Methodology for Residential Building Energy Simulations Implemented in the International Code Compliance Calculator (IC3)

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ABSTRACT

Since 2001, Texas has been proactive in initiating clean air and energy efficiency in building policies. The Texas Emissions Reduction Plan legislation (SB 5, 77TH Leg., 2001) mandates statewide adoption of energy codes, creates a 5% annual energy savings goal for public facilities in affected counties through 2007 and provides approximately $150 million in cash incentives for clean diesel emissions grants and energy research. The Texas Legislation extended this annual electric reduction goal in public facilities through 2013. Texas was the first state in the nation to create NOx emissions reduction credits for energy efficiency and renewable energy through the State Implementation Plan under the Federal Clean Air Act.

This paper presents the methodology for calculating the energy usage from a proposed residential house and the corresponding 2001 International Energy Conservation Code baseline house. This methodology is applied in the International Code Compliance Calculator, which is a publicly accessible web-based energy code compliance software developed by the Energy Systems Laboratory based on the Texas Building Energy Performance Standards. This calculator evaluates and certifies above-code compliance for homes in Texas. It also calculates NOx, SOx and CO_2 emissions reductions from the energy savings of the proposed house for the electric utility associated with the user using the data from the Emissions and Generation Resource Integrated Database provided by U.S. Environmental Protection Agency.

BACKGROUND

Residential energy standards provide for more energy-efficient homes and thus help reduce emissions from electricity generation. Texas programs have partially transformed the housing market in Dallas/Fort Worth and Houston with 30,000 Energy Star homes (approximately 27%) in 2006, greatly reduced emissions from building energy-efficient homes, and created new manufacturing jobs for energy-efficient equipment and windows (Morgan, R. et.al, 2007). The ESL has developed several web-based energy efficiency and emissions reduction calculators. International Code Compliance Calculator (IC3) [1] is provided for use by builders, home energy raters, and code officials to benchmark the estimated energy performance of new construction single family homes in Texas. It is very easy to use and does more than calculate the above-code performance of a new home. It also calculates how much pollution has been reduced through the home's energy efficiency. The ESL is also working with the different Councils of Government in Texas to develop a verification mechanism in order to maximize the emissions reductions claimed by County. When this feature is developed, emissions data will be displayed on the certificate and aggregated in our database for SIP (State Implementation Plans) reporting. This paper presents the methodology used in the IC3 for calculating the energy usage for the proposed residential house compared to the house meeting the minimum requirement of 2001 IECC. The result is then used to demonstrate if the proposed house is at or above IECC [2001] and to quantify the emissions reductions.

METHODOLOGY

In order to calculate the reduction of NOx emissions from above-code homes, simulation models were created for typical single-family configurations. Each simulation model was modified to accommodate the different scenarios of envelope construction and HVAC equipment typically used in residences. The settings for the corresponding 2001 IECC baseline house were then created for calculating the above-code percentage of the proposed house. The simulation models, created with the DOE-2.1e simulation program (LBNL 1993a, 1993b), were then linked to a web-based graphical

[1] IC3 (ver. 3.2) is available at http://ic3.tamu.edu/.

user interface (IC3) or can be used in the DOE-2 Desktop Processor (DDP) to calculate the energy use from the code-compliant house and a proposed house. Finally the USEPA's eGRID[2] is used to convert the energy savings to NOx emissions reduction. In the web-based interface, only one user house is allowed to be input at a time in the current version of IC3. By contrast, in the DDP, multiple simulation runs can be submitted by an input spreadsheet at the same time which is very convenient for the users, developers, and for testing purposes.

Overview:

In the 2001 IECC, two simulations are needed for the assessment of energy savings and emissions reduction in a code-compliance calculator. One is the code-compliant run based on the minimum construction requirement of the 2001 IECC standard design and the second run is the simulation of the proposed design with the user input. The code-compliant simulation represents a simulation of the same user house with specific characteristics made compliant with the 2001 IECC. The comparison of the simulated annual energy use of the user's proposed design to the code-compliant simulation allows the user to see if their house is more efficient than a code-compliant house. The complete process flow using two different input interfaces is depicted in Figure 1.

The 2001 IECC code characteristics for the single family residences are based on the minimum requirements according to the climate zone where the user's county is located. For a performance simulation, exterior wall and glazing U-factors are found in Tables 402.1.1(1) and 402.1.1(2) of Chapter 4 of the 2001 IECC. The remaining envelope characteristics and minimum HVAC equipment efficiency requirements are acquired from the prescriptive tables in Chapter 5. For example, if the user chooses Harris County then the code house characteristics will be as shown in Table 1[3].

Typical Meteorological Year 2 (TMY2) data files are used in the simulations. Figure 2 shows the available weather stations for Texas, which includes 17 NOAA stations from which the TMY2 data have been derived, 15 NREL solar sites[4] and 10 TCEQ solar sites. Currently weather files are assigned according to the counties chosen by the user. Figure 2 shows the assignment of the counties to the 17 TMY2 weather stations. For Harris County, TMY2 weather data from Houston's Bush Intercontinental Airport is used.

The two sets of inputs are then processed using DOE-2 to determine the energy consumption of the building. For the 2001 IECC code compliance, values of interest from the DOE-2, i.e. outputs are the annual electricity and gas consumption in kWh and therms, respectively. The results from the user's run are then compared with the results from the code compliant simulation to determine if the house is more or less energy efficient than the code-compliant house. The savings values are then further processed by the routine that uses eGRID to calculate the annual and Ozone Season Day (OSD) NOx emissions reduction number in lbs of NOx for the power plant that supplied the electricity use to the county in which the house was built.

Simulation Input File:

The simulation input files consist of 4 basic files, one DOE-2 "input" file and three DOE-2 "include" files (i.e., county.txt, shades.txt, and parameters.txt). The input file contains the flexible simulation model for the single family residence with pre-defined parameters. Three include files are generated through a calculation engine based on the user input, as shown in Figure 1. County.txt includes such information as heating degree days, latitude, longitude, time-zone, altitude and infiltration which is determined from the county in which the house is located. Shades.txt provides interior shading schedule to the simulation input file. Parameters.txt is generated from the user inputs and default settings. They are divided into two major categories as defined by the DOE-2 program; LOADS and SYSTEMS. The LOADS parameters are then further divided into building, construction, space, and shading parameter subsets.

The building parameters are used to define the location, orientation, and the basic dimensions and layout of the building. The current simulation mode has the provision of either one or two stories with a crawlspace or a slab on grade. The switch between quick (i.e., pre-calculated ASHRAE weighting factors) and thermal mass (i.e., DOE-2's custom

[2] eGRID, is the EPA's Emissions and Generation Resource Integrated Database (Version 2). This publicly available database can be found at www.epa.gov/airmarkets/egrid/. The information in this table is from a special edition of the eGRID database, provided by Art Diem at the USEPA for the TCEQ for use with Senate Bill 5.

[3] NOx emissions from natural gas used on-site are calculated with data from the EPA's AP-42 database

[4] The NREL solar sites were disconnected in 2002.

weighting factors) mode is fixed for thermal mass construction for the current version. The layer of the wall is decided based on the requirement in Section 402.1.1 of Chapter 4 of the 2000 IECC. Framing factors are determined for walls, ceilings, and floors according to the recommended values by ASHRAE research project RP-904 (Carpenter, S. C. et.al, 2003).

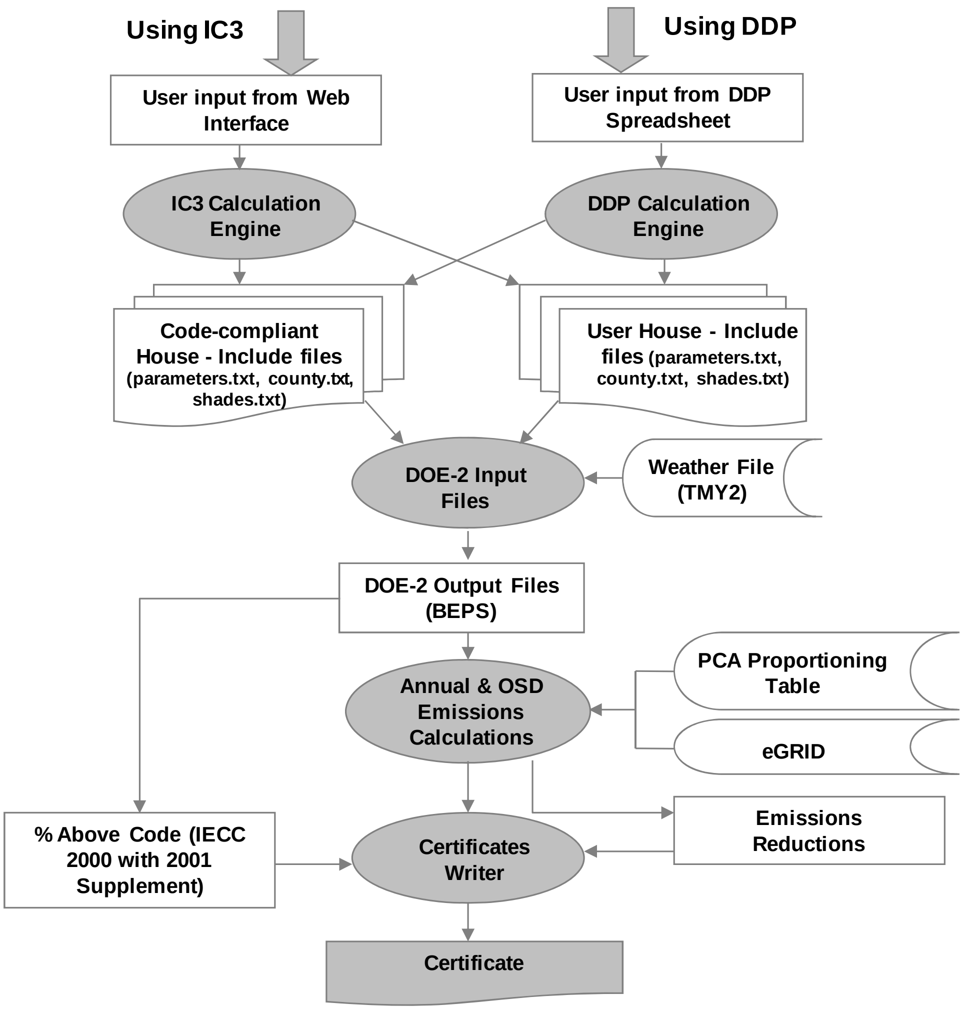

Figure 1: Single Family Analysis Flowchart

Table 1: Code Building Characteristics for Harris County

County	Building Characteristics	Glazing Properties		Envelope Properties		Minimum HVAC Efficiencies	
		U-Factor	SHGC	Wall R-value	Roof R-Value	Cooling[5] (SEER)	Heating (AFUE)
Harris	2000/2001 Supplement	0.47	0.4	13	30	13	0.78

[5] The SEER 13 is required by the Jan 2006 Federal Appliance Standards.

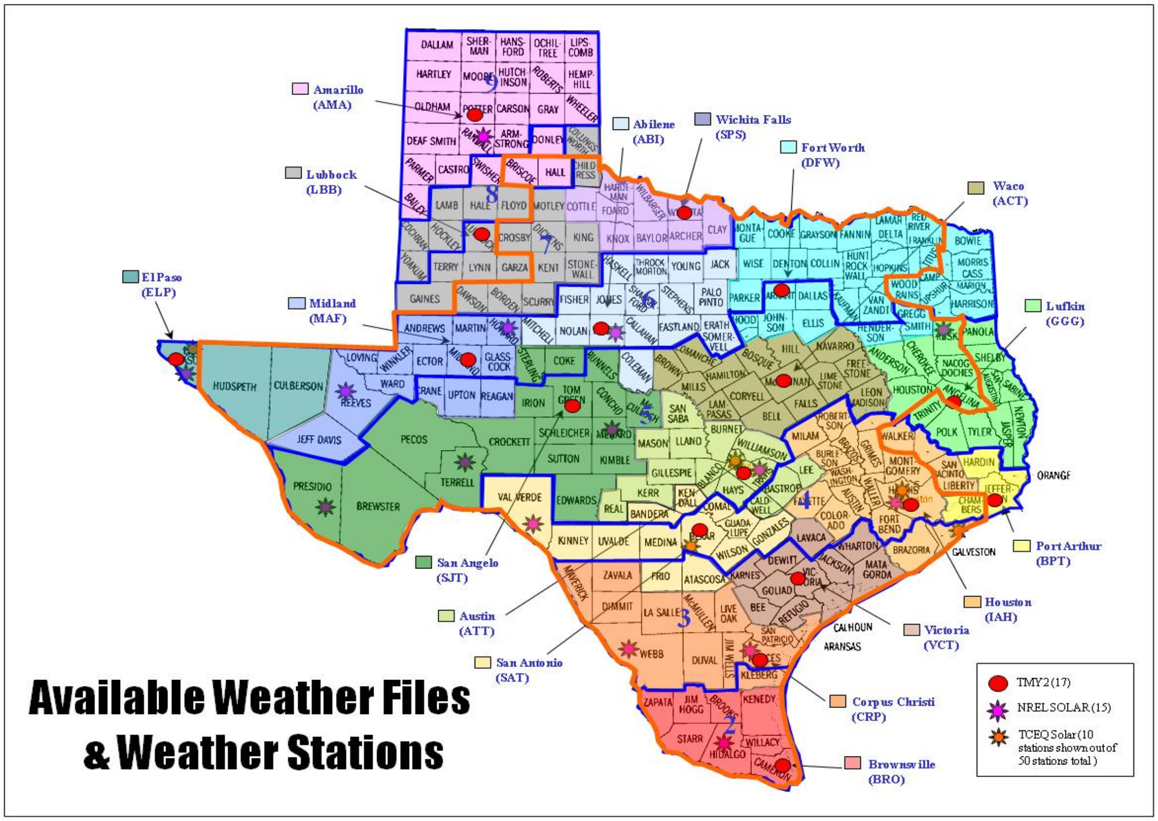

Figure 2: Weather Station Assignment by the ESL for Texas Counties

The construction parameters include the material properties and U-values for the different components including the glazing properties and the window-to-wall ratio. The user has the option of changing the window areas for the different orientations. However, for the code run, the window area is fixed at 18% of conditioned floor area and is divided equally between four cardinal directions, and by floor if needed. An annual average air change per hour method is used as the infiltration method in the simulation, which are determined using the normalized leakage multiplied by the weather factor. The weather factor is determined in accordance with the weather factors given by ASHRAE 136 (ASHRAE 136, 1993 and IECC 2000), as taken from the assigned weather station.

For simulating residential buildings, according to the 2001 IECC, internal heat gains are fixed at 3,000 Btu/hr for a single-family dwelling, which limits the user's ability to change the lighting, occupancy and equipment gains. The space parameters are currently fixed at no occupants and the same number of bedrooms is input by the user for the code run. The number of bedrooms is used to calculate the daily domestic hot water consumption, which in turn is used to size the domestic water heater according to Section 420.1.3.7 of the 2001 IECC. An Energy Factor (EF) is used for the domestic water heating system efficiency according to Table 504.2 of Chapter 5 of the 2001 IECC for the code run.

The system parameters include the type of systems, the system capacity and the efficiencies of the system selected. The user can choose from three kinds of systems: 1) gas heating, gas DHW and electric cooling, 2) electric heating, electric DHW and electric cooling, and 3) electric heat pump heating, electric DHW and electric cooling. No pilot light is assumed for both the user and code house since the energy use of the pilot light is included in the EF. Currently, three system sizing choices are available in the DDP. The heating and cooling system can be sized by DOE-2 according to the loads entered in DOE-2's LOADS sub-program, or by Manual J spreadsheet linked to the DDP, or by a rule of thumb of 500 ft^2/ton. In the current IC3 web-based software, the 500 ft^2/ton is used for sizing the system. A value of 360 cfm/ton is used for heating and cooling coil airflow capacity. The user can define the system efficiencies according to the system type that is selected. For the code simulations, the HVAC efficiencies will be according to the values in Table 1.

Improved approaches to properly account for the part-load performance of residential air conditioning systems developed by H.I. Henderson, Florida Solar Energy Center (Henderson, et.al, 2000) are utilized within the simulation model. For simulating a heat pump, the heating EIR (Energy Input Ratio) and cooling EIR values come from an evaluation of the data for several thousand air conditioners and heat pumps listed in the California Energy Commission appliance database (Fairey, et.al, 2004). The ducts are in the unconditioned space (attic) for the code-compliant house. The duct loss is calculated using a duct model based on ASHRAE Standard 152-2004 (Seongchan Kim, 2006).

Running the Simulations:

There are two tools to run the simulations. One is through the IC3 web interface and the other is through the batch mode DOE-2 Desktop Processor. Those two independent tools allow for continuous cross-check. Figure 3 shows one of the web-interface screens. All seven input screens need to be completed for the comparison analysis of the user input with code-compliant characteristics. Figure 4 shows the DOE-2 Desktop Processor screen and the DDP spreadsheet which allows 1,000s of simulation instructions in one file. Besides the parameters shown in the web-interface, more parameters can be changed in this DDP tool for comparing a user house and the house meeting minimum code requirement. It also allows multiple simulations to be processed at the same time. This desktop tool is more complicated than the web version but provides more options for calibrating the simulation, comparing results against other software, and testing the model performance.

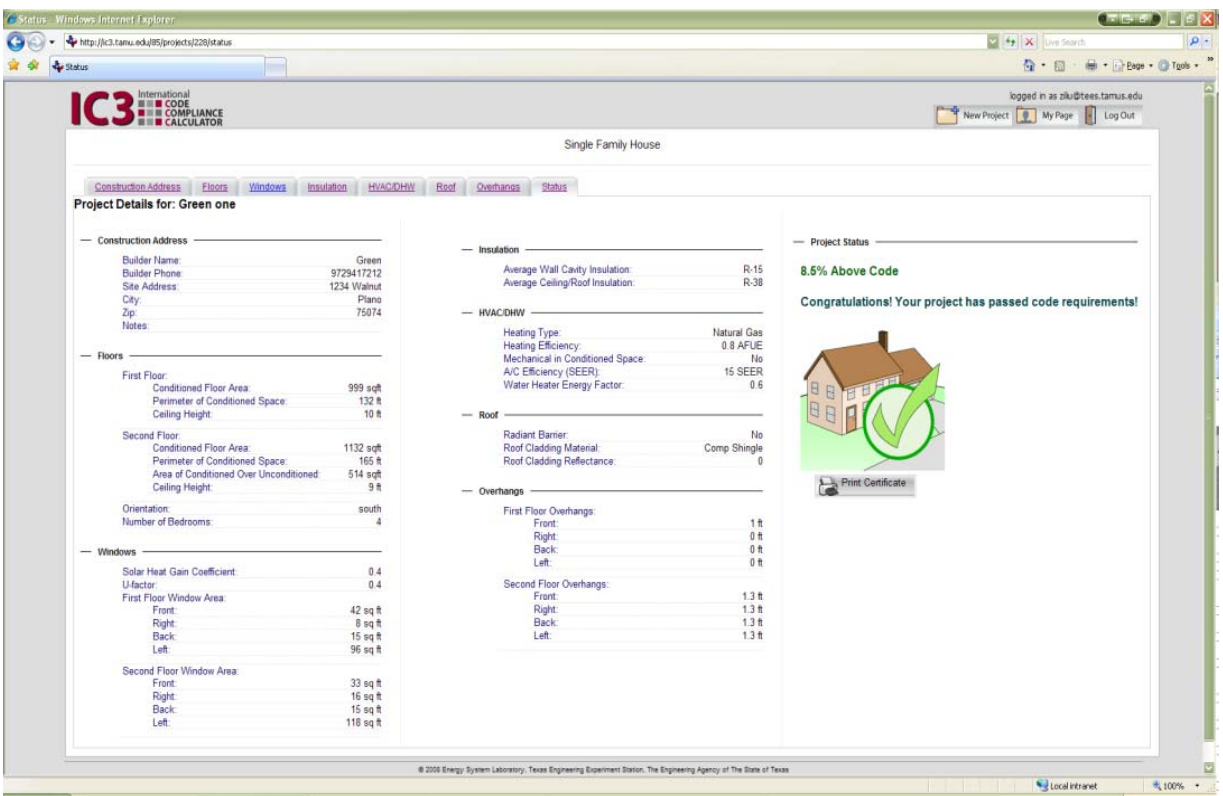

Figure 3: International Code Compliance Calculator (IC3) Example Screen

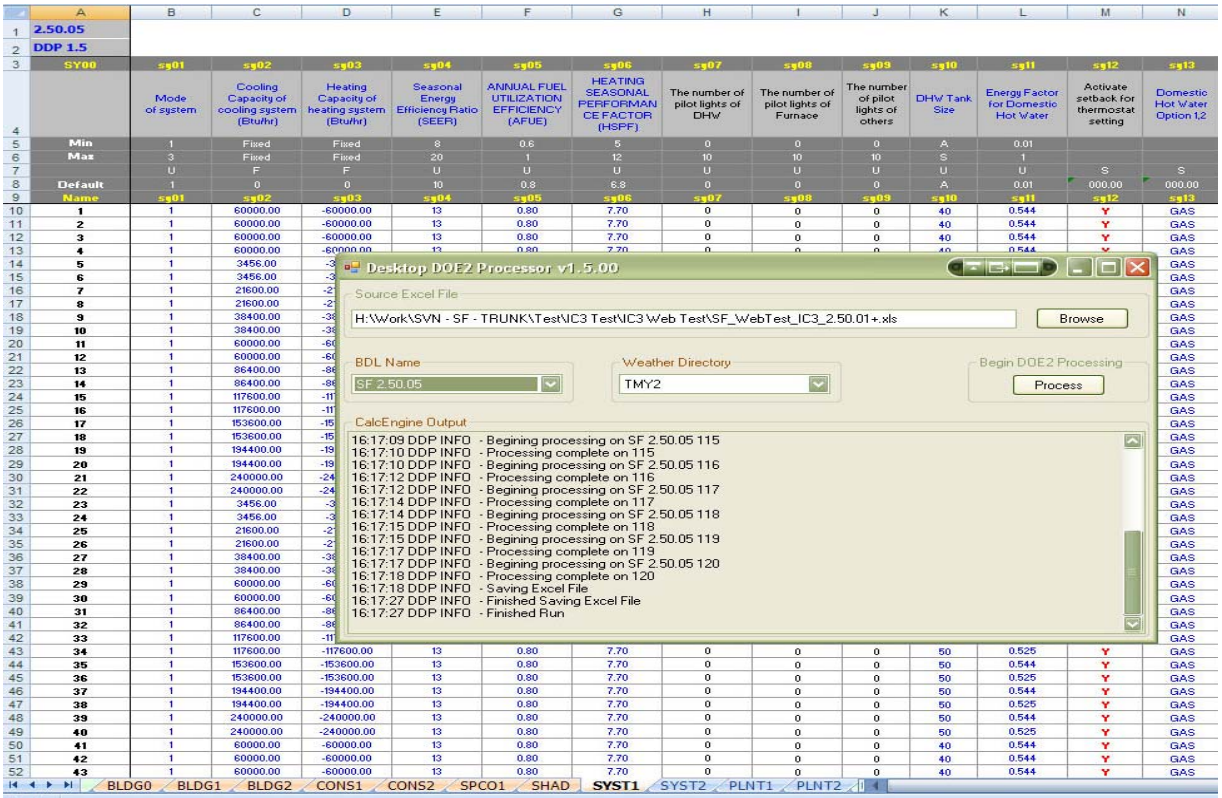

Figure 4: DOE-2 Desktop Processor (DDP) and Example Input Spreadsheet

APPLICATION: SELECTING ABOVE CODE FEATURES

Beyond certifying an above-code house, IC3 can also help a user develop a high performance house. Table 2 summarizes the inputs for some of the simulations conducted for Harris County for a single-family slab-on-grade residence, with different fuel options and building layouts (i.e., 1-story or 2-story). These simulations are used as examples to show how to define the requirements that meet 15% above code levels with several options by using IC3 or DDP[6]. Runs No.1 to No.6 are the simulations for 1-story and 2-story houses with natural gas space heating, and natural gas water heater and electric cooling. Runs No.7 to No.12 simulate 1-story and 2-story house using heat pump heating, electric water heater, and electric cooling. Runs No13 to No.16 simulate the electric resistance heating house. The parameters of No.14 and No. 16 are the same as code runs of No. 9 and No.12 respectively. This is because heat pump is used in the code simulations for the house using electric resistance heating. In these simulations, the USER 1 House represents a house, which was set the same as the code characteristics except for a smaller window area. The USER 2 House is the proposed house with energy efficient measures chosen to produce 15% above code. The CODE house is simulated to meet the minimum requirements of 2001 IECC.

Table 3 shows the results from 16 simulation runs. In Figure 5 and Figure 6, it is shown that the small window area house with heat pump heating, electric DHW and electric cooling has the lowest annual energy use, which is 22% less than the house using natural gas heating. 1-story houses are less consumptive than 2-story houses for all fuel options[7]. This is because this 2-story house has more exterior wall area than a 1-story house although the 1-story house has larger roof area. The proposed baseline house using electric resistance heating consumes 3.8% more energy for 1-story and 3.9% for 2-story house compared with heat pump heating house. Among the proposed baseline houses, the highest percentage above code house occurs in the house with heat pump heating, ranging from 4.5% above

[6] IC3 version 3.2 was used in this application. The DOE-2 input file version implemented in this IC3 version is 2.50.05.

[7] In order to calculate this, the residence was assumed to have the same window area as a 1-story residence, with window area divided evenly between the first and second floors.

code for 1-story to 4.8% above code for 2-story house. The proposed natural gas heating baseline house is 3.3% above code for 1-story and 4.1% above code for 2-story house. The proposed baseline house with electric resistance heating has the worst performance when compared to the code requirement, 0.8% above code for 1-story and 1.4% for 2-story house.

Table 2: Code-compliant and Proposed Single-Family Residence Input

PARAMETERS	DESCRIPTION	Gas Heating, Gas DHW and Electric Cooling						Heat Pump Heating, Electric DHW and Electric Cooling						Electric Heating, Electric DHW and Electric Cooling			
		1-story			2-story			1-story			2-story			1-story		2-story	
		USER 1	USER 2	CODE	USER 1	USER 2	CODE	USER 1	USER 2	CODE	USER 1	USER 2	CODE	USER	CODE	USER	CODE
		Run1	Run2	Run3	Run4	Run5	Run6	Run7	Run8	Run9	Run10	Run11	Run12	Run 13	Run 14	Run 15	Run 16
b10	Option of Second Floor	1	1	1	2	2	2	1	1	1	2	2	2	1	1	2	2
b09	Conditioned Floor Area - First Floor (ft^2)	2500	2500	2500	1250	1250	1250	2500	2500	2500	1250	1250	1250	2500	2500	1250	1250
	Perimeter of Conditioned Floor - 1st Floor (ft)	200	200	200	141.4	141.4	141.4	200	200	200	141.4	141.4	141.4	200	200	141.4	141.4
b06	1st Floor Height (ft)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
b21	Conditioned Floor Area - Second Floor (ft^2)				1250	1250	1250				1250	1250	1250			1250	1250
	Perimeter of Conditioned Floor -2nd Floor (ft)				141.4	141.4	141.4				141.4	141.4	141.4			141.4	141.4
b18	2nd Floor Height (ft)				8	8	8				8	8	8			8	8
b29	Conditioned over Unconditioned Area (ft^2)				0	0	0				0	0	0			0	0
b03	Building Orientation	South	South	South	South	South	South	South	South	South	South	South	South	South	South	South	South
sp02	Number of bedroom	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
c12	Solar Heat Gain Coefficient (SHGC)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	***0.3***	0.4	0.4	***0.3***	0.4	0.4	0.4	0.4	0.4
c11	U-Factor of Glazing (Btu/hr-sq.ft-F)	0.47	***0.3***	0.47	0.47	***0.4***	0.47	0.47	***0.3***	0.47	0.47	***0.3***	0.47	0.47	0.47	0.47	0.47
c21	Window Area for 1st Floor Front Wall (ft^2)	***80***	***80***	112.5	***40***	***40***	56.3	***80***	***80***	112.5	***40***	***40***	56.3	***80***	112.5	***40***	56.3
c23	Window Area for 1st Floor Right Wall (ft^2)	***80***	***80***	112.5	***40***	***40***	56.3	***80***	***80***	112.5	***40***	***40***	56.3	***80***	112.5	***40***	56.3
c22	Window Area for 1st Floor Back Wall (ft^2)	***80***	***80***	112.5	***40***	***40***	56.3	***80***	***80***	112.5	***40***	***40***	56.3	***80***	112.5	***40***	56.3
c24	Window Area for 1st Floor Left Wall (ft^2)	***80***	***80***	112.5	***40***	***40***	56.3	***80***	***80***	112.5	***40***	***40***	56.3	***80***	112.5	***40***	56.3
c30	Window area for 2nd Floor Front Wall (ft^2)				***40***	***40***	56.3				***40***	***40***	56.3			***40***	56.3
c29	Window area for 2nd Floor Right Wall (ft^2)				***40***	***40***	56.3				***40***	***40***	56.3			***40***	56.3
c31	Window area for 2nd floor Back Wall (ft^2)				***40***	***40***	56.3				***40***	***40***	56.3			***40***	56.3
c25	Window area for 2nd floor Left Wall (ft^2)				***40***	***40***	56.3				***40***	***40***	56.3			***40***	56.3
c08	Wall R-value (Hr-sq.ft-F/Btu)	13	13	13	13	13	13	13	***16***	13	13	***16***	13	13	13	13	13
c04	Roof R-value (Hr-sq.ft-F/Btu)	30	***38***	30	30	30	30	30	***38***	30	30	***38***	30	30	30	30	30
sy01	Mode of System	NG	NG	NG	NG	NG	NG	HP	HP	HP	HP	HP	HP	ER	HP	ER	HP
sy05/sy06	AFUE/HSPF	0.78	***0.9***	0.78	0.78	***0.9***	0.78	7.7	***9***	7.7	7.7	***9***	7.7				
sy22	Duct in Conditioned Space	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
sy04	Seasonal Energy Efficiency Ratio (SEER)	13	***15***	13	13	***15***	13	13	***15***	13	13	***15***	13	13	13	13	13
sy11	Energy Factor (%) for Domestic Hot Water	0.54	***0.62***	0.54	0.54	***0.62***	0.54	0.86	***0.95***	0.86	0.86	***0.95***	0.86	0.86	0.86	0.86	0.86
b22	Radiant Barrier	N	N	N	N	N	N	N	***Y***	N	N	***Y***	N	N	N	N	N
c02	Roof Reflectance = 1-absotptance (c02)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
s01	Front Shade (ft)	0	0	0	0	0	0	0	***4***	0	0	***4***	0	0	0	0	0
s04	Right Shade (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
s02	Back Shade (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
s03	Left Shade (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
s05	2nd Front shade (ft)				0	0	0				0	0	0			0	0
s08	2nd Right shade (ft)				0	0	0				0	0	0			0	0
s06	2nd Back shade (ft)				0	0	0				0	0	0			0	0
s07	2nd Left shade (ft)				0	0	0				0	0	0			0	0

Table 3: Code-compliant and Proposed Single-Family Residence Simulation Results

Simulation Results in MMBtu/yr	Gas Heating, Gas DHW and Electric Cooling						Heat Pump Heating, Electric DHW and Electric Cooling						Electric Heating, Electric DHW and Electric Cooling			
	1-story			2-story			1-story			2-story			1-story		2-story	
	USER 1	USER 2	CODE	USER 1	USER 2	CODE	USER 1	USER 2	CODE	USER 1	USER 2	CODE	USER1	CODE	USER1	CODE
	Run1	Run2	Run3	Run4	Run5	Run6	Run7	Run8	Run9	Run10	Run11	Run12	Run13	Run14	Run15	Run16
Cooling Energy	11.4	10.1	13.7	12.8	11.4	15.1	11.7	7.9	14	13.1	9.3	15.5	11.7	14	13.1	15.5
Heating Energy	14.8	9.4	14.9	15.4	10.1	16.2	4.6	3.9	4.7	4.8	3.9	5.1	6.8	4.7	7.1	5.1
DHW	20.4	17.9	20.4	20.4	17.9	20.4	12.8	11.7	12.8	12.8	11.7	12.8	12.8	12.8	12.8	12.8
Other	27.8	27.8	28.1	28	28	28.2	28.7	27.9	29	28.9	28	29.3	28.6	29	28.8	29.3
Total	74.4	65	76.9	76.5	67.3	79.8	57.7	51.2	60.4	59.5	52.8	62.5	59.9	60.4	61.8	62.7
% Above Code	3.3%	15.5%		4.1%	15.7%		4.5%	15.2%		4.8%	15.5%		0.8%		1.4%	

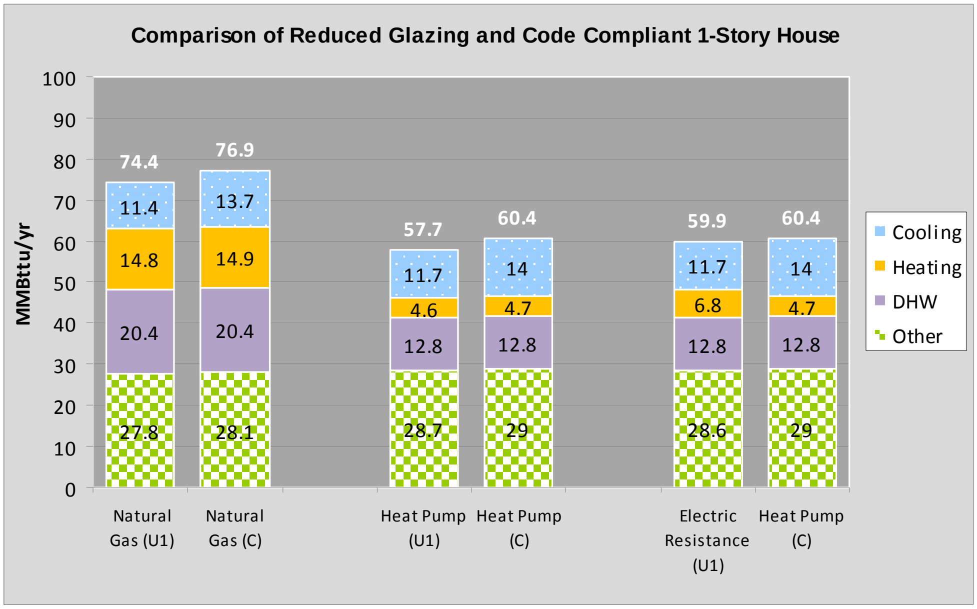

Figure 5: Comparison of Energy Consumption for 1-Story Houses with Different Fuel Options

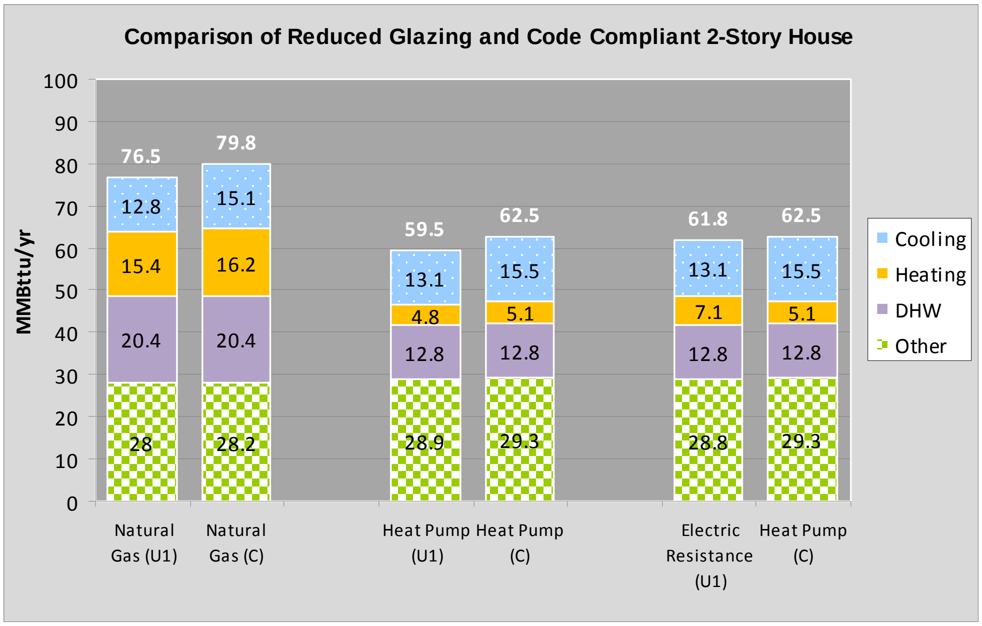

Figure 6: Comparison of Energy Consumption for 2-Story Houses with Different Fuel Options

Table 2 and Table 3 show that by combining the following measures: 1) decreasing the U factor of the window from 0.47 to 0.30, 2) increasing the roof insulation from R-30 to R-38, 3) increasing the heating efficiency from 0.78 to 0.9, 4) increasing the cooling efficiency from SEER 13 to SEER 15, 5) increasing the energy factor from 0.544 to 0.62; the proposed 1-story house with gas heating/DHW (i.e., run 2) can be 15.1% above code. A simulation was also run for the 2-story gas house and the proposed house (run 5) which resulted in 15.4% above code. For the proposed house with heat pump heating, the 1-story house (run 8) can reach 15.2% above code and the 2-story house (run 11) has a 15.5% better than code performance by improving the performance from the following measures: 1) decreasing the U factor of the window from 0.47 to 0.30, 2) decreasing SHGC from 0.40 to 0.30, 3) increasing the wall insulation from R-13 to R-16, 4) increasing the roof insulation from R-30 to R-38, 6) increasing the cooling efficiency from SEER 13 to SEER 15, 6) increasing the energy factor from 0.86 to 0.95, 7) installing shades (4 feet projection) on the south wall, 8) increasing the heat pump efficiency from 7.70 to 9, 8) installing a radiant barrier in the attic. Table 4 lists the step-by-step input changes in the IC3 and the corresponding % above code values from each step for both gas heating and heat pump heating one story house. Other combination of energy efficient measures can also be developed to meet 15% above code depending on different need and requirement from user.

To make IC3 easy-to-use on a web interface, some of the parameters used in the simulation are set as the default for the proposed house and thus are not allowed to be changed in the interface, for example, duct leakage, infiltration rate, system size, internal heat gain, etc. As a result, the user is limited to a smaller number of choices to make the house more efficient. By using the DOE-2 Desktop Processor, more options are available to the user so more energy efficient measures can be simulated for evaluating the savings. A future version of IC3 will continue to enhance its interface functionality for better assisting a user to determine a prescriptive house meeting 15% to 30% above code scope.

SUMMARY

This paper explains in detail the residential simulation models that are used in the Energy Systems Laboratory's code-compliance calculator. To accomplish this, the DOE-2.1e simulation program was used to create pre-configured, single-family models. These models were then linked to the web-based interface or the DOE-2 Desktop Processor to determine if the user input house is more energy efficient than the code-compliant house. An example of the utilization of the desktop processor to evaluate features to achieve 15% above code performance is also included.

Table 4: Step by Step Changes in IC3 for Meeting 15% above Code for the Example Houses

Changes in IC3 - House with Natural Gas Heating - 1 Story		**% Above Code**
Steps	Baseline house	3.30%
1	Decreasing U factor of the window from 0.47 to 0.30	7.02%
2	Step1 + Increasing the roof insulation from R-30 to R-38	8.19%
3	Step2 + Increasing the heating efficiency from 0.78 to 0.9	10.14%
4	Step3 + Increasing the cooling efficiency from SEER 13 to SEER 15	12.22%
5	Step4 + Increasing the energy factor from 0.544 to 0.62	15.47%

Changes in IC3 - House with Heat Pump Heating - 1 Story		**% Above Code**
Steps	Baseline house	4.47%
1	Decreasing the SHGC from 0.4 to 0.3	6.29%
2	Step1 + Decreasing the U factor of the window from 0.47 to 0.3	7.28%
3	Step2 + Increasing the wall insulation from R-13 to R-16	7.62%
4	Step3 + Increasing the roof insulation from R-30 to R-38	8.28%
5	Step4 + Increasing the cooling efficiency from SEER 13 to SEER 15	10.43%
6	Step5 + Increasing the energy factor from 0.86 to 0.95	12.42%
7	Step6 + 4-feet shades in the south wall	12.91%
8	Step7 + Increasing the heat pump efficiency from 7.7 to 9.0	14.57%
9	Step8 + Installing a radiant barrier in the attic	15.07%

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