DETAILED ANALYSIS OF THE BUILDER OPTION PACKAGES FOR CLIMATE ZONES 3,4,5 AND 6 FOR TEXAS' SENATE BILL 5 LEGISLATION FOR REDUCING POLLUTION IN NON-ATTAINMENT AND AFFECTED AREAS

Project for Texas' Senate Bill 5 Legislation For Reducing Pollution in Non-attainment and Affected Areas

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INTRODUCTION

This report is a detailed description of the analysis completed on the Energy Star Builder Option Packages (BOPs) using the Energy Systems Laboratory's (ESL) Code Compliant Test Suite of Tools. This report outlines the basic procedure, which was followed. A description of the Test Suite, along with a detailed explanation of the naming the procedure of the different runs is also a part of this report. A CD-ROM is also provided which has all the 137 runs, inputs and outputs, the window inputs and the summary spreadsheets.

BOPs for climate zones 3,4,5 and 6 were submitted for approval to ESL on April 29,2002. It was stated that the suggested BOPs were 10 to 15% less consumptive than the IECC chapter 4/5 house. Analysis was done on these BOPs and the BOPs which were less consumptive than the standard house were posted on the ESL's website. The same tables have also been included in this report along with the detailed spreadsheets.

ESL'S CODE COMPLIANT TEST SUITE OF TOOLS

The Code Compliant Test Suite of Tools comprises of the following two sections:

- 1. The IECC input file
- 2. The Automated glass input

Following is a description of how the IECC input file, based on DOE-2.1e version 119, can be used to simulated and verify the energy consumption of the Builder Option Packages. The complete input file can be accessed from the following link:

iecc1103.inp

PROCEDURE FOR RUNNING DIFFERENT SIMULATIONS THROUGH THE IECC TRACEABLE INPUT FILE:

The IECC input file uses the parameter command of DOE-2 to simulate different weather conditions and construction details for different parts of Texas. IECC1100 is not a dynamic file, so if the area changes as in the case of east and west Texas, changes have to made inside the code in addition to the parameters so that all the windows and walls have the correct geometry and connected layout. However for a particular region (same area), changes are only incorporated at the top in the parameters. Following is the complete list parameters along with the corresponding DOE-2 keyword and user input, the shaded ones are changed with every different run.

User Input	Doe-2 Keyword	Corresponding Parametric Input	Examples Values
	Gross-Area		
	(total floor area)		
House dimensions	(floor-weight = 0)	P-AREA	2500 ft ²
	Gross-Area		
	(perimeter)		
House dimensions	(floor-weight > 0)	P-AREA1	200 ft ²
House dimensions	Volume	P-VOLUME	
	Width (for exterior		
House dimensions	wall, shades etc)	P-BUILDINGWIDTH	50 ft
	Length (for exterior		
House dimensions	wall, shades etc)	P-BUILDINGLENGTH	50 ft
Internal wall height	Height (Wall)	P-WALLHEIGHT	8 ft
	Azimuth (Building		
	Location		
Orientation of house	Command)	P-BUILDINGAZIMUTH	0°
Weather Station	Latitude	P-LATITUDE	29.98°

Weather Station	Longitude	P-LONGITUDE	95.37°
Weather Station	Time-zone	P-TIME-ZONE	6
Weather Station	Altitude	P-ALTITUDE	108 ft
No. of Occupants	Number-of-people	P-OCCUPANCY	2
Width of the left wall	Width	P-LEFTWALLWIDTH	28
R-value (roof) (1/U-value)	U-value (Roof)	P-ROOFUVALUE	0.5
Roof outside emissivity	Outside-emiss	P-ROOFOUTEMISS	0.9(fixed)
Roof absorptance	Absorptance	P-ROOFABSORPTANCE	0.5(fixed)
Roof roughness	Roughness	P-ROOFROUGHNESS	1(fixed)
R-value (wall) (1/U-value)	U-value (Wall)	P-WALLUVALUE	0.077
Wall absorptance	Absorptance	P-WALLABSORPTANCE	0.55 (fixed)
Wall roughness	Roughness	P-WALLROUGHNESS	2 (fixed)
Wall outside emissivity	Outside-emiss	P-WALLOUTEMISS	0.9 (fixed)
Wall ground reflectance	Gnd-reflectance	P-GND-REFLECTANCE	0.24 (fixed)
R-value (ceiling) (1/U-value)	U-value (Ceiling)	P-CLNGUVALUE	0.0385
Door height	Height	P-DOORHEIGHT	6.67ft (fixed)
Door width	Width	P-DOORWIDTH	3 ft (fixed)
Window to wall ratio	Width (Window)	P-WINDOWWIDTH	12 ft
Window to wall ratio	Height	P-WINDOWHEIGHT	5 ft (fixed)
Solar heat gain factor (SHGF)	Shading-coeff	P-SHADINGCOEFFICIENT	0.528 (pre-calculated from NFRC 200)
U-Value (Window)	Glass-conductance	P-GLASSCONDUCTANCE	0.65 (pre-calculated from NFRC 100)
Type of frame	Frame-width	P-FRAMEWIDTH	0.23
Type of frame	Frame- conductance	P-FRAMECONDUCTANCE	3.037
Type of frame	Frame-		0.7
	Panes		2
Floor weight	Floor-weight	P-FLOORWEIGHT	$\frac{2}{11.5 \text{ lbs/ft}^2}$
Floor U-value	U-value (floor)	P-FLOORUVALUE	0.06
U-effective	U-value (floor)	P-UEFFECTIVE	0.0628
Roof Overhang	Height (Building-	P-SHADEWIDTHE	3
Roof Overhang	Height (Building- shade)	P-SHADEWIDTHR	3
Roof Overhang	Height (Building- shade)	P-SHADEWIDTHB	3
Roof Overhang	Height (Building- shade)	P-SHADEWIDTHL	3
Roof Overhang	Transmittance	P-TRANSMITTANCE	1

Roof Overhang	Transmittance schedule	P-SCHEDULE	1
A/C SEER	Cooling-EIR	P-EIR	0.341
Furnace AFUE	Furnace-HIR	P-HIR	1.25
DHW efficiency	DHW-HIR	P-DHWHIR	1.31

The explanation of how the highlighted parameters are put in the simulation.

House Dimension:

Related parameters

P-AREA P-AREA1 P-VOLUME P-BUILDINGLENGTH P-BUILDINGWIDTH P-LEFTWALLWIDTH

P-AREA:

It is the total floor area of the building and in this case it is the product of the P-BUILDINGLENGTH and P-BUILDINGWIDTH. Right now no external routine is being used to take the product of the two parameters so the area is put in manually.

P-AREA1:

It is the perimeter of the building and it can also be calculated from the P-BUILDINGLENGTH and P-BUILDINGWIDTH, but right now it is being put in manually. This is used for the floor area when the custom weighting factors are not being used, which is the case for the current simulation runs.

P-VOLUME:

It is the product of P-AREA and the P-BUILDINGHEIGHT, the latter is fixed at 8 ft. For this input file this value is being put in manually.

P-BUILDINGLENGTH:

For these simulations the building is being considered rectangular so this parameter corresponds to the two sides of the building.

P-BUILDINGWIDTH:

This gives the dimensions of the remaining two sides of the building.

P-LEFTWALLWIDTH:

This gives the width of the wall, which is exterior after the garage.

Material Properties:

P-ROOFUVALUE P-WALLUVALUE P-CLNGUVALUE

P-ROOFUVALUE:

This is the total U-value for the combined construction of the roof. The user inputs an R-value, which is the reciprocal of the U-value. The inversion of the value is manual.

P-WALLUVALUE:

This is the total U-value for the combined construction of the wall. The user inputs an R-value, which is the reciprocal of the U-value. The inversion of the value is manual.

P-CLNGUVALUE:

This is the total U-value for the combined construction of the ceiling. The user inputs an R-value, which is the reciprocal of the U-value. The inversion of the value is manual.

P-FLOORUVALUE:

This gives the total U-value of the floor including the slab and the added insulation.

P-UEFFECTIVE:

This value is calculated to just consider the heat transfer from the slab perimeter.

Glazing Dimensions and Properties:

P-WINDOWWIDTH P-SHADINGCOEFFICIENT P-FRAMEWIDTH P-GLASSCONDUCTANCE P-FRAMECONDUCTANCE

P-WINDOWWIDTH:

This is the equivalent width if a single window is considered on each exterior wall of the house. The value is calculated through a spreadsheet created to input windows in DOE-2. The user just puts in the window to wall ratio.

P-SHADINGCOEFFICIENT:

This is the center of glass shading coefficient, which needs to input into the DOE-2 file. This is also calculated through the spreadsheet. The user just provides the Solar Heat Gain Factor of the complete window.

P-FRAMEWIDTH:

This is the equivalent frame width if a single window is considered on each exterior wall. The value is calculated by the spreadsheet and the user input requires the type of frame.

P-GLASSCONDUCTANCE:

This is the main parameter, which is required as input to define the glass properties. The user defined U-value is transformed to the glass conductance through the NFRC 100 and Doe-2 defined formulae in the glass input spreadsheet.

P-FRAMECONDUCTANCE:

This value is taken from the DOE-2.1e supplement and it depends on the frame type chosen by the user.

The remaining 2 parameters are in the systems portion of the file.

P-EIR:

This input corresponds to the efficiency of the cooling equipment in DOE-2, which is usually defined in SEER. The conversion of Seasonal Energy Efficiency Ration (SEER) to the Energy Input Ratio (EIR) is:

EIR = 3.41/SEER

P-HIR:

This input corresponds to the efficiency of the heating equipment in DOE-2, which is usually defined in AFUE. The conversion of Annual Fuel Utilization Efficiency (AFUE) to the Heat input Ratio (HIR) is:

HIR = 1/ AFUE

Example of typical input for running the IECC code compliant simulation:

House Dimensions:

User Defined Input:

50x50 house with 8ft. ceiling.

Corresponding Parameters:

P-BUILDINGLENGTH = 50 ft.

P-BUILDINGWIDTH = 50 ft.

 $P-AREA = 50 \times 50$ = 2500 ft² (if the floor weight is taken as zero)

P-AREA1 = 2 x (50 + 50)= 200 ft. (if floor weight is greater then 0)

P-WALLHEIGHT = 8ft (Typical Value)

 $P-VOLUME = P-AREA \times P-WALLHEIGHT$ $= 2500 \times 8$ $= 20000 \text{ ft}^{3}$

Weather Station:

User Defined Input:

The house is situated in Houston, Texas. The TMY2 file will be of Houston

Corresponding Parameters:

P-LATITUDE = 29.98°

P-LONGITUDE = 95.37°

P-TIMEZONE = 6

P-ALTITUDE = 108 ft

Material Properties:

User Defined Input:

Roof R-value = R-2

Wall R-value = R-13

Ceiling R-value = R-26

Corresponding Parameters:

P-ROOFUVALUE = 1 / Roof R-value= 1 / 2= 0.5 Btu /hr.°F. ft²

P-WALLUVALUE = 1/ Wall R-value = 1/ 13 = 0.077 Btu /hr.°F. ft^2

P-CLNGUVALUE = 1/ Ceiling R-value = 1/ 26 = 0.0385 Btu /hr.°F. ft²

Glazing Dimensions and Properties:

User Defined Input:

Window to Wall Ratio = 15%

Window U-value = 0.75

Window Solar Heat Gain Factor = 0.4

Frame Type = Aluminum W/O thermal break

Corresponding parameters: (for calculating procedure of the following parameters refer to the attached Window input explanation)

P-WINDOWWIDTH = Equivalent width of a window if only one window is considered in each wall.

= 12 ft.

P-SHADINGCOEFFICIENT = Shading coefficient for the center of the glass.

= 0.528

P-FRAMEWIDTH =Equivalent width of a frame if only one window is considered each wall.

= 0.23 ft.

P-GLASSCONDUCTANCE = This is the center of glass U-value and is the main property for defining the type of glass.

= 0.65 Btu/hr.°F ft²

P-FRAMECONDUCTANCE=This values comes directly from the DOE-2 user's manual and is dependent on the type of frame chosen by the user.

 $= 3.037 \text{ Btu/hr.}^{\circ}\text{F ft}^{2}$

Equipment Efficiencies:

User Defined Inputs:

Furnace AFUE = 80%

A/C SEER = 10

Corresponding Parameters:

P-EIR = 3.413/SEER= 3.413/10= 0.341P-HIR = 1/AFUE= 1/0.8= 1.25

These are the main parameters, which are changed to run different simulations with the code traceable IECC input file.

The glazing properties used in the above simulation require post processing through a spreadsheet, which is based on the NFRC 100 and 200 calculations. The structure and explanation of the spreadsheet is given below:

CONVERSION OF WINDOW U-VALUE TO GLASS CONDUCTANCE ANDSHGF TO SHADING COEFFICIENT

The DOE-2 simulation software allows window to be entered in the following ways:

1. Shading Coefficient

```
Username = GLASS-TYPE

SHADING-COEFF =

PANES =

GLASS-CONDUCTANCE =

VIS-TRANS =

FRAME-CONDUCTANCE =

FRAME-ABS =

2. Glass-Type-Code < 11
```

- Username = GLASS-TYPE GLASS-TYPE-CODE = PANES = GLASS-CONDUCTANCE = VIS-TRANS = FRAME-CONDUCTANCE = FRAME-ABS =
- 3. Window Library (Glass-Type-Code \geq 1000) Username = GLASS-TYPE GLASS-TYPE-CODE = FRAME-CONDUCTANCE = FRAME-ABS =

The second of input restricts the user to the predefined U-values and SHGF of the window library while in the third type there is a choice to use windows already defined in the library or add new windows to the DOE-2 library following a certain method explained in the DOE-2.1e reference manual.

For the purposes of the project, which requires the user to input window U-value and Solar heat gain coefficient, the first method is feasible. It requires Shading Coefficient and Glass Conductance as input to the simulation program, while the general practice is to define the Solar Heat Gain Factor and the U-factor. To convert the U-factor and Solar Heat Gain Factor to Glass Conductance and Shading Coefficient, the following steps are required which have been incorporated in a spreadsheet for the ease of calculations. The spreadsheet, which has been used, is:

automated glassinput.xls

• This is a generalized spreadsheet, which requires the following inputs for the calculation of the shading coefficient and glass conductance.

House dimensions: Length Width Height of the interior wall

Glazing Properties: U-Factor Solar Heat Gain Factor

Window to wall ratio (%)

- Two separate sections in the spreadsheet calculate the glass-conductance and the SHGF to be input in the DOE-2 input file.
- In DOE-2 there is a choice of 5 types of frames, so in the spreadsheet there are five different rows, which calculate the glass conductance and SHGF for the different frame types.
- Next the total Wall or Floor area of the house is defined, which will be used to determine the area of window on each wall.
- The frame is taken to be a standard 11/2" for Aluminum and 2 ¹/₂" for Wood and Vinyl.
- The value of frame conductance is taken from the DOE-2.1e manual.

The rest of the calculation in the spreadsheet are explained below:

1. Calculation of the Frame U-value: The following formula is from DOE-2.1e Supplement (p. 2.116) Assumption: None

Frame U-value = $[(\text{frame conductance})^{-1} + 0.197]^{-1}$

1. Calculation of Area of Window on each wall: Assumption: window area is equal on all sides

Window area on each wall = $\underline{\text{Total wall area x Window to wall ratio (%)}}{4}$

2. Calculation of the number of Windows on each wall: Assumption: Each window is 3x5 (15 ft²)

Number of windows = $\frac{\text{Window area on each wall}}{\text{Area of one window (15 ft}^2)}$

 Calculation of Glass Area: Assumption: Frame width is 0.125 ft, window height is 5ft and width is 3ft.

Glass area = (Height of Window - 2x Width of frame) x (Width of Window – 2x Width of frame)

4. Calculation of Frame area: Assumption: None

Frame area = (Window area on each wall) – (Glass Area)

5. Calculation of Window width if one equivalent window: Assumption: Window height is 5ft and house is rectangular

Window Width = <u>Window to wall ratio(%) x Total wall area</u> No. of exterior walls x window height

6. Calculation of equivalent frame width Assumption: Window height is 5ft.

Equivalent frame width = $\frac{\text{Frame area}}{2x \text{ (equiv. Window width + window height)}}$

7. Calculation of center of glass U-value: The NFRC 100 is used for this calculation Assumption: Edge of glass U-value is neglected No dividers are considered

Center of glass U-value = <u>(Total U-value x Total area) – (Frame U-value x Frame area)</u> Glass Area

8. Calculation of the Glass Conductance: Assumption: None

Glass Conductance = $[(Center of glass U-value)^{-1} - 0.197]^{-1}$

This value is finally input into the code and this can be checked against the output since the output gives out the total U-value of the Window, which shows that the window is being simulated according to the U-factor provided.

The following two steps are used to calculate the shading coefficient when the solar heat gain coefficient is provided as the input.

9. Calculation of the Center of glass SHGF The following formula is from NFRC 200 Assumption: Edge of glass is neglected No dividers are considered Frame has zero SHGF

> Center of Glass SHGF = $\underline{\text{Total SHGF x Total Area}}$ Area of Glass

10. Calculation of Shading Coefficient The following formula is from NFRC 200 Assumption: None

Shading Coefficient = (Center of glass SHGF)/0.87

Sample Calculation:

Assuming the following Input values for the spreadsheet:

House dimensions: Length = 50 ft Width = 50 ft Height of the interior wall = 8 ft Window to wall ratio = 15% Glazing Properties: U-Factor = 0.75 Solar Heat Gain Factor = 0.4

Assuming an Aluminum frame without thermal break:

From the spreadsheet

Conductance of Aluminum w/o thermal break = 3.037

Frame U-value = $[(\text{frame conductance})^{-1} + 0.197]^{-1}$

$$= [(3.037)^{-1} + 0.197]^{-1}$$

= 1.9 Btu/hr ft² °F Frame-width = 0.125 ft

Total wall area = (2x width x height) + (2x length x height)

$$= (2 x 50 x 8) + (2 x 50 x 8)$$
$$= 1600 \text{ ft}^{2}$$

Total area of a single window = <u>Total wall area x Window to wall ratio (%)</u>

4

$$=\frac{1600 \text{ x } 15\%}{4}$$

= 60 ft²

Number of windows = $\frac{\text{Window area on each wall}}{\text{Area of one window (15 ft}^2)}$

= 60/15

= 4 windows

Glass area = (Height of Window - 2x Width of frame) x (Width of Window - 2x Width of frame)

$$= [(5 - 2 \times 0.125) \times (3 - 2 \times 0.125)] \times 4$$
$$= 52.25 \text{ ft}^2$$

Frame area = (Window area on each wall) – (Glass Area)

$$= 60 - 52.25$$

 $= 7.75 \text{ ft}^2$

Equivalent width of a single window = $\frac{\text{Window to wall ratio (\%) x Total wall area}}{\text{No. Of exterior walls x window height}}$

$$= \frac{15 \% x 1600}{4 x 5}$$

$$= 12$$
 ft.

Equivalent frame width for a single window

= <u>Frame area</u> .
2x (equiv. Window width x window height)
$= 7.75/[2 \times (12 \times 5)]$
= 0.23 ft.
Center of glass U-value = (Total U-value x Total area) – (Frame U-value x Frame area)
Glass Area

$$= \frac{(0.75 \text{ x } 60) - (1.9 \text{ x } 7.75)}{52.25}$$

$$= 0.58$$
 Btu/ hr ft² °F

Glass conductance = $[(Center of glass U-value)^{-1} - 0.197]^{-1}$

$$= [(0.58)^{-1} - 0.197]^{-1}$$
$$= 0.65 \text{ Btu/ hr ft}^2 \text{ }^\circ\text{F}$$

The second part of the spreadsheet is similar to the first one except for the following:

Center of glass SHGF = $\frac{\text{Total SHGF x Total Area}}{\text{Area of Glass}}$ = $\frac{0.4 \times 60}{52.25}$ = 0.459 Shading Coefficient = Center of glass SHGF/ 0.87 = 0.459/0.87

The spreadsheet is attached for the better understanding of this calculation procedure.

TYPICAL WINDOW CONSTRUCTION:

The following window construction and size is considered for all calculations. The frame is openable and can be of the materials already mentioned. The dividers and the edge of glass U-value are neglected. The height of the window is fixed at 5ft while the width depends on the window to wall ratio.



Complete glazing System

3D of Glass



RESULTS

The following tables summarize the analysis done for the Energy Star BOPs submitted. The tables contain only those BOPs whose annual energy use was less then the standard IECC chapter 4/5 house. The same tables are also posted at the ESL's website <u>http://eslsb5.tamu.edu/sbill5/download/EnergyStarletter2.pdf</u>. The detailed spreadsheets are also attached. In addition to that several other comparative analyses were performed, the details of which are included in the appendix.

_	_		_	_	_	_	_
		Status			Pass	Pass	Pass
Equipment	ements		Cool	(SEER)	11	11	14
Minimum	Require		Heat	(AFUE)	80%	80%	80%
	Infiltration		Max. Rate	(ACH)	0.35	0.35	0.35
			Crawlspace	Wall	R-6	R-6	R-6
	ments			Slab	R-0	R-0	R-0
. 	ation Require		Basement	Wall	R-6	R-6	R-6
· ·	nimum Insula	Floor Above	Unheated	Space	R-11	R-11	R-11
	Ξ		Exterior	Wall	R-13	R-11	R-11
				Attic	R-30	R-30	R-19
Mo	nents		Max.	SHGC	0.40	0.35	0.40
Wind	Require		Max.	U-value	0.65	09.0	0.60
	Maximum	Window to floor area	ratio		18%	18%	21%
		BOP	Number		Z3-1-ES	Z3-2-ES	Z3-3-ES
	DOE.2	file	name		escz33	escz35	escz318

Table 1 gives the details of the BOPs, which passed for climate zone 3. This climate zone was simulated using Houston TMY2 data.

Table 1 Building Option Packages (BOPS) for A-1 Single Family Residences in Climate Zone #3

Table 2 gives the details of the BOPs, which passed for climate zone 4. This climate zone was simulated using Houston TMY2 data.

6				
Status			Pass	Pass
	Cool	(SEER)	11	11
	Heat	(AFUE)	80%	%08
	Max. Rate	(ACH)	0.35	0.35
	Crawlspace	Wall	R-6	R-6
		Slab	R-0	R-0
	Basement	Wall	R-6	R-6
Floor Above	Unheated	Space	R-11	R-11
	Exterior	Wall	R-13	R-11
		Attic	R-30	R-30
	Max.	SHGC	0.40	0.35
	Max.	U-value	0.65	09.0
Window to floor area	ratio		18%	18%
BOP Number			Z4-1-ES	Z4-2-ES
file			escz33	escz318
	file Number floor area Above A	Floor Floor Floor file Number floor area name Number floor area name ratio Max. Max. Exterior Unheated Basement Crawlspace Max. Reat Cool	Ties Number floor area name ratio U-value SHGC Attic Wall Space Wall Slab Wall (ACH) (ACH) (ACH) (AEUE) (SEER)	Floor BOP Window to file Floor Floor name Mumber floor area Max. Above Above name Max. Max. Max. Above Max. secz33 24-1-ES 18% 0.65 0.40 R-30 R-11 R-6 R-0 R-6 0.35 80% 11 Pass

Table 2 Building Option Packages (BOPS) for A-1 Single Family Residences in Climate Zone #4

			Status	
4	Eq uipment	ements		Cool
	Minimum	Require		Heat
M NOT SITE		Infiltration		Max Rate
				Crawlspace
CDW VI		nents		
		tion Requiren		Basement
2010 2. 111		imum Insulat	Floor Above	Unheated
		Min		Exterior
NT INACCE				
	ow	nents		Max
6 TO T A	Wind	Requirer		Max
		Maximum	Window to floor area	ratio
			BOP Number	
data.		DOE:2	file	name

Pass Pass Pass

Cool (SEER) 2

Heat (AFUE) č

Max Rate (ACH)

Crawlspace Nall 8°-2

Basement Wal Ľ. 1 2 ż Ľ. 2 2 1

Wal

Attic

Max SHGC 40

J-value Max .50

15%

Escz52 Escz56

Z5-1-ES Z5-2-ES Z5-3-ES Z5-4-ES

Z5-5-ES Z5-6-ES

-scz57

escz511 escz510 escz512

Pass Pass Pass

2

80 80,

Res 1 84

è ż

R-13

R-30 R-30

040 0.40

.40 50

Z5-7-ES Z5-8-ES Z5-9-ES

ž

2 2 R-0

zone 5. This climate zone was simulated using Fort Worth TMY2 Table 3 gives the details of the BOPs, which passed for climate

Table 3 Building Option Packages (BOPS) for A-1 Single Family Residences in Climate Zone #5

Table 4 gives the details of the BOPs, which passed for climate zone 6. This climate zone was simulated using Fort Worth TMY2

		Status			Pass								
Equipment	ements		Cool	(SEER)	10	10	11	11	12	12	12	14	13
Minimum E	Require		Heat	(AFUE)	80%	80%	80%	80%	80%	80%	80%	80%	80%
	Infiltration		Max Rate	(ACH)	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
			Crawlspace	Wall	R-8								
	nents			Slab	R-0								
	ion Requiren		Basement	Wall	R-7								
	mum Insulat	Floor Above	Unheated	Space	R-19								
	Mini		Exterior	Wall	R-13	R-13	R-13	R-15	R-13	R-13	R-15	R-13	R-13
				Attic	R-30	R-38	R-30						
wo	ments		Max	SHGC	0.40	0.35	0.40	0.35	0.40	0.40	0.40	0.40	0.40
Wind	Require		Max	U-value	0.50	0.45	0.45	0.40	0.50	0.40	0.50	0.55	0.50
	Maximum	Window to floor area	ratio		15%	18%	18%	21%	18%	21%	21%	18%	21%
		BOP Number			Z6-1-ES	Z6-2-ES	Z6-3-ES	Z6-4-ES	Z6-5-ES	Z6-6-ES	Z6-7-ES	Z6-8-ES	Z6-9-ES
	DOE 3	file	allip		Escz52	Escz55	Escz56	Escz57	escz510	escz511	escz512	escz518	escz519

Table 4 Building Option Packages (BOPS) for A-1 Single Family Residences in Climate Zone # 6

Climate Zone 3(Energy Star)/Glazing % of Floor Area (HVAC Autosized)	Inflim.tion Texts Requirements Menturn Equipment requirements AMMAL, EREOV USI	Ger formace heating, Electric Consig, Ger Domenic Mar weir Electric Consig, Ger Domenic Mar weir Taak bes Usage and Phil Vione Taak Electric Usage And Phil Vione Taak Electric Usage	A Convince Interaction Provided For the control of	R.0 Red 035 006 105 76 87 710 81.06 23.76 81.78	R.0 Res 055 055 055 055 050 350 <th>0.0 84 0.5 0.6 0.6 0.5 0.6 0.5 0.6 0.5 0.6 0.6 0.5 0.6</th> <th>0.5 056 057 056 057 057 4.1 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.3 5.3 5.2.3 5.3<!--</th--><th>R-0 R-8 0.55 0.05 105 4.7 7.6 4.15 4.26 4.15 4.26 4.15 4.15 4.15 4.15 6.17 8104 8105 8105 8107 8108 8117 81082 82.176 81135</th><th>b Re 025 006 046 64 64 420 420 420 340 340 211 71.0 71.01 3500 3808 8203</th><th></th><th>Climate Zone 4(Energy Star)Glazing % of Floor Area (HVAC Autosized)</th><th>hefte facion bests Rooairements Minimum Ecolomentat recuirements AMMMAL BESOR VISE</th><th>Over Frunces healing, Electro control. Get Romer Level where Electro control. Get Romer Level V. Lasen Total Sea Useane Healing, Level Useane Verse Vis. Reserviced</th><th>the Convergence Interface Mediatoriale Mediatorial Mediatorial Conversion Con</th><th>260 Trian (24.01) (Prived) (26.04) (26.01) (26</th><th>R.0 R.4 0.35 0.06 105.06 11 4.6 7.6 4.0 11/21 3.4 4.030 3.16 3.16 3.18 4.6 7.20 3.108 3.241 5.25%</th><th>R.D R.O R.O<th>R.0 R-6 0.35 00% 16.2 7.91 18.94 32.2 22.30 19.96 44.8 35.47 19.020 38.06 38.54 0.1 0.6 0.5 00% 1.6 7.9 1.0 2.6 2.95 4.15 2.97 1.984 3.23 2.93 9.18 4.83 35.46 38.54 38.54 0.1 0.6 0.5 0.6 0.75 0.6 0.54 0.65</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></th></th>	0.0 84 0.5 0.6 0.6 0.5 0.6 0.5 0.6 0.5 0.6 0.6 0.5 0.6	0.5 056 057 056 057 057 4.1 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.2 4.3 5.3 5.2.3 5.3 </th <th>R-0 R-8 0.55 0.05 105 4.7 7.6 4.15 4.26 4.15 4.26 4.15 4.15 4.15 4.15 6.17 8104 8105 8105 8107 8108 8117 81082 82.176 81135</th> <th>b Re 025 006 046 64 64 420 420 420 340 340 211 71.0 71.01 3500 3808 8203</th> <th></th> <th>Climate Zone 4(Energy Star)Glazing % of Floor Area (HVAC Autosized)</th> <th>hefte facion bests Rooairements Minimum Ecolomentat recuirements AMMMAL BESOR VISE</th> <th>Over Frunces healing, Electro control. Get Romer Level where Electro control. Get Romer Level V. Lasen Total Sea Useane Healing, Level Useane Verse Vis. Reserviced</th> <th>the Convergence Interface Mediatoriale Mediatorial Mediatorial Conversion Con</th> <th>260 Trian (24.01) (Prived) (26.04) (26.01) (26</th> <th>R.0 R.4 0.35 0.06 105.06 11 4.6 7.6 4.0 11/21 3.4 4.030 3.16 3.16 3.18 4.6 7.20 3.108 3.241 5.25%</th> <th>R.D R.O R.O<th>R.0 R-6 0.35 00% 16.2 7.91 18.94 32.2 22.30 19.96 44.8 35.47 19.020 38.06 38.54 0.1 0.6 0.5 00% 1.6 7.9 1.0 2.6 2.95 4.15 2.97 1.984 3.23 2.93 9.18 4.83 35.46 38.54 38.54 0.1 0.6 0.5 0.6 0.75 0.6 0.54 0.65</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></th>	R-0 R-8 0.55 0.05 105 4.7 7.6 4.15 4.26 4.15 4.26 4.15 4.15 4.15 4.15 6.17 8104 8105 8105 8107 8108 8117 81082 82.176 81135	b Re 025 006 046 64 64 420 420 420 340 340 211 71.0 71.01 3500 3808 8203		Climate Zone 4(Energy Star)Glazing % of Floor Area (HVAC Autosized)	hefte facion bests Rooairements Minimum Ecolomentat recuirements AMMMAL BESOR VISE	Over Frunces healing, Electro control. Get Romer Level where Electro control. Get Romer Level V. Lasen Total Sea Useane Healing, Level Useane Verse Vis. Reserviced	the Convergence Interface Mediatoriale Mediatorial Mediatorial Conversion Con	260 Trian (24.01) (Prived) (26.04) (26.01) (26	R.0 R.4 0.35 0.06 105.06 11 4.6 7.6 4.0 11/21 3.4 4.030 3.16 3.16 3.18 4.6 7.20 3.108 3.241 5.25%	R.D R.O R.O <th>R.0 R-6 0.35 00% 16.2 7.91 18.94 32.2 22.30 19.96 44.8 35.47 19.020 38.06 38.54 0.1 0.6 0.5 00% 1.6 7.9 1.0 2.6 2.95 4.15 2.97 1.984 3.23 2.93 9.18 4.83 35.46 38.54 38.54 0.1 0.6 0.5 0.6 0.75 0.6 0.54 0.65</th> <th></th>	R.0 R-6 0.35 00% 16.2 7.91 18.94 32.2 22.30 19.96 44.8 35.47 19.020 38.06 38.54 0.1 0.6 0.5 00% 1.6 7.9 1.0 2.6 2.95 4.15 2.97 1.984 3.23 2.93 9.18 4.83 35.46 38.54 38.54 0.1 0.6 0.5 0.6 0.75 0.6 0.54 0.65																
			071 Wh Themalyei	302 326	3843 318	102 231	323	3894 322	3687 348					170	842 326	3843 318	5877 331 5908 323	\$894 322 eeo7 240		-				-		_						_		
isized)		y Usage	MERulyear 34	40.48	40.50	42.16	43.65	42.97	42.63		sized)		v Utseze	0	40.48	40.50	42.16	42.97		+				+		+	-					+	-	
HVAC Auto		Total Electricit	(osu)(V)	3.92	3.84	4.16	4,37	4.15	4.20		HVAC Auto		Total Electricit	Configure 1	3.92	3.84	4.16	4.15	AW													Ţ		
loor Area			M e Bay) kMhJyeor	11,985	11,871	12,357	12,793	12,583	12,495		loor Area			N a	11,865	11,871	12,357	12,593																
zing % of F	irements	a. Hot water	Efficiency Siz (%) (gal8	76 40	76 40	76 40	76 40	76 40	76 40		zing % of F	irements	a. Hot water	Efficiency Sta	(w) (amo	76 40	76 40	76 40	2															
ay Star)Gla	quipment requ	: Furnace Heating	ool A/C size EP() (Tons)	10 4.6	4.6	4.7	1 4.7	13 4.7	4.6	_	ay Star)Gla	oupment regu	Furnace Heating	ool A/C size	10 4.5	48	14	13 4.7		 -				-		+						-	-	
one 3(Energ	Minimum E	Get Electric Coolir	Furnsce size C (Bhuhr) (SS	106,558	106,558	106,558	106,558	106,558	106,558		one 4(Energ	Minimum E	Gettic Coolit	Furnace size C	106,558	106,558	106,558	106,558	ALA ⁰ AA															
Climate Zo	tration ements		tion Rate Heat	35 80%	808	32	35 80%	808	30%		Climate Zo	tration		tion Rate Heat	(U) (N)(C)	35 80%	30 K	22 20 20 20 20																
	Infik Requir		space Infilmet	9	9	8	8	8	8			Infilt		space Infilmat	5 0 8 9	9	8 8	999																
			Crawf Stab	R. 0 8	8. O	8- 0 8	9. B	82 0 82	0 6					Crawf	R- 0 1	R- 0	62 62 0 62 62																	
	bequir ements		Besement	R- 0	8.6	8-8	8-6	8	8			equirements		Basement	R- 0	8	60 66 62 62	60 9 62 0						+								ŧ		
	um Insulation R		Floor Above Inheated Space	R. 11	R- 11	R- 11	R- 11	8. 11	11			um Insulation R		Floor Above	R- 11 R- 11	R- 11	8 1 1 1	až a							a considered.							ed design		
	Minim		Exterior Well U	R. 11	R- 13	R- 11	R- 13	8 1	я 11			Minim		Ederior viter 11	R- 11	R. 13	R-11 12 12	ak a		(11, job 8 80, 11) ju					actor is not being			5				dard and proposi- to unit (ECC300)		
			Attic	8, 30	R. 30	R- 30	R- 30	8	R- 19					1	900 8-30	R- 30	8 8 8 8	8 9 00 0		equal 10 44 heet	5				age of glass U-ti		version 119.	ding to ECC 200	6 hours.	(q)		units in the stand once in each livin		
	ents	~~~	w window t	20.60%	24.75%	24.75%	20.00%	28.89%	26.68%				203	w window t	20.60%	24.75%	24.75% 26.86%	20.09%		naving each sig	ang or shade tre	or crawi space.		é	k, no dividers, e	tioss.	by the DOE-2:16	d settings accord	1 SF setback for untotion is given	iay= (30ca)+(10	ste	number of living number of bedro	RGY STAR.	
	we Requireme		forw Witnich	0.70 <i= 0.40<="" td=""><td>0.65 <!--= 0.40</td--><td>0.60 <=> 0.35</td><td>0.55 <\= 0.35</td><td>0.55 <= 0.40</td><td>0.60 <== 0.40</td><td></td><td></td><td>quirements</td><td></td><td>for Vincin</td><td>0.70 <!--= 0.40</td--><td>0.65 <!--= 0.40</td--><td>0.00 0.30</td><td>0.55 <== 0.40</td><td>ALLA ARCA</td><td>It locng west</td><td>or adjacent build</td><td>de.</td><td>and one on back</td><td>Denor well is U.S.</td><td>rio thermal break</td><td>o penaly for duc</td><td>ment are sized (</td><td>with customize</td><td>F for cooling and total dail consu-</td><td>pilite</td><td>whe</td><td>- e</td><td>is define by BIE</td><td></td></td></td></td></i=>	0.65 = 0.40</td <td>0.60 <=> 0.35</td> <td>0.55 <\= 0.35</td> <td>0.55 <= 0.40</td> <td>0.60 <== 0.40</td> <td></td> <td></td> <td>quirements</td> <td></td> <td>for Vincin</td> <td>0.70 <!--= 0.40</td--><td>0.65 <!--= 0.40</td--><td>0.00 0.30</td><td>0.55 <== 0.40</td><td>ALLA ARCA</td><td>It locng west</td><td>or adjacent build</td><td>de.</td><td>and one on back</td><td>Denor well is U.S.</td><td>rio thermal break</td><td>o penaly for duc</td><td>ment are sized (</td><td>with customize</td><td>F for cooling and total dail consu-</td><td>pilite</td><td>whe</td><td>- e</td><td>is define by BIE</td><td></td></td></td>	0.60 <=> 0.35	0.55 <\= 0.35	0.55 <= 0.40	0.60 <== 0.40			quirements		for Vincin	0.70 = 0.40</td <td>0.65 <!--= 0.40</td--><td>0.00 0.30</td><td>0.55 <== 0.40</td><td>ALLA ARCA</td><td>It locng west</td><td>or adjacent build</td><td>de.</td><td>and one on back</td><td>Denor well is U.S.</td><td>rio thermal break</td><td>o penaly for duc</td><td>ment are sized (</td><td>with customize</td><td>F for cooling and total dail consu-</td><td>pilite</td><td>whe</td><td>- e</td><td>is define by BIE</td><td></td></td>	0.65 = 0.40</td <td>0.00 0.30</td> <td>0.55 <== 0.40</td> <td>ALLA ARCA</td> <td>It locng west</td> <td>or adjacent build</td> <td>de.</td> <td>and one on back</td> <td>Denor well is U.S.</td> <td>rio thermal break</td> <td>o penaly for duc</td> <td>ment are sized (</td> <td>with customize</td> <td>F for cooling and total dail consu-</td> <td>pilite</td> <td>whe</td> <td>- e</td> <td>is define by BIE</td> <td></td>	0.00 0.30	0.55 <== 0.40	ALLA ARCA	It locng west	or adjacent build	de.	and one on back	Denor well is U.S.	rio thermal break	o penaly for duc	ment are sized (with customize	F for cooling and total dail consu-	pilite	whe	- e	is define by BIE	
1	l ĝ		Wind U-va	4	÷	÷	4	*	\$			Window Re	v Ster	dow Wind	5% <=	8% <j=< td=""><td>18% ch 21% ch</td><td>21% <4</td><td></td><td>agre nouse, tro sight is 8 feet.</td><td>foundation units</td><td>ge on north sid</td><td>one on front 4</td><td>indow shades.</td><td>w munimule si e</td><td>conditioned, m</td><td>d cooling equip</td><td>programmable</td><td>etting and 78</td><td>_</td><td></td><td>+</td><td>e is 0.35 ACH a.</td><td></td></j=<>	18% ch 21% ch	21% <4		agre nouse, tro sight is 8 feet.	foundation units	ge on north sid	one on front 4	indow shades.	w munimule si e	conditioned, m	d cooling equip	programmable	etting and 78	_		+	e is 0.35 ACH a.	
	м		Ascimum Mindow Area ⁶	15%	18%	18%	219	51	5				5	39.	2 -	-				 84 ×		10 10	65	8 2	- X	1991.0	8 6	. 69	2 2					

Table 5 spreadsheet for BOPs analysis for climate zones 3&4

											Climat	e Zone 5(E	inergy S	tar)Glazii	ng % of F	Floor Are	a (HVAC	Autosize	(p										
	1		₁								Inditration	1			1	<u> </u>							outpoor nee						
uper	Enercy Star	And house and		3							and an announce in a	Bedric	Gas Fun Cooling, Ga	sce Heating, 1 Domestic Ho	t writer	-	TotalE	lectricity Used			Total Gas Usa	10	Healing, cooli and DHN us	2 8	Total Energy	Usabe	% en ivsier		
N doa	Macimum Window Area ⁴	Window W Uvalue	Mindown wi SHOC w	quivalent indow to vali ratio ²	Allio.	Etterior Vial U	Floor Above Inheated Space	Basement	-BES	Crawlspace	Infitration Rate (ACH) (Furnso Heat size AFUE) (Bhuhr)	Cool (SEER)	AlC size Ef (Tons)	DHW D ficiency S1 (%) (gal)	HN' ize ider) INMv	iesr IV/(m	million (m	Vear \$4000	1 Thermoly	ear McBurle	0.615 or \$them	MBtulree	Milleule	ar SiVear	Bhu' sq.ft- year	to total ECC Chapter 46 house	% equivalent CHHDW of E Chatter 45 ho	4 CO 800
2	15%	d= 0.50 d=	0.40 20	100%	8	5 5	R. 19	R. 7	0 2	88	0.35	80% 107,400	9	47	92	40 12;	224 4.4	20	5 \$87	75 380	38.00	\$234	53.7	80.05	\$1'1	60 41,34	8 97.399	8	21%
\$	18%	c)= 0.45 	- 0.35 24	175%	8	8-13 13	R. 19	R. 7	8-D	8-8	0.35	80% 107,40	9	5.0	76	40 12;	305 4.4	21	.08	1/2	37.10	\$228	52.9	79.29	\$1,18	60,40,95	5 96.473	8	78%
9	16%	ela 0.45 ela	0.40 24	175%	R- 30	8-13 13	R-19	R. 7	8-D	8-8	0.35	80% 107,40.	÷	47	76	40 11/	3.91	39.7	185	27 372	37.20	\$228	50.6	76.94	\$1,0	39,74	33,619	8	72%
7	21%	<i= 0.40="" <i="</td"><td>• 0.35 28</td><td>888%</td><td>R. 30</td><td>R. 15</td><td>R. 19</td><td>R. 7</td><td>R. J</td><td>8-8</td><td>0.35</td><td>80% 107,40.</td><td>=</td><td>4.6</td><td>76 4</td><td>40 12,</td><td>582 4.41</td><td>23</td><td>385</td><td>358</td><td>35.80</td><td>\$220</td><td>52.4</td><td>78.73</td><td>\$1,12</td><td>13 40,66</td><td>82.739</td><td>8</td><td>31%</td></i=>	• 0.35 28	888%	R. 30	R. 15	R. 19	R. 7	R. J	8-8	0.35	80% 107,40.	=	4.6	76 4	40 12,	582 4.41	23	385	358	35.80	\$220	52.4	78.73	\$1,12	13 40,66	82.739	8	31%
10	18%	ele 0.50 ele	0.40 24	%5/1	8. 30	8 5	R. 19	R. 7	R. D	R.8	0.35	80% 107,40.	12	5.0	78	40 12,	164 4.2	515	20	362	38.23	\$226	53.4	0//62	\$1,0	41,16	6.979	2	%89
÷	21%	<i= 0.40="" <="</td"><td>0.40 28</td><td>¥.007</td><td>8.30</td><td>5 2</td><td>R. 19</td><td>R. 7</td><td>9</td><td>8-8</td><td>0.35</td><td>80% 107,40.</td><td>12</td><td>4.6</td><td>76 4</td><td>40 12,</td><td>753 4.4</td><td>435</td><td>100</td><td>365</td><td>35.50</td><td>\$218</td><td>52.7</td><td>79.01</td><td>31,15</td><td>24 40,81</td><td>3 96.139</td><td>8</td><td>44%</td></i=>	0.40 28	¥.007	8.30	5 2	R. 19	R. 7	9	8-8	0.35	80% 107,40.	12	4.6	76 4	40 12,	753 4.4	435	100	365	35.50	\$218	52.7	79.01	31,15	24 40,81	3 96.139	8	44%
12	21%	<is 0.50="" <="" s<="" td=""><td>0.40 28</td><td>%003</td><td>8</td><td>\$2 62</td><td>9 19</td><td>R. 7</td><td>e a</td><td>R.8</td><td>0.35</td><td>80% 107,40.</td><td>12</td><td>5.0</td><td>4 87</td><td>40 12/</td><td>150 4.5</td><td>3</td><td>80</td><td>379</td><td>37.90</td><td>\$223</td><td>54.7</td><td>81.06</td><td>\$1,5</td><td>31 41,87</td><td>1 98.623</td><td>8</td><td>365%</td></is>	0.40 28	%003	8	\$2 62	9 19	R. 7	e a	R.8	0.35	80% 107,40.	12	5.0	4 87	40 12/	150 4.5	3	80	379	37.90	\$223	54.7	81.06	\$1,5	31 41,87	1 98.623	8	365%
18	18%	die 0.55 die	0.40 28	\$100%	R. 30	8 5	R. 19	R. 7	с. О	R.8	0.35	80% 107,40.	4	5.0	4 92	40 11.5	3.84	396	38	38	39.53	\$243	52.8	79.15	\$1,0	40,08	2 86 239	8	62%
19	21%	ela 0.50 ela	0.40	N001	R. 30	8. 5	R. 19	R- 7	в, С	R-8	0.35	80% 107,40	5	47	2	40 12;	377 4.3.	2	38	8	38.53	\$237	54.4	80.73	515	16 41,70	0 \$8.225	8	45%
			1	+	+	+	-	+	+	-		+			+	+	+	+	+	+	+	_		_	_	_			
											Climat	e Zone 6(E	inergy S	tar)Glazi	ng % of !	Floor Are	a (HVAC	Autosize	6										
	Winde	nu Beniremer	1			Mielm	um headation	Institute			Infiltration	Minim	um Faujor	ent recuire	mente	<u> </u>						ANNIAL	PRECY LISE						
uper	Freedor Day			5								Perfo	Gas Fun	sce Heating,	- Ander	-	Tear	interior that			Total Case Lisa	2	Heating.cools and DHW us	2 5	Trêni Fransu	201	the second s		
nN dC	Window	Window W	Mindow wi	quirvalent Indow to		Ederior	Floor Above	Basement		Crawitspace	Infibration Rate	Furnaci Heat size	C O	A/C size Et	DHN DI ficiency SI	NH (0			1000	-		0.615			16.000	Bhu sq.ft.	to ECC Chapter 46	% equivalent CHHDW of B	£ 0
а	Area	U-value	SHOC W	rsli rsto ²	Attio	VM L	Inheeted Spect	1N94	Sleb	Wal	(ACH)	AFLE) (Btuhr	(SEER)	(Tons)	(%) (gal	Iday) KMM	year M/(m	to) MARTUL	year \$AM	h Therredy	tear Milleurys	tor Sthern	MREtulyes.	r MMEtulys	str SN'est	year	house	Chapter 4/5 hc	oute
C1 40	15%	de 0.50 de de 0.45 de	0.40 20	222W	8 8 ¢ é	8 5 5 5	8 8 5 5	R. 7 7. 9	2 2 2 2	00 00 00 00	80 80	80% 107,40 80% 107,402	9 9 9 9	4.7	92 92	40 12,	324 4.4 165 4.45	21	20 50 202	371 380	38.00	\$228	53.7	80.05	\$1,1 \$1,5	00 41,34 05 40,95	8 98.343 5 97.413	8 8	58%
9	ŝ	c)= 0.45 	040	75%	R- 30	5	R- 19	R. 7	2	82	0.35	80% 107,40	=	47	8	11	3.94	39.7	100	27 372	37.23	8228	505	76.94	212	56 39,74	3 94.539	5	10.
r 4	21%	<i= 0.40="" <="" p=""></i=>	0.35 26	3.88%	8 3 1	8.5	R. 19	R. 7	8 G	8- 2- 4	0.35	80% 107,40	= :	4.6	92 3	6 S	582 4.4	87	22 20 20	368 1	35.80	\$220	52.4	78.73	51.5	13 40,66	8 98.729	3 2	24%
2 ₽	21%	Ci: 0.40	0.40 23	4.C.1	8 8 2 2	2 (2 2 2	r 9;		2 2	9 92 8 8	0.35	00% 107,400	12 2	4.6	6 8	40 12, 12, 12,	753 446	435	8 8	20 20 20 20 20 20	36.4)	907 8	527	16/62	21°2	28 41,76 29 41,27	7 58.183	8 35	100
12	21%	< 0.50	0.40 26	100%	8 3	R. 5	R. 19	R. 7	9 0	88	80	80% 107,40	2 2	50	92	6 12	650 4.5	12	100	379	37.50	\$223	547	81,06	515	31 41,87	1 29.539	8	100
e 6	21%	cii 0.55 ch cii 0.50 cii	0.40 28	100 K	8 8 8 8	8 2 2 2	8 6 6 6	R. 7	8 0 8	92 B	80	80% 107,40 80% 107,40	4 5	50 47	2 2	40 12.5	177 4.31 177 4.31	31	2 2	8 8	39.51	5243 5240	54.4	81.33	51,0	40,00 19 42,00	57.243 60.920	5 5	18% 18%
OLIAMISS	ŝ														2														
. One story	square hout	se, front facing v	wet having e.	ach side equal	to 44 feet(1,	(ju ba 905						-				+	-		+										
Interior with	al height is 8	I feet.	a la dista car al	and show											_														
Sistion g	ade foundat	ion with no base	ment or crawl	spece.												$\left \right $													
Attached Enterior do	garage on nu	orth side.	-	+	+	t	-	+				+			+	+	+	+	+	+	-	+		_	_	_			
Solar abou	riptance of	the exterior wall	is 0.55.	\square												$\left \right $													
. No moveb	ie window si ame is starté	hades. Irum wild thermal	break. no div	iders. edue of c	Vieto LI-fact	or is not being	a considered.	+				+		+	+	+	+	+	+	+	-	_		_	_	_			
). The effici	s unconfilor	ned, no penaly fu	or duct loss.					$\left \right $							$\ $	$\left \right $	$\left \right $		$\left \right $										
. The heads	is fild with a	solar absorptant	ce of 0.5. sized by the t	DCE-2.1e. vers	ion 110	t		+				+		1	+	+	+	+	+	_	-	_		_	_	_			
3. Thermost	it is program	makie with cust	onized setting	as according to	ECC 2001	Ħ		$\left \right $							$\left \right $	+	$\left \right $		$\left \right $										
with 68F	for heating a	and 70F for coolin	ng and SF sett	back for 6 tour	44	+		_							-	+	-	_	+	_									
A. Wolder the	otter is nature	al gas. , tota tam	consumptions salidary= (30	is given by ha)+(10ht)	F	t		-	F	F		+			+	+	-	_	+	_	_	_		_	_	_			
			where	-				-	F			+			+	\vdash	-		-										
			b = number o	of fivergures in	each living u	offersproyed init (ECC200	1) (1	-	F	-		-			+	+	+	-	+	4	_	_		_	1				
5. Infibration	rate is 0.35	ACH as define b	IV BNBROY ST	TAR.	H	Ħ		$\left \right $	H	Ħ		$\left \right $	\square		\parallel	\parallel	$\left \right $	\square	$\left \right $	\square	\square	\square							
. The ettor. . Window g	vercentage is	Aurhabbe of the re. It based on condi	ference nous froned floor as	e is 78%. Tea.											-	-	-		-					_					
3. TM/2 we	ather file for	Houston was up	bed																										Γ

Table 6 spreadsheet for BOPs analysis for climate zones 5&6

											Climat	e Zone 3(Builder's	Guide) (h	IVAC Aut	osized)											
Window Require	iments		Minim	einsul mn.	tion Requir	Tements		Infiltration Requiremen	s	Minim	um Equipm	ent requiren	Tents							ANNU	AL ENERGY US					÷	
				Floor						Bectric	Gas Furni Cooling, Gau	ace Heating, s Domestic Hot	water		200	Total Electricit	y Utsage		Total Ga	s Usage	Heating and Df	,cooling 4V use	Total En	argy Usage	nte %	valent % equ	ivalent to
IECC Maximum Window Window I Area ¹⁶ value ⁹	J. Window SHOI	Attic	Exterior Wall ⁷	Above Unheated Space	Basement Well	Slab	Crawlspa e Well	: Infiltration Rat (ACH)	e Hest (AFUE)	Furnace size (Btuthr)	(SEEK)	A/C size (Tons)	DHMV Efficiency 1 (%)	DHW Size (galiday) k	W/M/year k	W(max) M	MBtulyear 0.07	1\$MV/h Therm	s/year MMB1	Jyear 0.6151	therm MMBt	uhear MM	Bulyear	8~	/sq.ft- Chapt /ear hou	ILECC CHIDH ar 4/5 Cheph ise house	HW of ECC er 4/5
15%(Standard) 0.75	0.40	R- 19	R- 11	R. 11	R- 0	R. 0	R-5	15.0	78%	106,558	10	4.7	76	9	12,334	4.40	42.08 \$	876 36	8	40 \$	224 S	2.4	78.48 \$	1,100	40,539 11	\$00.00	100.00%
20% 0.70	0.40	R. 30	R- 13	R. 11	R- 0	R. 0	R- 5	15.0	78%	106,558	9	4.9	92	ş	12,685	4.51	43.28 \$	904 34	3	20 \$	210	-	77.48 \$	1,111	40,021	38.72%	802.78
25% 0.55	0.40	R- 30	R- 13	R. 11	R- 0	R. 0	R- 5	15.0	78%	106,558	0	4.9	92	99	13,423	4.84	45.80 \$	953 32	11 32	\$ 02	210 S	51	78.50 \$	1,163	40,547	00.02%	99.43%
																						-					
											Climat	e Zone 4(I	Builder's	Guide) (H	IVAC Aut	osized)											
Mindow Remite	stremt		Minim	im heuta	tion Remit	streme		Infiltration	9	Minim	im Farring	ent remiren	hute							INN	AL ENERGY IIS						
										Betrie	Gas Fume	Ice Heating,	and an	t		Total Baching	al looke	-	Total Co	and look	Heating	(cooling	Total So	and loans	8	and	in a local de la constante de la const
ECC Maximum Window Window L			Exterior	Above Unheated	Basement		Crawlspa	Infitration Rat	Feat	Furnace	Cool	A/C size	DHM	OHM Size			afaco (0,000	5			Bhu	/saft- Chast	CC CHDF	HW of ECC er 46
Area ¹⁵ value ⁹	Window SHO	Attic	Mall	Space	Wal	Sleto	e Well	(ACH)	(AFUE)	(Btuhr)	(SEER)	(Tons)	(%)	(galiday)	kiviniyear k	M(max) M	MBturyear 0.07	1\$AV/In Therm	slyeer MMBh	Jyear 0.6151	therm MMBt	ulyear MM	Btulyear		rear hou	ise house	2
15%(Stenderd) 0.75	0.40	R. 26	R- 13	R- 11	R- 5	R- 0	R- 5	15.0	78%	106,558	¢	4.9	92	ŧ	12,000	4.17	4122 \$	868 34	8	30 \$	211 4	95	75.52 \$	1,069	39,007 11	\$00.00	100.00%
20% 0.60	0.40	R. 30	R- 13	R- 11	R-5	R. 0	R- 5	15.0	78%	106,558	9	4.9	92	ę	12,708	4.46	43.36 \$	902	33	s 06	202 4	88	76.26 \$	1,105	39,390	00.98%	100.61%
25% 0.52	040	R. 3	R-13	R. 13	R- 6	R. 0	8-6	150	%82	106,558	ę	4.9	92	ş	13,437	4.82	45.05 \$	354 33	32	10 \$	197 5-	9	77.95 \$	1,151	40,262	13.22%	104.24%
ASSUMPTIONS:																		-									
 One story square hous Interior well height is 8 t 	e, tront facing v.	est having e	ach side eq.	ual to 44 fee	et(1,936 sq.t	e												_									
3. No exterior shading dev	tices or adjacent	building or s	hade trees.																								
4. Slab on grade foundation	on with no basen	ient or crawn	space.																								
 Allaureu garage ul III Exterior doors, one on 1 	ront and one on	beck.																	_		-	-					
7. Solar absorptance of th	he exterior wall	s 0.55.																									
8. No moveble window sh	ledes.	1																	_								
 Writeow institute is autril 10. The attic is uncondition. 	ed, no penely to	duct loss.	aña' sian	-n State in		nellig cuits	neteu.																				
11. The roof is flat with a :	volar absorptanc	e of 0.5.																	_		_						
 The heating and coolin Thermostat is program. 	g equipment are rehie with custo	sized by the mirred setting	DOE-2.1e, v s anomine	ersion 110. th FCC 201	=													+							_		
with 68F for heating ar	d 78F for coolin	and SF sett	veck for 6 ho	urs.	5																						
14. Weter heater is natural	gas., total dail c	onsumption	s given by																								
		galiday= (;	30xa)+(10xb			#										T											
		where a = number	· of living un	ts in the sta	andard and p	proposed de	ngisi																				
		b = numbe	r of bedroon	ts in each ir	Ming unit (E.	002001)												_						_			
15. Infiltration rate is given	š	ACH= no	maized lea	keape x we	eather factor																-	+	+				
		where																	_								
		normalized	i leakage = 0	15										Ħ	H						-						
A total and a subscription of the	and an include	weather fa	actor = deter	mined from	ASHRAE St	tandard 136												_			_	_	_	_			
 Window percenage is 17. TMY2 weather file for l 	Houston was us	wêli area. sd.	+	-	+	+								+	-	-	+	+	-	-	-	+	+	-	_		

Table 7 Spreadsheet of the simulation results for IECC chapter 4/5 house for climate zones 3&4

Window Requirem	ents		Minimu	'm Insulati	on Require	ments	Rec	nfittration wirements		Minimum	Equipmen	t requiremen	ţ							ANNUA	L ENERGY USI				2		
				Floor						6 Bectric Co.	Nas Furnace Ding, Gas Du	Heating, mestic Hot wa	ter		2	ttal Electricity	Usage		Total Ga	Usage	Heating and DF	,cooling MV use	TotalE	nerov Usage	*	ouivalent %	auralent to
ECC Maximum Window Window U- Area ¹⁶ value ⁹ V	Vindow SHOC	Allo A	Etterior U Well ⁷	Above Inheated Space	Basement	Steb	wispac Infi Well	Tration Rate (ACH) (Heat 'AFUE)	Furnace size (Btuhr) (19 (AB)	A/C size Eff (Tons)	DHN Totency DHA (%) (ga	V Size Iday) KW	hiyear MA	(xeu))	Blukyear 0.07	\$MMh Them	Isiyear MMBu	lyear 0.615\$4	hem MMB	ulyear MME	tulyear		year year	o ECC CH spter 415 Ch rouse ho	DHW of ECC pter 415 se
15%(Standard) 0.65	0.40	R. 30	R. 13	R. ±	R. 5	R- 0	R. 6	150	382	107,402	9	5.1	36	40 11	686	411	38.89 \$	809 4	8	8 8	35	54 8	2.19 \$	1,076	42,455	100.00%	100.00%
20% 0.52	0.40	R. 38	R. 13	R-11	5.5	R- 0	R. 6	150	3692	107,402	ę	51	92	40 12	1,291	4.69	41.94 \$	873 4	6		248 5		234 \$	1,121	42,529	100.17%	99.29%
25% 0.50	0.40	R- 38	R- 13	R-19	R- 8	R- 0	R. 10	150	78%	107,402	10	5.1	76	40 13	3,002	5.10 4	44.36 \$	923 4	00 40.	0 \$	246 56	81 8	4.36 \$	1,169	43,576	102.64%	103.01%
																						_					
										0	limate Z	one 6(Bui	ilder's Gu	ide) (HV,	AC Auto	sized)			÷	4							
Window Requirem	ents		Minimu	m Insulativ	on Requires	nents	Rec	nfiltration uirements		Minimum	Equipment	1 requirement	\$	_						ANNUA	L ENERGY USI						
				Floor			-			6 Flectric Cor	Vino Gas Dr	Heating, mestic Hrt wal	t,			Ital Flectricity	Isane	-	Total Ga	a lisane	Heating	,cooling MV use	Total	nerov I Isane	1	or instant %	micelent to
ECC Maximum Window Window U- Area ¹⁶ value ⁵ V	Vindow SHGC		Etterior U Well ⁷	Above Inheated	Basement Wall	5 °	wispec Infi Wall	(ACH) (Heat AFLE)	Furnace size (Btuhr) (3	A/C size Eff (Tons)	DHN biency DH	V Size Iday) kW	hiyear KA	(max) MME	Stulyear 0.077	SMMh There	Isiyear MABu	lyear 0.615%	men MBM	ulyear MME	tuhear	- 68	year year	olECC CH spter 415 Ch nouse ho	OHW of ECC pter 415 se
15%(Standard) 0.60	0.40	R. 30	R. 13	R. 19	8.6	R-42H	R. 7	0.57	388	107,402	ę	5.1	92	40 11	140	4.09	38.90 \$	809 4	25 42.	8 8	192	8	1.40 \$	1,071	42,044	100.00%	100.00%
20% 0.50	0.40	R. 38	R. 13	R. 19	R. 6	R- 0	R. 7	250	78%	107,402	ę	5.1	92	40 12	2,947	5.04	44.18 \$	919	8		8	8 13	3.08	1,158	42,911	102.06%	101.98%
25% 0.46	0.40	8.3	R. 16	R- 19	R. 6	R- 0	R. 7	150	\$92	107,402	9	51	36	40 12	2,966	5.02	44.24 \$	921	8	8	55	8	224 \$	1,154	42,479	101.04%	100.54%
ASSUMPTIONS:														-				+			_						
. One story square house,	front facing we	st having eac	ch side eque,	al to 44 feet((1,936 sq.ft)													-									
 Intertor wai neight is o ter. No exterior shading device 	s or adjacent by	ulding or sha	de trees.															+									
 State on grade foundation v 	with no baseme	ert or crawl sp	CORCE.																								
6. Attached garage on north	side.	14																-		_	_	-					
". Solar absorptance of the	exterior well is (0.55.							1					-		+	+	+	-	-	-				1		
8. No movable window shad a Minimu frame is auminum	es. win thermal hr	eak nn divide	ars adop of	Indece IL for	ther is not he	no considered													-		+	+					
10. The attic is unconditioned,	no penaly for c	ouct loss.			-						1			-				-		-	-				-	ľ	
11. The roof is flat with a sole	rr alosorptance	of 0.5.																									
12. The heating and cooling e	quipment are si.	zed by the DC	0E-2.1e, ver.	sion 110.														+		_	_						
 Thermostat is programma with 68F for heation and 7 	ble with custon.	and FF sethar	4 for 6 hour	0 ECC 200					1				+	+	-	-	+	+		-	-						
14. Weter heater is netural ga	s. , total dall col	nsumption is c	jven by		-				T	+	t	+	+	┝	+	-	+	+	-	-	-		t	+	+	T	
		galitiary= (30.	00)+(10tb)		H													$\left \right $				_					
		where	1. The second se						T		+	+	+	+		-	-	+	-	_	_	_		_			
		b = number o	of the grant	S In urici skan	ng unit (EOC	1002 (100			1		+	+	-	-	-		+	+	-	_	-	+		1			
15. Infibration rate is given by															-	-	+	$\left \right $									
		ACH = non	malized leak	saye x wea	ather tactor	+			1	-	+	-	-	-	-	-	-	+	_	_	_	_		-			
		where normalized la	rakatoe = 0.5	12													_	+		_				_			
		weather fact	for = determi	ined from A	SHRAE Stan	dard 136						-						+		_							
 Window percentage is te ThVD weather file for For 	vised on gross v	val area. set		+	-	+																-				T	

Table 8 Spreadsheet of the simulation results for IECC chapter 4/5 house for climate zones 5&6

APPENDICES

- A. Input file name explanation
- B. Simulation file name list
- C. Detailed spreadsheets of the analysis

The accompanying CD contains the following materials related to the current analysis:

- Input simulation files
- Output files
- Simulation detailed spreadsheets
- Glass input spreadsheet
- IECC input file
- The weather files
- The complete report

APPENDIX A:

INPUT FILE NAME EXPLANATION:

In addition to verifying the different Builder Option Packages, detailed analysis was performed to check the performance of an IECC chapter 4/5 house to average 1999 house. Another set of simulations were performed by enhancing the equipment efficiency of an IECC chapter 4/5 house. Also simulations were performed by fixing the equipment size according house instead of allowing the simulation program to auto size. So the analysis and the input files are divided into four main sections:

- 1. Comparison of the Energy Star BOPs with the standard IECC chapter 4/5 house (HVAC auto sized).
- 2. Comparison of the Energy Star BOPs with the standard IECC chapter 4/5 house (HVAC sized fixed).
- 3. Comparison of the average residential house of 1999 with the standard IECC chapter 4/5 house.
- 4. Comparison of the standard IECC chapter 4/5 house with enhanced equipment efficiencies and reduced infiltration rates with a standard IECC chapter 4/5 house.

The naming procedure of the simulation runs is as follows:

• The IECC standard house

Input file name example: bgcz31.inp

bg = Builder's guide cz = Climate zone 3 = Climate zone number 1 = Window to wall ratio (1=15%, 2=20%, 3=25%)

Input file name example: bgcz31f

f = HVAC size fixed

Input file name example: bgcz31a (for enhanced features in the standard house) a= A/C SEER 12 b= A/C SEER 13 c= ACH 0.35 d= A/C SEER 12, ACH 0.35

e= A/C SEER 13, ACH 0.35

Input file name example: bgcz31af (for enhanced features in the standard house) f= HVAC fixed

• Energy Star house

Input file name example: escz31

es= Energy Star cz= Climate zone 3= Climate zone number 1= BOPs number

Input file name example: escz31W

W= window to wall area ratio

Input file name example: escz31f

f= HVAC equipment size fixed

• Average 1999 house

Input file name example: arb1999

arb= Average residential building 1999

Input file name example: arb1999a

a= for climate zones 5 and 6

Input file name example: arb19991

1= average 1999 house with A/C SEER 11

Input file name example: arb1999f

f= HVAC equipment size fixed

APPENDIX B:

SIMULATION FILE NAME LIST:

INPUT FILES:

arb1999.inp arb19991.inp arb19991a.inp arb19991af.inp arb19991f.inp arb1999a.inp arb1999af.inp arb1999f.inp bgcz31.inp bgcz31f.inp bgcz32.inp bgcz32f.inp bgcz33.inp bgcz33a.inp bgcz33af.inp bgcz33b.inp bgcz33bf.inp bgcz33c.inp bgcz33cf.inp bgcz33d.inp bgcz33df.inp bgcz33e.inp bgcz33ef.inp bgcz41.inp bgcz41f.inp bgcz42.inp bgcz42f.inp bgcz43.inp bgcz43a.inp bgcz43af.inp bgcz43b.inp bgcz43bf.inp bgcz43c.inp bgcz43cf.inp bgcz43d.inp bgcz43df.inp bgcz43e.inp bgcz43ef.inp bgcz51.inp

bgcz51f.inp bgcz52.inp bgcz52f.inp bgcz53.inp bgcz53a.inp bgcz53af.inp bgcz53b.inp bgcz53bf.inp bgcz53c.inp bgcz53cf.inp bgcz53d.inp bgcz53df.inp bgcz53e.inp bgcz53ef.inp bgcz61.inp bgcz61f.inp bgcz62.inp bgcz62f.inp bgcz63.inp bgcz63a.inp bgcz63af.inp bgcz63b.inp bgcz63bf.inp bgcz63c.inp bgcz63cf.inp bgcz63d.inp bgcz63df.inp bgcz63e.inp bgcz63ef.inp escz32.inp escz32f.inp escz32w.inp escz32wf.inp escz34.inp escz34f.inp escz34w.inp escz34wf.inp escz35.inp escz35f.inp escz35w.inp

escz35wf.inp escz316.inp escz316f.inp escz316w.inp escz316wf.inp escz318.inp escz318f.inp escz318w.inp escz318wf.inp escz52.inp escz52f.inp escz52w.inp escz52wf.inp escz55.inp escz55f.inp escz55w.inp escz55wf.inp escz56.inp escz56f.inp escz56w.inp escz56wf.inp escz57.inp escz57f.inp escz57w.inp escz57wf.inp escz510.inp escz510f.inp escz510w.inp escz510wf.inp escz511.inp escz511f.inp escz511w.inp escz511wf.inp escz512.inp escz512f.inp escz512w.inp escz512wf.inp escz518.inp escz518f.inp escz518w.inp escz518wf.inp escz519.inp escz519f.inp escz519w.inp escz519wf.inp

OUTPUT FILES:

arb1999.out arb19991.out arb19991a.out arb19991af.out arb19991f.out arb1999a.out arb1999af.out arb1999f.out bgcz31.out bgcz31f.out bgcz32.out bgcz32f.out bgcz33.out bgcz33a.out bgcz33af.out bgcz33b.out bgcz33bf.out bgcz33c.out bgcz33cf.out bgcz33d.out bgcz33df.out bgcz33e.out bgcz33ef.out bgcz41.out bgcz41f.out bgcz42.out bgcz42f.out bgcz43.out bgcz43a.out bgcz43af.out bgcz43b.out bgcz43bf.out bgcz43c.out bgcz43cf.out bgcz43d.out bgcz43df.out bgcz43e.out bgcz43ef.out bgcz51.out bgcz51f.out bgcz52.out bgcz52f.out bgcz53.out bgcz53a.out

bgcz53af.out bgcz53b.out bgcz53bf.out bgcz53c.out bgcz53cf.out bgcz53d.out bgcz53df.out bgcz53e.out bgcz53ef.out bgcz61.out bgcz61f.out bgcz62.out bgcz62f.out bgcz63.out bgcz63a.out bgcz63af.out bgcz63b.out bgcz63bf.out bgcz63c.out bgcz63cf.out bgcz63d.out bgcz63df.out bgcz63e.out bgcz63ef.out escz32.out escz32f.out escz32w.out escz32wf.out escz34.out escz34f.out escz34w.out escz34wf.out escz35.out escz35f.out escz35w.out escz35wf.out escz316.out escz316f.out escz316w.out escz316wf.out escz318.out escz318f.out escz318w.out escz318wf.out escz52.out

escz52f.out escz52w.out escz52wf.out escz55.out escz55f.out escz55w.out escz55wf.out escz56.out escz56f.out escz56w.out escz56wf.out escz57.out escz57f.out escz57w.out escz57wf.out escz510.out escz510f.out escz510w.out escz510wf.out escz511.out escz511f.out escz511w.out escz511wf.out escz512.out escz512f.out escz512w.out escz512wf.out escz518.out escz518f.out escz518w.out escz518wf.out escz519.out escz519f.out escz519w.out escz519wf.out

APPENDIX C:

DETAILED SPREADSHEETS OF THE ANALYSIS:

The links to the following spreadsheets have been included in the appendix to explain the analysis:

- 1. Comparison of an average 1999 house with the standard IECC chapter 4/5 house for climate zones 3,4,5 & 6. (Average residential building(1999)comp.xls)
- Comparison of an average 1999 house with the standard IECC chapter 4/5 house for climate zones 3,4,5 & 6. (A/C size fixed)(<u>Average residential</u> <u>building(1999)comp(ac fix).xls</u>)
- 3. Comparison of the Energy Star BOPs with the standard IECC chapter 4/5 house, climate zones 3,4,5 & 6. (comparison(energystar&BG)selected(cor).xls)
- Comparison of the Energy Star BOPs with the standard IECC chapter 4/5 house, climate zones 3,4,5 & 6. (A/C size fixed) (comparison(energystar&BG)selected(cor)(ac fix).xls)
- 5. Comparison of an IECC house with increased system efficiencies with a standard IECC chapter 4/5 house. (ieccplus.xls)
- 6. Comparison of an IECC house with increased system efficiencies with a standard IECC chapter 4/5 house. (A/C size fixed) (<u>ieccplus(ac fixed).xls</u>)