ESL-TR-07-05-01

Comparative Testing of the ESL's Code-Compliant Simulation Model and the FSEC's EnergyGauge Software

A Project for
Texas' Senate Bill 5 Legislation
For Reducing Pollution
in Nonattainment and Affected Areas

Seongchan Kim, Ph.D.
Zi Liu, Ph.D.
Jeff S. Haberl, Ph.D., P.E.

Energy Systems Laboratory (ESL)
Texas A&M University System

May 2007

ENERGY SYSTEMS LABORATORY

Texas Engineering Experiment Station
Texas A&M University System

Executive Summary

This report presents a study of the comparison of the results of the ESL's code-compliant simulation model and the FSEC's EnergyGauge (version 2.42).

Sensitivity analyses were performed by varying window-to-wall ratio (WWR), SEER for the air conditioner, AFUE for the gas furnace, EF for the domestic hot water system, wall insulation level, ceiling insulation level, infiltration, SHGC, U-value, HSPF for the heat pump, and the different sizes of the house.

The results of sensitivity analyses show acceptable agreements for window-to-wall ratio (WWR), SEER for the air conditioner, AFUE for the gas furnace, EF for the domestic hot water system, wall insulation level, ceiling insulation level, infiltration, SHGC, U-value, and HSPF for the heat pump. Agreement for the different sizes of the house test could not be obtained because of the different internal heat gain.

This report includes the BDI spreadsheet (BDI-ENERGY-GAUGE.xls), GAWK scripts (ENERGYGAUGE.awk and ENERGYGAUGE.bat), DOE-2 input file (SNGFAM2ST.inp), and result spreadsheet (IECC_ENERGYGAUGE.xls) for simulations.

Table of Contents

List of Tables

Error! No table of figures entries found.

List of Figures

1. INTRODUCTION

The comparative analysis was performed using the ESL's code-compliant simulation model and the FSEC's EnergyGauge (version 2.42) by varying window-to-wall ratio (WWR), SEER for the air conditioner, AFUE for the gas furnace, energy factor (EF) for the domestic hot water system, wall insulation level, ceiling insulation level, infiltration, SHGC, U-value, HSPF for the heat pump, and the different sizes of the house. For each sensitivity test, two circumstances, i.e. with duct leakage and without duck leakage were considered in the comparison.

The following are the characteristics of the base-case house used in this comparative analysis:

- An average house size in Texas is 2,325 ft^2, 8 ft height, 4 bedrooms, single story, slab-on-grade construction, based on published characteristics from the National Association of Home Builders (NAHB), and F.W. Dodge data for the State of Texas (1999-2003).
- The house is square shaped as required by Section 402.1.3.1.1 of the 2001 IECC.
- The window area of the base-case house (2001 IECC) is 18% of the conditioned floor area as required Section 402.1.1 of the 2001 IECC.
- The ducts are in the unconditioned space (attic). The duct loss is calculated using a duct model based on ASHRAE Standard 152-2004.
- The duct insulation is R-8 for the supply and R-4 for the return, as required by Table 503.3.3.3 of the 2001 IECC.
- The duct leakage is assumed to be 10% of the total CFM.
- Thermal mass (i.e. DOE-2 Custom Weighting Factors) is used in the simulation model to account for the dynamic effect of the building materials.
- The internal loads are fixed at 3,000 Btu/hr as required by Section 402.1.3.6 of the 2001 IECC.
- The fenestration properties and wall U-factor are from Table 402.1.1 of Chapter 4 of the 2001 IECC.
- The system types are 1) electric cooling, gas heating and gas domestic hot water, and 2) electric cooling, heat pump and electric domestic hot water.
- The heating and cooling system efficiencies are according to NAECA 2006. System type is electric cooling, gas heating and gas domestic hot water (according to NAHB 1999 building survey, 80% of the single family houses built have electric cooling and gas heating). Heating (the gas furnace and the heat pump) and cooling system efficiencies are AFUE 78% for the gas furnace, HSPF 7.7 for the heat pump and SEER 13, respectively. An Energy Factor (EF) is used for the domestic hot water system efficiency according to Table 504.2 of Chapter 5 of the 2001 IECC.
- An Energy Factor (EF) is used for the domestic hot water system efficiency according to Table 504.2 of Chapter 5 of the 2001 IECC. In the case of an electric DHW, the EF is 0.93-0.00132V, and in the case of a gas-fired DHW, the EF is 0.62-0.0019V, where V is rated storage volume in gallons. It is assumed that the volume of the tank is the same as the daily hot water consumption, and the gallons are (30 x a) + (10 x b), where *a* is number of living units, and *b* is number of bedrooms from Section 402.1.3.7 of the 2001 IECC. For example, a four-bedroom

single house needs 30*1+10*4 = 70 gallons, and the EF will be 0.8376 (=0.93-0.00132*70) for the electric DHW. In the case of the gas DHW, EF is 0.62-0.0019V. For a four-bedroom house, the EF will be 0.62-0.0019*70 = 0.487.

2. SIMULATION PARAMETERS

Table 1 lists the parameters that were changed in each sensitivity test for both the ESL model and FSEC's EnergyGauge model in this analysis. Runs No. 1 to No. 49 were designed to test the sensitivity of the models assuming the duct leakage is 10%, 5% for supply and 5% for return duct system. In runs No. 1 to 5, the window to wall ratios of 10%, 20%, 27.1% (base case), 40%, and 50% were used in the simulations. In runs No. 6 to 9, the SEER rating for the air conditioning system was changed from 13 (base case) to 15, 17, and 20. In runs No. 10 to 14, the efficiency of the gas furnace was changed from 0.78 AFUE (base case) to more efficient systems of 0.82, 0.86, 0.90, and 0.95 AFUE. In runs No. 15 to 19, the energy factor (EF) of the domestic hot water systems was changed from 0.49 (base case) to 0.65, 0.75, 0.85, and 0.95. In runs No. 20 to 24, different wall insulation levels, R-11.78 (base case), R-20, R-30, R-40 and R-50, were used in the simulation. Runs No. 25 to 28 simulated the house with a ceiling insulation of R-30 (base case) and higher levels of R-40, R-50, and R-60. Runs No. 29 to No.32 simulated the house at different air exchange rate per hour, i.e., 0.2, 0.3, 0.462 (base case) and 0.6. Runs No. 33 to 36 simulated the house with different SHGC values of 0.2, 0.3, 0.4 (base case) and 0.5. In runs 37 to 40, a U-value of 0.27, 0.37, 0.47 (base case), and 0.57 was used in each simulation. In runs No. 41 to 44, four different HSPF value for the heat pump, 7.7, 8.7 (base case), 9.7 and 10.7 were used. In runs No. 45 to 49, five different house sizes were used to test the sensitivity of the model, i.e., 1000 ft^2, 2325 ft^2 (base case), 3000 ft^2, 4000 ft^2, and 5000 ft^2. For runs No. 50 to 98, the same parameter changes were made from the same 11 aspects to test the sensitivity of model assuming there is no duct leakage in the simulation.

Table 1. Simulation parameters.

Runs	W/ Duct leakage (10% total for supply and return)		Runs	W/O Duct leakage	
1	Window to Wall Ratio (%)	10	50	Window to Wall Ratio (%)	10
2		20	51		20
3		**27.1 (Base case)**	52		**27.1 (Base case)**
4		40	53		40
5		50	54		50
6	SEER	**13 (Base case)**	55	SEER	**13 (Base case)**
7		15	56		15
8		17	57		17
9		20	58		20
10	AFUE	**0.78 (Base case)**	59	AFUE	**0.78 (Base case)**
11		0.82	60		0.82
12		0.86	61		0.86
13		0.90	62		0.90
14		0.95	63		0.95
15	EF	**0.49 (Base case)**	64	EF	**0.49 (Base case)**
16		0.65	65		0.65
17		0.75	66		0.75
18		0.85	67		0.85
19		0.95	68		0.95
20	Wall insulation	**R-11.78 (Base case)**	69	Wall insulation	**R-11.78 (Base case)**
21		R-20	70		R-20
22		R-30	71		R-30
23		R-40	72		R-40

24		R-50	73		R-50
25	Ceiling insulation	**R-30 (Base case)**	74	Ceiling insulation	**R-30 (Base case)**
26		R-40	75		R-40
27		R-50	76		R-50
28		R-60	77		R-60
29	Infiltration	0.200	78	Infiltration	0.200
30		0.300	79		0.300
31		**0.462 (Base case)**	80		**0.462 (Base case)**
32		0.600	81		0.600
33	SHGC	0.20	82	SHGC	0.20
34		0.30	83		0.30
35		**0.40 (Base case)**	84		**0.40 (Base case)**
36		0.50	85		0.50
37	U-value	0.27	86	U-value	0.27
38		0.37	87		0.37
39		**0.47 (Base case)**	88		**0.47 (Base case)**
40		0.57	89		0.57
41	HSPF	6.7	90	HSPF	6.7
42		**7.7 (Base case)**	91		**7.7 (Base case)**
43		8.7	92		8.7
44		9.7	93		9.7
45	Size of the house (ft^2)	1000	94	Size of the house (ft^2)	1000
46		**2325 (Base case)**	95		**2325 (Base case)**
47		3000	96		3000
48		4000	97		4000
49		5000	98		5000

3. COMPARISONS OF THE ESL MODEL AND FSEC'S ENERGYGAUGE.

3.1 With the duct leakage

In Figure 1 to Figure 22, the results of varying the window to wall ratio (WWR), SEER for the air conditioner, AFUE for the gas furnace, EF for the domestic hot water system, wall insulation level, ceiling insulation level, infiltration, SHGC, U-value, HSPF for the heat pump, and the different sizes of the house when compared to the base case are shown for using ESL model and FSEC's EnergyGauge, respectively. It is assumed that the duck leakage is 10% of the total CFM.

Figure 1 shows the percentage difference (%) when varying window to wall ratio (WWR) from 10% to 50% versus the base case using the ESL model. Figure 2 shows the same comparisons using FSEC's EnergyGauge model. When compared to the base case where the window to wall ratio is 27.1%, the simulation results on the total annual energy use (kWh) for different window to wall ratios from the ESL model (Figure 1) show a 6.8% reduction for a 10% WWR, a 3.1% reduction for a 20% WWR, a 5.4% increase for a 40% WWR, and a 9.5% increase for a 50% WWR. EnergyGauge shows similar results with a 7.7% deduction for a 10% WWR, a 3.3% reduction for a 20% WWR, a 6.2% increase for a 40% WWR, and a 11.1% increase for a 50% WWR (Figure 2).

Figure 3 shows the percentage difference (%) when varying the SEER ratings of the air conditioning system from 13 to 20 versus the base case using the ESL model. Figure 4 shows the same comparisons using FSEC's EnergyGauge model. When compared to the base case where the SEER rating is 13, the simulation results on the total annual energy use (kWh) for different SEER ratings from the ESL model (Figure 3) show a 2.5% reduction for a 15 SEER, a 4.5% reduction for a 17 SEER, and a 6.8% reduction for a 20 SEER air conditioning system. EnergyGauge shows similar results with a 3.9% reduction for a 15 SEER, a 5.9% reduction for a 17 SEER, and a 8.2% reduction for a SEER 20 air conditioning system (Figure 4).

The comparisons of AFUE for the gas furnace (Figure 5) changing the AFUE from the base case, where the AFUE is 0.78, reveal that the total annual energy use shows a 0.5% decrease for a 0.82 AFUE, a 1.0% decrease for a 0.86 AFUE, a 1.5% decrease for a 0.90 AFUE, and a 1.9% decrease for a 0.95 AFUE from the ESL model. EnergyGauge (Figure 6) shows a 0.7% decrease for a 0.82 AFUE, a 1.2% decrease for a 0.86 AFUE, a 1.7% decrease for a 0.90 AFUE, and a 2.2% decrease for a 0.95 AFUE, which is similar to the results from the ESL model.

The comparisons of the energy factor for the domestic water heater (Figure 7) shows a 7.7% decrease on the total annual energy use for a 0.65 EF, a 10.8% decrease for a 0.75 EF, a 13.2 % decrease for a 0.85 EF, and a 15.0% decrease for a 0.95 EF from the base case (0.49 EF) using the ESL model. EnergyGauge shows similar results with a 7.2% decrease for a 0.65 EF, a 10.1% decrease for a 0.75 EF, a 12.0% decrease for a 0.85 EF, and a 13.4% decrease for a 0.95 EF from the base case (Figure 8).

For different wall insulation levels (Figure 9), the ESL model shows a 1.6% reduction for a R-20 wall insulation on the total annual energy use, a 2.3% decrease for a R-30 wall insulation, a 2.6% decrease for a R-40 insulation, and a 2.9% decrease for a R-50 insulation, as compared to the base case which is a R-11.76 wall insulation. EnergyGauge shows a similar 1.7% reduction for a R-20 wall insulation, a 2.7% decrease for a R-30 wall insulation, a 3.1% decrease for a R-40 insulation, and a 3.5% decrease for a R-50 insulation from the base case (Figure 10).

When a different ceiling insulation level (Figure 11) is applied to the base case (R-30 ceiling insulation), there is a 1.0% decrease for R-40 ceiling insulation, a 1.7% decrease for R-50 ceiling insulation, and a 2.1% decrease for R-60 ceiling insulation on the total annual energy use from the ESL model. For EnergyGauge, there is a 1.6% decrease for R-40 ceiling insulation, a 2.5% decrease for R-50 ceiling insulation, and a 3.1% decrease for R-60 ceiling insulation from the base case (Figure 12).

When the infiltration is changed from the base case, which is 0.462 air exchange per hour in the simulations (Figure 13), the ESL model shows a 4.5% decrease for a 0.2 infiltration rate, a 2.9% decrease for a 0.3 infiltration rate, and a 2.4% increase for a 0.6 infiltration rate on the total annual energy use. EnergyGauge shows a 6.6% decrease for a 0.2 infiltration rate, a 4.2% decrease for a 0.3 infiltration rate, and a 3.6% increase for a 0.6 infiltration rate from the base case (Figure 14).

Figure 15 and Figure 16 show the percentage difference (%) when varying solar heat gain coefficient (SHGC) from 0.2 to 0.5 versus the base case using the ESL model and EnergyGauge model, respectively. When compared to the base case where the SHGC is 0.4, the simulation results on the total annual energy use for different SHGC from the ESL model show a 0.9% reduction for a 0.20 SHGC, a 0.7% reduction for a 0.3 SHGC, and a 1.4% increase for a 0.5 SHGC. EnergyGauge shows a 2.2% reduction for a 0.20 SHGC and a 1.5% reduction for a 0.3 SHGC, and a 1.2% increase for a 0.5 SHGC from the base case.

The comparisons of the U-value of the window (Figure 17) shows a 3.7% decrease on the total annual energy use for a 0.27 U-value, a 1.9% decrease for a 0.37 U-value, and a 2.0 % increase for a 0.57 U-value from the base case (0.47 U-value) using the ESL model. EnergyGauge shows similar results, a 3.3% decrease on the total annual energy use for a 0.27 U-value, a 1.7% decrease for a 0.37 U-value, and a 1.8 % increase for a 0.57 U-value from the base case (Figure 18).

For different HSPF for the heat pump (Figure 19), the ESL model shows a 1.1% increase for a 6.7 HSPF on the total annual energy use, a 0.7% decrease for a 8.7 HSPF, and a 1.4% decrease for a 9.7 HSPF, as compared to the base case which is a 7.7 HSPF. EnergyGauge shows a 0.7% increase for a 6.7 HSPF, a 0.7% decrease for a 8.7 HSPF, and a 1.1% decrease for a 9.7 HSPF from the base care (Figure 20), which is similar to the ESL model.

When a different house size (Figure 21) is applied to the base case (2325 sq.ft.), there is a 16.8% decrease for a size of 1000 sq.ft., a 8.4% increase for a size of 3000 sq.ft., a 20.9% increase for a size of 1000 sq.ft , and a 33.4% increase for a size of 5000 sq.ft. on the total annual energy use from the ESL model. For EnergyGauge, there is a 28.7% decrease for a size of 1000 sq.ft., a 14.4% increase for a size of 3000 sq.ft., a 35.6% increase for a size of 1000 sq.ft , and a 56.6% increase for a size of 5000 sq.ft. from the base case (Figure 22). The simulations of house size variations show significant differences between the ESL model and EnergyGauge because of the different internal heat gain used in the two models.

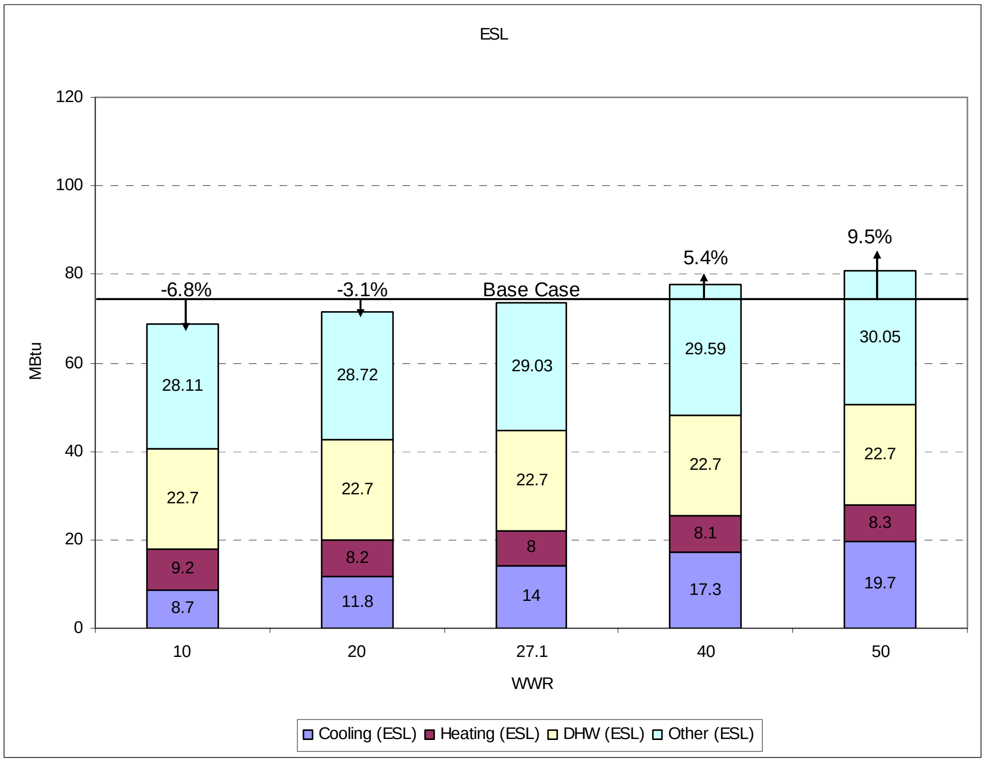

Figure 1. Window to Wall ratio (ESL) with the duct leakage.

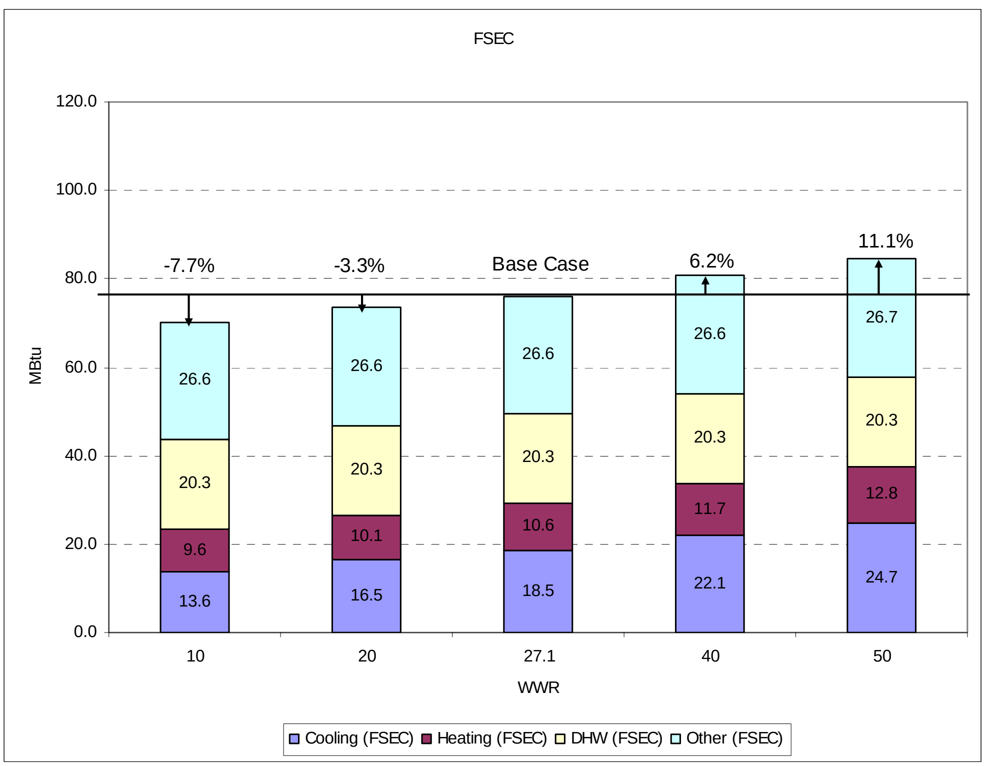

Figure 2. Window to Wall ratio (FSEC) with the duct leakage.

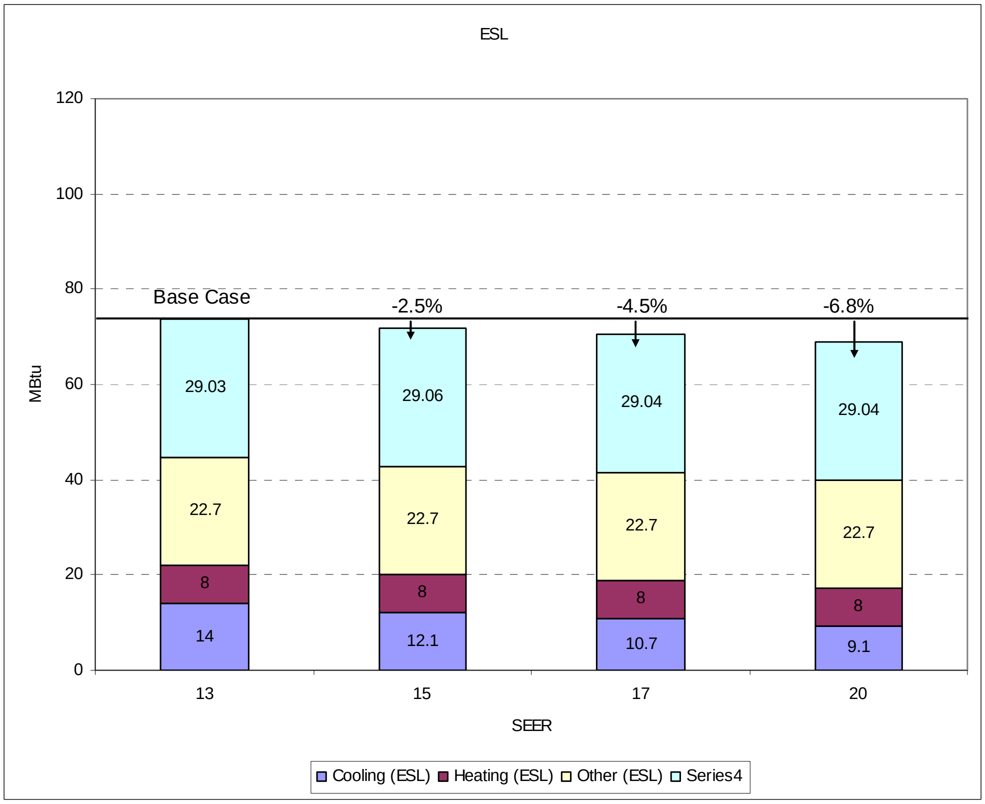

Figure 3. SEER (ESL) with the duct leakage.

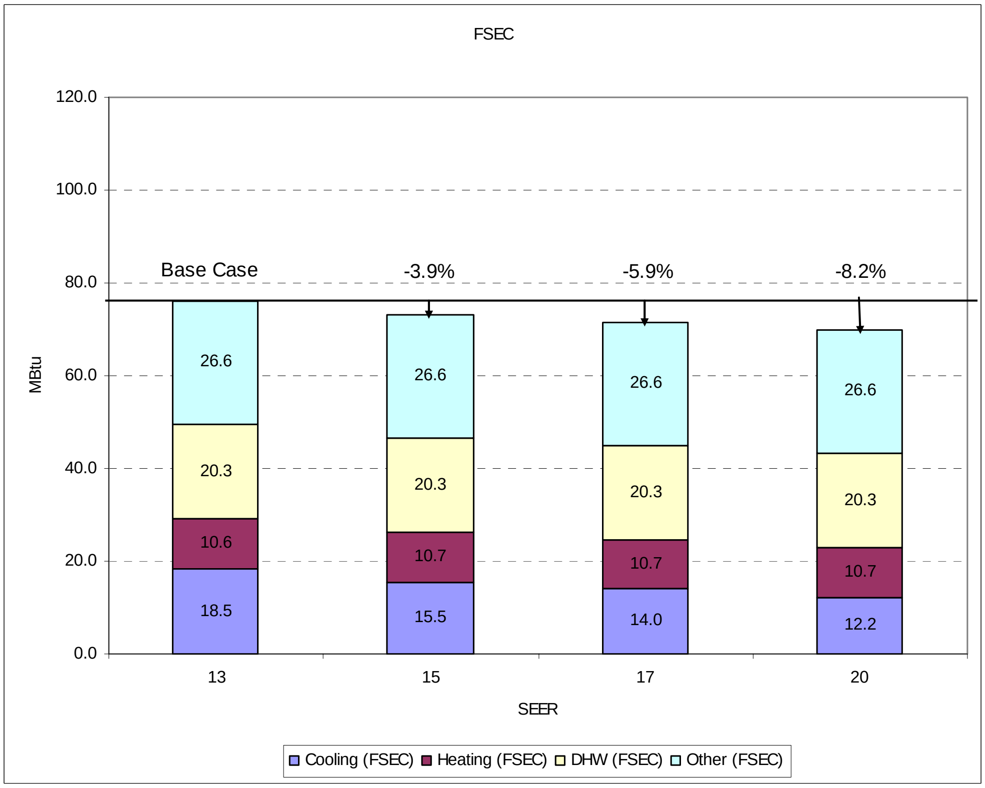

Figure 4. SEER (FSEC) with the duct leakage.

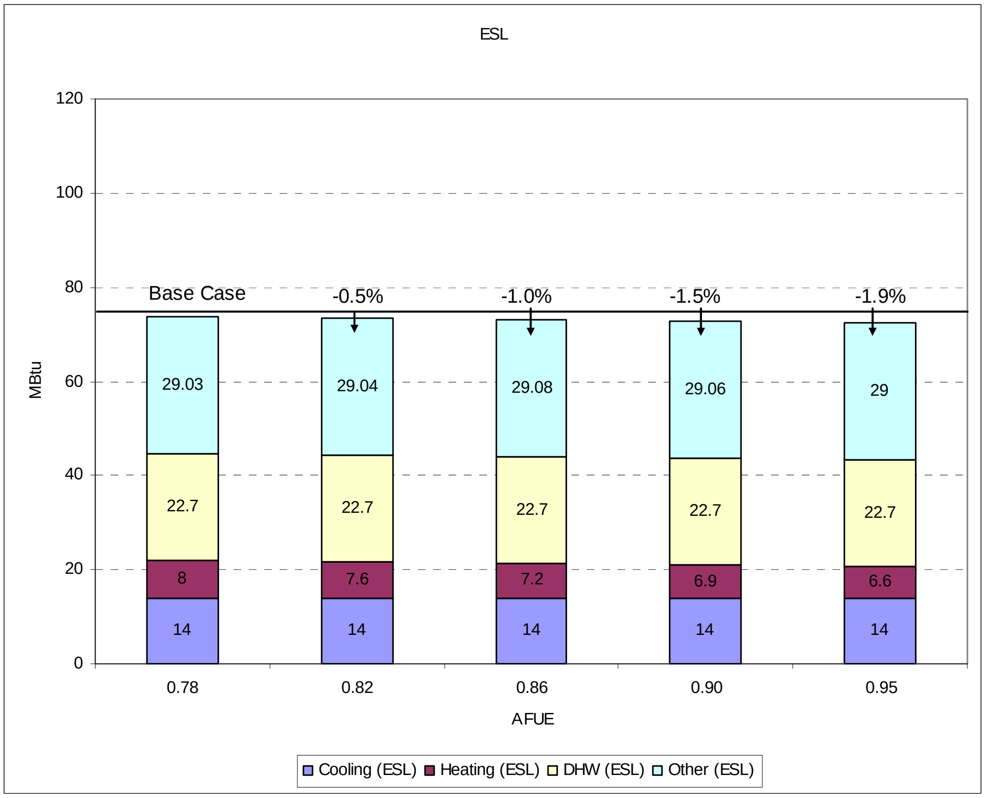

Figure 5. AFUE (ESL) with the duct leakage.

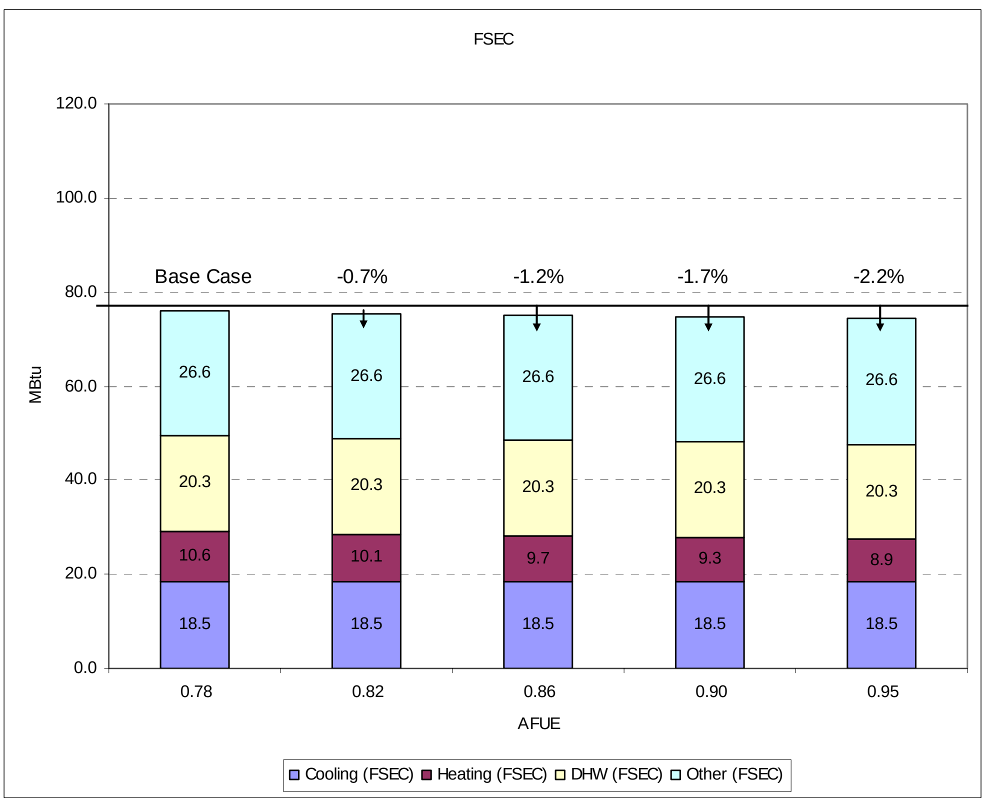

Figure 6. AFUE (FSEC) with the duct leakage.

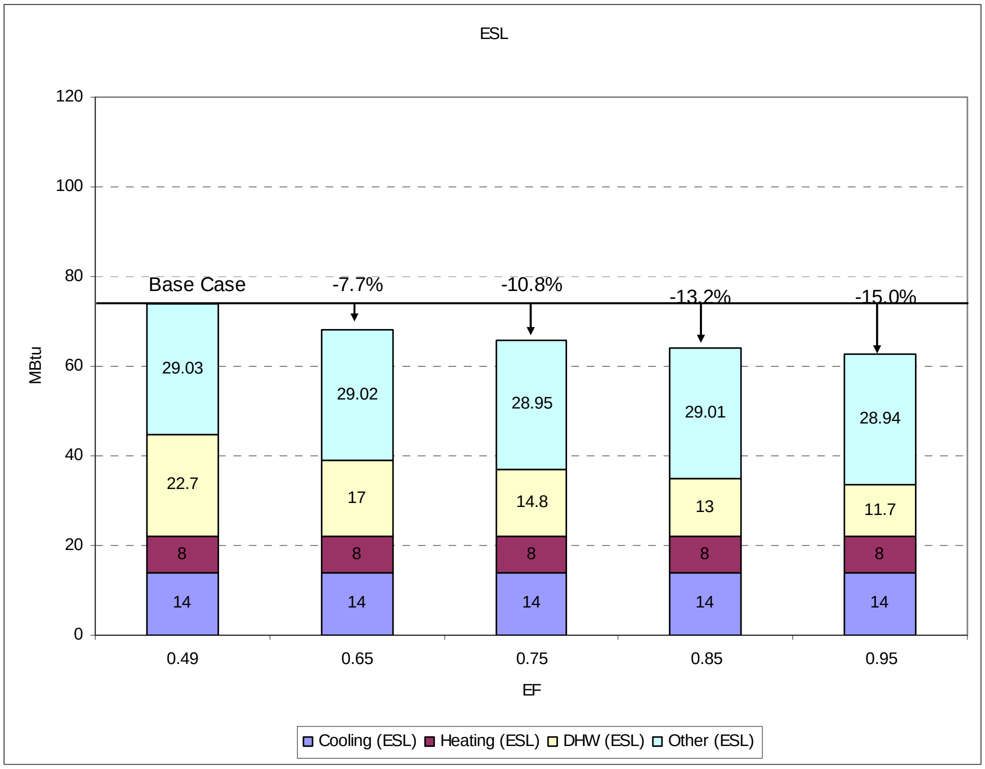

Figure 7. Energy Factor (EF) (ESL) with the duct leakage.

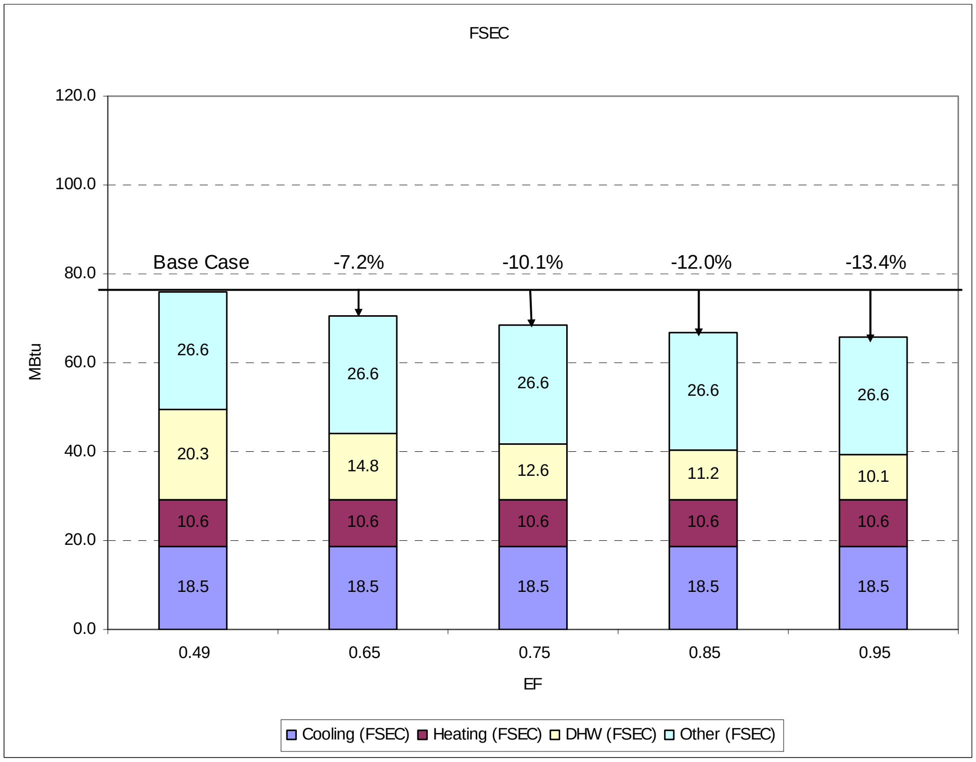

Figure 8. Energy Factor (EF) (FSEC) with the duct leakage.

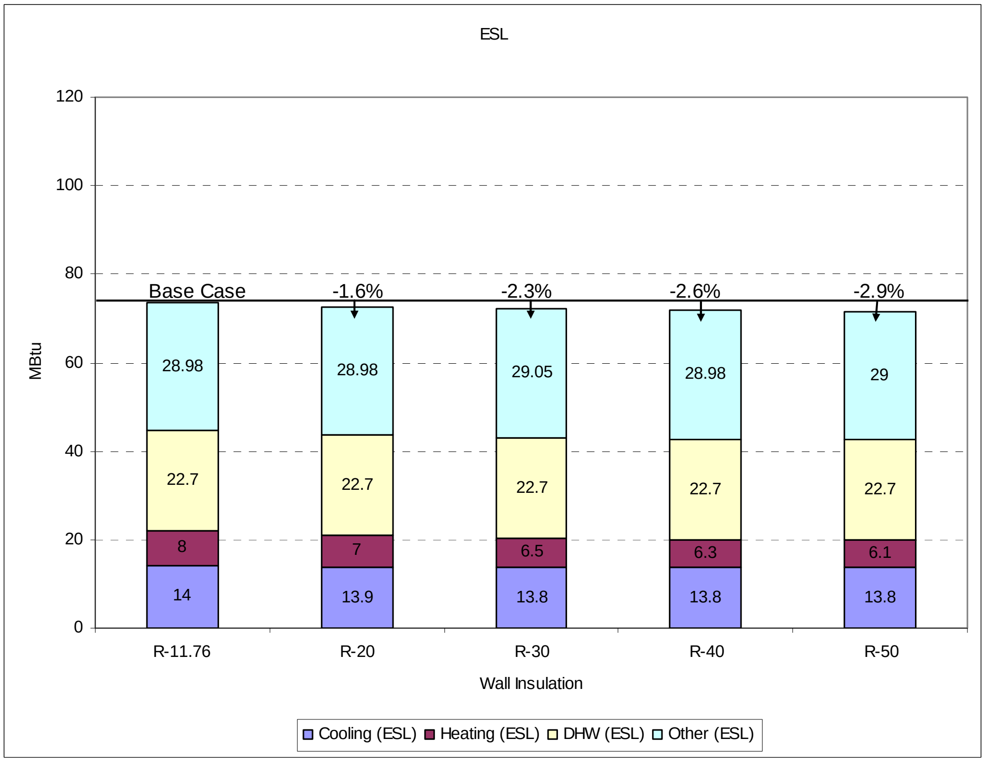

Figure 9. Wall insulation (ESL) with the duct leakage.

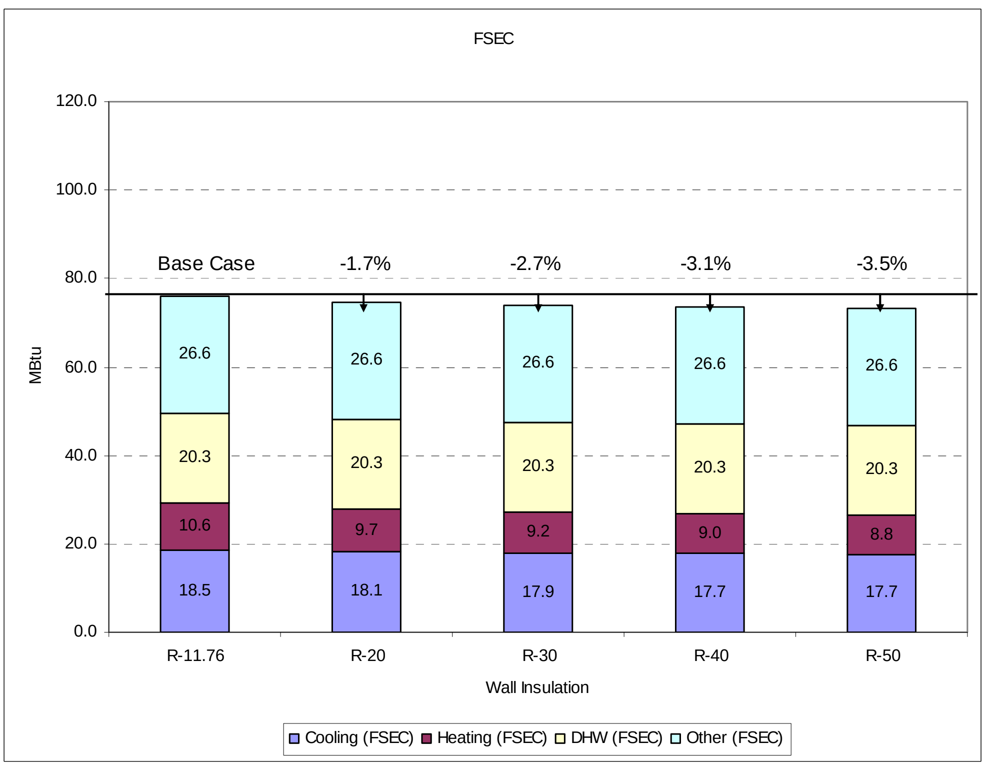

Figure 10. Wall insulation (FSEC) with the duct leakage.

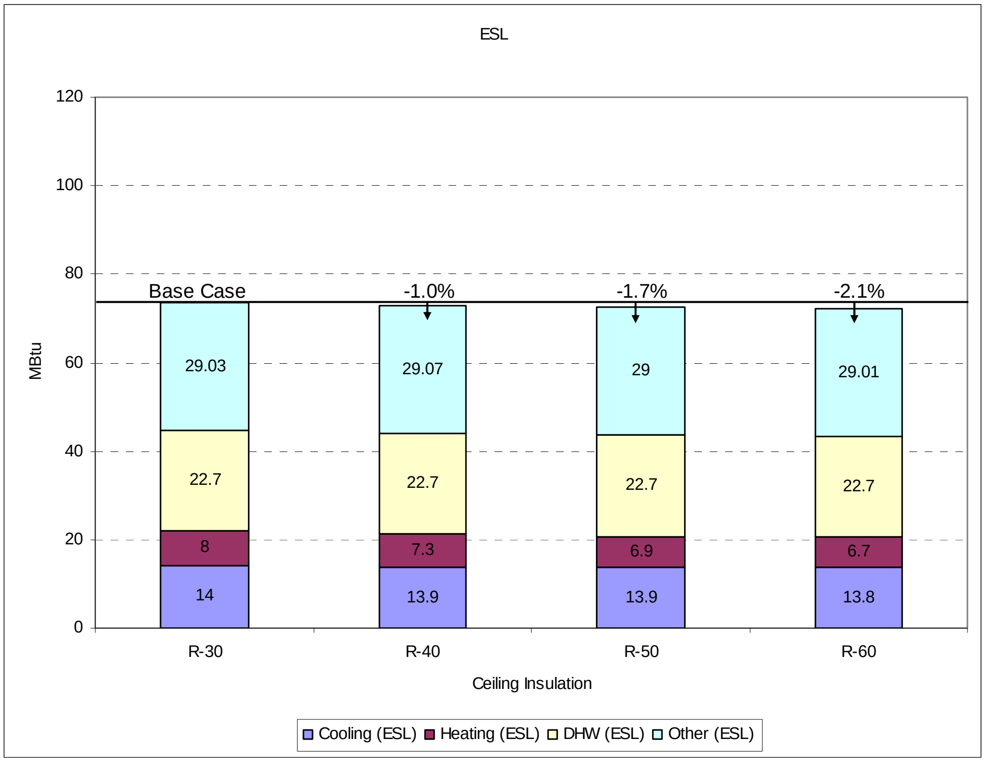

Figure 11. Ceiling insulation (ESL) with the duct leakage.

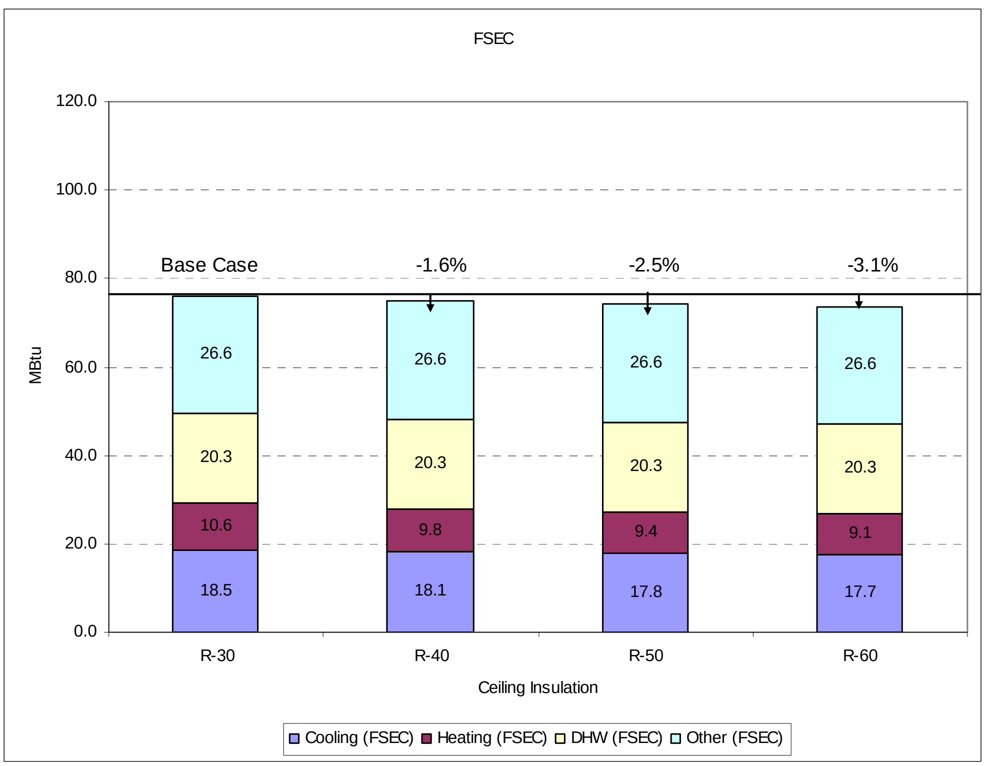

Figure 12. Ceiling insulation (FSEC) with the duct leakage.

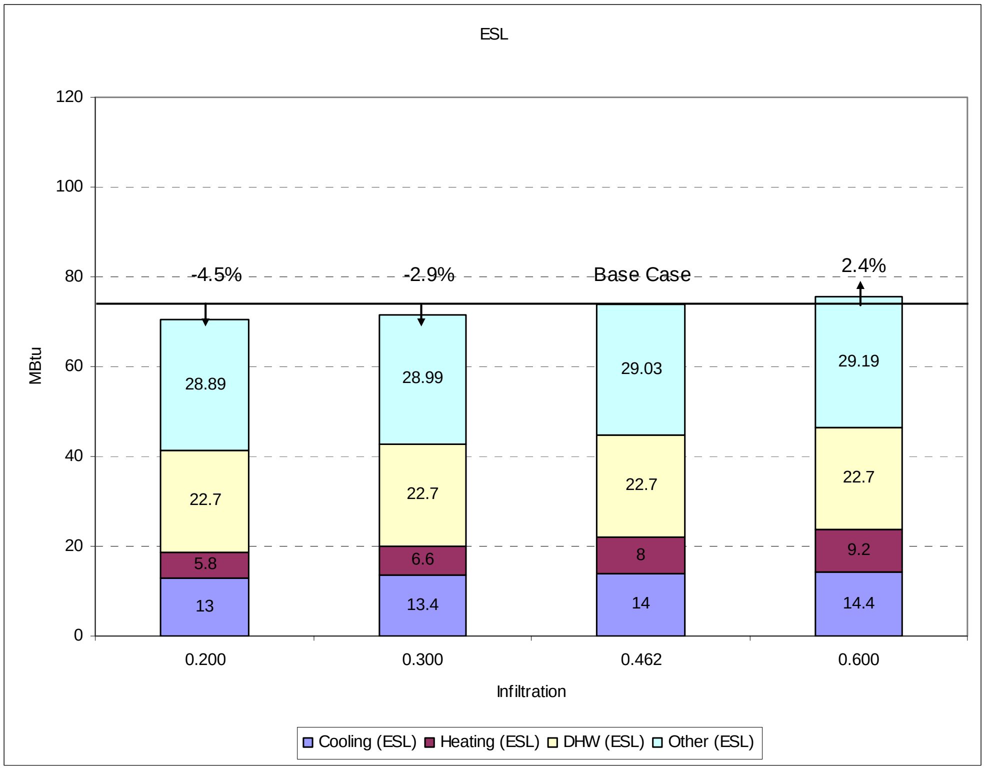

Figure 13. Infiltration (ESL) with the duct leakage.

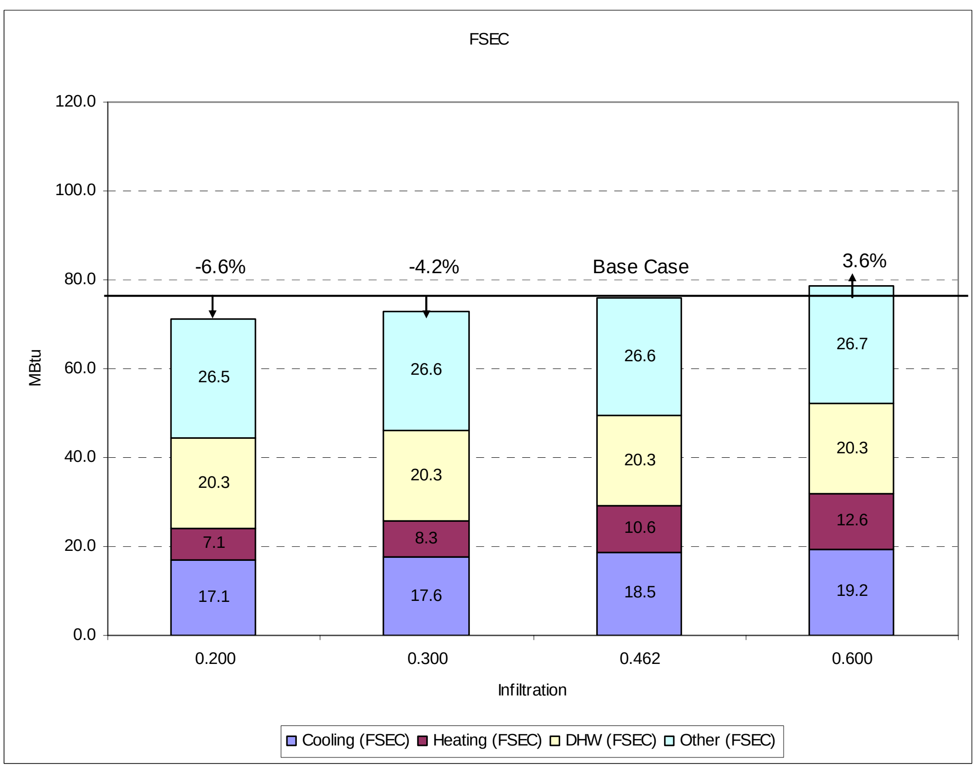

Figure 14. Infiltration (FSEC) with the duct leakage.

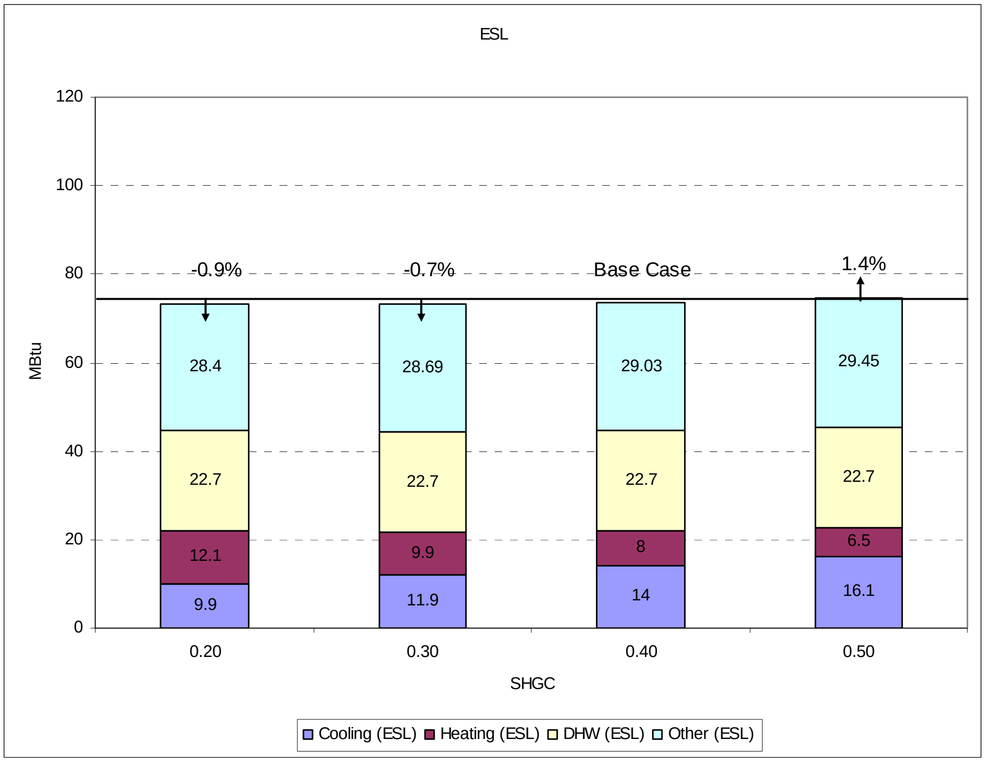

Figure 15. SHGC (ESL) with the duct leakage.

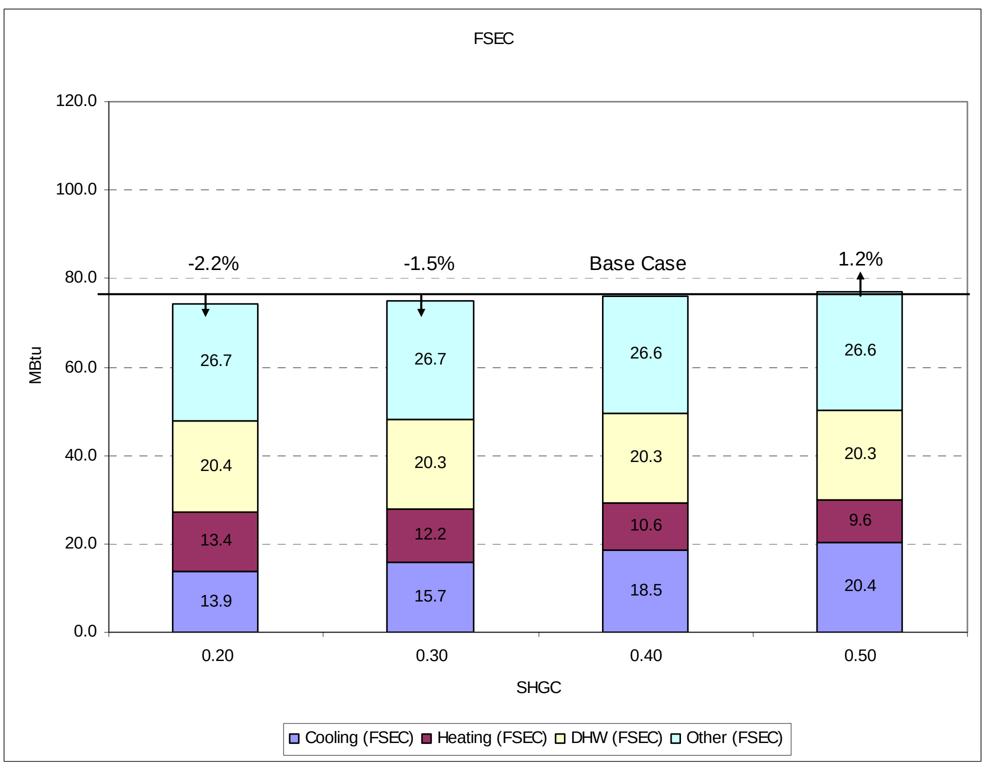

Figure 16. SHGC (FSEC) with the duct leakage.

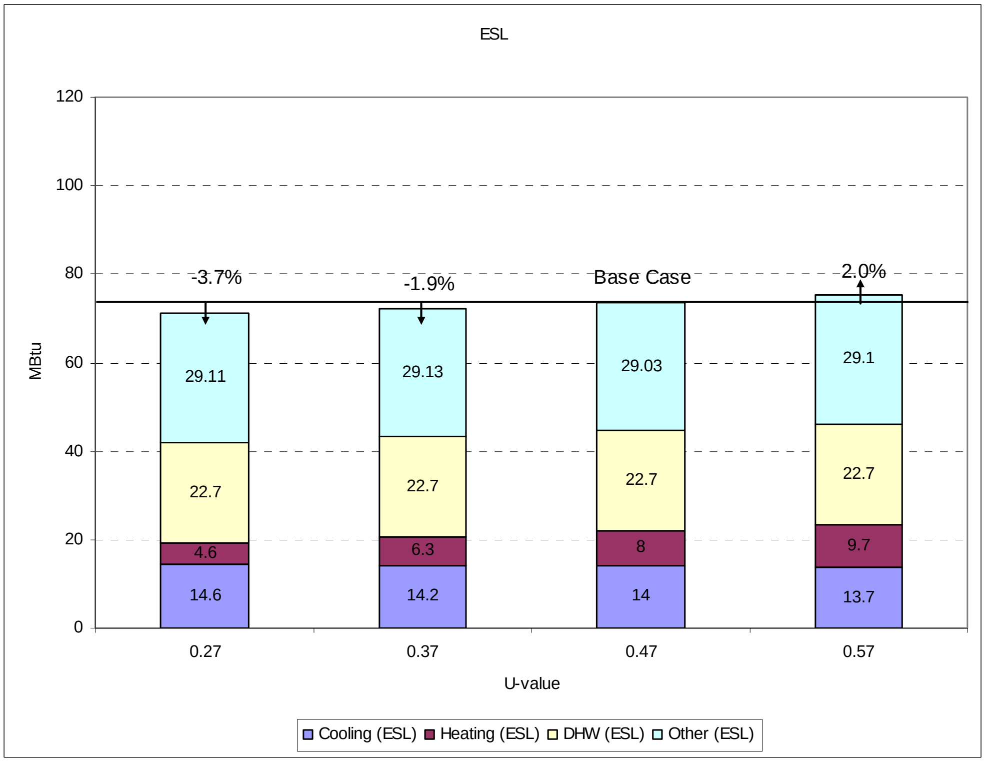

Figure 17. U-value (ESL) with the duct leakage.

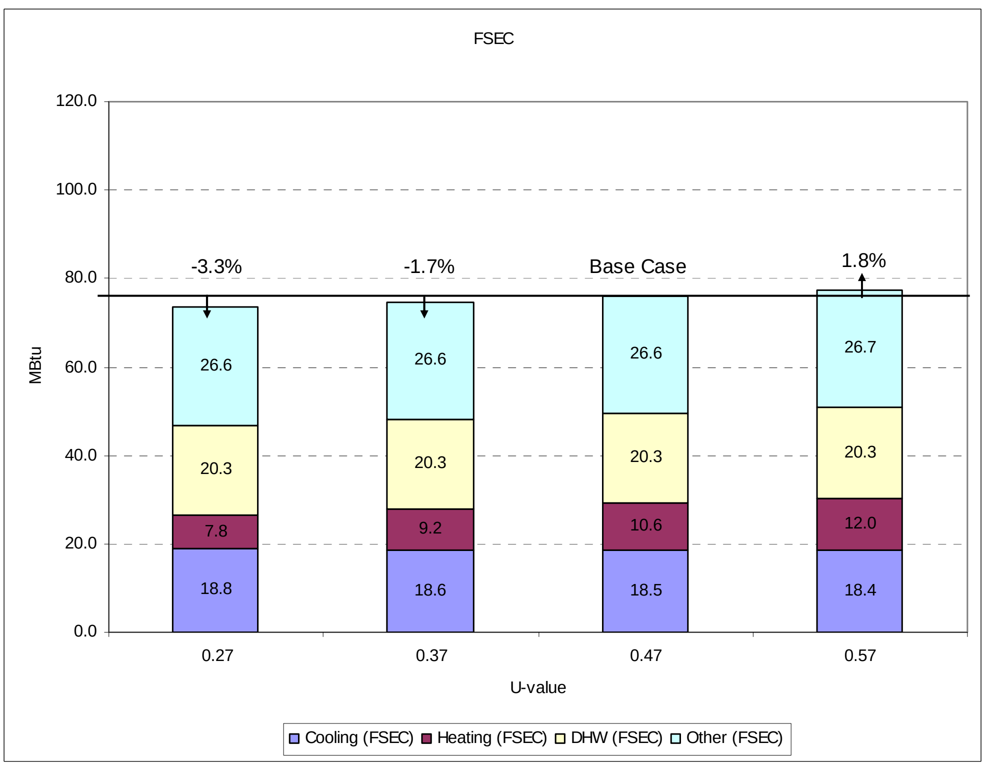

Figure 18. U-value (FSEC) with the duct leakage.

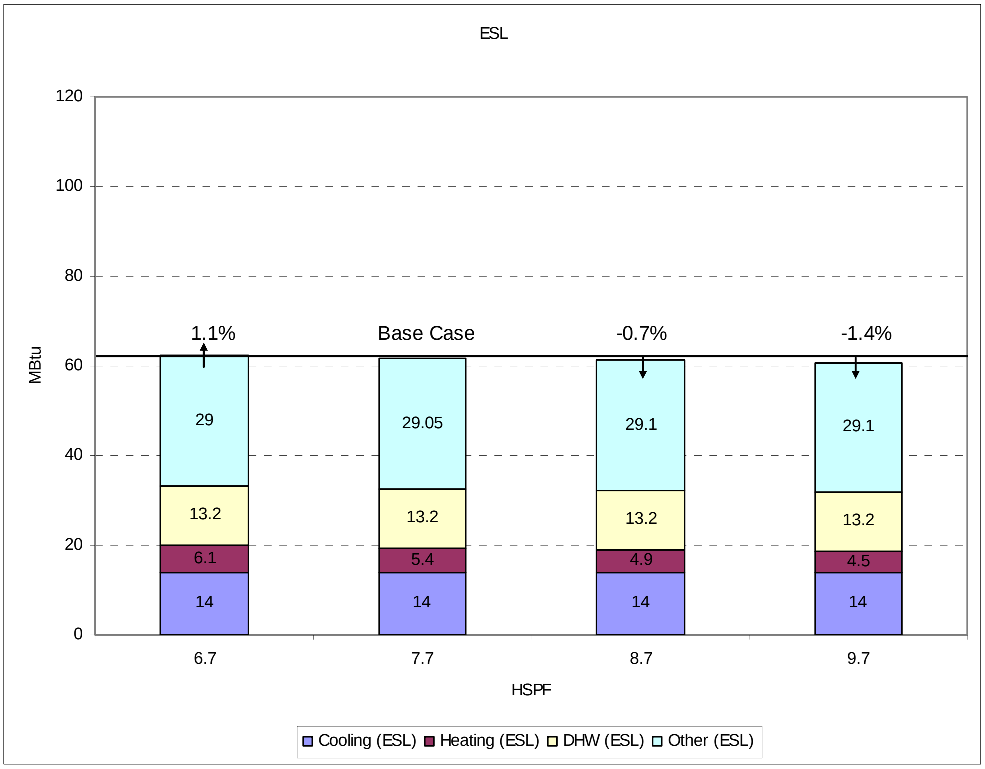

Figure 19. HSPF (ESL) with the duct leakage.

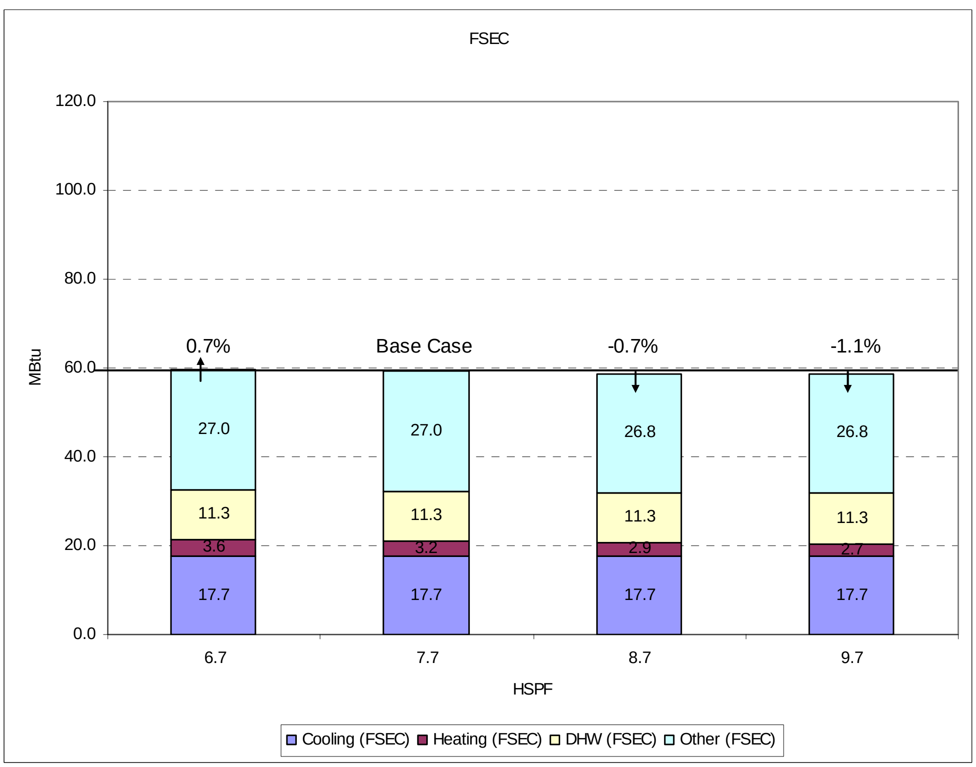

Figure 20. HSPF (FSEC) with the duct leakage.

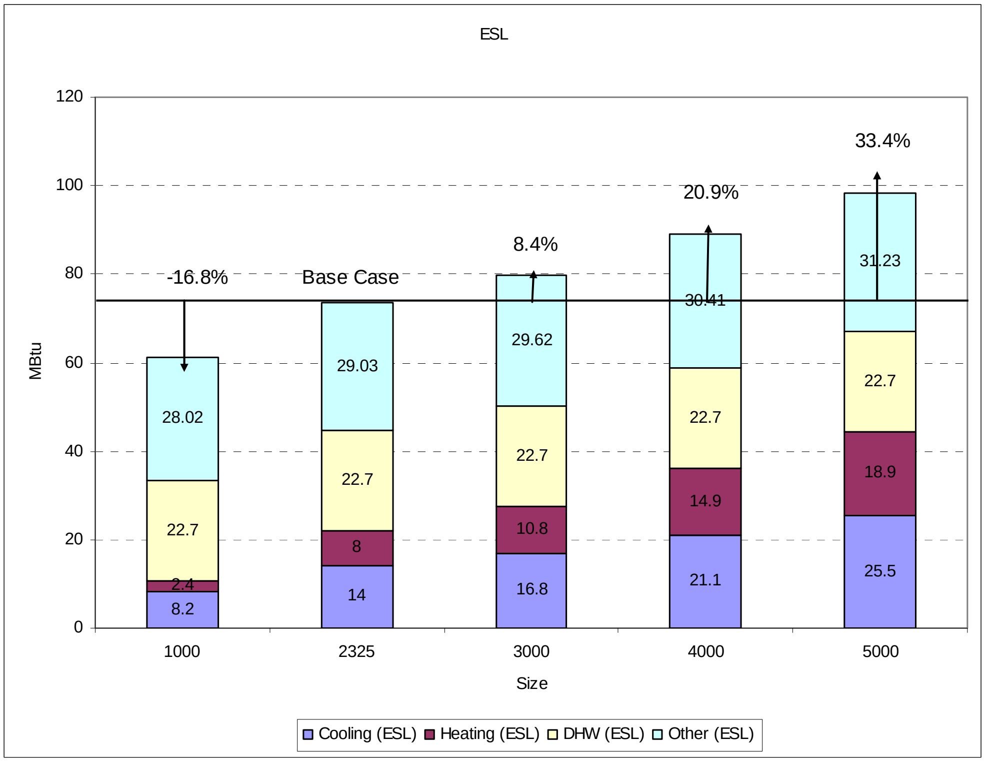

Figure 21. Size of the house (ft^2) (ESL) with the duct leakage.

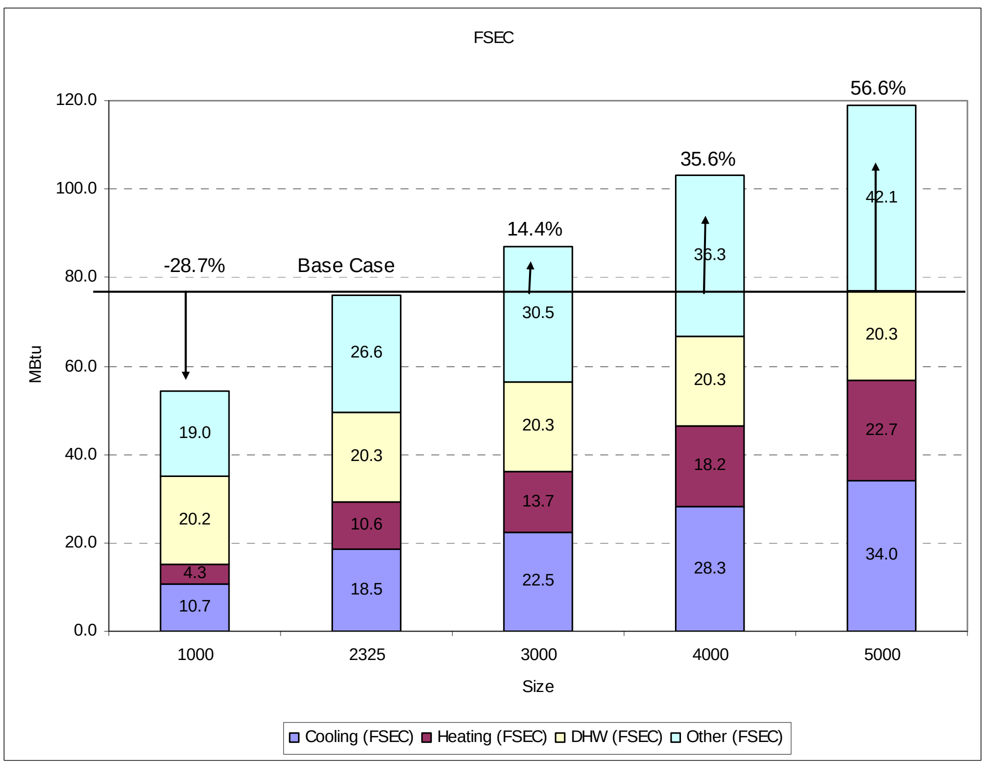

Figure 22. Size of the house (ft^2) (FSEC) with the duct leakage.

3.2 Without the duct leakage

In Figure 23 to Figure **44**, the same comparisons were made between the ESL model and FSEC's EnergyGauge assuming there is no duct leakage in the simulations.

Figure 23 shows the percentage difference (%) when varying window to wall ratio (WWR) from 10% to 50% versus the base case using the ESL model. Figure 24 shows the same comparisons using FSEC's EnergyGauge model. When compared to the base case where the window to wall ratio is 27.1%, the simulation results on the total annual energy use (kWh) for different window to wall ratios from the ESL model (Figure 23) show a 6.2% reduction for a 10% WWR, a 2.9% reduction for a 20% WWR, a 5.0% increase for a 40% WWR, and a 8.8% increase for a 50% WWR. EnergyGauge shows similar results with a 7.2% deduction for a 10% WWR, a 3.0% reduction for a 20% WWR, a 5.8% increase for a 40% WWR, and a 10.4% increase for a 50% WWR (Figure 24).

Figure 25 shows the percentage difference (%) when varying the SEER ratings of the air conditioning system from 13 to 20 versus the base case using the ESL model. Figure 26 shows the same comparisons using FSEC's EnergyGauge model. When compared to the base case where the SEER rating is 13, the simulation results on the total annual energy use (kWh) for different SEER ratings from the ESL model (Figure 25) show a 2.3% reduction for a 15 SEER, a 4.0% reduction for a 17 SEER, and a 5.9% reduction for a 20 SEER air conditioning system. EnergyGauge shows similar results with a 3.7% reduction for a 15 SEER, a 5.5% reduction for a 17 SEER, and a 7.7% reduction for a SEER 20 air conditioning system (Figure 26).

The comparisons of AFUE for the gas furnace (Figure 27) changing the AFUE from the base case, where the AFUE is 0.78, reveal that the total annual energy use shows a 0.5% decrease for a 0.82 AFUE, a 0.9% decrease for a 0.86 AFUE, a 1.4% decrease for a 0.90 AFUE, and a 1.8% decrease for a 0.95 AFUE from the ESL model. EnergyGauge (Figure 28) shows a 0.5% decrease for a 0.82 AFUE, a 1.1% decrease for a 0.86 AFUE, a 1.6% decrease for a 0.90 AFUE, and a 2.2% decrease for a 0.95 AFUE, which is similar to the results from the ESL model.

The comparisons of the energy factor for the domestic water heater (Figure 29) shows a 8.0% decrease on the total annual energy use for a 0.65 EF, a 11.2% decrease for a 0.75 EF, a 13.7 % decrease for a 0.85 EF, and a 15.6% decrease for a 0.95 EF from the base case (0.49 EF) using the ESL model. EnergyGauge shows similar results with a 7.5% decrease for a 0.65 EF, a 10.5% decrease for a 0.75 EF, a 12.4% decrease for a 0.85 EF, and a 13.9% decrease for a 0.95 EF from the base case (Figure 30).

For different wall insulation levels (Figure 31), the ESL model shows a 1.5% reduction for a R-20 wall insulation on the total annual energy use, a 2.1% decrease for a R-30 wall insulation, a 2.5% decrease for a R-40 insulation, and a 2.7% decrease for a R-50 insulation, as compared to the base case which is a R-11.76 wall insulation. EnergyGauge shows similar results with a 1.6% reduction for a R-20 wall insulation, a

2.4% decrease for a R-30 wall insulation, a 2.9% decrease for a R-40 insulation, and a 3.2% decrease for a R-50 insulation from the base case (Figure 32).

When a different ceiling insulation level (Figure 33) is applied to the base case (R-30 ceiling insulation), there is a 1.0% decrease for R-40 ceiling insulation, a 1.5% decrease for R-50 ceiling insulation, and a 1.9% decrease for R-60 ceiling insulation on the total annual energy use from the ESL model. For EnergyGauge, there is a 1.5% decrease for R-40 ceiling insulation, a 2.3% decrease for R-50 ceiling insulation, and a 2.9% decrease for R-60 ceiling insulation from the base case (Figure 34).

When the infiltration is changed from the base case, which is 0.462 air exchange per hour in the simulations (Figure 35), the ESL model shows a 4.2% decrease for a 0.2 infiltration rate, a 2.6% decrease for a 0.3 infiltration rate, and a 2.2% increase for a 0.6 infiltration rate on the total annual energy use. EnergyGauge shows a 6.4% decrease for a 0.2 infiltration rate, a 4.0% decrease for a 0.3 infiltration rate, and a 3.5% increase for a 0.6 infiltration rate from the base case (Figure 36).

Figure 37 and Figure 38 show the percentage difference (%) when varying solar heat gain coefficient (SHGC) from 0.2 to 0.5 versus the base case using the ESL model and EnergyGauge model, respectively. When compared to the base case where the SHGC is 0.4, the simulation results on the total annual energy use for different SHGC from the ESL model show a 0.7% reduction for a 0.20 SHGC, a 0.6% reduction for a 0.3 SHGC, and a 1.3% increase for a 0.5 SHGC. EnergyGauge shows similar results with a 1.2% reduction for a 0.20 SHGC and a 0.7% reduction for a 0.3 SHGC, and a 1.1% increase for a 0.5 SHGC from the base case.

The comparisons of the U-value of the window (Figure 39) shows a 3.4% decrease on the total annual energy use for a 0.27 U-value, a 1.8% decrease for a 0.37 U-value, and a 1.9 % increase for a 0.57 U-value from the base case (0.47 U-value) using the ESL model. EnergyGauge shows similar results, a 3.2% decrease on the total annual energy use for a 0.27 U-value, a 1.6% decrease for a 0.37 U-value, and a 1.7 % increase for a 0.57 U-value from the base case (Figure 40).

For different HSPF for the heat pump (Figure 41), the ESL model shows a 1.0% increase for a 6.7 HSPF on the total annual energy use, a 0.8% decrease for a 8.7 HSPF, and a 1.3% decrease for a 9.7 HSPF, as compared to the base case which is a 7.7 HSPF. EnergyGauge shows a 0.6% increase for a 6.7 HSPF, a 0.6% decrease for a 8.7 HSPF, and a 1.0% decrease for a 9.7 HSPF from the base care (Figure 42), which is similar to the ESL model.

When a different house size (Figure 43) is applied to the base case (2325 sq.ft.), there is a 15.6% decrease for a size of 1000 sq.ft., a 7.8% increase for a size of 3000 sq.ft., a 19.4% increase for a size of 1000 sq.ft , and a 31.0% increase for a size of 5000 sq.ft. on the total annual energy use from the ESL model. For EnergyGauge, there is a 28.0% decrease for a size of 1000 sq.ft., a 14.1% increase for a size of 3000 sq.ft., a 34.9% increase for a size of 1000 sq.ft , and a 55.3% increase for a size of 5000 sq.ft. from the base case (Figure 44). The simulations of house size variations show significant differences between the ESL model and EnergyGauge because of the different internal heat gain used in the two models.

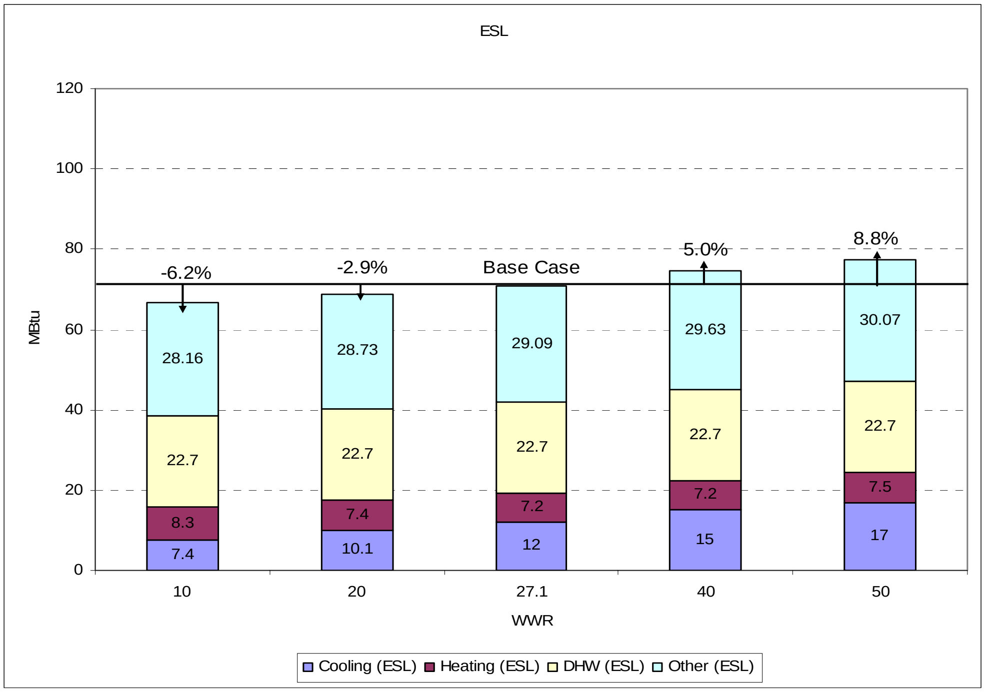

Figure 23. Window to Wall ratio (ESL) without the duct leakage.

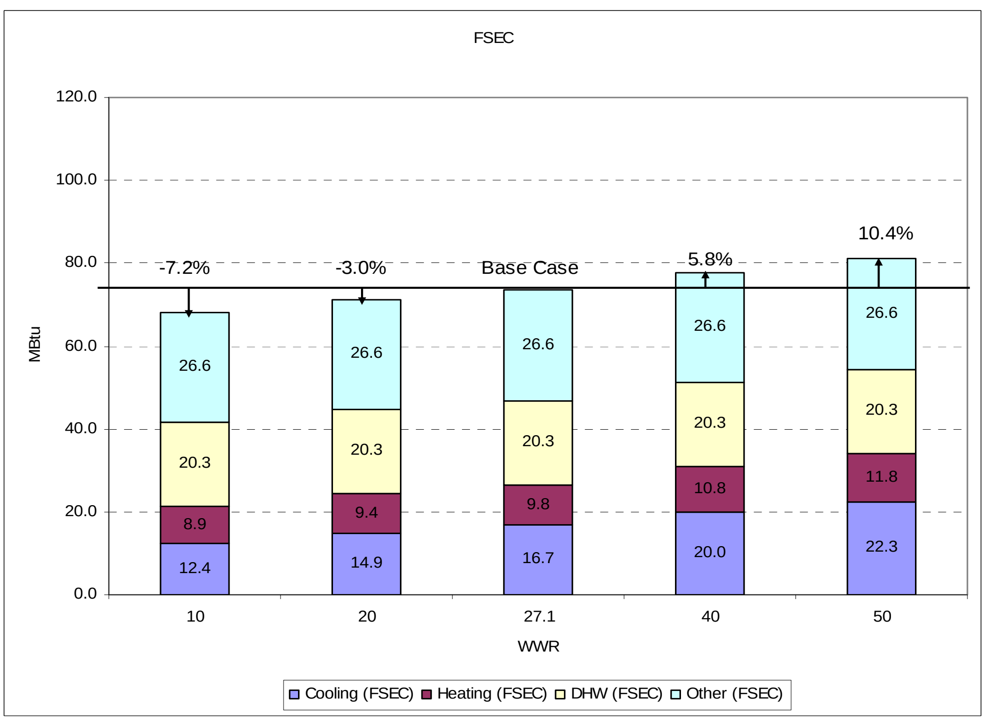

Figure 24. Window to Wall ratio (FSEC) without the duct leakage.

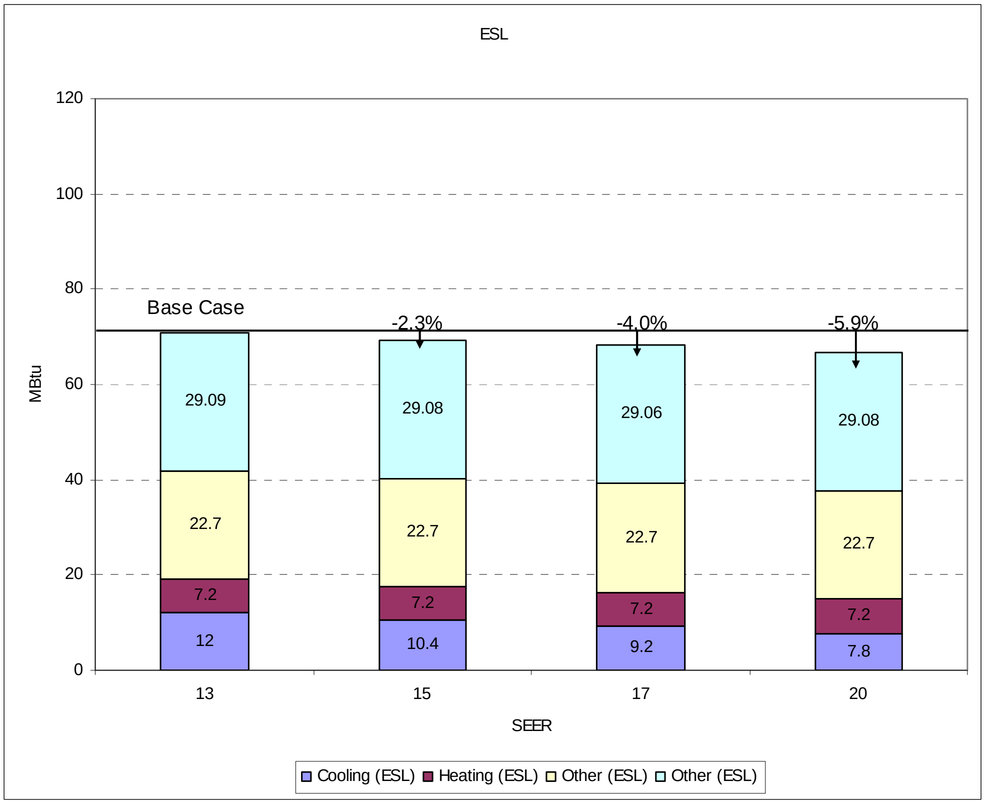

Figure 25. SEER (ESL) without the duct leakage.

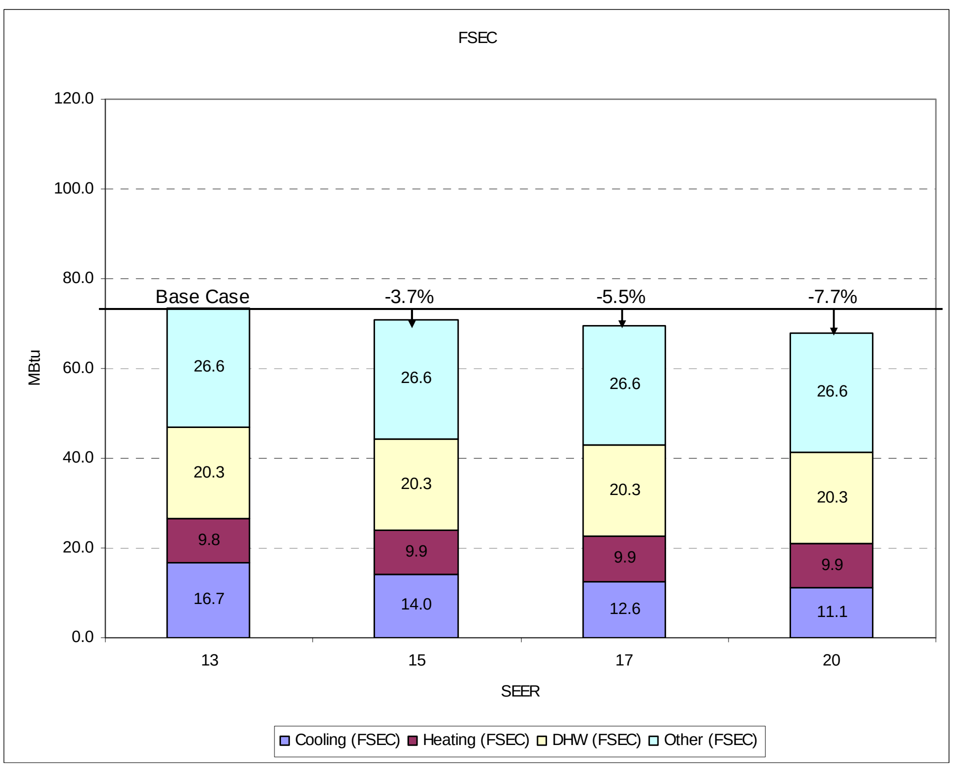

Figure 26. SEER (FSEC) without the duct leakage.

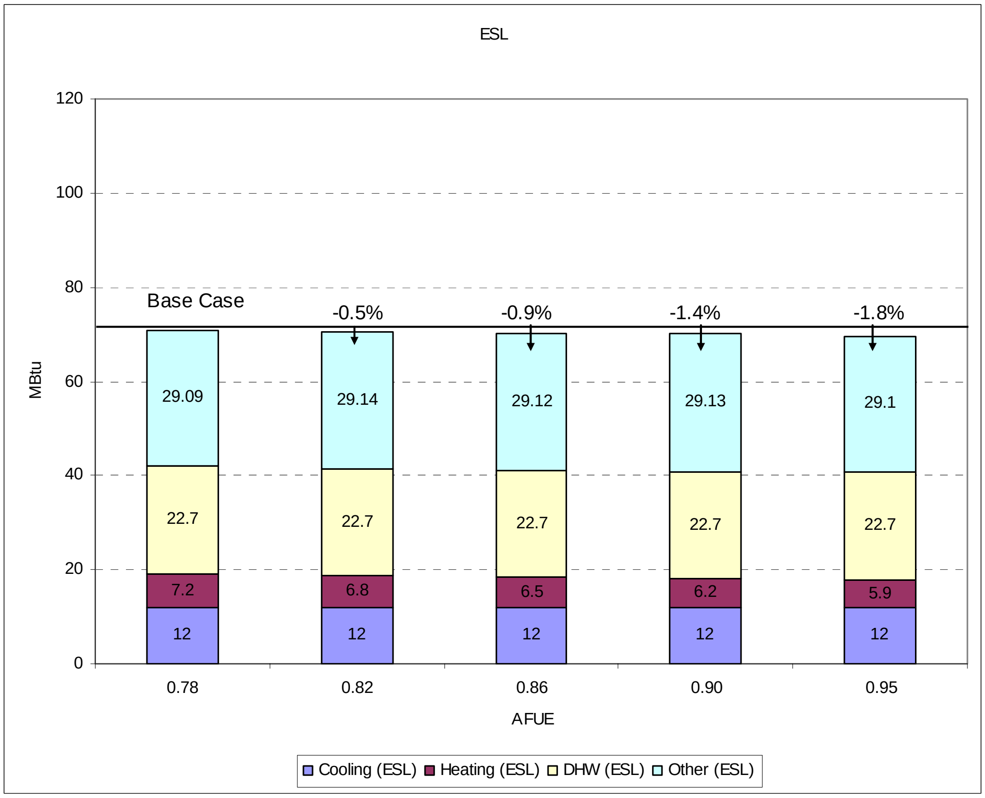

Figure 27. AFUE (ESL) without the duct leakage.

Figure 28. AFUE (FSEC) without the duct leakage.

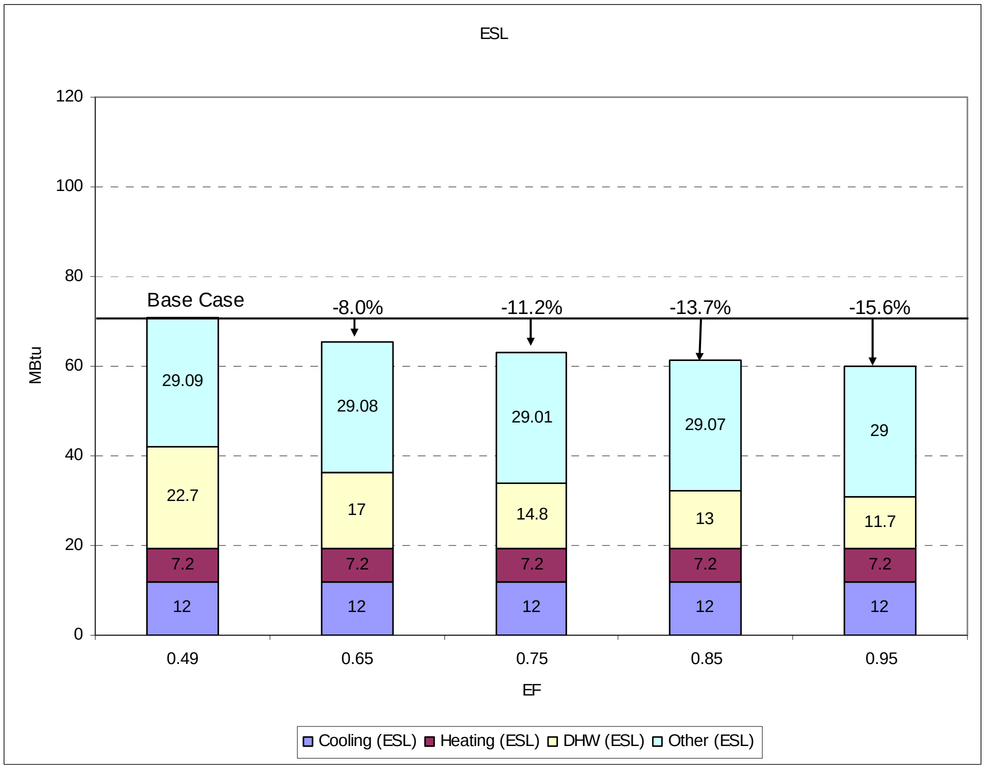

Figure 29. Energy Factor (EF) (ESL) without the duct leakage.

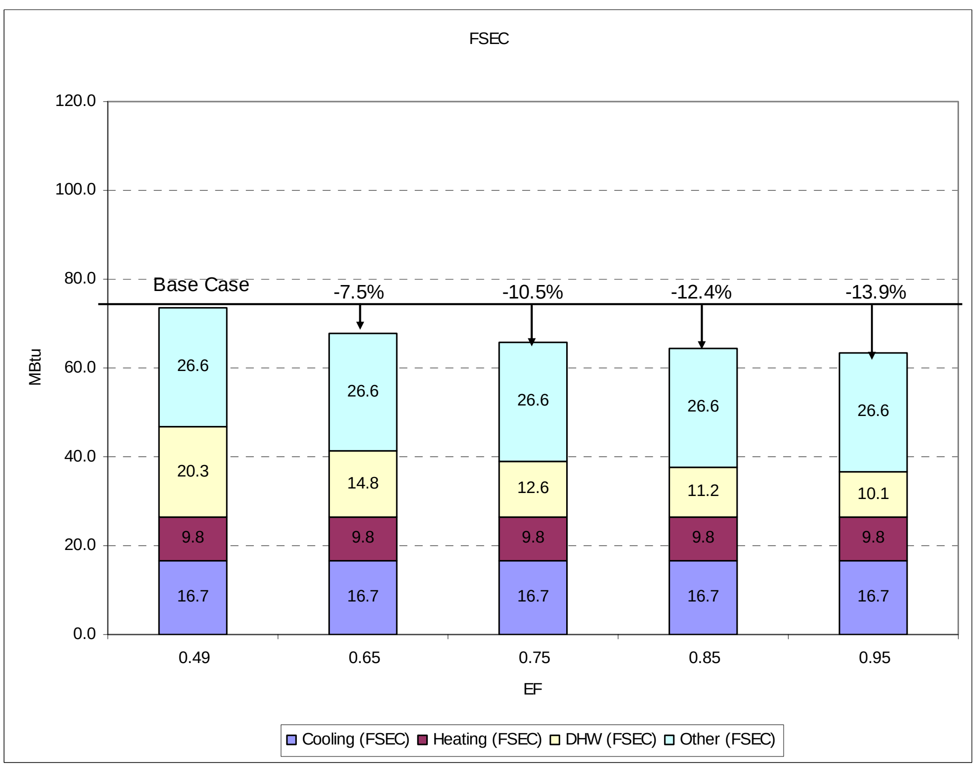

Figure 30. Energy Factor (EF) (FSEC) without the duct leakage.

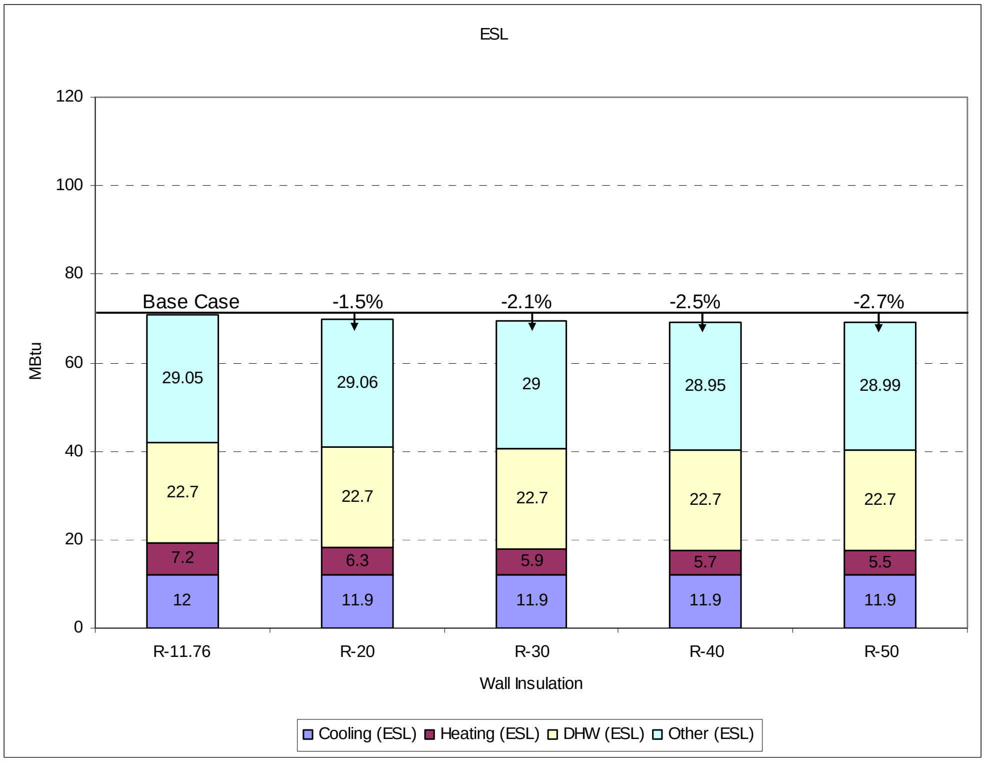

Figure 31. Wall insulation (ESL) without the duct leakage.

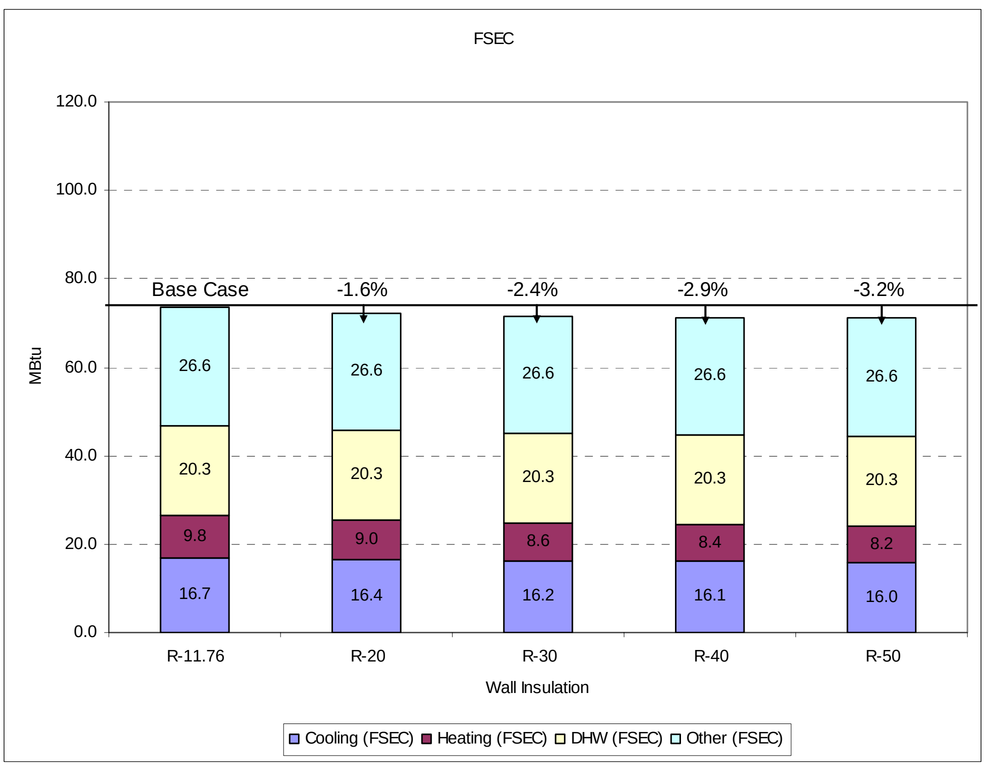

Figure 32. Wall insulation (FSEC) without the duct leakage.

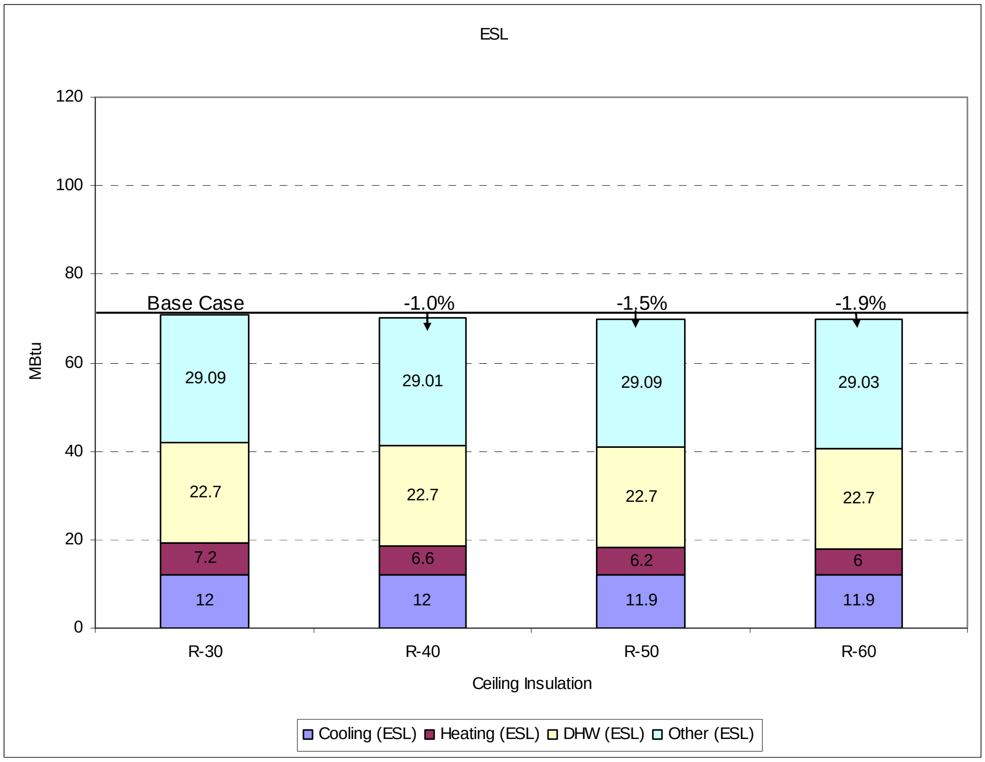

Figure 33. Ceiling insulation (ESL) without the duct leakage.

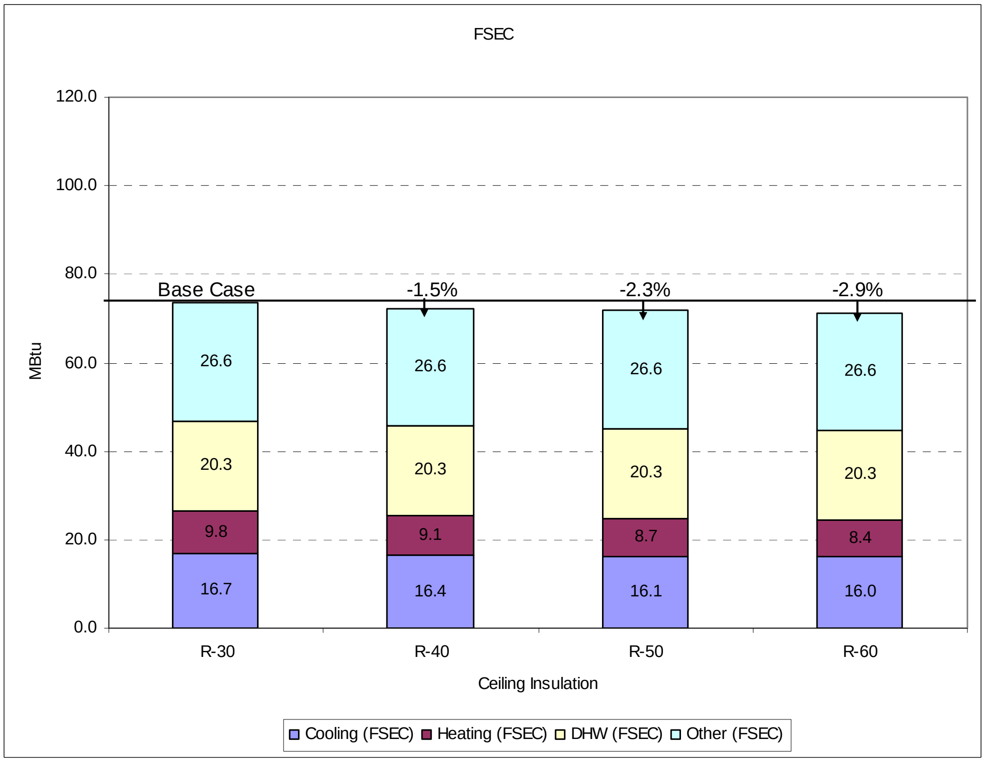

Figure 34. Ceiling insulation (FSEC) without the duct leakage.

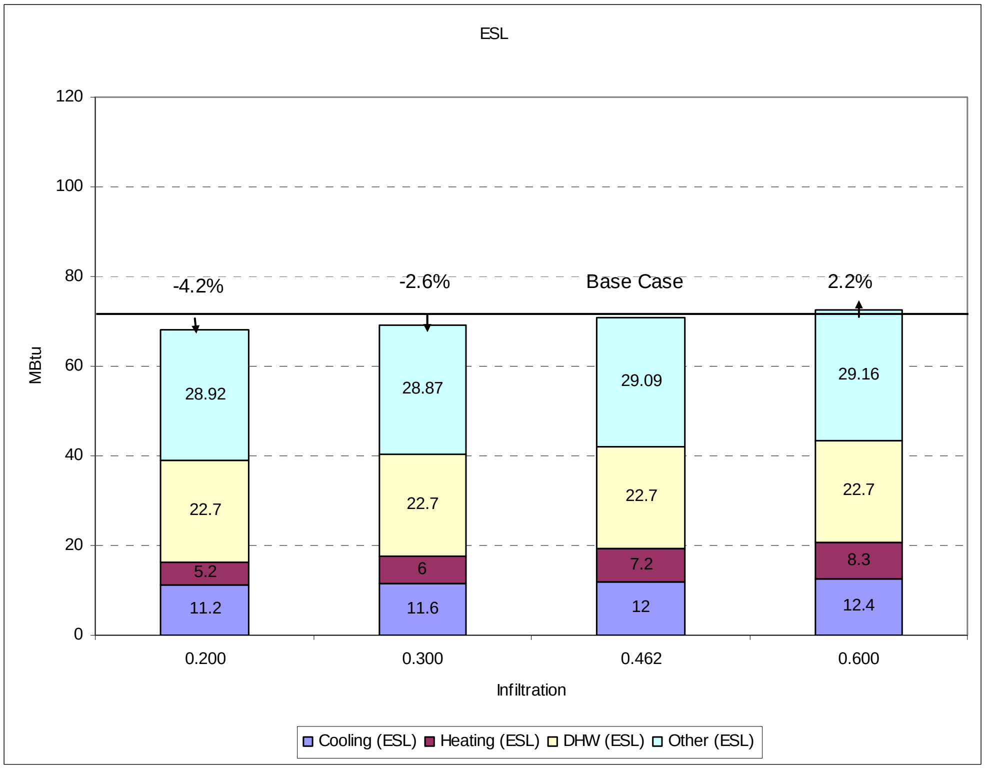

Figure 35. Infiltration (ESL) without the duct leakage.

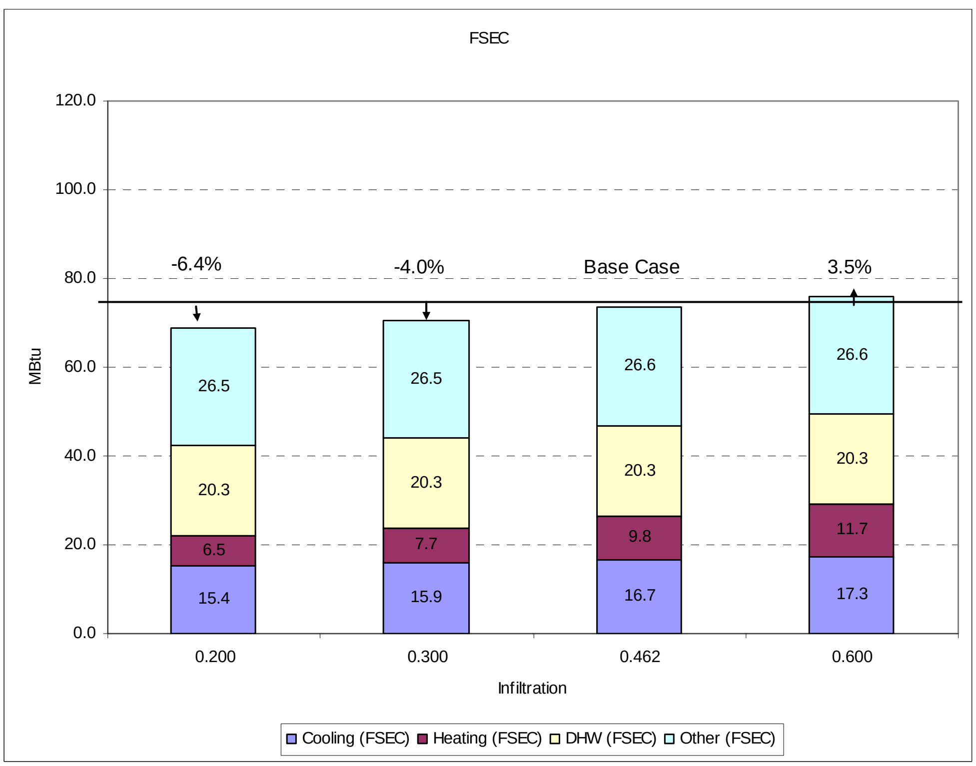

Figure 36. Infiltration (FSEC) without the duct leakage.

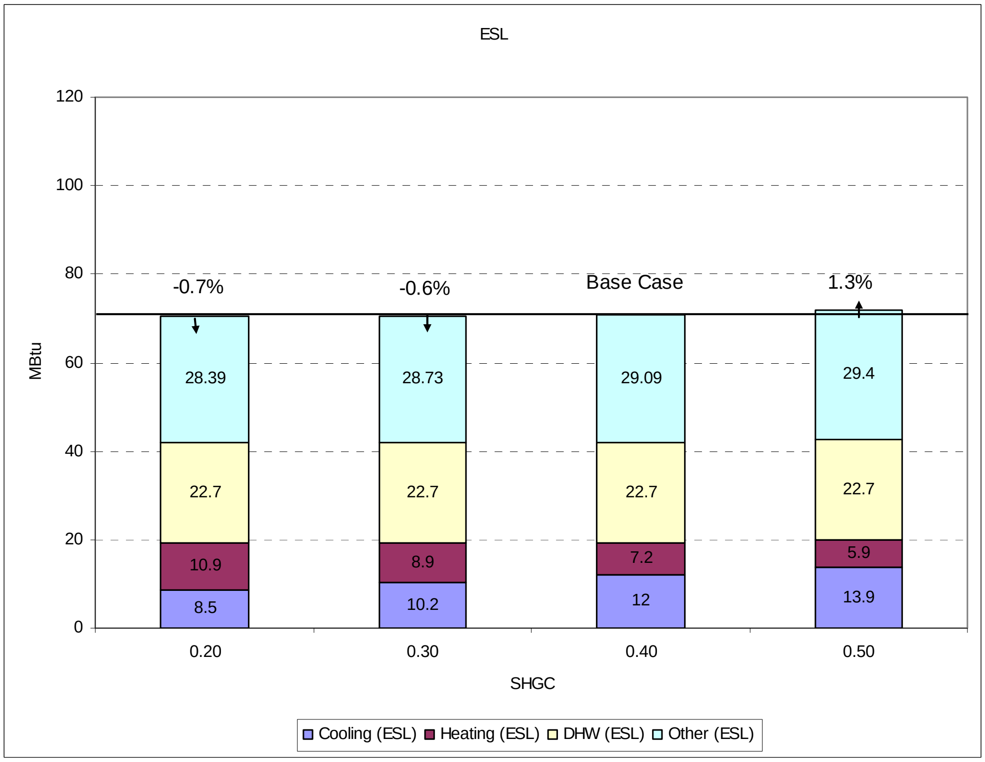

Figure 37. SHGC (ESL) without the duct leakage.

Figure 38. SHGC (FSEC) without the duct leakage.

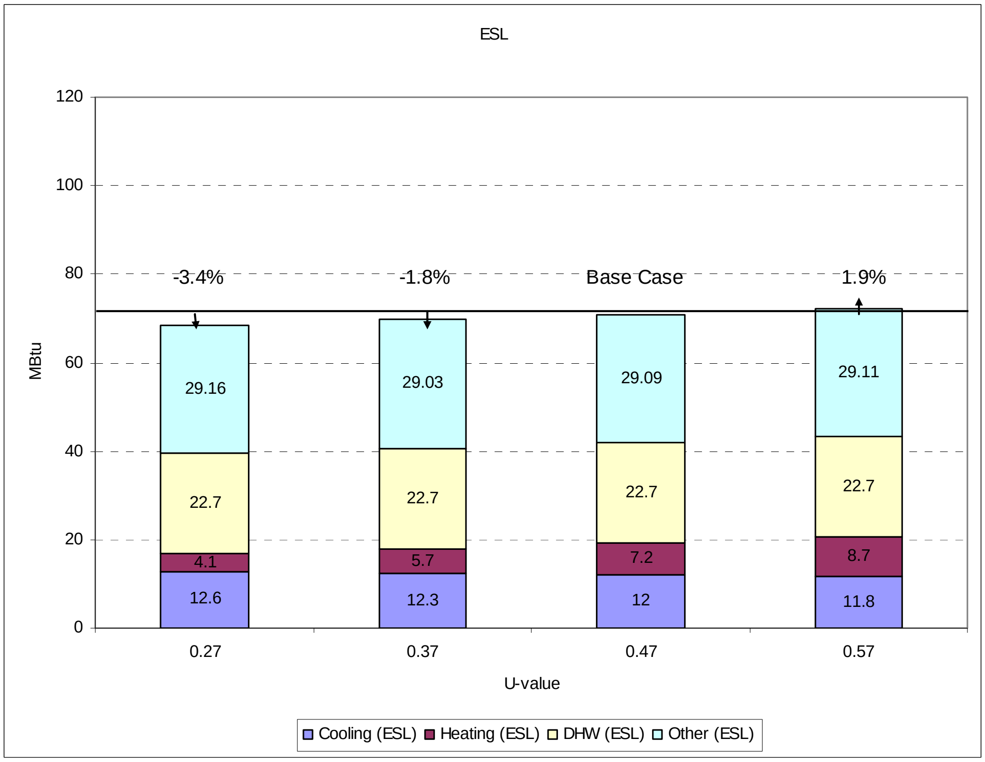

Figure 39. U-value (ESL) without the duct leakage.

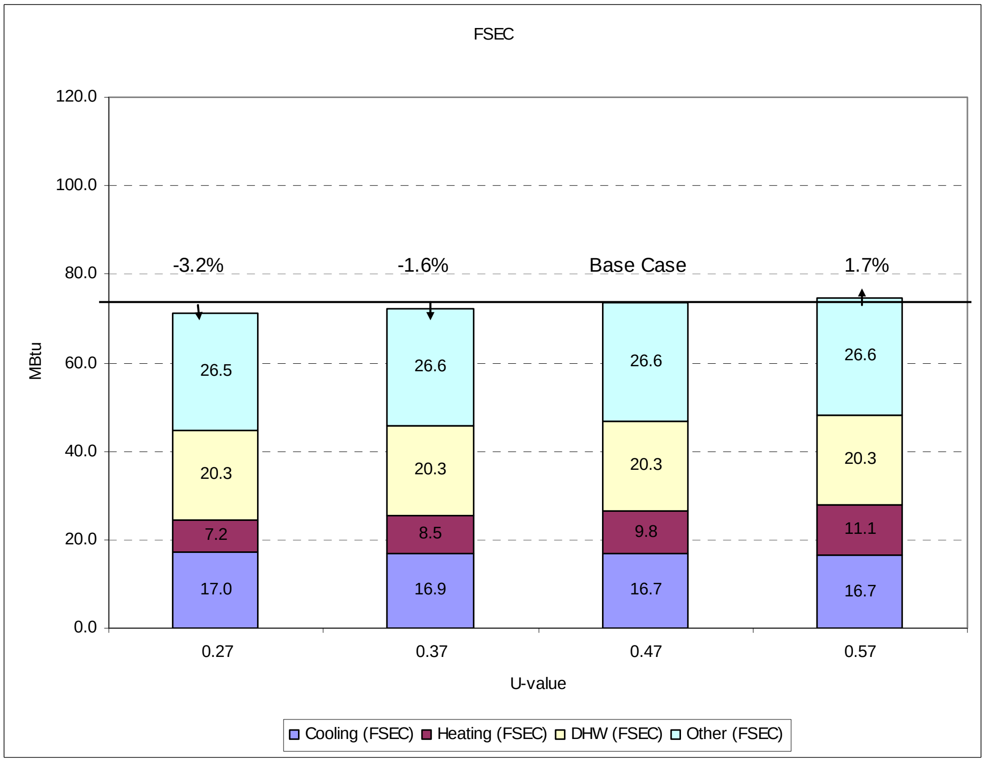

Figure 40. U-value (FSEC) without the duct leakage.

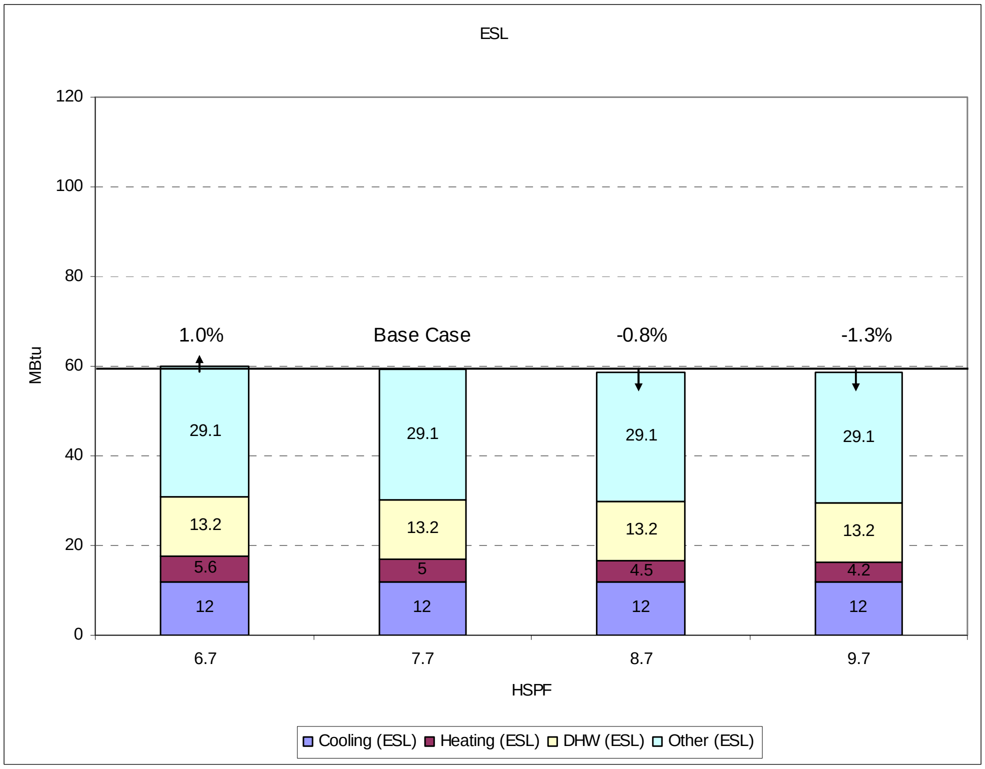

Figure 41. HSPF (ESL) without the duct leakage.

Figure 42. HSPF (FSEC) without the duct leakage.

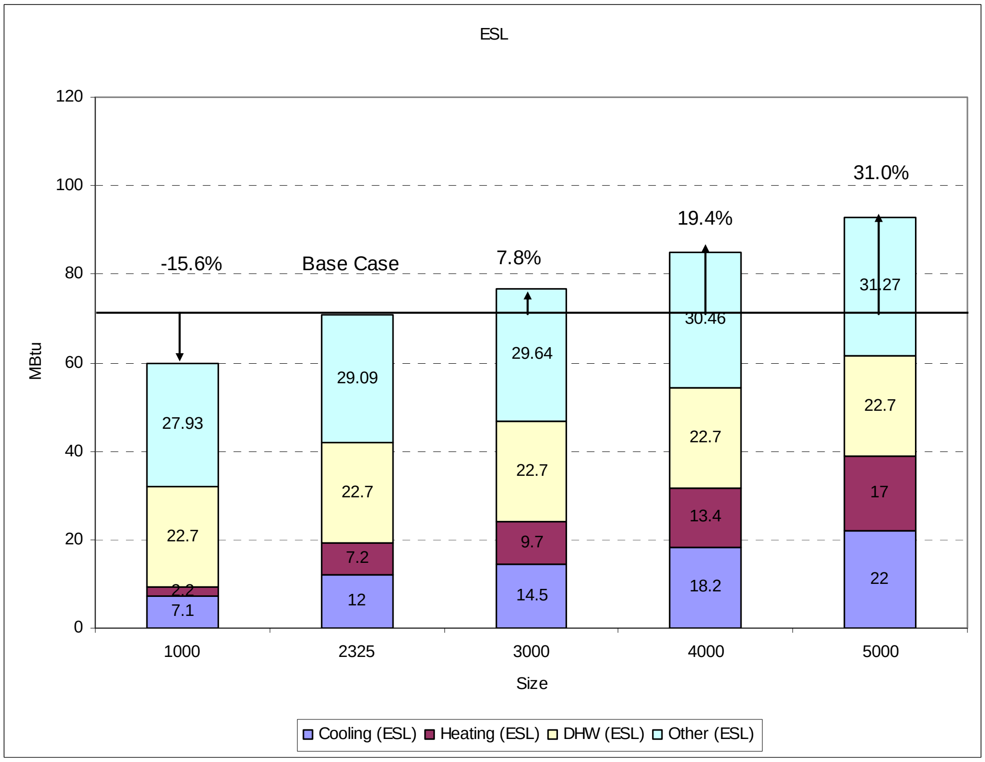

Figure 43. Size (ESL) without the duct leakage.

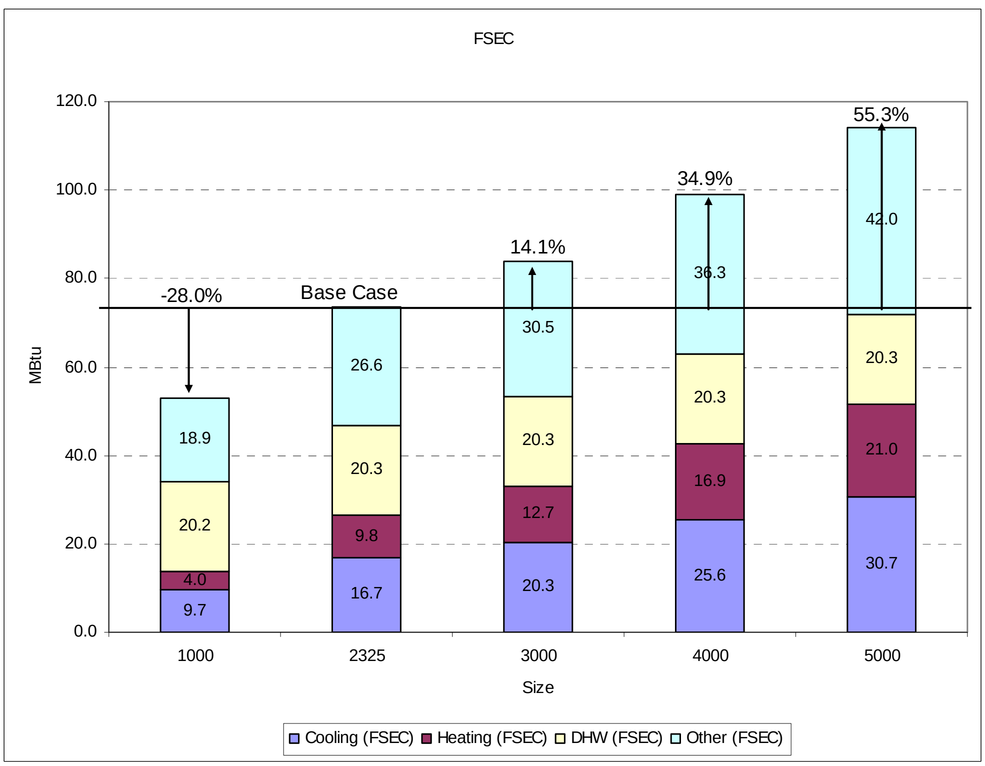

Figure 44. Size of the house (ft^2) (FSEC) without the duct leakage.

4. SUMMARY

As shown in Table 2, the sensitivity tests comparing the ESL model versus FSEC's EnergyGauge model shows acceptable agreements for window-to-wall ratio (WWR), SEER for the air conditioner, AFUE for the gas furnace, EF for the domestic hot water system, wall insulation level, ceiling insulation level, infiltration, SHGC, U-value, and HSPF for the heat pump. Agreement for the different sizes of the house test could not be obtained because of the different internal heat gain.

Table 2. Simulation summary.

	Item		W/ Duct Leakage						W/O Duct Leakage					
			ESL			FSEC			ESL			FSEC		
1	WWR (10% - 50%)	MBtu	68.71	-	80.75	70.14	-	84.49	66.56	-	77.27	68.13	-	81.09
		% Diff.	-6.8%	-	9.5%	-7.7%	-	11.1%	-6.2%	-	8.8%	-7.2%	-	10.4%
2	SEER (13-20)	MBtu	73.73	-	68.84	76.02	-	69.81	70.99	-	66.78	73.43	-	67.81
		% Diff.	-2.5%	-	-6.6%	-3.9%	-	-8.2%	-2.3%	-	-5.9%	-3.7%	-	-7.7%
3	AFUE (0.78 - 0.95)	MBtu	73.73	-	72.3	76.02	-	74.32	70.99	-	69.70	73.43	-	71.83
		% Diff.	-0.5%	-	-1.9%	-0.7%	-	-2.2%	-0.5%	-	-1.8%	-0.5%	-	-2.2%
4	EF (0.49 - 0.95)	MBtu	73.73	-	62.64	76.02	-	65.82	70.99	-	59.90	73.43	-	63.23
		% Diff.	-7.7%	-	-15.0%	-7.2%	-	-13.4%	-8.0%	-	-15.6%	-7.5%	-	-13.9%
5	Wall Insulation (R-11.78 - R-50)	MBtu	73.73	-	71.6	76.02	-	73.34	70.99	-	69.09	73.43	-	71.05
		% Diff.	-1.6%	-	-2.9%	-1.7%	-	-3.5%	-1.5%	-	-2.7%	-1.6%	-	-3.2%
6	Ceiling Insulation (R-30 - R-60)	MBtu	73.73	-	72.21	76.02	-	73.68	70.99	-	69.63	73.43	-	71.26
		% Diff.	-1.0%	-	-2.1%	-1.6%	-	-3.1%	-1.0%	-	-1.9%	-1.5%	-	-2.9%
7	Infiltration (0.2 - 0.6)	MBtu	70.39	-	75.49	71.02	-	78.74	68.02	-	72.56	68.73	-	75.98
		% Diff.	-4.5%	-	2.4%	-6.6%	-	3.6%	-4.2%	-	2.2%	-6.4%	-	3.5%
8	SHGC (0.2 - 0.5)	MBtu	73.1	-	74.75	74.35	-	76.90	70.49	-	71.90	72.57	-	74.23
		% Diff.	-0.9%	-	1.4%	-2.2%	-	1.2%	-0.7%	-	1.3%	-1.2%	-	1.1%
9	U-value (0.27 - 0.57)	MBtu	71.01	-	75.2	73.48	-	77.38	68.56	-	72.31	71.08	-	74.69
		% Diff.	-3.7%	-	2.0%	-3.3%	-	1.8%	-3.4%	-	1.9%	-3.2%	-	1.7%
10	HSPF (6.7 - 9.7)	MBtu	62.3	-	60.8	59.59	-	58.54	59.90	-	58.50	57.49	-	56.54
		% Diff.	1.1%	-	-1.4%	0.7%	-	-1.1%	1.0%	-	-1.3%	0.6%	-	-1.0%
11	Size (sq.ft) (1000 - 5000 sq.ft)	MBtu	61.32	-	98.33	54.18	-	119.08	59.93	-	92.97	52.87	-	114.05
		% Diff.	-16.8%	-	33.4%	-28.7%	-	56.6%	-15.6%	-	31.0%	-28.0%	-	55.3%