			

Table 2: Individual Energy Efficient Measures for an Electric/Gas Base Case Building and All-Electric Base Case Building

	Base case Natural Gas	Base case Heat Pump	Source
1	PV Array for 6kW	PV Array for 6kW	City of Houston Officials
2	PV Array for Partial Demand at 4kW	PV Array for Partial Demand at 4kW	City of Houston Officials
3	PV Array for Partial Demand at 2kW	PV Array for Partial Demand at 2kW	City of Houston Officials
4	Decreased Supply Airflow*	Decreased Supply Airflow*	City of Houston Officials
5	Decreased Duct Static Pressure	Decreased Duct Static Pressure	City of Houston Officials
6	Decreased Duct Leakage (For 2nd Floor Units)	Decreased Duct Leakage (For 2nd Floor Units)	City of Houston Officials
7	Mechanical Systems within Conditioned Spaces (For 2nd Floor Units)	Mechanical Systems within Conditioned Spaces (For 2nd Floor Units)	15% Above code analysis
8	Improved SEER	Improved SEER	15% Above code analysis
9	Improved Furnace Efficiency	Improved Heat pump	15% Above code analysis
10	Decreased SHGC & U Value	Decreased SHGC & U Value	15% Above code analysis
11	Window Shading	Window Shading	15% Above code analysis
12	Decreased Infiltration	Decreased Infiltration	15% Above code analysis
13	25% Energy Star CFL Indoor Lamps	25% Energy Star CFL Indoor Lamps	City of Houston Officials
14	50% Energy Star CFL Indoor Lamps	50% Energy Star CFL Indoor Lamps	City of Houston Officials
15	Tankless Gas Water Heater	Tankless Gas Water Heater	15% Above code analysis
16	Solar DHW System	Solar DHW System	15% Above code analysis

Table 3: Solar DHW System Characteristics

Number of collector panels	2
Collector panel area	32 sq. ft.
Collector slope	30 deg.
Collector azimuth (South=0)	0 deg.
Number of glazings	1
Collector flow rate/area	11 lb/hr-sq. ft.
Water set temperature	120 deg. F
Daily hot water usage	70 gal.

Table 4: Simulation Input for Electric/Gas Base Case Building

EEM #	Unit #	Energy Efficiency Measure	Cooling System Sizing (ft2/ton)	Supply Air Flow (CFM/ton)	Supply Fan Static Pressure	Supply Duct Leakage (%)	Return Duct Leakage (%)	Duct in Conditioned Space	Improved SEER	Improved AFUE	Improved HSPF	SHGC	U-Value	Shading	Shading	Shading	Shading	WWR% for front Side Wall	WWR% area for back Side Wall	WWR% for right Side Wall	WWR% for left Side Wall	Radiant Barrier	Roof Abs	Infiltration Rate (ACH/hr)	Pitch of Roof (degree)	Lighting (kW)	Energy Factor
B	**B1**	Base case Natural Gas w/o setback	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	B2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	B3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	B4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	B5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	B6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	B7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	B8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
2	1	PV Array for 6kW	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
3	1	PV Array for Partial Demand at 4kW	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
4	1	PV Array for Partial Demand at 2kW	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
6	1	Decreased Supply Airflow	500	**250**	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	**250**	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	**250**	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	**250**	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	**250**	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	**250**	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	**250**	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	**250**	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
8	1	Decreased Duct Static Pressure	500	360	**0.5**	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	**0.5**	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	**0.5**	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	**0.5**	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	**0.5**	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	**0.5**	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	**0.5**	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	**0.5**	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
9	1	Decreased Duct Leakage	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	**6.70%**	**3.30%**	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	**6.70%**	**3.30%**	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	**6.70%**	**3.30%**	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	**6.70%**	**3.30%**	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
10	1	Mechanical Systems within Conditioned Spaces	500	360	1.0	**0%**	**0%**	**ROOM**	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	**0%**	**0%**	**ROOM**	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	**0%**	**0%**	**ROOM**	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	**0%**	**0%**	**ROOM**	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	**0%**	**0%**	**ROOM**	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	**0%**	**0%**	**ROOM**	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	**0%**	**0%**	**ROOM**	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	**0%**	**0%**	**ROOM**	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
11	1	Improved SEER	500	360	1.0	0%	0%	ROOM	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563

Table 4: Simulation Input for Electric/Gas Base Case Building (cont.)

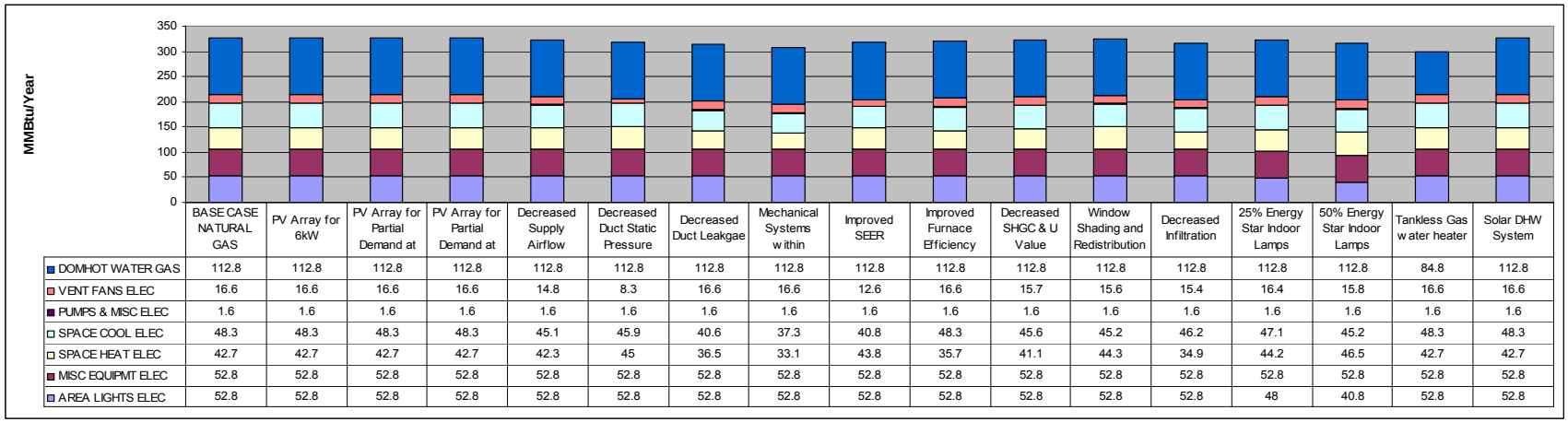
EEM #	Unit #	Energy Efficiency Measure	Cooling System Sizing (ft2/ton)	Supply Air Flow (CFM/ton)	Supply Fan Static Pressure	Supply Duct Leakage (%)	Return Duct Leakage (%)	Duct in Conditioned Space	Improved SEER	Improved AFUE	Improved HSPF	SHGC	U-Value	Shading	Shading	Shading	Shading	WWR% for front Side Wall	WWR% area for back Side Wall	WWR% for right Side Wall	WWR% for left Side Wall	Radiant Barrier	Roof Abs	Infiltration Rate (ACH/hr)	Pitch of Roof (degree)	Lighting (kW)	Energy Factor
B	B1	Base case Natural Gas w/o setback	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	B2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	B3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	B4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	B5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	B6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	B7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	B8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
12	1	Improved Furnace Efficiency	500	360	1.0	0%	0%	ROOM	13	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
14	1	Decreased SHGC & U Value	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
16	1	Window Shading and Redistribution	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	**2**	**2**	**2**	**2**	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	**2**	**2**	**2**	**2**	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	**2**	**2**	**2**	**2**	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	**2**	**2**	**2**	**2**	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	**2**	**2**	**2**	**2**	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	**2**	**2**	**2**	**2**	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	**2**	**2**	**2**	**2**	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	**2**	**2**	**2**	**2**	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
20	1	Decreased Infiltration	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	**0.35**	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	**0.35**	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	**0.35**	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	**0.35**	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	**0.35**	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	**0.35**	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	**0.35**	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	**0.35**	23	0.22	0.563
24	1	25% Energy Star CFL Indoor Lamps	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	**0.2**	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	**0.2**	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	**0.2**	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	**0.2**	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	**0.2**	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	**0.2**	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	**0.2**	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	**0.2**	0.563
25	1	50% Energy Star CFL Indoor Lamps	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	**0.17**	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	**0.17**	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	**0.17**	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	**0.17**	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	**0.17**	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	**0.17**	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	**0.17**	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	**0.17**	0.563
29	1	Tankless Gas Water Heater	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	**0.748**
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	**0.748**
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	**0.748**
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	**0.748**
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	**0.748**
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	**0.748**
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	**0.748**
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	**0.748**
31	1	Solar DHW System	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563

Table 5: Simulation Results for the Electric/Gas Base Case Building (w/o setback)

	Total Energy Consumed (MMBtu)	Cooling Load (MMBtu)	Heating Load (MMBtu)	Others (MMBtu)	Fans &Pumps (MMBtu)	DHW (MMBtu)	Diff. %
Base case Natural Gas w/ setback	326.7	48.3	42.7	105.6	18.2	112.8	0
PV Array for 6kW	101.02	48.30	42.70	105.60	18.20	112.80	69.08%
PV Array for Partial Demand at 4kW	176.24	48.30	42.70	105.60	18.20	112.80	46.05%
PV Array for Partial Demand at 2kW	251.47	48.30	42.70	105.60	18.20	112.80	23.03%
Decreased Supply Airflow*	321.70	45.10	42.30	105.60	16.40	112.80	1.53%
Decreased Duct Static Pressure	318.70	45.90	45.00	105.60	9.90	112.80	2.45%
Decreased Duct Leakage (For 2nd Floor Units)	313.10	40.60	36.50	105.60	18.20	112.80	4.16%
Mechanical Systems within Conditioned Spaces (For 2nd Floor Units)	306.50	37.30	33.10	105.60	18.20	112.80	6.18%
Improved SEER	316.40	40.80	43.80	105.60	14.20	112.80	3.15%
Improved Furnace Efficiency	319.90	48.30	35.70	105.60	18.20	112.80	2.08%
Decreased SHGC & U Value	321.70	45.60	41.10	105.60	17.30	112.80	1.53%
Window Shading	324.60	45.20	44.30	105.60	17.20	112.80	0.64%
Decreased Infiltration	316.00	46.20	34.90	105.60	17.00	112.80	3.28%
25% Energy Star CFL Indoor Lamps	322.00	47.10	44.20	100.80	18.00	112.80	1.44%
50% Energy Star CFL Indoor Lamps	314.80	45.20	46.50	93.60	17.40	112.80	3.64%
Tankless Gas Water Heater	298.90	48.30	42.70	105.60	18.20	84.80	8.51%
Solar DHW System	250.07	48.30	42.70	105.60	29.95	23.52	23.46%

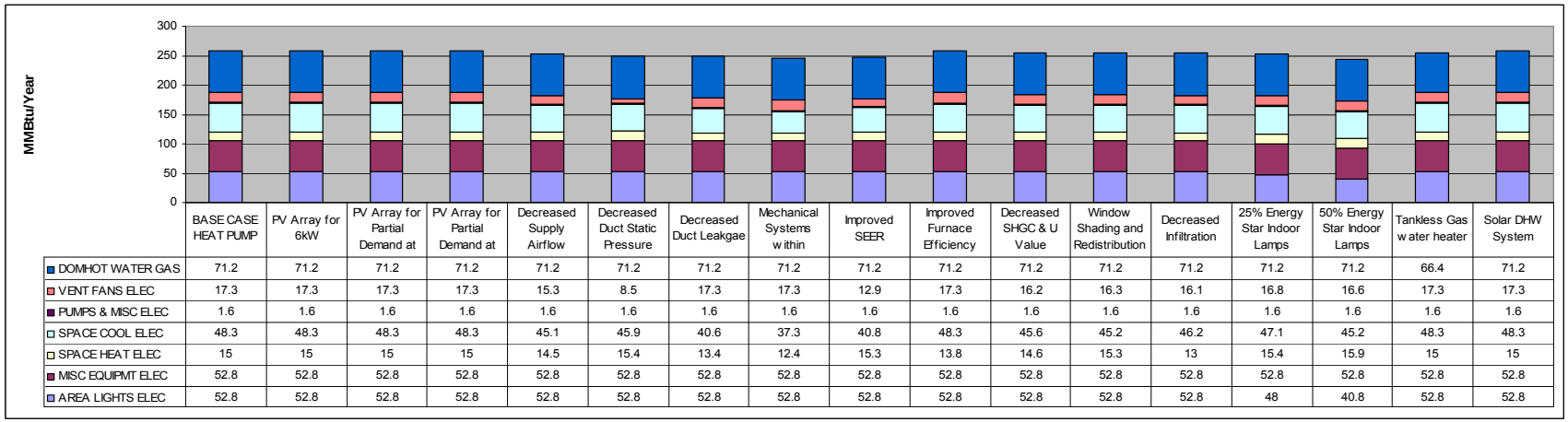
Table 6: Simulation Results for the All-Electric Base Case Building (w/o setback)

	Total Energy Consumed (MMBtu)	Cooling Load (MMBtu)	Heating Load (MMBtu)	Others (MMBtu)	Fans &Pumps (MMBtu)	DHW (MMBtu)	Diff. %
Base case Heat Pump w/ setback	258.2	48.3	15	105.6	18.9	71.2	0
PV Array for 6kW	32.52	48.30	15.00	105.60	18.90	71.20	87.41%
PV Array for Partial Demand at 4kW	107.74	48.30	15.00	105.60	18.90	71.20	58.27%
PV Array for Partial Demand at 2kW	182.97	48.30	15.00	105.60	18.90	71.20	29.14%
Decreased Supply Airflow	252.80	45.10	14.50	105.60	16.90	71.20	2.09%
Decreased Duct Static Pressure	247.90	45.90	15.40	105.60	10.10	71.20	3.99%
Decreased Duct Leakage (For 2nd Floor Units Only)	248.90	40.60	13.40	105.60	18.90	71.20	3.60%
Mechanical Systems within Conditioned Spaces (For 2nd Floor Units Only)	244.60	37.30	12.40	105.60	18.90	71.20	5.27%
Improved SEER	246.80	40.80	15.30	105.60	14.50	71.20	4.42%
Improved Heat Pump Efficiency	257.20	48.30	13.80	105.60	18.90	71.20	0.39%
Decreased SHGC & U Value	254.00	45.60	14.60	105.60	17.80	71.20	1.63%
Window Shading	254.80	45.20	15.30	105.60	17.90	71.20	1.32%
Decreased Infiltration	253.10	46.20	13.00	105.60	17.70	71.20	1.98%
25% Energy Star CFL Indoor Lamps	252.20	47.10	15.40	100.80	18.40	71.20	2.32%
50% Energy Star CFL Indoor Lamps	243.50	45.20	15.90	93.60	18.20	71.20	5.69%
Tankless Gas Water Heater	253.70	48.30	15.00	105.60	18.90	66.40	1.74%
Solar DHW System	214.35	48.30	15.00	105.60	30.65	14.80	16.98%



	BASE CASE NATURAL GAS	PV Array for 6kW	PV Array for Partial Demand at	PV Array for Partial Demand at	Decreased Supply Airflow	Decreased Duct Static Pressure	Decreased Duct Leakgae	Mechanical Systems w ithin	Improved SEER	Improved Furnace Efficiency	Decreased SHGC & U Value	Window Shading and Redistribution	Decreased Infiltration	25% Energy Star Indoor Lamps	50% Energy Star Indoor Lamps	Tankless Gas w ater heater	Solar DHW System
DOMHOT WATER GAS	112.8	112.8	112.8	112.8	112.8	112.8	112.8	112.8	112.8	112.8	112.8	112.8	112.8	112.8	112.8	84.8	112.8
VENT FANS ELEC	16.6	16.6	16.6	16.6	14.8	8.3	16.6	16.6	12.6	16.6	15.7	15.6	15.4	16.4	15.8	16.6	16.6
PUMPS & MISC ELEC	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
SPACE COOL ELEC	48.3	48.3	48.3	48.3	45.1	45.9	40.6	37.3	40.8	48.3	45.6	45.2	46.2	47.1	45.2	48.3	48.3
SPACE HEAT ELEC	42.7	42.7	42.7	42.7	42.3	45	36.5	33.1	43.8	35.7	41.1	44.3	34.9	44.2	46.5	42.7	42.7
MISC EQUIPMT ELEC	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8
AREA LIGHTS ELEC	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	48	40.8	52.8	52.8

Figure 2:Energy Use of various EEMs for Electric/Gas Base Case Building (w/o setback), Houston, TX



	BASE CASE HEAT PUMP	PV Array for 6kW	PV Array for Partial Demand at	PV Array for Partial Demand at	Decreased Supply Airflow	Decreased Duct Static Pressure	Decreased Duct Leakgae	Mechanical Systems w ithin	Improved SEER	Improved Furnace Efficiency	Decreased SHGC & U Value	Window Shading and Redistribution	Decreased Infiltration	25% Energy Star Indoor Lamps	50% Energy Star Indoor Lamps	Tankless Gas w ater heater	Solar DHW System
DOMHOT WATER GAS	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	66.4	71.2
VENT FANS ELEC	17.3	17.3	17.3	17.3	15.3	8.5	17.3	17.3	12.9	17.3	16.2	16.3	16.1	16.8	16.6	17.3	17.3
PUMPS & MISC ELEC	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
SPACE COOL ELEC	48.3	48.3	48.3	48.3	45.1	45.9	40.6	37.3	40.8	48.3	45.6	45.2	46.2	47.1	45.2	48.3	48.3
SPACE HEAT ELEC	15	15	15	15	14.5	15.4	13.4	12.4	15.3	13.8	14.6	15.3	13	15.4	15.9	15	15
MISC EQUIPMT ELEC	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8
AREA LIGHTS ELEC	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	48	40.8	52.8	52.8

Figure 3:Energy Use of various EEMs for All-Electric Base Case Building (w/o setback), Houston, TX

Table 7: Grouping of Results for the Electric/Gas Base-Case Building (w/o setback)

Range	Individual Measures	Total Energy Consumed (MMBtu)	Diff. %	Number of Units	Cost per Unit	Total Cost for 8 Units	Type of Cost
	Base case Natural Gas w/o setback	326.7	0.0%	8			
Above 10%	**Solar DHW System**	250.1	23.5%	8	$2,900 - $5,200	$23,200 - $41,600	New Installation
	PV Array for Partial Demand at 16 kW	251.5	23.0%	8	$17,000	$136,000	New Installation
5-10%	**Tankless Gas Water Heater** Energy Factor: 0.563 to 0.748	298.9	8.5%	8	$900 - $1,500	$7,200 - $12,000	Marginal
	Mechanical Systems within Conditioned Spaces (For 2nd Floor Units)	306.5	6.2%	4	$400 - $2,800	$1,600 - $11,200	Marginal
0-5%	**Decreased Duct Leakage** (For 2nd Floor Units) Supply: 20% - 6.7% Return: 10% - 3.3%	313.1	4.2%	4	$200	$800	Marginal
	50% Energy Star CFL Indoor Lamps 0.22 kW - 0.17 kW	314.8	3.6%	8	$250 $400	$2,000 - $3,200	Marginal
	Decreased Infiltration 0.462 - 0.35	316.0	3.3%	8	$230 - $700	$1,840 - $5,600	Marginal
	Improved SEER SEER 13 to SEER 15	316.4	3.2%	8	$360 $1,000	$2,880 $8,000	Marginal
	Decreased Duct Static Pressure 1" - 0.5"	318.7	2.4%	8	$100	$800	Marginal
	Improved Furnace Efficiency AFUE0.78 to AFUE 0.93	319.9	2.1%	8	$250 - $400	$2,000 - $3,200	Marginal
	Decreased SHGC & U Value SHGC 0.4 - 0.3 U-Value 0.47 - 0.35	321.7	1.5%	8	$160 - $220	$1,280 - $1,760	Marginal
	25% Energy Star CFL Indoor Lamps 0.22 kW - 0.2 kW	322.0	1.4%	8	$50	$400	Marginal
	Window Shading* 4 ft. Projection	324.6	0.6%				

Table 8: Grouping of Results for the All-Electric Base Case Building (w/o setback)

Range	Individual measures	Total Energy Consumed (MMBtu)	Diff. %	Electricity (kWh)	Number of Units	Cost per Unit	Total Cost for 8 Units	Type of Cost
	Base case Heat Pump w/ setback	258.2	0.0%	75674				
Above 10%	**PV Array for Partial Demand at 16kW**	183.0	29.1%	53626	8	$17,000	$136,000	New Installation
	Solar DHW System	214.3	17.0%	62821	8	$2,900 - $5,200	$23,200 - $41,600	New Installation
5-10%	**50% Energy Star CFL Indoor Lamps** 0.22 kW - 0.17 kW	243.5	5.7%	71366		$250 $400	$0 - $0	Marginal
	Mechanical Systems within Conditioned Spaces (For 2nd Floor Units Only)	244.6	5.3%	71688	4	$400 - $2,800	$1,600 - $11,200	Marginal
0-5%	**Improved SEER** SEER 13 to SEER 15	246.8	4.4%	72333	8	$360 $1,000	$2,880 - $8,000	Marginal
	Decreased Duct Static Pressure 1" - 0.5"	247.9	4.0%	72655	8	$100	$800	Marginal
	Decreased Duct Leakage (For 2nd Floor Units) Supply: 20% - 6.7% Return: 10% - 3.3%	248.9	3.6%	72948	4	$200	$800	Marginal
	25% Energy Star CFL Indoor Lamps 0.22 kW - 0.2 kW	252.2	2.3%	73916	8	$50	$400	Marginal
	Decreased Infiltration 0.462 - 0.35	253.1	2.0%	74179	8	$230 - $700	$1,840 - $5,600	Marginal
	Tankless Water Heater 0.89 - 0.95	253.7	1.7%	74355	8	$700 $1,300	$5,600 - $10,400	
	Decreased SHGC & U Value SHGC 0.4 - 0.3 U-Value 0.47 - 0.35	254.0	1.6%	74443	8	$160 - $220	$1,280 - $1,760	Marginal
	Window Shading* 4 ft. Projection	254.8	1.3%	74678				
	Improved Heat Pump Efficiency* HSPF 7.7 - HSPF 8.5	257.2	0.4%	75381				

Table 9: Group Measures for Electric/Gas and All-Electric Base Case Building

	Base Case with Natural Gas Heating	Base Case with Heat-Pump Heating
GROUP 1	-Solar DHW System	- PV Array for Partial Demand at 2kW
GROUP 2	-PV Array for Partial Demand at 2kW	-Solar DHW System
GROUP 3	-Tankless DHW -Decreased Duct Leakage -Improved SEER	-50% Energy Star CFL Indoor Lamps -Mechanical in Conditioned Space -Improved SEER -Decreased Static Pressure
GROUP 4	- Reduced Static Pressure -Mechanical in Conditioned Space -Decreased Infiltration -Improved SEER -Improved AFUE - 25% Energy Star Indoor Lamps	-Tankless Water Heater -Reduced Duct Leakage -Improved SEER -Reduced Infiltration -25% Energy Star CFL Indoor Lamps -Decreased SHGC & U-Value -Reduced Duct StatiC Pressure
GROUP 5	-Mechanical in Conditioned Space -Improved SEER - 50% Energy Star Indoor Lamps - Decreased SHGC & U-Value	-50% Energy Star CFL Indoor Lamps -Decreased Duct Leakage -Improved SEER -Decreased Static Pressure
GROUP 6	-50% Energy Star CFL Indoor Lamps - Tankless Water Heater - Decreased Infiltration	

Table 10:Simulation Inputs for the Group Measures for the Base Case Building with Gas-Electric

EEM #	Unit #	Energy Efficiency Measure	Cooling System Sizing (ft2/ton)	Supply Air Flow (CFM/ton)	Supply Fan Static Pressure	Supply Duct Leakage (%)	Return Duct Leakage (%)	Duct in Conditioned Space	Improved SEER	Improved AFUE	Improved HSPF	SHGC	U-Value	Shading	Shading	Shading	Shading	WWR% for front Side Wall	WWR% area for back Side Wall	WWR% for right Side Wall	WWR% for left Side Wall	Radiant Barrier	Roof Abs	Infiltration Rate (ACH/hr)	Pitch of Roof (degree)	Lighting (kW)	Energy Factor
B	**B1**	Base case Natural Gas w/o setback	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	0.563
	B2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	0.563
	B3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	0.563
	B4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	0.563
	B5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	0.563
	B6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	0.563
	B7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	0.563
	B8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	0.563
1	**1**	GROUP 1 MEASURE: -Solar DHW System	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	0	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	0	15.7	N	0.75	0.462	23	0.22	0.563
2	1	GROUP 2 MEASURE: -PV Array for Partial Demand at 2kW	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	0.563
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	0.563
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	0.563
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	0.563
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	0.563
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	0.563
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	0.563
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	0.563
3	1	GROUP 3 MEASURE: -Tankless DHW -Decreased Duct Leakage -Improved SEER	500	360	1.0	0%	0%	ROOM	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	**0.748**
	2		500	360	1.0	0%	0%	ROOM	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	**0.748**
	3		500	360	1.0	0%	0%	ROOM	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	**0.748**
	4		500	360	1.0	0%	0%	ROOM	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	**0.748**
	5		500	360	1.0	**6.70%**	**3.30%**	ATTIC	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	**0.748**
	6		500	360	1.0	**6.70%**	**3.30%**	ATTIC	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	**0.748**
	7		500	360	1.0	**6.70%**	**3.30%**	ATTIC	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	0.462	23	0.22	**0.748**
	8		500	360	1.0	**6.70%**	**3.30%**	ATTIC	**15**	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	0.462	23	0.22	**0.748**
4	1	GROUP 4 MEASURE: - Reduced Static Pressure -Mechanical in Conditioned Space -Decreased Infiltration -Improved SEER -Improved AFUE - 25% Energy Star Indoor Lamps	500	360	**0.5**	0%	0%	**ROOM**	**15**	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.2**	0.563
	2		500	360	**0.5**	0%	0%	**ROOM**	**15**	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.2**	0.563
	3		500	360	**0.5**	0%	0%	**ROOM**	**15**	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.2**	0.563
	4		500	360	**0.5**	0%	0%	**ROOM**	**15**	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.2**	0.563
	5		500	360	**0.5**	**0%**	**0%**	ROOM	**15**	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.2**	0.563
	6		500	360	**0.5**	**0%**	**0%**	ROOM	**15**	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.2**	0.563
	7		500	360	**0.5**	**0%**	**0%**	ROOM	**15**	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.2**	0.563
	8		500	360	**0.5**	**0%**	**0%**	ROOM	**15**	**0.93**	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.2**	0.563
5	1	GROUP 5 MEASURES: -Mechanical in Conditioned Space -Improved SEER - 50% Energy Star Indoor Lamps - Decreased SHGC & U-Value	500	360	1.0	0.0%	0.0%	ROOM	**15**	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.17**	0.563
	2		500	360	1.0	0.0%	0.0%	ROOM	**15**	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.17**	0.563
	3		500	360	1.0	0.0%	0.0%	ROOM	**15**	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.17**	0.563
	4		500	360	1.0	0.0%	0.0%	ROOM	**15**	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.17**	0.563
	5		500	360	1.0	**0.0%**	**0.0%**	**ROOM**	**15**	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.17**	0.563
	6		500	360	1.0	**0.0%**	**0.0%**	**ROOM**	**15**	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.17**	0.563
	7		500	360	1.0	**0.0%**	**0.0%**	**ROOM**	**15**	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.17**	0.563
	8		500	360	1.0	**0.0%**	**0.0%**	**ROOM**	**15**	0.78	7.70	**0.3**	**0.35**	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.17**	0.563
6	1	GROUP 6 MEASURE: -50% Energy Star CFL Indoor Lamps - Tankless Water Heater - Decreased Infiltration	500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.17**	**0.748**
	2		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.17**	**0.748**
	3		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.17**	**0.748**
	4		500	360	1.0	0%	0%	ROOM	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.17**	**0.748**
	5		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.17**	**0.748**
	6		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.17**	**0.748**
	7		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	15.7	**0**	N	0.75	**0.35**	23	**0.17**	**0.748**
	8		500	360	1.0	20%	10%	ATTIC	13	0.78	7.70	0.4	0.47	0	0	0	0	0	15.7	**0**	15.7	N	0.75	**0.35**	23	**0.17**	**0.748**

Table 11: Combined Energy Savings of Grouped Measures for Electric/Gas Base-Case Building (w/o setback)

Groups		Diff. %	Electricity (kWh)	Gas (CCF)
Base Case w/ Natural Gas Heating			**50176**	**1510**
GROUP 1	Solar DHW System	23.50%	53882	643
GROUP 2	PV Array for Partial Demand at 16kW	23.00%	28128	1510
GROUP 3	Tankless DHW Decreased Duct Leakage Improved SEER	15.60%	44959	1187
GROUP4	Reduced Static Pressure Mechanical in Conditioned Space Decreased Infiltration Improved SEER Improved AFUE 25% Energy Star Indoor Lamps	16.20%	39801	1340
GROUP 5	Mechanical in Conditioned Space Improved SEER 50% Energy Star Indoor Lamps Decreased SHGC & U-Value	16.30%	38482	1381
GROUP 6	50% Energy Star CFL Indoor Lamps Tankless Water Heater Decreased Infiltration	15.50%	44812	1197

Table 12: Combined Energy Savings of Grouped Measures for All-Electric Base Case Building (w/o setback)

Groups		Diff. %	Electricity (kWh)
Base Case with Heat pump Heating			**75674**
GROUP 1	PV Array for Partial Demand at 16kW	29.10%	53626
GROUP 2	Solar DHW System	17.00%	62821
GROUP 3	50% Energy Star CFL Indoor Lamps Mechanical in Conditioned Space Improved SEER Decreased Static Pressure	17.10%	62720
GROUP 4	50% Energy Star CFL Indoor Lamps Decreased Duct Leakage Improved SEER Decreased Static Pressure	15.70%	63775
GROUP 5	Tankless Water Heater Reduced Duct Leakage Improved SEER Reduced Infiltration 25% Energy Star CFL Indoor Lamps Decreased SHGC & U-Value Reduced Duct Static Pressure	16.80%	62984