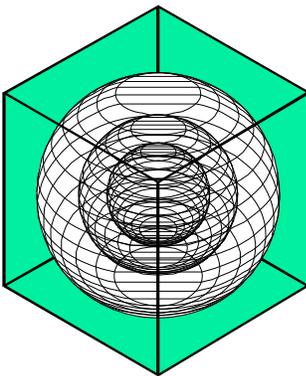


**DESCRIPTION AND COMPARISON OF THE RESULTS OF THE  
PROPOSED HOUSE: HABITAT FOR HUMANITY AT FRAZIER COURT,  
DALLAS, TEXAS, WITH THE 2004 IECC STANDARD REFERENCE  
HOUSE**

**A Report to the U.S. EPA  
through the Laboratory's Center of Excellence  
on Displaced Emission Reduction (CEDER)**

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## **Executive summary**

The Energy Systems Laboratory was requested to calculate the emissions reductions associated with the Habitat for Humanity Housing Project at Frazier Court, Dallas Texas. This report presents the results of the required analysis, a set of houses was compared to a corresponding standard reference house as described in the 2004 International Energy Conservation Code (2004 IECC). The energy consumption calculations were carried out using DOE-2.1e input file RES3ST.inp (Version 4.01.07) and DDP (Version: 1.7.03). Based on this comparison, the % above/below code for the proposed house was determined. The resultant emissions calculations were carried out using eCALC software (ESL, 2006). This report also contains detailed information about the description of the proposed house in terms of its building parameters, resultant energy consumption and emission reductions. Calculations are carried out using TMY2 weather file for Tarrant County, TX which is in climate zone 3 of the IECC 2004 climate zone categories. For the 1285 sq. ft. houses, the energy consumption of the Habitat for Humanity houses is in the range of 10.3% - 11.7% above code and for the 843 sq. ft. houses, the energy consumption is in the range of 20.9% - 21.4% below code. The HERS ratings calculated by IC3 is in the range of 71.7–74.2 for the 1285 sq. ft. houses and in the range of 79.4 – 80.6 for the 843 sq. ft. houses.

## Table of Contents

1. Organization of Report.....	5
2. Introduction.....	5
3. Base Case Building Description.....	5
4. Proposed house Description.....	6
5. Results.....	7
6. Appendix A: Blower Door and Duct Blaster Tests .....	5

**List of Tables**

Table 1: Specification for Standard Reference and Proposed Design .....	11
Table 2: Test Results.....	13
Table 3: Simulated and measured monthly energy consumption (kWh) for selected houses.....	14
Table 4: Blower door and duct blaster tests.....	19

### List of Figures

Figure 1: Comparison of monthly measured data and simulated data for four Habitat houses. ....	15
Figure 2: Comparison of monthly kWh/day consumption for measured and simulated data for four Habitat houses with variation in ambient temperature.....	16
Figure 3: Scatter plot of simulated vs. measured monthly kWh/day consumption for the four Habitat houses.....	17
Figure 4: Comparison of monthly normalized savings (kWh/day) for measured and simulated energy savings with ambient temperature for average of three Habitat houses with variation in ambient temperature. ....	18
Figure 5: Scatter plot of normalized monthly savings (kWh/day) for measured vs. simulated energy savings for average of three Habitat houses. ....	18

## **1. Organization or Report**

This report is organized in the following order. Section 2 presents the introduction and purpose of the report. Section 3 describes the base case building which is based on the 2004 IECC standard reference house. Section 4 explains the proposed house in terms of its parameters and its corresponding values. Section 5 represents the results of the simulation runs and also a breakdown of the annual energy consumption, total annual energy consumption and the sum of heating cooling and DHW consumption for HERS score calculations.

## **2. Introduction**

The study is part of the EPA's Sustainable Skylines Project. The Energy Systems Laboratory, along with Region 6 EPA, Habitat for Humanity, and the City of Dallas are partners in this effort. A number of houses belonging to the Habitat for Humanity Project were constructed at Frazier Court, in Dallas, Texas. The objectives were to understand the measures impacting energy performance in these homes, and to understand what impact the implementation of these measures would have on actual utility bills. The Energy Systems Lab was requested to perform an energy analysis of these homes. The lab was also requested to calculate the resultant emission reductions.

In the first part of the analysis, the houses were compared to a corresponding standard reference house as described in the 2004 International Energy Conservation Code (2004 IECC). Based on this comparison, the % above/below code for the proposed house is determined. The energy consumption calculations were carried out using DOE-2.1e input file RES3ST.inp (Version 4.01.07) and DDP (Version: 1.7.03). A HERS rating was also performed. In the second part of the analysis, the corresponding emission reductions for NO<sub>x</sub>, SO<sub>x</sub> and CO<sub>2</sub> were calculated. The resultant emissions calculations are carried out using eCALC software (ESL, 2006). In the third part of the analysis, the simulated energy consumption was compared to the actual energy consumption of the houses which was obtained from the utility bills.

This report gives detailed information about the description and comparison of the proposed house, with the 2004 IECC standard reference house in terms of its building parameters, resultant energy consumption, and emission reductions.

## **3. Base Case Building Description**

The 2004 IECC standard reference house is described in terms of the envelope, space conditions and systems (Table 404.5.2(1), IECC 2004). The envelope is described further, in terms of the following building components: above grade walls, ceilings, roofs, attics, doors and glazing. The above grade walls are of the wood frame type, with the gross area same as that of the proposed house, with a U-factor of 0.082, solar absorptance of 0.75 and emittance of 0.90. The ceilings are also of wood frame with the same area as that of the proposed house. The insulation is located on the ceiling, and has a U-factor of 0.035. The roof type is composition shingle on wood sheathing, with its gross area same as that of the proposed, solar absorptance of 0.75 and emittance of 0.90. The attics are vented, with 1ft<sup>2</sup> of leakage area per 300 ft<sup>2</sup> ceiling area. The doors are oriented toward the North with an area of 40 ft<sup>2</sup> and a U-factor of 0.65. The glazing for the standard reference house is 18% of conditioned floor area, and is equally distributed on four orientations (N, E, S & W). The fenestration has a U-factor of 0.65 and SHGC of 0.4. The interior shade fraction for glazing during summer (all hours when cooling is required) is set at 0.70; and during winter (all hours when heating is required) is set at 0.85. There is no external shading. The orientation of the base-case house is assumed to be the same as that for the proposed houses. For the 1285 sq. ft. house, the front faces South. For the 863 sq. ft. house, the front faces Northwest.

The space conditions are described in terms of air exchange rate, mechanical ventilation, and internal gains. The leakage of the conditioned area of the house is defined in terms of specific leakage area, which is set at 0.00048, assuming no energy recovery. The annual vent fan energy use due to the installation of mechanical ventilation can be calculated using the following equation:

$$\text{kWh/yr} = 0.03492 \times \text{CFA} + 29.565 \times (\text{N}_{\text{br}} + 1).$$

Where:

CFA = Conditioned floor area

N<sub>br</sub> = Number of bedrooms

The internal heat gains are calculated using the following equation:

$$I_{\text{gain}} = 17,900 + 23.8 \times \text{CFA} + 4104 \times \text{N}_{\text{br}} \text{ (Btu/day per dwelling unit)}$$

Where:

CFA = Conditioned floor area

N<sub>br</sub> = Number of bedrooms

The systems are described in terms of duct position, duct leakage, duct insulation, heating system, cooling system, service water heating and thermostat settings. The ducts are positioned in the attic. The duct leakage for the code house is set at 20% (10% for supply ducts and 10% for return ducts). The value of both supply duct insulation and return duct insulation is set at R-8. The heating system has heat pump

as the fuel type with efficiency of 7.7 and capacity similar to that of the proposed house. The cooling system fuel type is electric with efficiency set at SEER13 and capacity similar to that of the proposed house. The service water heating has an electric fuel type. The efficiency of this water heater is dictated by the equation provided in Table 804.2 of the IECC 2004. 804.2 of the IECC 2004.

$$\text{Energy Factor for Electric Water Heaters} = 0.93 - 0.00132V$$

Where:

V = Storage capacity of the DHW tank

Domestic hot water usage is provided by an equation in the Table 404.5.2(1) of the IECC 2004 code:

$$\text{Usage} = 30 + 10 \times N_{br} \text{ (gal/day)}$$

Where:

$N_{br}$  = Number of bedrooms

The tank temperature is set at 120°F.

The code also provides thermostat settings for the standard reference design house. The house has a manual thermostat, with cooling temperature set point of 78°F and heating temperature set point of 68°F. The specifications of the base-case house are provided in Table 1.

#### 4. Proposed House Description

Similar to the Standard Reference Design house, the proposed design is described in terms of the envelope, space conditions, and systems, with all the relevant parameters. Most of the specifications are provided by TexEnergySolutions, and are summarized in Table 1. The above-grade walls of the proposed design have a gross area as per drawings provided, and an insulation value R-13. The solar absorptance and emittance are the same as in the standard design house. The attic is sealed. The ceiling has a gross area as per drawings, with insulation on the roof. The roof has an insulation of R-20. The doors have an area of 20ft<sup>2</sup>, with orientation on the front/back and a U-factor of 0.329. The glazing has a total area and orientation as per drawings provided by TexEnergySolutions, with a U-value of 0.35 and an SHGC of 0.27 for 1285 sq. ft. house and an SHGC of 0.31 for 843 sq. ft. house. The interior shade fraction, external shading, and frame type are the same as that of the standard reference design.

Values for the internal heat gain have been adopted from the Manual J sizing calculations provided by TexEnergySolutions. The internal heat gain values for the 1285 sq. ft. house was set at 0.82 kW and for 843 sq. ft. house was set at 0.44 kW.

Mechanical ventilation has been installed in all the proposed houses. Infiltration rate values for the houses were measured and have been provided in the appendix of this report. For the 1285 sq. ft. house,

35 cfm of outside air is provided, and for the 843 sq. ft. house, 31 cfm of outside air is being provided by this installation. The installation is set to provide ventilation for 10 minutes every 30 minutes, regardless of the cooling or heating requirements of the house. The infiltration of the sealed attic is set at zero. The annual vent fan energy use is same as that of the standard reference design. The ducts are in the attic, and the values for duct leakage have been measured and are provided in the appendix. Supply duct insulation and return duct insulation are set at R-6. The heating system has heat pump with an efficiency of 8.2. The cooling system is electric and has an efficiency of SEER 14. The capacity of the system is 2.5 ton for 1285 sq. ft. house and 2 tons for the 843 sq. ft. house. The service water heating has an electric fuel type with efficiency of 0.91, the usage and tank water temperature are similar to that in the standard reference design house. The thermostat settings are same as those of the standard reference design house. The specifications for standard reference house and proposed house; and the test results are given in Table 1 and 2 respectively. The blower door and duct blasters test details are provided in Appendix 1.

**Table 1: Specification for Standard Reference and Proposed Design**

BUILDING COMPONENT	STANDARD REFERENCE HOUSE	PROPOSED HOUSE	COMMENTS
<b>Envelope</b>			
Above grade walls:	Type: Wood frame Gross Area: Same as proposed U-factor: 0.082 Solar Absorptance = 0.75 Emittance = 0.90	Type: Same as Std. Ref. Design Gross Area: As per drawings U-factor: 0.064 Solar Absorptance = 0.75 Emittance = 0.90	Improvement over standard design
Ceilings:	Type: wood frame Gross area: same as proposed U-factor: 0.035	Type: Same as Std. Ref. Design Gross area: As per drawings U-factor: Insulation on roof	Sealed attic, insulation on roof
Roofs:	Type: Composition shingle on wood sheathing Gross Area: same as proposed Solar absorptance = 0.75 Emittance = 0.90	Same as Std. Ref. Design U = 0.051	
Attics:	Type: vented with aperture = 1 ft <sup>2</sup> per 300 ft <sup>2</sup> ceiling area	Sealed Attic Infiltration = Provided in Table from TexEnergy Solutions	Sealed attic, infiltration same as that for house which is provided in the spreadsheet from TexEnergy Solutions.
Doors:	Area: 40 ft <sup>2</sup> Orientation: North U-factor: 0.65	Area: 20 ft <sup>2</sup> Orientation: Front / Back U-factor: 0.329	Improvement over standard design
Glazing:	Total area = 18% of conditioned floor area; Orientation: equally distributed to four cardinal compass orientations (N,E,S & W); U-factor: 0.65 SHGC: 0.4 Interior shade fraction: Summer (all hours when cooling is required) = 0.70; Winter(all hours when heating is required) = 0.85; External shading: none Frame: Wood	Total area: As per drawings Orientation: As per drawings U-factor: 0.35 SHGC: 0.27 / 0.31 For 1285 sqft house: 0.27 For 843 sqft house: 0.31 Interior shade fraction: Same as Std. Ref. Design External shading: Same as Std. Ref. Design Frame: Same as Std. Ref. Design	Improvement over standard design
<b>Space Conditions</b>			
Air exchange rate:	Specific Leakage Area SLA = 0.00048 assuming no energy recovery	Provided in Table from TexEnergy Solutions	
Mechanical ventilation	In case mechanical ventilation provided in proposed design, Annual vent fan energy use: kWh/yr = 0.03492 x CFA +29.565 x (Nbr +1) For 1285 sqft house = 168.91 kWh/yr For 843 sqft house = 121.93 kWh/yr	Ventilation rate: Ventilation cfm of fan + measured infiltration rate For 1285 sqft house = 35 cfm For 843 sqft house = 31 cfm Infiltration = Provided in Table from TexEnergy Solutions Annual vent fan energy use: Same as Std. Ref. Design For 1285 sqft house = 168.91 kWh/yr For 843 sqft house = 121.93 kWh/yr	
Internal gains:	Igain = 17,900 + 23.8 x CFA + 4104 x N <sub>br</sub> (Btu/day per dwelling unit)	For 1285 sqft house = 0.82 kW For 843 sqft house = 0.44 kW	
<b>Systems</b>			
Duct Position	Attic	Attic	
Duct leakage	Supply: 10% Return: 10%	Provided in Table from TexEnergy Solutions	
Duct Insulation	Supply: R-8 Return: R-8	Supply: R-6 Return: R-6	
Heating system:	Fuel type: Heat Pump Efficiency: 7.7 Capacity: 500 sqft /ton	Fuel type: Heat Pump Efficiency: 8.8 Capacity: For 1285 sqft house: 2.5 ton For 843 sqft house: 2 ton	
Cooling system:	Fuel Type: Electric Efficiency: 13 Capacity: 500 sqft /ton	Fuel Type: Electric Efficiency: 14 Capacity: For 1285 sqft house: 2.5 ton For 843 sqft house: 2 ton	
Service water heating:	Fuel Type: Electric Efficiency: 0.93 - 0.00132V (Table 804.2) Use: gal/day = 30 + 10 X N <sub>br</sub> Tank temperature: 120 F	Fuel Type: Electric Efficiency:0.91 Use: gal/day = 30 + 10 X N <sub>br</sub> Tank temperature: 120 F	
Thermostat:	Type: manual, cooling temperature set point = 78°F; heating temperature set point = 68°F	Same as Std. Ref. Design	

## 5. Results

Table 2 presents the results of the simulation runs for the two sets of houses for the first and second part of analysis. Results are provided for the base-case house for each of the two houses, followed by the simulated runs for the Habitat houses. Results are presented in terms of a breakdown of the annual energy consumption, the sum of heating cooling, and DHW consumption for HERS score calculations. Overall percentages above code are obtained, as well as HERS scores. HERS scores calculated by RemRate have also been provided.

For the 1285 sq. ft. house, the energy consumption of the habitat homes is in the range of 10.3% - 11.7% below code and for the 843 sq. ft. house, the energy consumption of the habitat houses are in the range of 20.9% - 21.4% below code. The HERS ratings calculated by IC3 is in the range of 71.7 – 74.2 for the 1285 sq. ft. house and in the range of 79.4 – 80.6 for the 843 sq. ft. house. The HERS ratings and trends obtained from the simulation results are similar to those obtained from the RemRate calculations provided by TexEnergySolutions. Total emission reductions have been calculated for all the houses being simulated. A total of 67.6lbs of NO<sub>x</sub> emission reduction, 52.7lbs of SO<sub>x</sub> emission reduction, and 54,854 lbs of CO<sub>2</sub> emission reduction were obtained.

For the third part of analysis the measured data obtained from the houses was compared to the simulated data on a monthly basis. Measured data was obtained for four houses. All the houses considered had a conditioned area of 843 sq. ft. The measurements were obtained for the time period of January 2009 to June 2010. Table 3 presents the simulated and measured monthly data for the Habitat homes. Monthly simulated data for the base-case is also presented. Figure 1 presents a comparison of the normalized monthly energy consumption for the base-case house, the simulated Habitat houses and measured data available from utility bills. Figure 2 presents the variation of the normalized monthly energy usage of the base-case, simulated and measured results of the Habitat house with the ambient temperature. Figure 3 presents the scatter plot of simulated and measured monthly energy consumption for the four houses. Figure 4 presents the variation of monthly energy savings of the base-case, simulated and measured average results of the three Habitat houses with the ambient temperature. Data from the fourth house was discarded, as it was providing outliers which were causing the measured savings to follow a different trend than the trends followed by simulated savings. Upon removing the measured data of the fourth house, the savings data for measured and simulated cases projected similar trends. Figure 5 presents the scatter plot of the simulated and measured average energy savings for the three houses.

**Table 2: Test Results**

Address	ENERGY CONSUMPTION (MBtu)									HERS Ratings				EMISSIONS REDUCTIONS From eCalc (ESL, 2006)			
	Total	Lights	Equip	Heat	Cool	Pumps & Misc	Vent Fans	DHW	% Above Code	Heat + Cool + DHW	% Above Code for Heat+ Cool+ DHW	ESL HERS	Rem-RATE HERS	Energy Savings + Transmisson Losses (kWh)	Nox (lbs)	Sox (lbs)	CO2 (lbs)
Base Case, 2004 IECC, FC3L, FC3R	49.6	9.3	13.2	6.6	6.9	0.2	2.9	10.5	0.0	24.0	0.0	100	100				
2902 Clifford Jackson Street	44.1	10.2	14.4	3.4	4.2	0.3	1.7	9.9	11.1	17.5	27.1	72.9	71	1,725	2.1	1.6	1,710
2906 Clifford Jackson Street	44.5	10.2	14.4	3.6	4.3	0.3	1.8	9.9	10.3	17.8	25.8	74.2	72	1,599	2.0	1.5	1,585
2909 Clifford Jackson Street	44.0	10.2	14.4	3.3	4.2	0.3	1.7	9.9	11.3	17.4	27.5	72.5	72	1,756	2.1	1.7	1,740
2910 Clifford Jackson Street	43.9	10.2	14.4	3.3	4.1	0.3	1.7	9.9	11.5	17.3	27.9	72.1	70	1,787	2.2	1.7	1,771
2913 Clifford Jackson Street	44.3	10.2	14.4	3.5	4.2	0.3	1.8	9.9	10.7	17.6	26.7	73.3	70	1,662	2.0	1.6	1,647
2914 Clifford Jackson Street	44.5	10.2	14.4	3.6	4.3	0.3	1.8	9.9	10.3	17.8	25.8	74.2	72	1,599	2.0	1.5	1,585
2917 Clifford Jackson Street	44.2	10.2	14.4	3.4	4.2	0.3	1.8	9.9	10.9	17.5	27.1	72.9	70	1,693	2.1	1.6	1,678
2918 Clifford Jackson Street	44.4	10.2	14.4	3.5	4.3	0.3	1.8	9.9	10.5	17.7	26.3	73.8	73	1,631	2.0	1.6	1,617
2921 Clifford Jackson Street	44.2	10.2	14.4	3.4	4.2	0.3	1.8	9.9	10.9	17.5	27.1	72.9	72	1,693	2.1	1.6	1,678
2922 Clifford Jackson Street	43.8	10.2	14.4	3.2	4.1	0.3	1.7	9.9	11.7	17.2	28.3	71.7	70	1,819	2.2	1.7	1,803
2906 Lyons Street	43.8	10.2	14.4	3.2	4.1	0.3	1.7	9.9	11.7	17.2	28.3	71.7	70	1,819	2.2	1.7	1,803
2910 Lyons Street	43.9	10.2	14.4	3.3	4.1	0.3	1.7	9.9	11.5	17.3	27.9	72.1	70	1,787	2.2	1.7	1,771
2914 Lyons Street	44.2	10.2	14.4	3.4	4.2	0.3	1.8	9.9	10.9	17.5	27.1	72.9	72	1,693	2.1	1.6	1,678
2918 Lyons Street	44.2	10.2	14.4	3.4	4.2	0.3	1.8	9.9	10.9	17.5	27.1	72.9	70	1,693	2.1	1.6	1,678
4702 Spring Avenue	44.0	10.2	14.4	3.3	4.2	0.3	1.7	9.9	11.3	17.4	27.5	72.5	71	1,756	2.1	1.7	1,740
4706 Spring Avenue	44.2	10.2	14.4	3.4	4.2	0.3	1.8	9.9	10.9	17.5	27.1	72.9	71	1,693	2.1	1.6	1,678
4714 Spring Avenue	44.2	10.2	14.4	3.4	4.2	0.3	1.8	9.9	10.9	17.5	27.1	72.9	71	1,693	2.1	1.6	1,678
4722 Spring Avenue	44.2	10.2	14.4	3.4	4.2	0.3	1.8	9.9	10.9	17.5	27.1	72.9	71	1,693	2.1	1.6	1,678
Base Case, 2004 IECC, FC2	36.9	6.9	9.9	3.8	5.1	0.2	1.9	9.1	0.0	18.0	0.0	100.0	100				
4702 Joseph Wiley Street	29.0	5.4	7.8	2.8	3.0	0.3	1.2	8.5	21.4	14.3	20.6	79.4	78	2,477	3.0	2.4	2,455
4720 Joseph Wiley Street	29.1	5.4	7.8	2.9	3.0	0.3	1.2	8.5	21.1	14.4	20.0	80.0	78	2,446	3.0	2.3	2,424
4708 Joseph Wiley Street	29.0	5.4	7.8	2.8	3.0	0.3	1.2	8.5	21.4	14.3	20.6	79.4	77	2,477	3.0	2.4	2,455
4714 Joseph Wiley Street	29.2	5.4	7.8	2.9	3.1	0.3	1.2	8.5	20.9	14.5	19.4	80.6	78	2,415	3.0	2.3	2,394
4804 Joseph Wiley Street	29.0	5.4	7.8	2.8	3.0	0.3	1.2	8.5	21.4	14.3	20.6	79.4	81	2,477	3.0	2.4	2,455
4712 Joseph Wiley Street	29.0	5.4	7.8	2.8	3.0	0.3	1.2	8.5	21.4	14.3	20.6	79.4	77	2,477	3.0	2.4	2,455
4802 Joseph Wiley Street	29.2	5.4	7.8	2.9	3.1	0.3	1.2	8.5	20.9	14.5	19.4	80.6	81	2,415	3.0	2.3	2,394
4706 Joseph Wiley Street	29.2	5.4	7.8	2.9	3.1	0.3	1.2	8.5	20.9	14.5	19.4	80.6	78	2,415	3.0	2.3	2,394
4716 Joseph Wiley Street	29.0	5.4	7.8	2.8	3.0	0.3	1.2	8.5	21.4	14.3	20.6	79.4	77	2,477	3.0	2.4	2,455
4718 Joseph Wiley Street	29.0	5.4	7.8	2.8	3.0	0.3	1.2	8.5	21.4	14.3	20.6	79.4	79	2,477	3.0	2.4	2,455
<b>TOTAL EMISSION REDUCTIONS</b>															<b>67.6</b>	<b>52.7</b>	<b>54,854</b>

**Table 3: Simulated and measured monthly energy consumption (kWh) for selected houses.**

Service Address	Month	Base-Case 2004 IECC (kWh)	Base Case Normalized (kWh/day)	Simulated Habitat House (kWh)	Simulated KWH Normalized (kWh/day)	Measured Habitat House (kWh)	Measured KWH Normalized (kWh/day)	Simulation Savings over Base-Case (kWh)	Measured Savings over Base-Case (kWh)
Joseph Wiley Street 4708	Jan	1,177.0	38.0	941.0	30.4			236.0	
	Feb	916.0	32.7	761.0	27.2	975.6	34.8	155.0	-59.6
	Mar	778.0	25.1	657.0	21.2	741.5	23.9	121.0	36.5
	Apr	683.0	22.8	551.0	18.4	537.0	17.9	132.0	146.0
	May	711.0	22.9	557.0	18.0	509.2	16.4	154.0	201.8
	Jun	891.0	29.7	654.0	21.8	713.5	23.8	237.0	177.5
	July	1,072.0	34.6	771.0	24.9	915.8	29.5	301.0	156.2
	Aug	1,104.0	35.6	798.0	25.7	877.9	28.3	306.0	226.1
	Sept	864.0	28.8	666.0	22.2	660.5	22.0	198.0	203.5
	Oct	724.0	23.4	585.0	18.9	486.6	15.7	139.0	237.4
	Nov	731.0	24.4	593.0	19.8	713.8	23.8	138.0	17.2
	Dec	1,011.0	32.6	817.0	26.4			194.0	
4712	Jan	1,177.0	38.0	940.0	30.3	893.7	28.8	237.0	283.3
	Feb	916.0	32.7	760.0	27.1	738.9	26.4	156.0	177.1
	Mar	778.0	25.1	656.0	21.2	631.1	20.4	122.0	146.9
	Apr	683.0	22.8	551.0	18.4	496.5	16.5	132.0	186.5
	May	711.0	22.9	557.0	18.0	481.2	15.5	154.0	229.8
	Jun	891.0	29.7	654.0	21.8	672.7	22.4	237.0	218.3
	July	1,072.0	34.6	771.0	24.9	982.5	31.7	301.0	89.5
	Aug	1,104.0	35.6	798.0	25.7	680.1	21.9	306.0	423.9
	Sept	864.0	28.8	666.0	22.2	400.4	13.3	198.0	463.6
	Oct	724.0	23.4	585.0	18.9	336.5	10.9	139.0	387.5
	Nov	731.0	24.4	592.0	19.7	712.8	23.8	139.0	18.2
	Dec	1,011.0	32.6	816.0	26.3			195.0	
4714	Jan	1,177.0	38.0	955.0	30.8	995.2	32.1	222.0	181.8
	Feb	916.0	32.7	770.0	27.5	895.5	32.0	146.0	20.5
	Mar	778.0	25.1	660.0	21.3	846.7	27.3	118.0	-68.7
	Apr	683.0	22.8	552.0	18.4	512.2	17.1	131.0	170.8
	May	711.0	22.9	558.0	18.0	442.7	14.3	153.0	268.3
	Jun	891.0	29.7	659.0	22.0	660.2	22.0	232.0	230.8
	July	1,072.0	34.6	777.0	25.1	847.9	27.4	295.0	224.1
	Aug	1,104.0	35.6	805.0	26.0	689.3	22.2	299.0	414.7
	Sept	864.0	28.8	667.0	22.2	462.2	15.4	197.0	401.8
	Oct	724.0	23.4	584.0	18.8	426.6	13.8	140.0	297.4
	Nov	731.0	24.4	597.0	19.9	719.5	24.0	134.0	11.5
	Dec	1,011.0	32.6	827.0	26.7			184.0	
4718	Jan	1,177.0	38.0	938.0	30.3	1,173.7	37.9	239.0	3.3
	Feb	916.0	32.7	759.0	27.1	954.2	34.1	157.0	-38.2
	Mar	778.0	25.1	656.0	21.2	768.4	24.8	122.0	9.6
	Apr	683.0	22.8	551.0	18.4	661.1	22.0	132.0	21.9
	May	711.0	22.9	557.0	18.0	851.7	27.5	154.0	-140.7
	Jun	891.0	29.7	655.0	21.8	930.8	31.0	236.0	-39.8
	July	1,072.0	34.6	772.0	24.9	934.3	30.1	300.0	137.7
	Aug	1,104.0	35.6	800.0	25.8	818.6	26.4	304.0	285.4
	Sept	864.0	28.8	668.0	22.3	887.3	29.6	196.0	-23.3
	Oct	724.0	23.4	586.0	18.9	878.3	28.3	138.0	-154.3
	Nov	731.0	24.4	591.0	19.7	953.4	31.8	140.0	-222.4
	Dec	1,011.0	32.6	814.0	26.3			197.0	
Average 3 houses	Jan	1,177.0	38.0	945.3	30.5	944.4	30.5	231.7	232.6
	Feb	916.0	32.7	763.7	27.3	870.0	31.1	152.3	46.0
	Mar	778.0	25.1	657.7	21.2	739.8	23.9	120.3	38.2
	Apr	683.0	22.8	551.3	18.4	515.2	17.2	131.7	167.8
	May	711.0	22.9	557.3	18.0	477.7	15.4	153.7	233.3
	Jun	891.0	29.7	655.7	21.9	682.1	22.7	235.3	208.9
	July	1,072.0	34.6	773.0	24.9	915.4	29.5	299.0	156.6
	Aug	1,104.0	35.6	800.3	25.8	749.1	24.2	303.7	354.9
	Sept	864.0	28.8	666.3	22.2	507.7	16.9	197.7	356.3
	Oct	724.0	23.4	584.7	18.9	416.6	13.4	139.3	307.4
	Nov	731.0	24.4	594.0	19.8	715.4	23.8	137.0	15.6
	Dec	1,011.0	32.6	820.0	26.5			191.0	

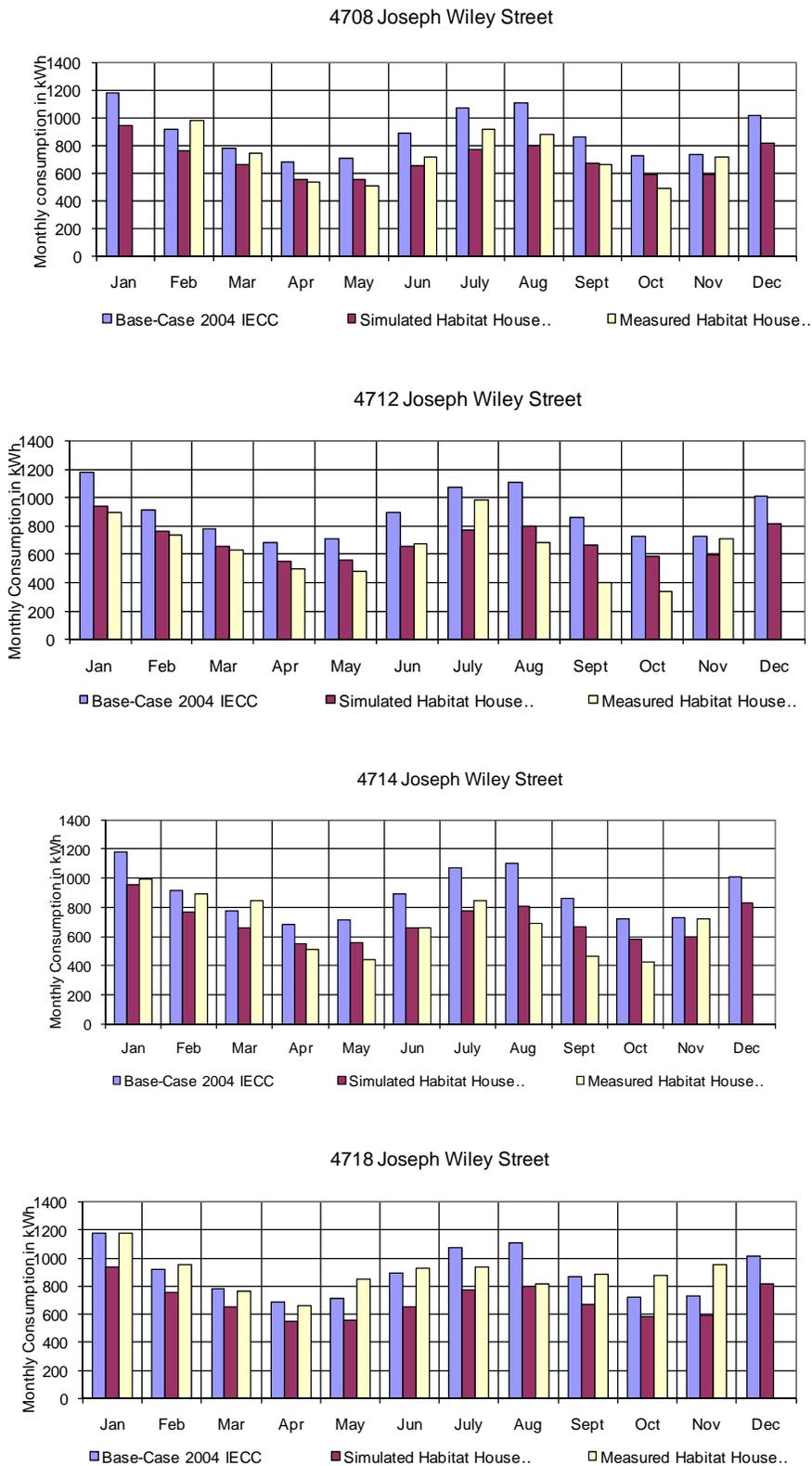
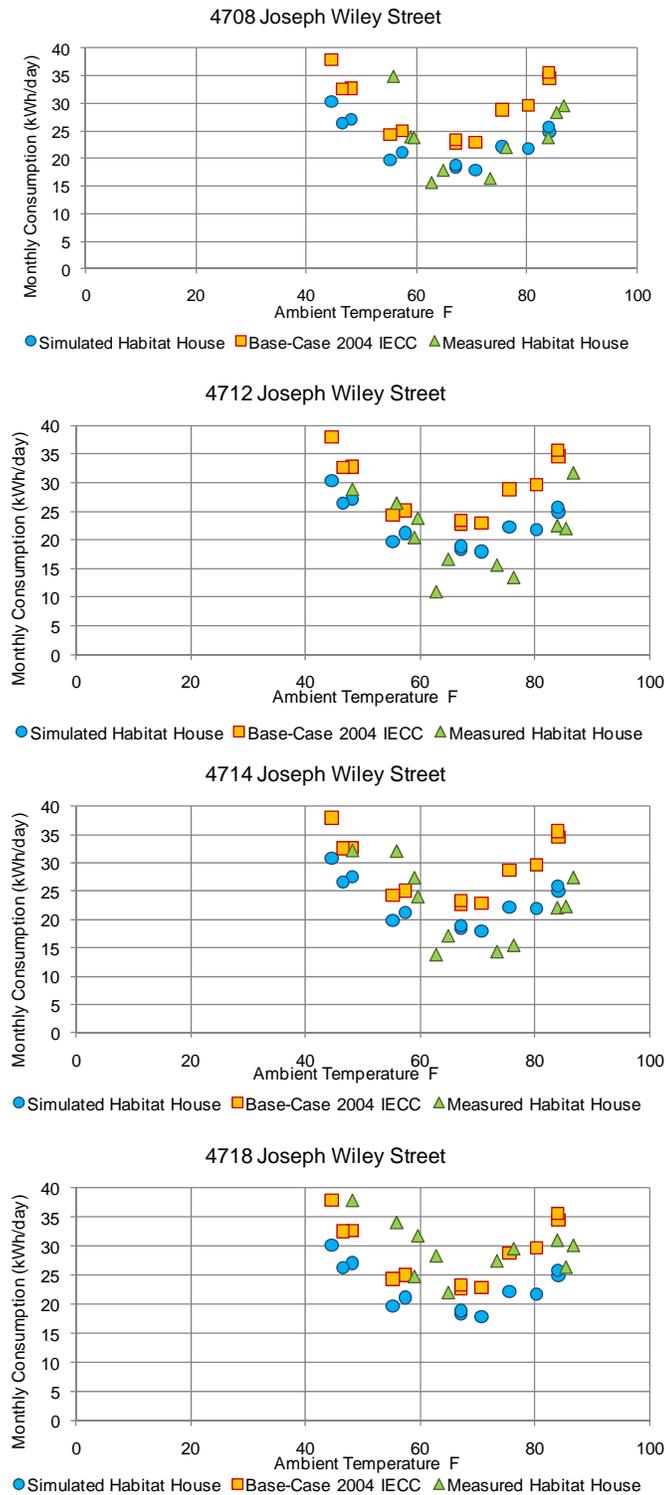


Figure 1: Comparison of monthly measured data and simulated data for four Habitat houses.



**Figure 2: Comparison of monthly kWh/day consumption for measured and simulated data for four Habitat houses with variation in ambient temperature.**

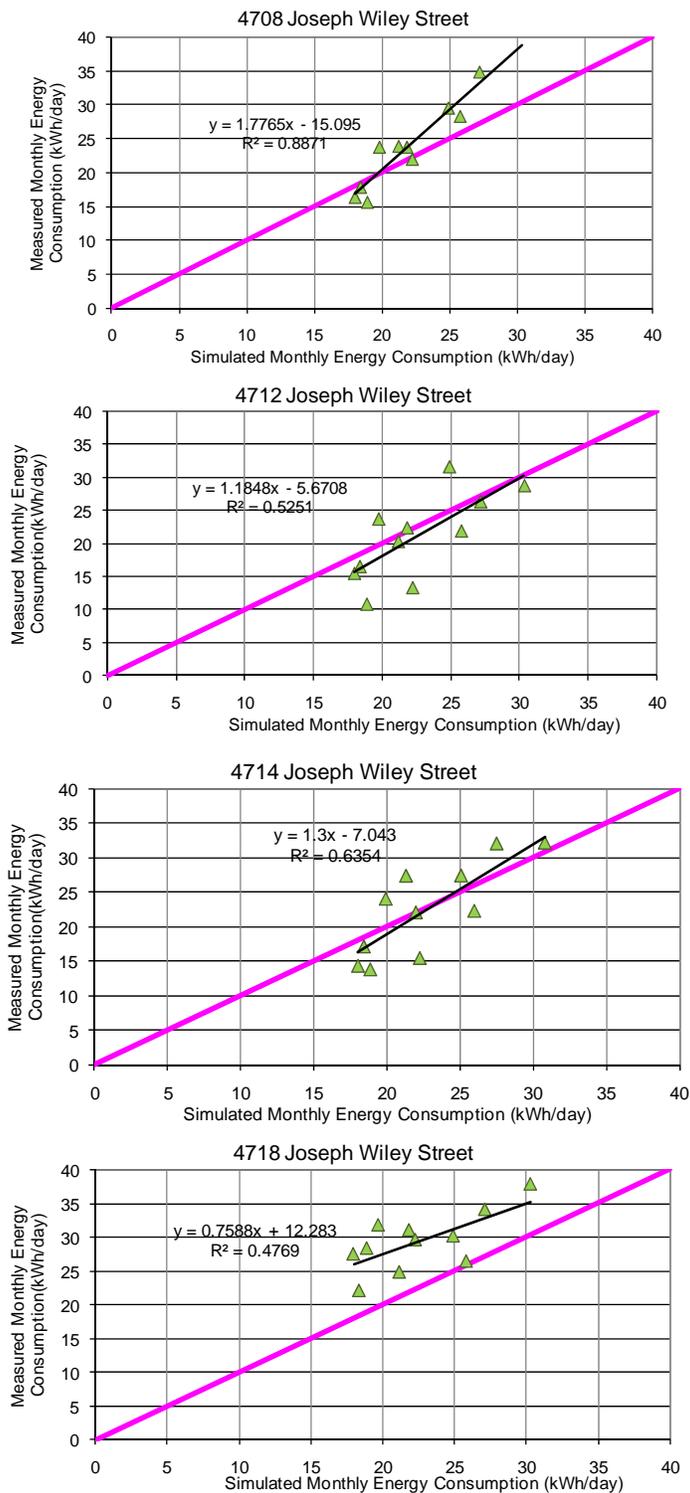
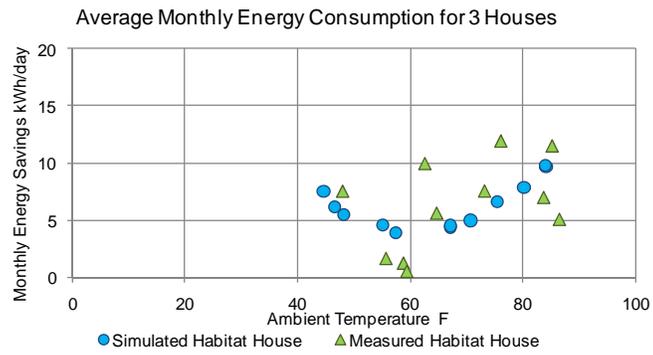
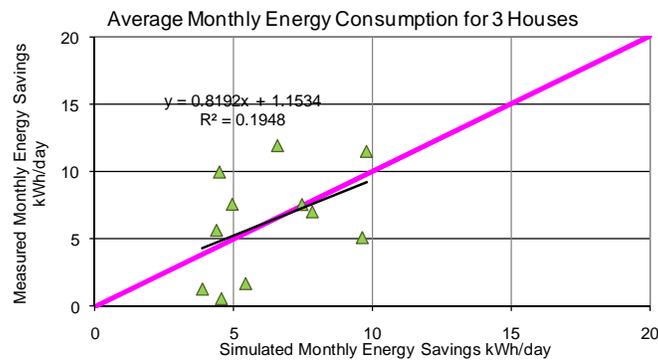


Figure 3: Scatter plot of simulated vs. measured monthly kWh/day consumption for the four Habitat houses



**Figure 4: Comparison of monthly normalized savings (kWh/day) for measured and simulated energy savings with ambient temperature for average of three Habitat houses with variation in ambient temperature.**



**Figure 5: Scatter plot of normalized monthly savings (kWh/day) for measured vs. simulated energy savings for average of three Habitat houses.**

**Appendix 1: Blower Door and Duct Blasters Test**

**Table 4: Blower door and duct blaster tests**

	Street Address	Area	No. Bed	Original HERS	Current HERS	DB1	CFM per 100sqft	BD	NACH	ACH NACH* WF	cfm from inf	Duct Leakage	Duct Leakage for Sealed Attic	cfm from Mech vent	Total cfm for the house Mech + Inf	Eqv ACH	Eqv NACH	Cond. Space SLA	Cond. Space SLA w/ Sealed Attic
1	2902 Clifford Jackson Street	1,285	3	69	71	39	3.04	650	0.17	0.15	25.62	0.02	0.0111	11.67	37.28	0.22	0.24	0.000245	0.000183385
2	2906 Clifford Jackson Street	1,285	3	70	72	45	3.50	954	0.25	0.22	37.60	0.03	0.0129	11.67	49.27	0.29	0.32	0.000323	0.000242315
3	2909 Clifford Jackson Street	1,285	3	70	72	68	5.29	474	0.12	0.11	18.68	0.04	0.0194	11.67	30.35	0.18	0.20	0.000199	0.000149267
4	2910 Clifford Jackson Street	1,285	3	69	70	27	2.10	623	0.16	0.14	24.55	0.02	0.0077	11.67	36.22	0.21	0.24	0.000238	0.000178151
5	2913 Clifford Jackson Street	1,285	3	69	70	21	1.63	841	0.22	0.19	33.15	0.01	0.0060	11.67	44.81	0.26	0.29	0.000294	0.000220410
6	2914 Clifford Jackson Street	1,285	3	70	72	59	4.59	901	0.23	0.21	35.51	0.03	0.0169	11.67	47.18	0.28	0.31	0.000309	0.000232041
7	2917 Clifford Jackson Street	1,285	3	69	70	43	3.35	680	0.18	0.16	26.80	0.02	0.0123	11.67	38.47	0.22	0.25	0.000252	0.000189200
8	2918 Clifford Jackson Street	1,285	3	71	73	67	5.21	849	0.22	0.20	33.46	0.04	0.0191	11.67	45.13	0.26	0.30	0.000296	0.000221961
9	2921 Clifford Jackson Street	1,285	3	70	72	62	4.82	644	0.17	0.15	25.38	0.04	0.0177	11.67	37.05	0.22	0.24	0.000243	0.000182222
10	2922 Clifford Jackson Street	1,285	3	68	70	26	2.02	410	0.11	0.09	16.16	0.01	0.0074	11.67	27.83	0.16	0.18	0.000182	0.000136861
11	2906 Lyons Street	1,285	3	68	70	32	2.49	370	0.10	0.09	14.58	0.02	0.0091	11.67	26.25	0.15	0.17	0.000172	0.000129107
12	2910 Lyons Street	1,285	3	69	70	32	2.49	540	0.14	0.12	21.28	0.02	0.0091	11.67	32.95	0.19	0.22	0.000216	0.000162061
13	2914 Lyons Street	1,285	3	70	72	56	4.36	740	0.19	0.17	29.17	0.03	0.0160	11.67	40.83	0.24	0.27	0.000268	0.000200831
14	2918 Lyons Street	1,285	3	69	70	39	3.04	741	0.19	0.17	29.20	0.02	0.0111	11.67	40.87	0.24	0.27	0.000268	0.000201025
15	4702 Spring Avenue	1,285	3	69	71	47	3.66	558	0.14	0.13	21.99	0.03	0.0134	11.67	33.66	0.20	0.22	0.000221	0.000165550
16	4706 Spring Avenue	1,285	3	70	71	51	3.97	684	0.18	0.16	26.96	0.03	0.0146	11.67	38.62	0.23	0.25	0.000253	0.000189976
17	4714 Spring Avenue	1,285	3	70	71	44	3.42	732	0.19	0.17	28.85	0.03	0.0126	11.67	40.52	0.24	0.27	0.000266	0.000199280
18	4722 Spring Avenue	1,285	3	69	71	43	3.35	701	0.18	0.16	27.63	0.02	0.0123	11.67	39.30	0.23	0.26	0.000258	0.000193271
1	4702 Joseph Wiley Street	843	2	77	78	37	4.36	420	0.18	0.16	17.85	0.03	0.0142	10.33	28.19	0.25	0.28	0.000282	0.000211332
2	4720 Joseph Wiley Street	843	2	77	78	20	2.36	620	0.26	0.23	26.36	0.02	0.0077	10.33	36.69	0.33	0.37	0.000367	0.000275075
3	4708 Joseph Wiley Street	843	2	76	77	15	1.77	485	0.21	0.18	20.62	0.01	0.0058	10.33	30.95	0.28	0.31	0.000309	0.000232049
4	4714 Joseph Wiley Street	843	2	77	78	14	1.65	665	0.28	0.25	28.27	0.01	0.0054	10.33	38.60	0.34	0.39	0.000386	0.000289418
5	4804 Joseph Wiley Street	843	2	80	81	15	1.77	550	0.23	0.21	23.38	0.01	0.0058	10.33	33.71	0.30	0.34	0.000337	0.000252765
6	4712 Joseph Wiley Street	843	2	76	77	19	2.24	466	0.20	0.18	19.81	0.01	0.0073	10.33	30.14	0.27	0.30	0.000301	0.000225993
7	4802 Joseph Wiley Street	843	2	80	81	19	2.24	665	0.28	0.25	28.27	0.01	0.0073	10.33	38.60	0.34	0.39	0.000386	0.000289418
8	4706 Joseph Wiley Street	843	2	77	78	19	2.24	665	0.28	0.25	28.27	0.01	0.0073	10.33	38.60	0.34	0.39	0.000386	0.000289418
9	4716 Joseph Wiley Street	843	2	76	77	14	1.65	509	0.22	0.19	21.64	0.01	0.0054	10.33	31.97	0.28	0.32	0.000320	0.000239698
10	4718 Joseph Wiley Street	843	2	78	79	37	4.36	408	0.17	0.15	17.34	0.03	0.0142	10.33	27.68	0.25	0.28	0.000277	0.000207508