ESL-TR-03-09-02

DETAILED ANALYSIS OF THERMAL MASS EFFECTS IN A CODE-TRACEABLE DOE-2 SIMULATION OF THE 2000 IECC FOR A SINGLE-FAMILY RESIDENCE IN TEXAS

A Project for
Texas' Senate Bill 5 Legislation
For Reducing Pollution
In Non-Attainment and Affected Areas

September 2003
Revised July 2007

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ABSTRACT

This study examines the thermal mass effects in a code-traceable DOE-2 simulation of the 2000 IECC (International Energy Conservation Code) for a single-family residence in Texas. This report is composed of two major simulations: 1) the simulation according to the location of the insulation of IECC2000, and 2) the simulation according to the types of real brick and block walls which are practically used at the residential house. In this study, the 2000 IECC was used to develop the base case simulation model in Houston, Texas. The DOE-2 energy simulation program was used to analyze changes to the annual energy use caused by changing various building materials. The best energy conservative material layout was then chosen that contained reduced annual energy use, peak cooling and heating loads, and peak day electricity use.

The attached CD-ROM includes all DOE-2 input files which were used for this study and the documents that were used for this research.

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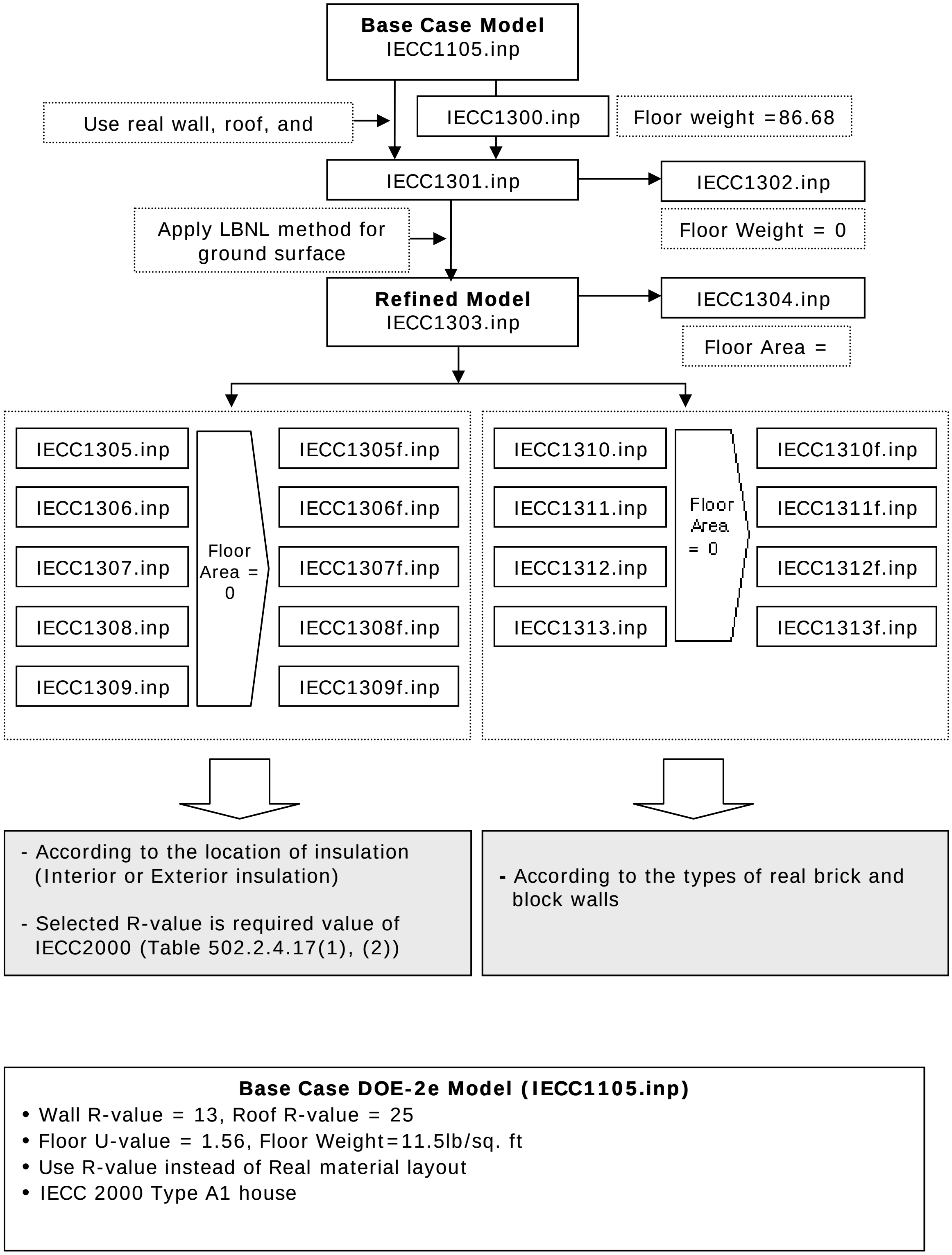


Figure 1-1. House dimension / heating and cooling controls of the base case house.

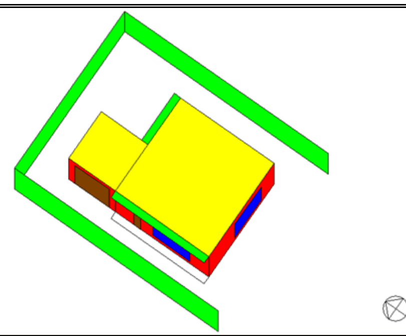
2 Descriptions of Simulation Cases

2.1 Base Case DOE-2e Model (IECC1105.inp)

The thermal properties construction materials, such as wall, roof, window, and floor of the base case model, are based on the International Energy Conservation Code 2000 (IECC 2000). The inputs include assumptions about Chapters 4 and 5 of IECC 2000 to describe the standard house.

2.1.1 House Dimension / Heating and Cooling Controls

Table 2-1. House dimension / heating and cooling controls of the base case house.

Parameter	Value	DrawBDL of IECC1105.inp
Length*Width*Height	44*44*8	
Room Temp.	73 □	
Heating	68 □	
Cooling	78 □	
Set back / Set up	5 □	

* Room temperature is the average value of winter and summer set points that are taken from Table 402.1.3.5 of IECC 2000. Set back is adjusted in the systems.

2.1.2 Thermal Properties of IECC1105.inp

The values that are used to develop the base case model (IECC1105.inp) are from Type A-1 Residential Buildings of IECC 2000.

Table 2-2. Thermal properties of IECC1105.inp.

Heating Degree Days	Maximum	Minimum			
	Glazing U-factor	Ceiling R-value	Exterior wall R-value	Floor U-value	Floor weight (Lb/sq.ft)
1,500-1,999	0.75	R-26	R-13	1.56	11.5

* Table 502.2.4(3) of IECC 2000 Type A-1 Residential Buildings and window area 15 % of gross exterior wall area.

2.2 Refined Base Case DOE-2e Model (IECC1303.inp)

Several changes are applied to IECC1105.inp, such as real roof, wall and new method for ground surface to perform the real residential house simulation. The R-value of all real materials that are applied to IECC1303 is identical to the recommended R-value of Table 502.2.4(3), Type A-1 Residential Buildings and window area 15 % of the gross exterior wall area of IECC 2000.

2.2.1 Thermal properties of wall construction

Table 2-3. Thermal properties of wall construction of the refined base case model.

No	Name	Conductivity	R	Thickness	DOE code
		Btu-ft/Hr-ft2-F	Ft2.hr.F/Btu	Ft	
1	Asbestos-Vinyl Tile		0.05		AV01
2	Plywood ½”	0.0667	0.63	0.0417	PW03
3	Mineral wool / fiber Insulation	0.027	15	0.405	
4	2*4” stud	0.0667	4.37	0.3333	WD05
5	Gypsum board ½”	0.0926	0.45	0.0417	GP01

Calculated R-value

	Insulation Part	Frame Part
1	0.05	0.05
2	0.63	0.63
3	15	
4		4.37
5	0.45	0.45
Tot	16.13	5.5

Atot (12*16"): 192 in^2
Ains (14.5*12"): 174 in^2
Astud (12"*1 1/2"): 18in^2

Ut = 1/Rt = (1/At) * ((Astud/Rstud)+(Ains/Rins))
= (1/192)*((18/5.5)+(174/16.13))
= 0.073 Btu/h.ft^2.F

R_{tot}= 13.65568329 h.ft^2·°F /Btu

The required R-value of wall of IECC 2000 code is R-13

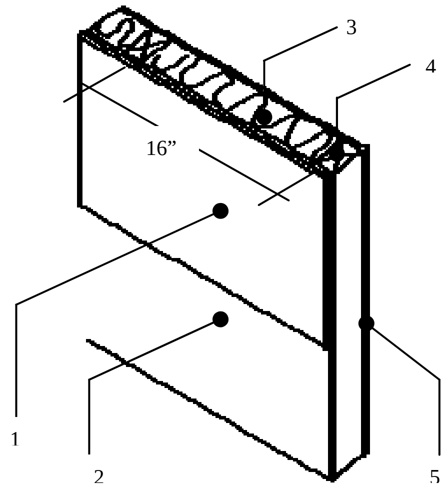


Figure 2-1 Wall dimension and calculated R-Value.

2.2.2 The comparison of original IECC1105.inp and refined IECC1303.inp

While the original IECC1105.inp uses U-value of the wall, the refined IECC1303.inp uses a real layout to investigate thermal mass effects. The following codes are explanations of how to change the original IECC1105.inp to the refined IECC1303.inp.

<u>DOE code of IECC1105.inp (Base case model)</u>

```
P-WALLUVALUE = 0.0769                  $1ECC 2001 VALUE FOR TYPE A1 HOUSE WITH
$                                       GLAZING 15% OF WALL AREA(HR.FT^2.F/BTU)
$                                       ROOFRVALUE WILL BE INPUT BY THE USER WHICH WILL
$                                       BE CONVERTED TO U-VALUE BY AN EXTERNAL ROUTINE
$                                       S.KIM, REPLACE 0.0625 WITH 0.0769

WALL-CON1 = CONSTRUCTION
$          LAYERS = WALL-LAY1
           ABSORPTANCE = P-WALLABSORPTANCE
           ROUGHNESS = P-WALLROUGHNESS
           U = P-WALLUVALUE ..

RIGHT-1 = EXTERIOR-WALL
$            HEIGHT = P-WALLHEIGHT              PLACED IN SET-DEFAULT(FT)
             WIDTH = P-BUILDINGWIDTH            $(FT)
             X = 0  Y = 0   Z = 0               $COORDINATES
             AZIMUTH = 180                       $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                                DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-CON1
$            LOCATION =                         UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10              $DOE-2 DEFAULT
$            INF-COEFF =                    USED WHEN INFILTRATION
METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5              $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5              $ARBITRARY(0 TO 1)
             SOLAR-FRACTION = 0.2             $EQUAL DIVISION AMONG THE 5
SURFACES(0 TO 1)
             INSIDE-VIS-REFL =  0.5             $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5               $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS     $DOE-2 DEFAULT=0.9(0 TO 1)
$            FUNCTION                           UNUSED
                      ..                        $END OF EXTERIOR WALL COMMAND
```

Figure 2-2. DOE code of wall section of the base case model (IECC1105.inp).

DOE code of IECC1303.inp (Refined model)

```
WA-1 = LAYERS
       MATERIAL = (VINYL-TILE, PLY-WOOD,
                   INSULATION-R15, GYPSUM-BOARD)  ..
              $ Insulation Part of Wall
              $ VINYL-TILE = Asbestos Vinyl Siding
              $ PLY-WOOD = Plywood 1/2"
              $ INSULATION-R15 = MINERAL WOOL/FIBER
              $ GYPSUM-BOARD = Gypsum Board 1/2"
              $ The percentage of WA-1 = 87.5 %

WA-2 = LAYERS
       MATERIAL = (VINYL-TILE, PLY-WOOD,
                   STUD, GYPSUM-BOARD)  ..
              $ Stud Part of Wall
              $ VINYL-TILE = Asbestos Vinyl Siding
              $ PLY-WOOD = Plywood 1/2"
              $ STUD = 2*4 STUD
              $ GYPSUM-BOARD = Gypsum Board 1/2"
              $ The percentage of WA-2 = 12.5 %

WALL-1    = CONSTRUCTION
            LAYERS = WA-1   ..

WALL-2    = CONSTRUCTION
            LAYERS = WA-2   ..

RIGHT-1_1 = EXTERIOR-WALL                 $ THE INSULATION PART OF WALL
$            HEIGHT = P-WALLHEIGHT          PLACED IN SET-DEFAULT(FT)
             WIDTH = 38.5                 $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
             X = 0  Y = 0   Z = 0         $COORDINATES
             AZIMUTH = 180                $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                          DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-1
$            LOCATION =                        UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10             $DOE-2 DEFAULT
$            INF-COEFF =                   USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
$            SOLAR-FRACTION = 0.2        EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1)
             INSIDE-VIS-REFL =  0.5            $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5              $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
$            FUNCTION                          UNUSED

RIGHT-1_2 = EXTERIOR-WALL                    $ THE STUD PART OF WALL
$            HEIGHT = P-WALLHEIGHT             PLACED IN SET-DEFAULT(FT)
             WIDTH = 5.5                       $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
             X = 38.5  Y = 0   Z = 0           $COORDINATES
             AZIMUTH = 180                      $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                               DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-2

$            LOCATION =                        UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10             $DOE-2 DEFAULT
$          INF-COEFF =                      USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
$            SOLAR-FRACTION = 0.2            EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1),
             INSIDE-VIS-REFL =  0.5            $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5              $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
```

Figure 2-3. DOE code of wall section of the refined model (IECC1303.inp).

2.2.3 Thermal properties of roof construction

Table 2-4. Thermal properties of roof construction of the refined base case model.

No	Name	Conductivity	R	Thickness	DOE code
		Btu-ft/Hr-ft2-F	Ft2.hr.F/Btu	Ft	
1	Asphalt shingle		0.44		AR02
2	Plywood ½”	0.0667	0.63	0.0417	PW03
3	Air gap 24"		0.92		AL33
4	2*6 Stud	0.0667	7.5	0.5	
5	Mineral wool / fiber Insulation	.027	27		
6	Gypsum board ½”	0.0926	0.45	0.0417	GP01

<u>Calculated R-value</u>

	Insulation Part	Frame Part
1	0.44	0.44
2	0.63	0.63
3	0.92	0.92
4		7.5
5	27	
6	0.45	0.45
Tot	29.44	9.94

Atot (12*24"): 288 in^2
Ains (22.5*12"): 270 in^2
Astud (12"*1 1/2"): 18 in^2

Ut = 1/Rt = (1/At) * ((Astud/Rstud)+(Ains/Rins))
= (1/288)*((18/9.94)+(270/29.44))
= 0.038 Btu/h.ft^2.F

Rt= 26.35 h.ft^2.F/Btu

The required R-value of wall of IECC 2000 code is R-26

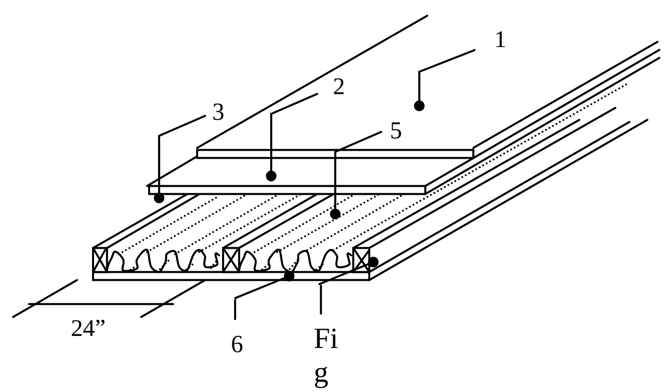


Figure 2-4. Roof dimension and calculated R-value.

DOE code of IECC1105.inp (Base case model)

```
P-CLNGUVALUE = 0.0385                   $1ECC 2001 VALUE FOR TYPE A1 HOUSE WITH
$                                        GLAZING 15% OF WALL
AREA(HR.FT^2.F/BTU)
$                                        ROOFRVALUE WILL BE INPUT BY THE USER
WHICH WILL
$                                        BE CONVERTED TO U-VALUE BY AN EXTERNAL
ROUTINE
$                                        S.KIM, REPLACE 0.0263 WITH 0.0385

CLNG-CON1 = CONSTRUCTION
$          LAYERS = CLNG-LAY1
           U = P-CLNGUVALUE  ..         $IECC 2001(RESIDENTIAL
BUILDING)(BTU/HR.FT^2.F)

TOP-A1 = ROOF
         HEIGHT = P-BUILDINGLENGTH        $(FT)
         WIDTH = P-BUILDINGWIDTH          $(FT)
         X = 0   Y = 0   Z = 8            $COORDINATES
         AZIMUTH = 180                    $(DEGREES)
         TILT = 0                         $(DEGREES)
         CONSTRUCTION = CLNG-CON1
$        LOCATION =                       UNUSED
$        INF-COEFF =                      USED WHEN INFILTRATION METHOD=CRACK(0
TO 160)
         SKY-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
         GND-FORM-FACTOR = 0.0            $ARBITRARY(0 TO 1)
$        SOLAR-FRACTION = 0.2             APPROXIMATE VALUE(0 TO 1)
         INSIDE-VIS-REFL =  0.5           $DEFAULT(0 TO 1)
         INSIDE-SOL-ABS = 0.5             $DEFAULT(0 TO 1)
         SHADING-SURFACE = YES
         SHADING-DIVISION = 10            $DEFAULT
         OUTSIDE-EMISS = P-ROOFOUTEMISS      $DOE-2 DEFAULT=0.9(0 TO 1)
$        FUNCTION                         UNUSED
         ..                               $ END OF ROOF COMMAND
```

Figure 2-5. DOE code of roof section of the base case model (IECC1105.inp).

DOE code of IECC1303.inp (Refined model)

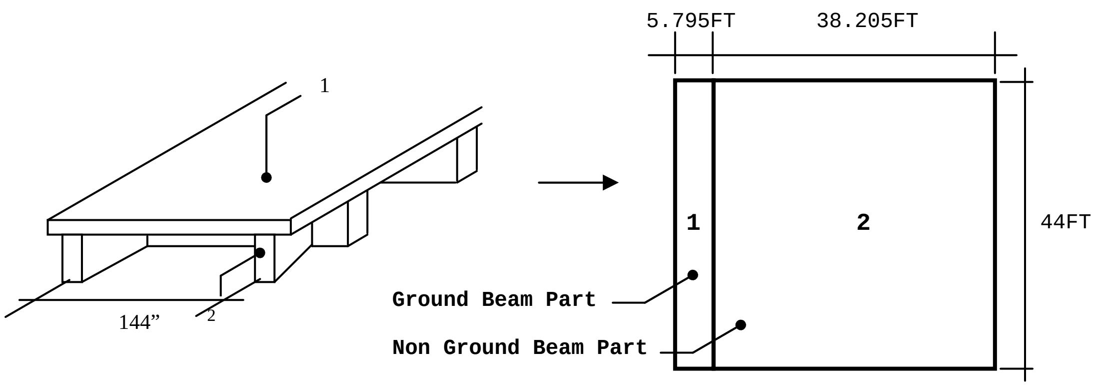
```
CL-1 = LAYERS
       MATERIAL = (ASPHALT-SIDING, PLY-WOOD, AIR-LAYER,
                   INSULATION-R27, GYPSUM-BOARD) ..
               $ Insulation Part of Ceiling
               $ PLY-WOOD = THICKNESS 1/2"
               $ AIR-LAYER = 4 INCH OR MORE, HORIZONTAL ROOF
               $ INSULATION-R27 = MINERAL WOOL/FIBER
               $ GYPSUM-BOARD = Gypsum Board 1/2"
               $ The percentage of CL-1 = 91.7 %

CL-2 = LAYERS
       MATERIAL = (ASPHALT-SIDING, PLY-WOOD,
                   AIR-LAYER, STUD6, GYPSUM-BOARD) ..
               $ Stud Part of Ceiling
               $ PLY-WOOD = THICKNESS 1/2"
               $ AIR-LAYER = 4 INCH OR MORE, HORIZONTAL ROOF
               $ STUD6 = 2*6 STUD
               $ The percentage of CL-2 = 8.3 %

CEIL-1    = CONSTRUCTION
            LAYERS = CL-1   ..

CEIL-2    = CONSTRUCTION
            LAYERS = CL-2   ..

TOP-A1 = ROOF
              HEIGHT = 40.44               $(FT)
              WIDTH = 44                   $(FT)
              X = 0   Y = 0   Z = 8
              AZIMUTH = 180                $(DEGREES)
              TILT = 0                     $(DEGREES)
              CONSTRUCTION = CEIL-1
$             LOCATION =                   UNUSED
$             INF-COEFF =                  USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
              SKY-FORM-FACTOR = 0.5        $ARBITRARY(0 TO 1)
              GND-FORM-FACTOR = 0.0        $ARBITRARY(0 TO 1)
$             SOLAR-FRACTION = 0.2         APPROXIMATE VALUE(0 TO 1)
              INSIDE-VIS-REFL =  0.5       $DEFAULT(0 TO 1)
              INSIDE-SOL-ABS = 0.5         $DEFAULT(0 TO 1)
              SHADING-SURFACE = YES
              SHADING-DIVISION = 10        $DEFAULT
              OUTSIDE-EMISS = P-ROOFOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
$             FUNCTION                        UNUSED
                      ..                      $ END OF ROOF COMMAND

TOP-A2 = ROOF
              HEIGHT = 3.67                $(FT)
              WIDTH = 44                   $(FT)
              X = 0   Y = 40.44   Z = 8
              AZIMUTH = 180                $(DEGREES)
              TILT = 0                     $(DEGREES)
              CONSTRUCTION = CEIL-2
$             LOCATION =                   UNUSED
$             INF-COEFF =                  USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
              SKY-FORM-FACTOR = 0.5        $ARBITRARY(0 TO 1)
              GND-FORM-FACTOR = 0.0        $ARBITRARY(0 TO 1)
$             SOLAR-FRACTION = 0.2         APPROXIMATE VALUE(0 TO 1)
              INSIDE-VIS-REFL =  0.5       $DEFAULT(0 TO 1)
              INSIDE-SOL-ABS = 0.5         $DEFAULT(0 TO 1)
              SHADING-SURFACE = YES
              SHADING-DIVISION = 10        $DEFAULT
              OUTSIDE-EMISS = P-ROOFOUTEMISS      $DOE-2 DEFAULT=0.9(0 TO 1)
$             FUNCTION                        UNUSED
                      ..                      $ END OF ROOF COMMAND
```

Figure 2-6. DOE code of roof section of the refined model (IECC1303.inp).

2.2.4 Floor

No	Name	Conductivity	R	Thickness	DOE code
		Btu-ft/Hr-ft2-F	Ft2.hr.F/Btu	Ft	
1	Concrete Slab	1.0417	0.32	0.3333	CC14
2	Ground Beam	1.0417	2.08	2.17	CC14

Table 2-5. Thermal properties of roof construction of the refined base case model.



<u>LBNL method for ground surface</u>

According to Winkelmann (1998), DOE-2 will account for thermal mass only if (1) the underground surface is entered with a layers-type construction following procedure and (2) custom weighting factors are calculated for the space, i.e., FLOOR-WEIGHT=0 in the SPACE or SPACE-CONDITIONS command.

The following procedure is how the LBNL method is applied to IECC1303.inp. The value and procedure used for this procedure are from “Underground Surface: How to Get a Better Underground Surface Heat Transfer Calculation in DOE-2.1E” by Fred Winkelmann. This article is also included in the attached CD.

1. Choose a value of the perimeter conduction factor, F2, from Tables 1, 2 or 3 for the configuration that best matches the type of surface.

- F2=0.77

2. Using F2, calculating R_{eff}, the *effective resistance* of the underground surface

- R_{eff} = A / (F2*P_{exp})
- R_{eff-1} = (44*5.795) / (0.77 * (44+5.795*2)) = 5.96
- R_{eff-2} = (44*38.205) / (0.77 * (44+38.205*2)) = 18.14

3. Set U-EFFECTIVE = 1 / R_{eff}

- U_1 = 1 / 5.96 = 0.168
- U_2 = 1 / 18.14 = 0.055

4. Define a construction

$R_{eff} = R_{us} + R_{soil} + R_{fic}$

$R_{fic} = R_{eff} – R_{us} - R_{soil}$

- Actual slab resistance: R_{us1} = 2.4 + 0.77 = 3.17
  R_{us2} = 0.32 + 0.77 = 1.09
- Rfic1 = R_{eff1} – R_{us1} - R_{soil} = 5.96 – 3.17 – 1.0 = 1.79
- Rfic2 = R_{eff2} – R_{us2} - R_{soil} = 18.14 – 1.09 – 1.0 = 16.04

Ground surface DOE input summary

This is the summary of the input for ground surface which will help describe how to apply code to DOE.

```
MAT-FIC-1            = MATERIAL
                     RESISTANCE = 1.79   ..

MAT-FIC-2            = MATERIAL
                     RESISTANCE = 16.04   ..

SOIL-12IN            =  MATERIAL
                     THICKNESS = 1.0
                     CONDUCTIVITY = 1.0
                     DENSITY = 115
                     SPECIFIC-HEAT = 0.1   ..

FL-1 = LAYERS
       MATERIAL = (MAT-FIC-2, SOIL-12IN, CONCRETE-SLAB)  ..
              $ Non Ground-beam Part of Slab
              $ CONCRETE-SLAB = 4" Concrete, Heavy weight
              $ The percentage of FL-1 = 87 %

FL-2 = LAYERS
       MATERIAL = (MAT-FIC-1, SOIL-12IN, GROUND-BEAM, CONCRETE-SLAB)
..
              $ Ground-beam Part of Slab
              $ CONCRETE-SLAB = 4" Concrete, Heavy Weight
              $ GROUND-BEAM = 26" Concrete, Heavy Weight
              $ The percentage of FL-2 = 13 %

FLOR-1    = CONSTRUCTION
            LAYERS = FL-1   ..

FLOR-2    = CONSTRUCTION
            LAYERS = FL-2   ..

FLOOR-R1 = UNDERGROUND-FLOOR                  $NON-GROUND BEAM PART
           AREA = 1681.02
           CONSTRUCTION = FLOR-1
           TILT = 0
           U-EFFECTIVE = 0.055       ..

FLOOR-R2 = UNDERGROUND-FLOOR                  $GROUND BEAM PART
           AREA = 254.98
           CONSTRUCTION = FLOR-2
           TILT = 0
           U-EFFECTIVE = 0.168       ..
```

Figure 2-7. DOE code of floor section of refined model (IECC1303.inp).

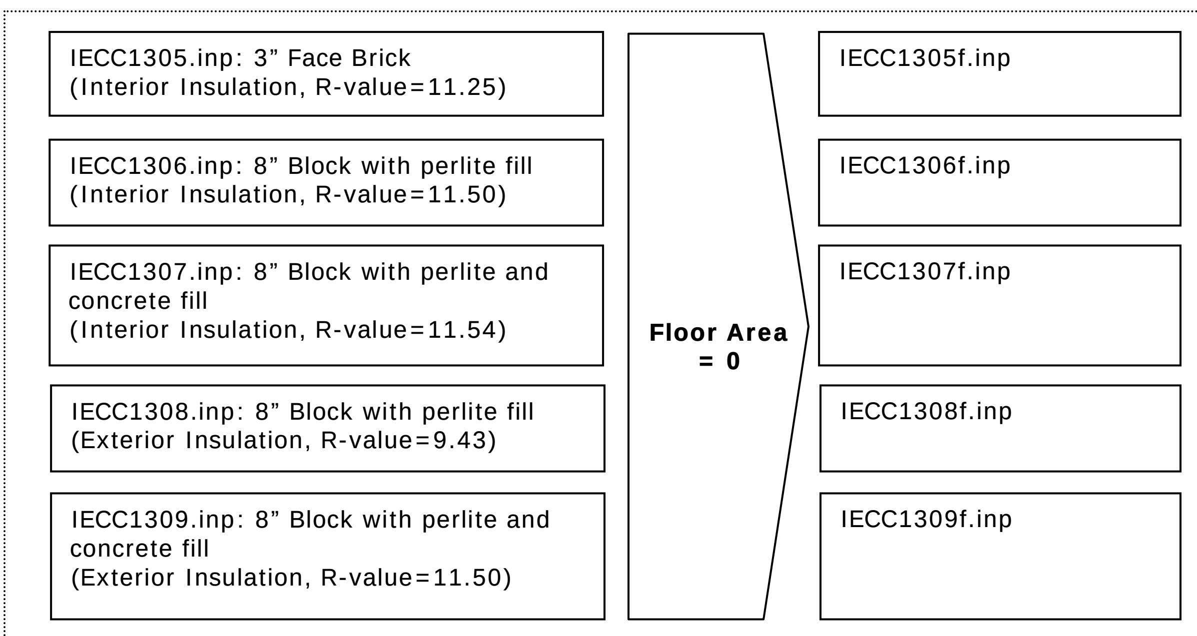
3 Simulation conditions according to the placement of insulation

According to IECC 2000, exterior walls constructed of high-mass materials have a heating capacity greater than or equal to 6 Btu/ft^2·°F of the exterior wall area shall meet the equivalent insulation R-values in Table 502.2.1.1.2(1) or Table 502.2.1.1.2(2), based on the placement of the insulation, the HDD of the building location, and the required overall U-value (Uw) for wood-framed walls. Therefore, each wall type (from IECC1305 to 1309) that is used for the simulation is matched to the recommended overall U-value of IECC 2000. Furthermore, in order to investigate the energy load caused by the effect of floor area, each input file has another input file whose floor area is 0.

Table 3-1. Recommended overall U-value of high-mass materials.

Wood framed wall R-value	HDD 0 - 1,999	
	Table 502.2.4.17(1)	Table 502.2.4.17(2)
R-13 (Uw=0.076)	Exterior insulation	Interior insulation
	0.13	0.09

<u>Simulation Procedure</u>



Wall description of each simulation

Table 3-2. Summary of the wall description of each simulation.

Name	R-value h. ft^2.□/Btu	Uw Btu/ h. ft^2.□	Heat Capacity Btu/ft^2.□	Insulation	Description
IECC1305	11.25	0.09	8.05	Inside	3" Face Brick + Plywood + Insulation + Gypsum board
IECC1305f	11.25	0.09	8.05	Inside	The same as above but w/o floor area
IECC1306	11.50	0.09	7.94	Inside	8" Block with perlite fill + Insulation + Gypsum board
IECC1306f	11.50	0.09	7.94	Inside	The same as above but w/o floor area
IECC1307	11.54	0.09	10.77	Inside	8" Block with perlite and concrete fill + Insulation + Gypsum board
IECC1307f	11.54	0.09	10.77	Inside	The same as above but w/o floor area
IECC1308	7.71	0.13	10.87	Outside	Stucco + Insulation + 8" Block with perlite fill + Stud + Air + Gypsum board
IECC1308f	7.71	0.13	10.87	Outside	The same as above but w/o floor area
IECC1309	7.59	0.13	13.68	Outside	Stucco + Insulation + 8" Block with perlite and concrete fill + Stud + Air + Gypsum board
IECC1309f	7.59	0.13	13.68	Outside	The same as above but w/o floor area

3.1 Face Brick (IECC1305.inp)

The following table describes the thermal properties and other dimensions that are used for the face brick wall.

Table 3-3. Thermal properties of the face brick wall (IECC1305.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft^2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Face Brick	0.25	0.76	0.33	130.00	0.22	BK04
2	Plywood	0.04	0.07	0.63	34.00	0.29	PW03
3	Insulation	0.29	0.03	10.80	6.00	0.20	IN11
4	2*4 Stud	0.33	0.07	5.00	32.00	0.33	WD05
5	Gypsum Board	0.04	0.09	0.45	50.00	0.20	GP01
Tot				11.26 (0.089)			

* The insulation is located at the interior side.

In order to determine if the R-value and the heat capacity of the brick wall agree with IECC 2001 code, the following procedures are performed:

No	Insulation Part	Frame Part
1	0.33	0.33
2	0.63	0.63
3	10.80	
4		5.00
5	0.45	0.45
Tot	12.21	6.41

Atot (12*16"): 192 in^2
Ains (14.5*12"): 174 in^2
Astud (12"*1 1/2"): 18in^2
Ut = 1/Rt = (1/At) * ((Astud/Rstud)+(Ains/Rins))
= (1/192)*((18/6.41)+(174/12.21))
= 0.089 Btu/h.ft^2.F

R_{tot}= 11.26 h.ft^2.F/Btu, Uw=0.089 Btu/ h.ft^2.F

The required U of wall of IECC 2000 code is 0.09 (Table 502.2.1.1.1.2(2) Interior Insulation)

Heat Capacity =
0.25*130*0.22+0.04*34*0.29+0.29*6*0.2+0.33*32*0.33+0.04*50*0.2 = 8.05 Btu/ft^2.□
(>6 Btu/ft^2.□: High mass material)

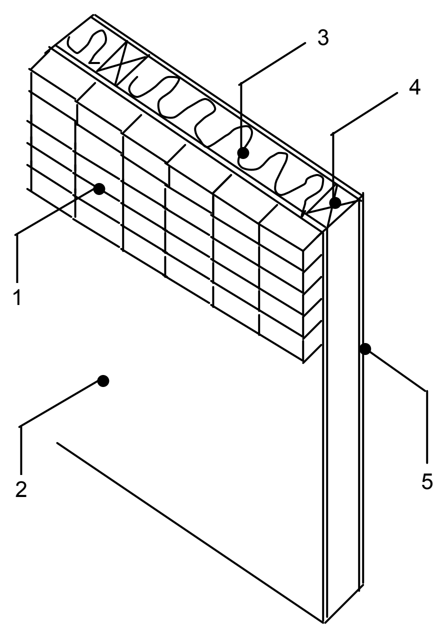


Figure 3-1. Face brick wall dimension and calculated R-Value.

The wall part of DOE code of IECC1305.inp

```
WA-1 = LAYERS
       MATERIAL = (BRICK-BK04, PLY-WOOD,
                   INSULATION-R15, GYPSUM-BOARD)  ..
              $ Insulation Part of Wall
              $ BRICK = 3 INCH FACE BRICK
              $ PLY-WOOD = Plywood 1/2”
              $ INSULATION-R15 = MINERAL WOOL/FIBER
              $ GYPSUM-BOARD = Gypsum Board 1/2”
              $ The percentage of WA-1 = 87.5 %

WA-2 = LAYERS
       MATERIAL = (BRICK-BK04, PLY-WOOD,
                   STUD, GYPSUM-BOARD)  ..
              $ Stud Part of Wall
              $ BRICK = 3 INCH FACE BRICK
              $ PLY-WOOD = Plywood 1/2”
              $ STUD = 2*4 STUD
              $ GYPSUM-BOARD = Gypsum Board 1/2”
              $ The percentage of WA-2 = 12.5 %

WALL-1    = CONSTRUCTION
            LAYERS = WA-1   ..

WALL-2    = CONSTRUCTION
            LAYERS = WA-2   ..

RIGHT-1_1 = EXTERIOR-WALL                   $ THE INSULATION PART OF WALL
$          HEIGHT = P-WALLHEIGHT            PLACED IN SET-DEFAULT(FT)
           WIDTH = 38.5                     $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
           X = 0  Y = 0   Z = 0             $COORDINATES
           AZIMUTH = 180                     $DEGREES
           GND-REFLECTANCE = P-GND-REFLECTANCE
$                                           DOE-2 DEFAULT=0.2(0 TO 1)
           CONSTRUCTION = WALL-1        S.KIM, 07/10/2002, CHANGE CONSTRUCTION(WALL-CON1)
$          LOCATION =                       UNUSED
           SHADING-SURFACE = YES
           SHADING-DIVISION = 10           $DOE-2 DEFAULT
$          INF-COEFF =                      USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
           SKY-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
           GND-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
$          SOLAR-FRACTION = 0.2        EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1), S.KIM
           INSIDE-VIS-REFL =  0.5            $DOE-2 DEFAULT(0 TO 1)
           INSIDE-SOL-ABS = 0.5              $DOE-2 DEFAULT(0 TO 1)
           OUTSIDE-EMISS = P-WALLOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
$          FUNCTION                          UNUSED
                     ..                      $END OF EXTERIOR WALL COMMAND

RIGHT-1_2 = EXTERIOR-WALL                    $ THE STUD PART OF WALL
$          HEIGHT = P-WALLHEIGHT             PLACED IN SET-DEFAULT(FT)
           WIDTH = 5.5                       $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
           X = 38.5  Y = 0   Z = 0           $COORDINATES
           AZIMUTH = 180                      $DEGREES
           GND-REFLECTANCE = P-GND-REFLECTANCE
$                                             DOE-2 DEFAULT=0.2(0 TO 1)
           CONSTRUCTION = WALL-2
$          LOCATION =                        UNUSED
           SHADING-SURFACE = YES
           SHADING-DIVISION = 10             $DOE-2 DEFAULT
$          INF-COEFF =                      USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
           SKY-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
           GND-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
$          SOLAR-FRACTION = 0.2        EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1), S.KIM
           INSIDE-VIS-REFL =  0.5            $DOE-2 DEFAULT(0 TO 1)
           INSIDE-SOL-ABS = 0.5              $DOE-2 DEFAULT(0 TO 1)
           OUTSIDE-EMISS = P-WALLOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
           FUNCTION                          UNUSED
                       ..                    $END OF EXTERIOR WALL COMMAND
```

Figure 3-2. DOE code of the face brick (IECC1305.inp).

3.2 8” Block with perlite fill (IECC1306.inp)

The following table and figure describe the thermal properties and other dimensions that are used for the 8” block with perlite fill.

Table 3-4 Thermal properties of 8” block with perlite fill (IECC1306.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Block	0.6667	0.114	5.84	56	0.20	CB33
2	Insulation	0.1042	0.020	5.21	1.8	0.29	IN34
3	Gypsum Board	0.0417	0.093	0.45	50	0.20	GP01
Tot				11.50 (0.087)			

* The insulation is located at the interior side.

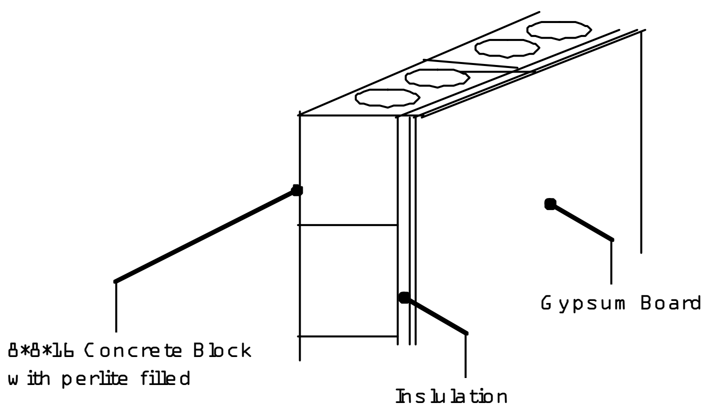


Figure 3-3. 8” block wall with perlite fill (IECC1306.inp).

The calculated R-value is 11.50 hr-F-ft^2 /Btu, and U_w is 0.087 Btu/hr-ft^2-F. U_w agrees with the required U_w-value of wall of Table 502.2.1.1.2(2) on IECC 2000 code (U_w = 0.09). The heat capacity is 7.94 Btu/ft^2·°F; this value also agrees with high mass material (6 Btu/ft^2·°F).

The wall part of DOE code of IECC1306.inp

```
WA-3 = LAYERS
       MATERIAL = (BLOCK-CB33, INSULATION-IN34, GYPSUM-BOARD)  ..
              $ BLOCK-CB33 – PERLITE FILL CONCRETE BLCOK
              $ INSULATON-IN34 – R5.21
              $ GYPSUM-BOARD = Gypsum Board 1/2”

WALL-3    = CONSTRUCTION
            LAYERS = WA-3   ..

RIGHT-1_1 = EXTERIOR-WALL                   $ INSIDE INSULATION BLOCK WALL
(PERLITE
FILL), CB33
$            HEIGHT = P-WALLHEIGHT             PLACED IN SET-DEFAULT(FT)
             WIDTH = 44                        $(FT) S.KIM, CHANGE (P-
BUILDINGWIDTH)
             X = 0  Y = 0   Z = 0              $COORDINATES
             AZIMUTH = 180                      $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                               DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-3

$S.KIM, 07/10/2002, CHANGE CONSTRUCTION(WALL-CON1)

$            LOCATION =                        UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10             $DOE-2 DEFAULT
$            INF-COEFF =                    USED WHEN INFILTRATION
METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
$            SOLAR-FRACTION = 0.2         L DIVISION AMONG THE 5 SURFACES(0 TO
1), S.KIM
             INSIDE-VIS-REFL =  0.5            $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5              $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
$            FUNCTION                          UNUSED
                    ..                        $END OF EXTERIOR WALL COMMAND
```

Figure 3-4. DOE code of the 8” block wall with perlite fill (IECC1306.inp).

3.3 8" Block with perlite and concrete fill (IECC1307.inp)

The following table and figure describe the thermal properties and other dimensions that are used for the 8" block with perlite and concrete fill.

Table 3-5. Thermal properties of the 8" block with perlite and concrete fill (IECC1307.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Block	0.6667	0.241	2.77	77	0.20	CB35
2	Insulation	0.1667	0.020	8.34	1.8	0.29	
3	Gypsum Board	0.0417	0.093	0.45	50	0.20	GP01
Tot				11.55 (0.087)			

* The insulation is located at the interior side.

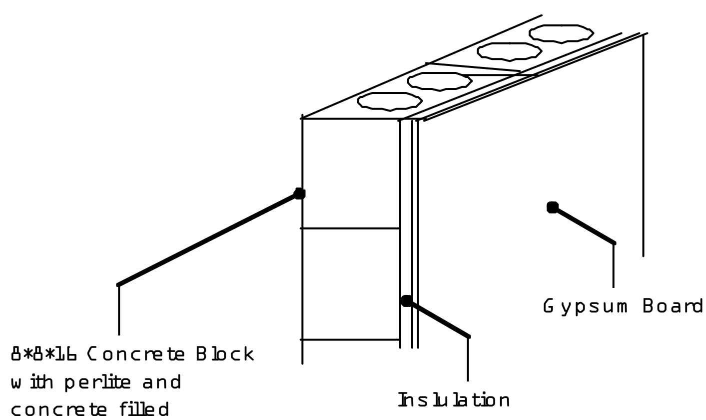


Figure 3-5. 8" block wall with perlite and concrete fill (IECC1307.inp).

The calculated R-value is 11.55 hr-F-ft^2 /Btu, and U_w is 0.087 Btu/hr-ft^{2}-F. U_w agrees with the required U_w-value of wall of Table 502.2.1.1.2(2) on IECC 2000 code (U_w = 0.09). The heat capacity is 10.77 Btu/ft^2·°F; this value also agrees with high mass material (6 Btu/ft^2·°F).

The wall part of DOE code of IECC1307.inp

```
WA-3 = LAYERS
       MATERIAL = (BLOCK-CB35, INSULATION-IN35, GYPSUM-BOARD)  ..
              $ BLOCK-CB35 – CONCRETE AND PERLITE FILL
              $ INSULATON-IN35 – R8.33
              $ GYPSUM-BOARD = Gypsum Board 1/2”

WALL-3    = CONSTRUCTION
            LAYERS = WA-3   ..

RIGHT-1_1 = EXTERIOR-WALL            $ INSIDE INSULATION BLOCK WALL (PERLITE FILL), CB33
$            HEIGHT = P-WALLHEIGHT             PLACED IN SET-DEFAULT(FT)
             WIDTH = 44                        $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
             X = 0  Y = 0   Z = 0              $COORDINATES
             AZIMUTH = 180                      $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                               DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-3             $S.KIM, 07/10/2002, CHANGE
CONSTRUCTION(WALL-CON1)

$            LOCATION =                        UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10             $DOE-2 DEFAULT
$            INF-COEFF =                    USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5             $ARBITRARY(0 TO 1)
$              SOLAR-FRACTION = 0.2   EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1), S.KIM
             INSIDE-VIS-REFL = 0.5            $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5              $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
$            FUNCTION                          UNUSED
                      ..                       $END OF EXTERIOR WALL COMMAND
```

Figure 3-6. DOE code of the 8” block wall with perlite and concrete fill (IECC1307.inp).

3.4 8" Block with perlite fill (IECC1308.inp)

The following table and figure describe the thermal properties and other dimensions that are used for the 8" block with perlite fill.

Table 3-6 Thermal properties of the 8" block with perlite fill (IECC1308.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Stucco	0.0833	1.042	0.08	166	0.20	SC01
2	Insulation	0.01	0.027	0.37	0.60	0.20	IN11
3	Block	0.6667	0.114	5.84	56	0.20	CB33
4	Stud	0.167	0.067	2.50	32	0.33	WD05
5	Air	.0167		0.89			AL21
6	Gypsum Board	0.0417	0.0926	0.45	50	0.20	GP01
Tot				7.71 (0.13)			

* The insulation is located at the exterior side.

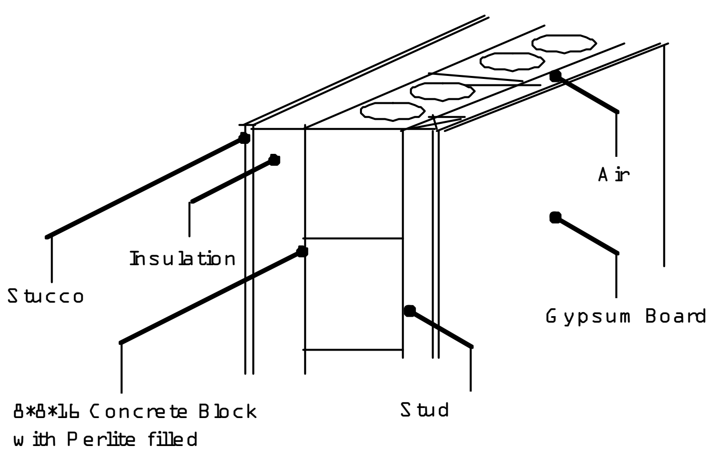


Figure 3-7. 8" block wall with perlite fill (IECC1308.inp).

The calculated R-value is 7.71 hr-F-ft^2 /Btu, and U_w is 0.13 Btu/hr-ft^2-F. U_w agrees with the required U_w-value of wall of Table 502.2.1.1.2(1) on IECC 2000 code (U_w = 0.13). However, the heat capacity is 10.88 Btu/ft^2·°F; this value also agrees with high mass material (6 Btu/ft^2·°F).

<u>The wall part of DOE code of IECC1308.inp</u>

```
WA-1 = LAYERS
       MATERIAL = (STUCCO-SC01, INSULATION-IN31,
                   BLOCK-CB33, AIR-AL21, GYPSUM-BOARD)  ..
              $ AIR Part of Wall
              $ STUCC0-SC01 – 1”
              $ INSULATION-IN31 – R-2.08
              $ BLOCK 8 INCH – PERLITE FILL
              $ AIR-AL21 – FOR VERTICAL WALL
              $ GYPSUM-BOARD = Gypsum Board 1/2”
              $ The percentage of WA-1 = 87.5 %
WA-2 = LAYERS
       MATERIAL = (STUCCO-SC01, INSULATION-IN31,
                   BLOCK-CB33, STUD1, GYPSUM-BOARD)  ..
              $ STUD Part of Wall
              $ STUCC0-SC01 – 1”
              $ INSULATION-IN31 – R-2.08
              $ BLOCK 8 INCH – PERLITE FILL
              $ STUD – 2*2”
              $ GYPSUM-BOARD = Gypsum Board 1/2”
              $ The percentage of WA-1 = 12.5 %
WALL-1    = CONSTRUCTION
            LAYERS = WA-1   ..

WALL-2    = CONSTRUCTION
            LAYERS = WA-2   ..

RIGHT-1_1 = EXTERIOR-WALL                   $ THE INSULATION PART OF WALL
$            HEIGHT = P-WALLHEIGHT            PLACED IN SET-DEFAULT(FT)
             WIDTH = 38.5                     $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
             X = 0  Y = 0   Z = 0             $COORDINATES
             AZIMUTH = 180                     $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                              DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-1     $S.KIM, 07/10/2002, CHANGE CONSTRUCTION(WALL-CON1)
$            LOCATION =                       UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10            $DOE-2 DEFAULT
$            INF-COEFF =                   USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
$            SOLAR-FRACTION = 0.2      EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1), S.KIM
             INSIDE-VIS-REFL =  0.5           $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5             $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS   $DOE-2 DEFAULT=0.9(0 TO 1)
$            FUNCTION                         UNUSED
                      ..                      $END OF EXTERIOR WALL COMMAND

RIGHT-1_2 = EXTERIOR-WALL                   $ THE STUD PART OF WALL
$            HEIGHT = P-WALLHEIGHT            PLACED IN SET-DEFAULT(FT)
             WIDTH = 5.5                      $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
             X = 38.5  Y = 0   Z = 0          $COORDINATES
             AZIMUTH = 180                     $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                             DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-2
$            LOCATION =                       UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10            $DOE-2 DEFAULT
$            INF-COEFF =                   USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
$            SOLAR-FRACTION = 0.2      EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1), S.KIM
             INSIDE-VIS-REFL =  0.5           $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5             $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS   $DOE-2 DEFAULT=0.9(0 TO 1)
$            FUNCTION                         UNUSED
                      ..                      $END OF EXTERIOR WALL COMMAND
```

Figure 3-8. DOE code of the 8” block wall with perlite fill (IECC1308.inp).

3.5 8” Block with perlite and concrete fill (IECC1309.inp)

The following table and figure describe the thermal properties and other dimensions that are used for the 8” block with perlite and concrete fill.

Table 3-7. Thermal properties of the 8” block with perlite and concrete fill (IECC1309.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Stucco	0.0833	1.042	0.08	166	0.20	SC01
2	Insulation	0.09	0.027	3.33	0.6	0.20	IN11
3	Block	0.6667	0.241	2.76	77	0.20	CB35
4	Stud	0.167	0.067	2.50	32	0.33	WD05
5	Air	.0167		0.89			AL21
6	Gypsum Board	0.0417	0.0926	0.45	50	0.20	GP01
Tot				7.59 (0.13)			

* The insulation is located at the exterior side.

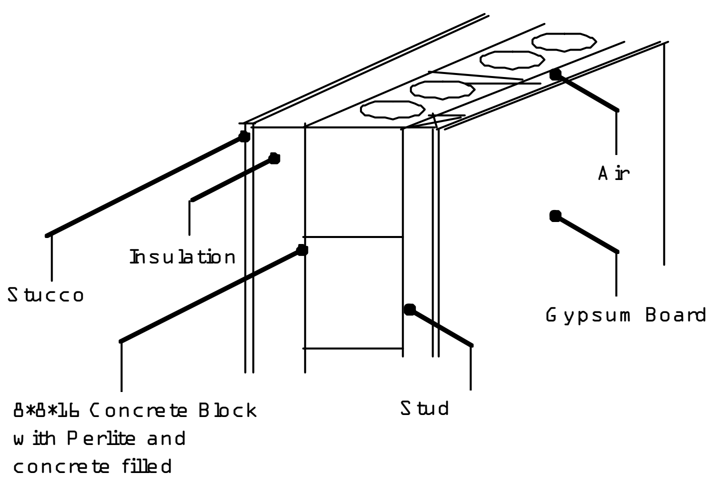


Figure 3-9. 8” block wall with perlite and concrete fill (IECC1309.inp).

The calculated R-value is 7.59 hr-F-ft^2 /Btu, and U_w is 0.13 Btu/hr-ft^2-F. U_w agrees with the required U_w-value of wall of Table 502.2.1.1.2(1) on IECC 2000 code (U_w = 0.13). However the heat capacity is 13.68 Btu/ft^2·°F; this value agrees with high mass material (6 Btu/ft^2·°F).

<u>The wall part of DOE code of IECC1309.inp</u>

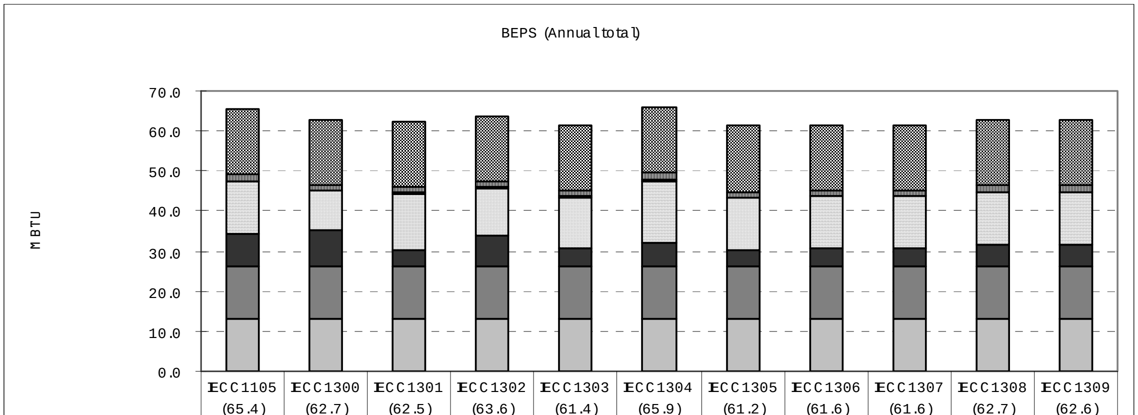
```
WA-1 = LAYERS
       MATERIAL = (STUCCO-SC01, INSULATION-IN31,
                   BLOCK-CB35, AIR-AL21, GYPSUM-BOARD)  ..
              $ AIR Part of Wall
              $ STUCC0-SC01 - 1"
              $ INSULATION-IN31 - R-2.08
              $ BLOCK 8 INCH - PERLITE AND CONCRETE FILL
              $ AIR-AL21 - FOR VERTICAL WALL
              $ GYPSUM-BOARD = Gypsum Board 1/2"
              $ The percentage of WA-1 = 87.5 %
WA-2 = LAYERS
       MATERIAL = (STUCCO-SC01, INSULATION-IN31,
                   BLOCK-CB35, STUD1, GYPSUM-BOARD)  ..
              $ STUD Part of Wall
              $ STUCC0-SC01 - 1"
              $ INSULATION-IN31 - R-2.08
              $ BLOCK 8 INCH - PERLITE AND CONCRETE FILL
              $ STUD - 2*2"
              $ GYPSUM-BOARD = Gypsum Board 1/2"
              $ The percentage of WA-1 = 12.5 %
WALL-1    = CONSTRUCTION
            LAYERS = WA-1   ..
WALL-2    = CONSTRUCTION
            LAYERS = WA-2   ..

RIGHT-1_1 = EXTERIOR-WALL                   $ THE INSULATION PART OF WALL
$            HEIGHT = P-WALLHEIGHT            PLACED IN SET-DEFAULT(FT)
             WIDTH = 38.5                     $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
             X = 0  Y = 0   Z = 0             $COORDINATES
             AZIMUTH = 180                     $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                              DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-1     $S.KIM, 07/10/2002, CHANGE CONSTRUCTION(WALL-CON1)
$            LOCATION =                       UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10            $DOE-2 DEFAULT
$            INF-COEFF =                   USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
$            SOLAR-FRACTION = 0.2      EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1), S.KIM
             INSIDE-VIS-REFL = 0.5           $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5             $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
$            FUNCTION                         UNUSED
                      ..                      $END OF EXTERIOR WALL COMMAND

RIGHT-1_2 = EXTERIOR-WALL                   $ THE STUD PART OF WALL
$            HEIGHT = P-WALLHEIGHT            PLACED IN SET-DEFAULT(FT)
             WIDTH = 5.5                      $(FT) S.KIM, CHANGE (P-BUILDINGWIDTH)
             X = 38.5  Y = 0   Z = 0          $COORDINATES
             AZIMUTH = 180                     $DEGREES
             GND-REFLECTANCE = P-GND-REFLECTANCE
$                                              DOE-2 DEFAULT=0.2(0 TO 1)
             CONSTRUCTION = WALL-2
$            LOCATION =                       UNUSED
             SHADING-SURFACE = YES
             SHADING-DIVISION = 10            $DOE-2 DEFAULT
$            INF-COEFF =                   USED WHEN INFILTRATION METHOD=CRACK(0 TO 160)
             SKY-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
             GND-FORM-FACTOR = 0.5            $ARBITRARY(0 TO 1)
$            SOLAR-FRACTION = 0.2      EQUAL DIVISION AMONG THE 5 SURFACES(0 TO 1), S.KIM
             INSIDE-VIS-REFL =  0.5           $DOE-2 DEFAULT(0 TO 1)
             INSIDE-SOL-ABS = 0.5             $DOE-2 DEFAULT(0 TO 1)
             OUTSIDE-EMISS = P-WALLOUTEMISS    $DOE-2 DEFAULT=0.9(0 TO 1)
$            FUNCTION                         UNUSED
                      ..                      $END OF EXTERIOR WALL COMMAND
```

Figure 3-10. DOE code of the 8” block wall with perlite and concrete fill (IECC1308.inp).

3.6 Results

The results of this report consist of annual energy usage (BEPS DOE Report), peak cooling / heating load (LS-C DOE Report), and peak day electricity use (PS-F DOE Report). The peak cooling of the base case model (IECC1105.inp) occurred on Jul 29 3PM; the peak heating of the base case model was on January 11 4AM; and the peak day electricity use was on August 26. In order to compare the results between the base case model and each model, the peak cooling and heating, and peak day electricity usage of the specific day based on IECC1105 results were recalculated using the hourly DOE report.

<u>BEPS (Annual Total)</u>



	IECC1105 (65.4)	IECC1300 (62.7)	IECC1301 (62.5)	IECC1302 (63.6)	IECC1303 (61.4)	IECC1304 (65.9)	IECC1305 (61.2)	IECC1306 (61.6)	IECC1307 (61.6)	IECC1308 (62.7)	IECC1309 (62.6)
DOM HOT WATER	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
VENT FANS	1.7	1.2	1.7	1.4	1.5	1.9	1.5	1.5	1.5	1.5	1.5
PUMPS & MISC	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
SPACE COOL	12.8	9.8	14.1	11.7	12.8	15.4	12.8	12.8	12.8	13.0	12.9
SPACE HEAT	8.0	8.8	3.8	7.6	4.2	5.7	4.0	4.4	4.4	5.3	5.3
MISC EQUIPMT	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
AREA LIGHTS	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2

Figure 3-11. BEPS (Annual Total) Report.

Of the 11 models, the original IECC1105.inp, which doesn't consider the thermal mass, predicted the highest energy consumption, and the IECC1305.inp (3" face brick wall) predicted the lowest energy use. The calculated floor weight (IECC1300.inp, 86.68 lb/ft^2) instead of 11.3 lb/ft^2 reduced the annual energy use by almost 4.13 % compared to the base case model (IECC1105.inp) due to the thermal mass effect of the floor.

By setting the floor weight to the calculated value (86.68 lb/ft^2), the addition of the real wall, roof, and floor (IECC1301.inp) reduced energy use by 4.43 %. In order to investigate the effect of the Floor Weight command of the DOE-2e program, the Floor Weight is set to 0 instead of 86.68 to calculate the custom weight factor by DOE-2e at IECC1302.inp, and the results show that space cooling is reduced by 8.6 % and space heating is reduced by 5.0 %. This indicates that the thermal mass of the construction material affects energy use as the DOE-2e program calculates the heating and cooling loads.

Applying the LBNL method for ground surface (IECC1303.inp) reduced the space heat by 47.5 %, compared to the base case model (IECC1105.inp), but there is no change on space cooling. In order to analyze the effect of the floor area, the floor area was set to 0 at IECC1304.inp, and the results show that heating and cooling of annual energy use are increased.

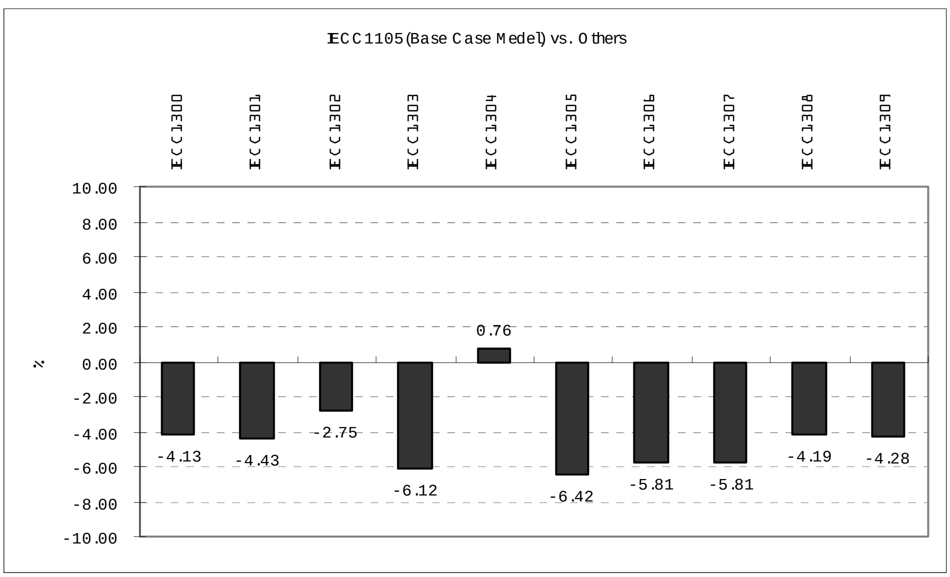


Figure 3-12. The comparison of IECC1105 (base case model) with others.

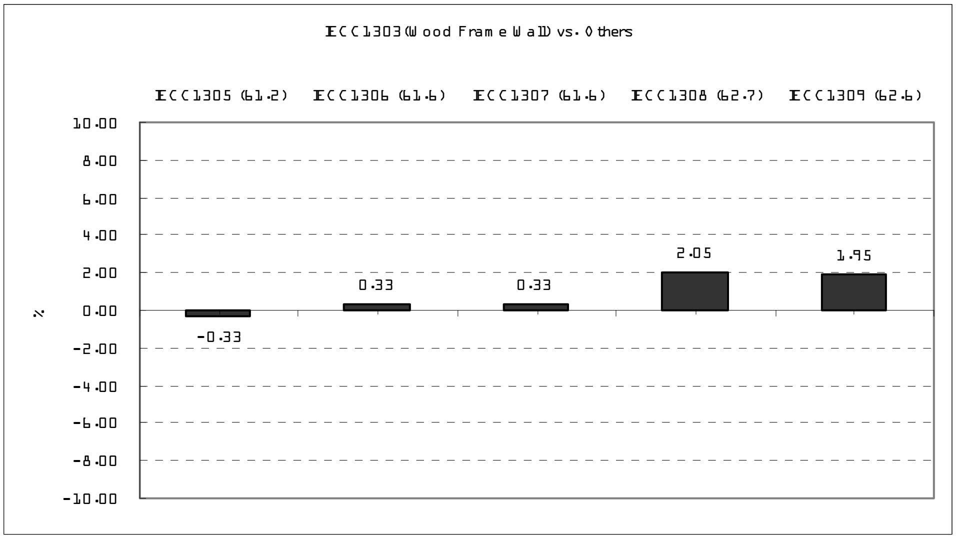
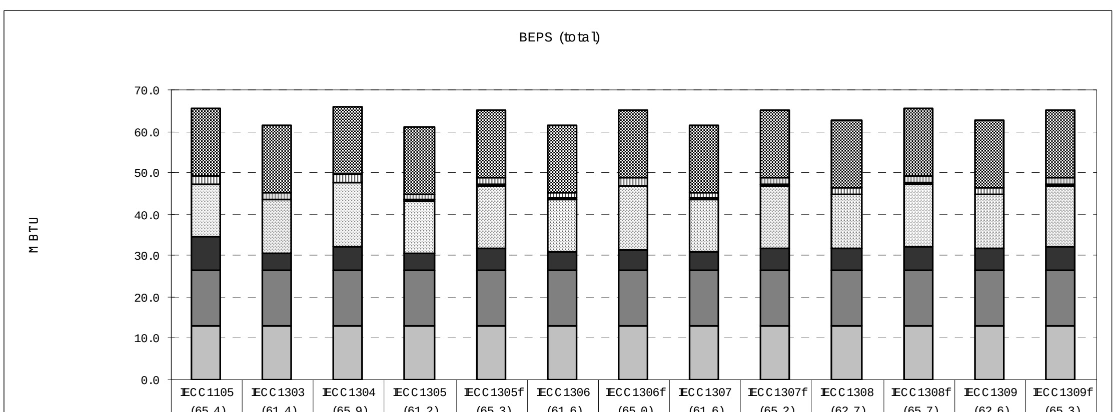


Figure 3-13. The comparison with IECC1303 (Wood frame wall) and others.

Of the 6 models (IECC1303, 1305, 1306, 1307, 1308, and 1309) in which real materials were applied, IECC1305 (Brick wall, interior insulation and R-11.25) was the most energy conservative material among the recommended R-values according to the location of the insulation of 2000 IECC.

BEPS (Annual Total) of With vs. Without Floor



	IECC1105 (65.4)	IECC1303 (61.4)	IECC1304 (65.9)	IECC1305 (61.2)	IECC1305f (65.3)	IECC1306 (61.6)	IECC1306f (65.0)	IECC1307 (61.6)	IECC1307f (65.2)	IECC1308 (62.7)	IECC1308f (65.7)	IECC1309 (62.6)	IECC1309f (65.3)
DOM HOT WATER	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
VENT FANS	1.7	1.5	1.9	1.5	1.8	1.5	1.8	1.5	1.8	1.5	1.8	1.5	1.8
PUMPS & MISC	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
SPACE COOL	12.8	12.8	15.4	12.8	15.4	12.8	15.2	12.8	15.3	13.0	15.1	12.9	15.0
SPACE HEAT	8.0	4.2	5.7	4.0	5.2	4.4	5.1	4.4	5.2	5.3	5.9	5.3	5.6
MISC EQUIPMT	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
AREA LIGHTS	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2

Figure 3-14. BEPS (Annual Total) Report of with and without floor.

All models are the same, except for the floor area = 0, to investigate the effect of the floor area. The models whose floor area is 0 show more energy use, especially on heating and cooling energy than the other models that have floor area. This means the floor of the residential buildings plays a role in calculating energy use due to the thermal capacity.

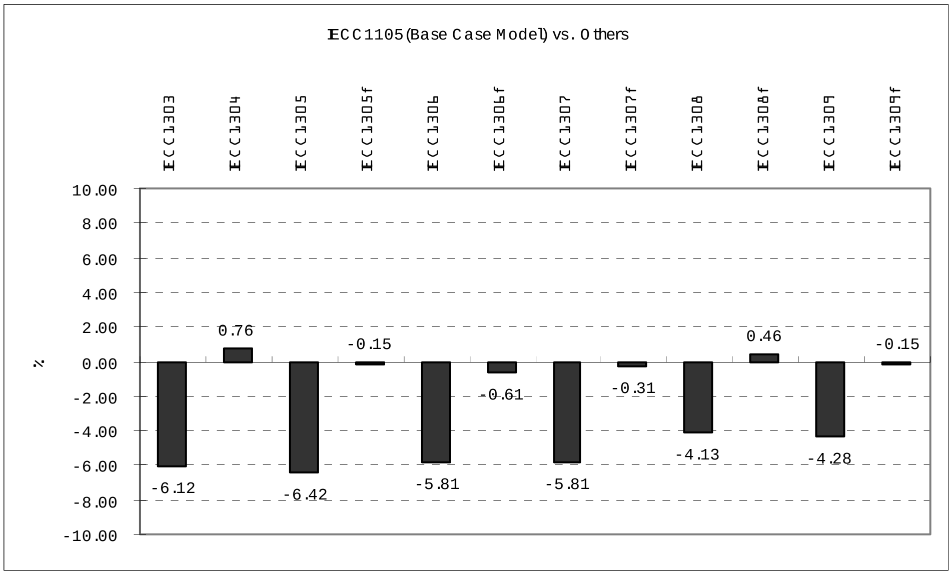
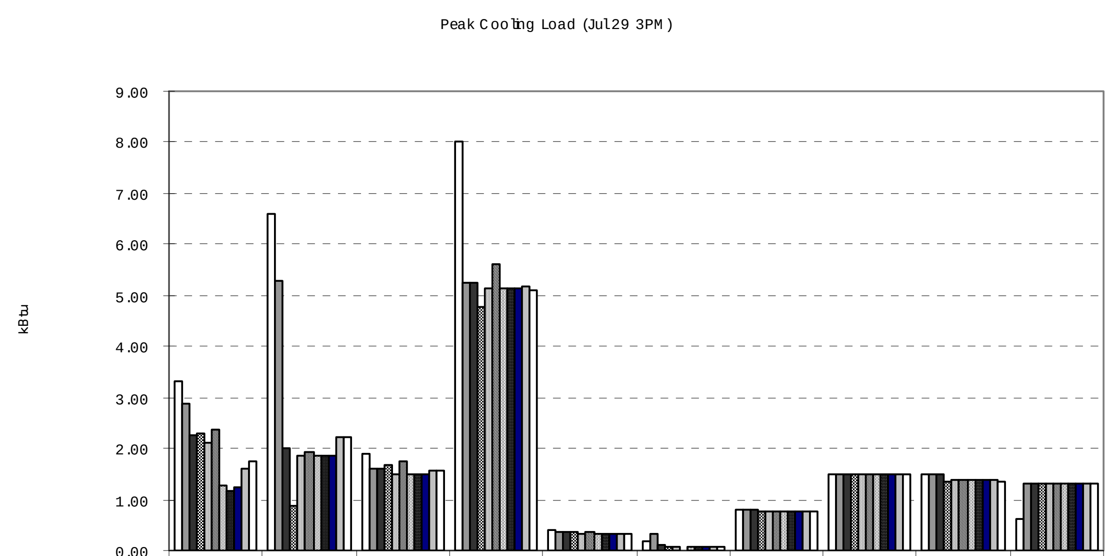


Figure 3-15. The comparison of IECC1105 with others of with and without floor.

Peak Cooling Load (Jul 29 3PM)



	WALL CONDUCTION	ROOF CONDUCTION	WINDOW GLASS+FRM COND	WINDOW GLASS SOLAR	DOOR CONDUCTION	UNDERGROUND SURF COND	OCCUPANTS TO SPACE	LIGHT TO SPACE	EQUIPMENT TO SPACE	INFILTRATION
1105 (24.81)	3.30	6.60	1.88	8.02	0.40	0.19	0.80	1.50	1.50	0.61
1300 (20.85)	2.89	5.29	1.61	5.25	0.36	0.34	0.80	1.50	1.50	1.32
1301 (16.72)	2.27	2.01	1.61	5.25	0.36	0.10	0.80	1.50	1.50	1.32
1302 (14.97)	2.30	0.86	1.69	4.77	0.36	0.09	0.76	1.50	1.33	1.32
1303 (16.01)	2.11	1.86	1.50	5.16	0.33	0.09	0.77	1.50	1.38	1.32
1304 (16.99)	2.38	1.92	1.75	5.60	0.37	0.00	0.77	1.50	1.39	1.32
1305 (15.19)	1.29	1.86	1.50	5.16	0.33	0.09	0.77	1.50	1.38	1.32
1306 (15.04)	1.16	1.87	1.50	5.13	0.33	0.09	0.77	1.50	1.38	1.32
1307 (15.14)	1.23	1.87	1.51	5.15	0.33	0.09	0.77	1.50	1.38	1.32
1308 (15.94)	1.61	2.22	1.58	5.17	0.32	0.09	0.76	1.50	1.37	1.31
1309 (15.99)	1.74	2.22	1.58	5.12	0.32	0.09	0.76	1.50	1.37	1.31

Figure 3-16. Peak cooling load.

This plot provides further insight into where the savings are. In this plot, the peak cooling loads indicate that the largest reductions are attributable to the window glass solar gain and heat conduction through the roof after adding the real material, because the roof and window glass solar receive the solar heat directly, so those are closely related to solar heat gain.

In terms of the peak cooling load, IECC1306 (8" Block wall with perlite fill, interior insulation and R-11.50) was the most energy conservative material among the recommended R-values according to the location of the insulation of 2000 IECC after the LBNL ground method was applied.

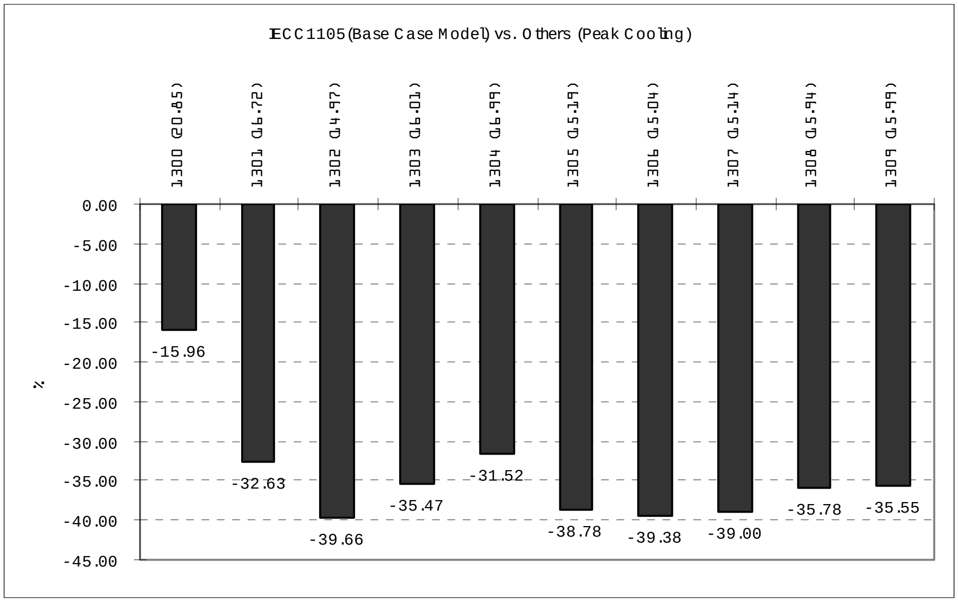


Figure 3-17. The comparison of peak cooling load between IECC1105 and others.

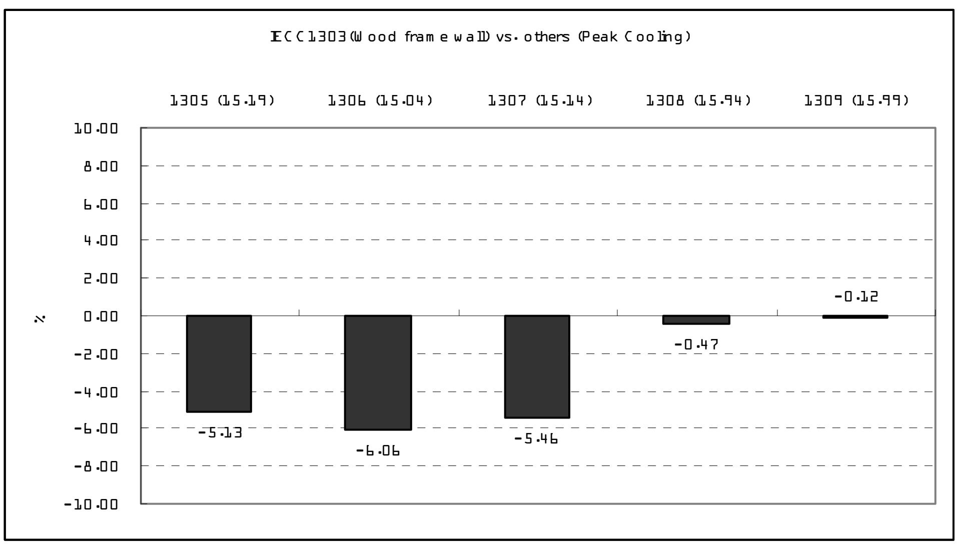
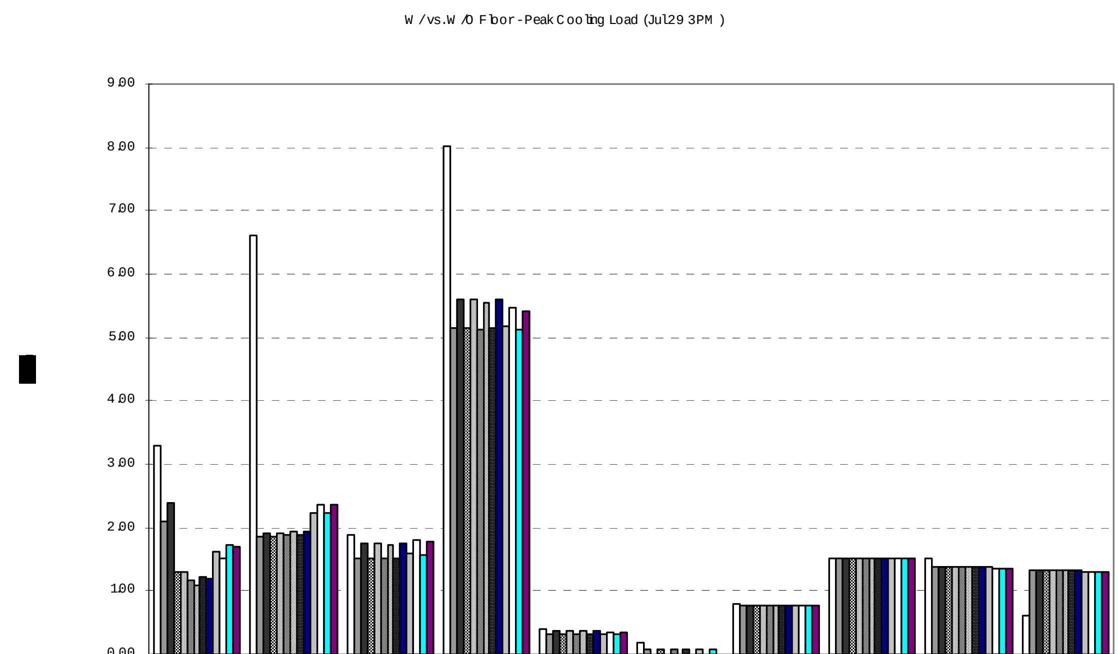


Figure 3-18. The comparison of IECC1303 (Wood frame wall) with others.

Peak Cooling Load (Jul 29 3PM) of With vs. Without Floor



	WALL CONDUCTION	ROOF CONDUCTION	WINDOW GLASS+FRM COND	WINDOW GLASS SOLAR	DOOR CONDUCTION	UNDERGROUND SURF COND	OCCUPANTS TO SPACE	LIGHT TO SPACE	EQUIPMENT TO SPACE	INFILTRATION
1105 (24.81)	3.30	6.60	1.88	8.02	0.40	0.19	0.80	1.50	1.50	0.61
1303 (16.01)	2.11	1.86	1.50	5.16	0.33	0.09	0.77	1.50	1.38	1.32
1304 (16.99)	2.38	1.92	1.75	5.60	0.37	0.00	0.77	1.50	1.39	1.32
1305 (15.19)	1.29	1.86	1.50	5.16	0.33	0.09	0.77	1.50	1.38	1.32
1305f (15.92)	1.31	1.92	1.75	5.60	0.37	0.00	0.77	1.50	1.39	1.32
1306 (15.04)	1.16	1.87	1.50	5.13	0.33	0.09	0.77	1.50	1.38	1.32
1306f (15.66)	1.10	1.94	1.74	5.55	0.37	0.00	0.77	1.50	1.38	1.32
1307 (15.14)	1.23	1.87	1.51	5.15	0.33	0.09	0.77	1.50	1.38	1.32
1307f (15.81)	1.18	1.94	1.75	5.59	0.37	0.00	0.77	1.50	1.38	1.32
1308 (15.94)	1.61	2.22	1.58	5.17	0.32	0.09	0.76	1.50	1.37	1.31
1308f (16.45)	1.52	2.35	1.79	5.48	0.36	0.00	0.76	1.50	1.37	1.31
1309 (15.99)	1.74	2.22	1.58	5.12	0.32	0.09	0.76	1.50	1.37	1.31
1309f (16.53)	1.70	2.36	1.77	5.41	0.35	0.00	0.76	1.50	1.37	1.31

Figure 3-19. Peak cooling load of with and without floor.

This figure shows that the largest reduction is due to solar heat gain through windows because of floor thermal mass and heat conduction from the roof. According to the DOE-2e reference manual, the glass solar is the heat gain caused by direct and diffuse solar radiation transmitted by the windows into the space. All sensible loads are calculated as "delayed in time with weighting factors." For example, it is possible to have heat gains from the glass solar long after the sun moved and no longer shines in the exposed walls of the space. This means that the floor area helps keep the temperature of the house constant as the floor conserves the solar heat gain through the windows and affects results in the simulations.

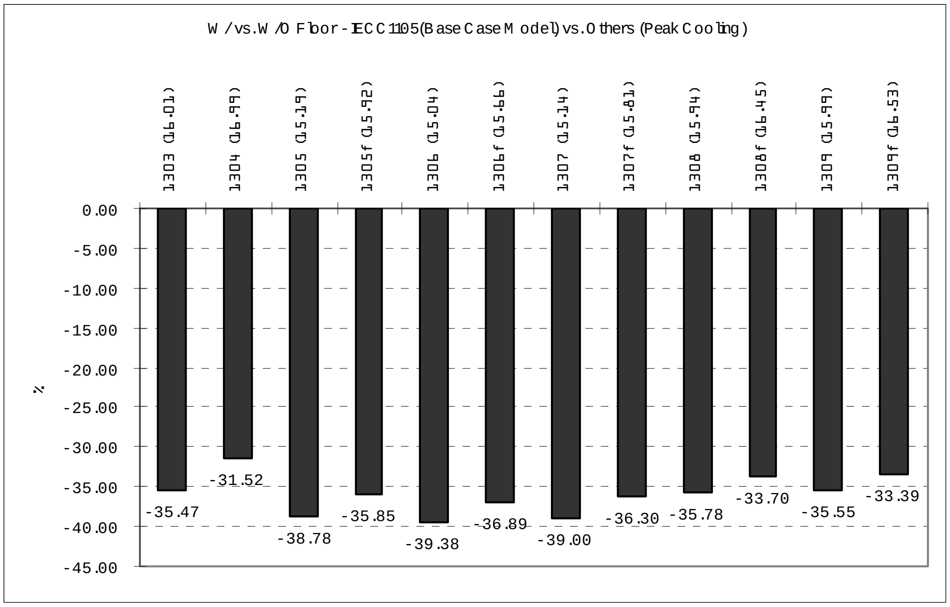
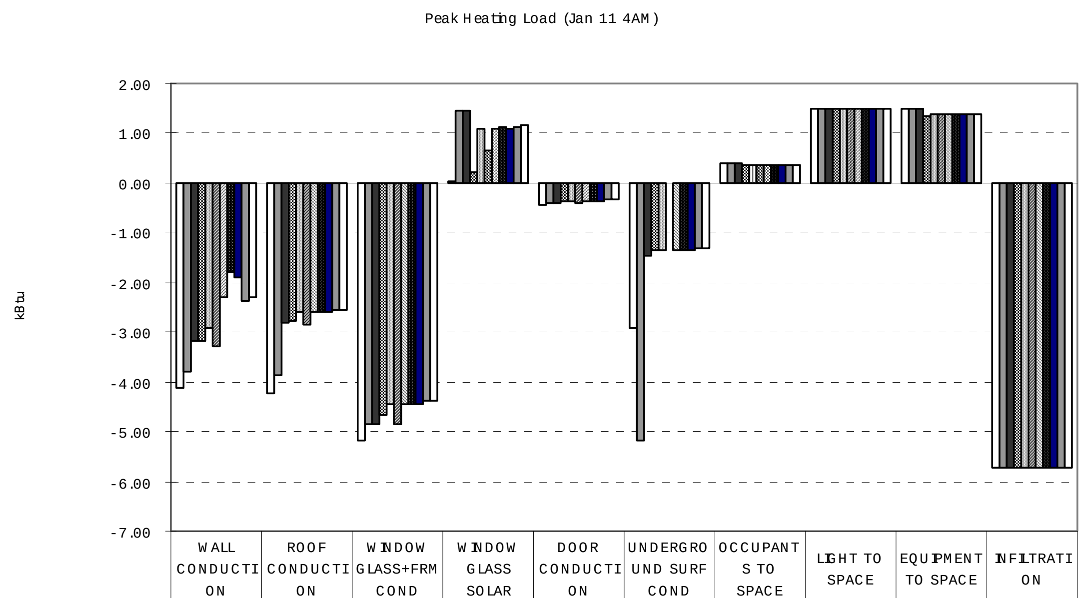


Figure 3-20. The comparison of peak cooling load of with and without floor.

Peak Heating Load (January 11 4AM)



	WALL CONDUCTION	ROOF CONDUCTION	WINDOW GLASS+FRM COND	WINDOW GLASS SOLAR	DOOR CONDUCTION	UNDERGROUND SURF COND	OCCUPANTS TO SPACE	LIGHT TO SPACE	EQUIPMENT TO SPACE	INFILTRATION
1105 (-19.21)	-4.13	-4.24	-5.19	0.03	-0.42	-2.93	0.40	1.50	1.50	-5.73
1300 (-18.95)	-3.78	-3.86	-4.86	1.46	-0.39	-5.19	0.40	1.50	1.50	-5.73
1301 (-13.57)	-3.16	-2.81	-4.86	1.46	-0.39	-1.48	0.40	1.50	1.50	-5.73
1302 (-14.62)	-3.16	-2.76	-4.67	0.23	-0.38	-1.34	0.36	1.50	1.33	-5.73
1303 (-13.04)	-2.91	-2.60	-4.45	1.10	-0.36	-1.34	0.37	1.50	1.38	-5.73
1304 (-13.19)	-3.27	-2.86	-4.83	0.65	-0.39	0.00	0.37	1.50	1.39	-5.73
1305 (-12.42)	-2.29	-2.60	-4.45	1.10	-0.36	-1.34	0.37	1.50	1.38	-5.73
1306 (-11.90)	-1.79	-2.60	-4.44	1.11	-0.35	-1.34	0.37	1.50	1.38	-5.73
1307 (-12.02)	-1.90	-2.60	-4.44	1.10	-0.35	-1.34	0.37	1.50	1.38	-5.73
1308 (-12.36)	-2.36	-2.56	-4.39	1.14	-0.35	-1.33	0.36	1.50	1.37	-5.73
1309 (-12.27)	-2.31	-2.56	-4.37	1.15	-0.35	-1.33	0.36	1.50	1.37	-5.73

Figure 3-21. Peak heating load.

This plot also has been provided to show the results where the savings occur. In terms of peak heating load, the largest change occurred as indicated in the column labeled "window glass solar" in Figure 3-21. When the floor-weight is 11.5 lb/ft^2 (IECC1105), window glass solar is just 0.03 KBtu/h. However, after using the calculated floor weight or the real floor material (from IECC1300 to IECC1309), the heat gain from window glass solar is increased. This means floor weight is closely related to the window glass solar, and the floor weight of IECC1105 seems to be low compared to other input files. As a result of peak heating loads, the thermal mass effect of the roof also plays an important role in calculating the heating load in DOE-2 simulations because of the solar effects just like the peak cooling load.

In terms of peak heating load, IECC1306 (8" Block wall, exterior insulation and R-11.50) was the most energy conservative material among the recommended R-values according to the location of the insulation of 2000 IECC.

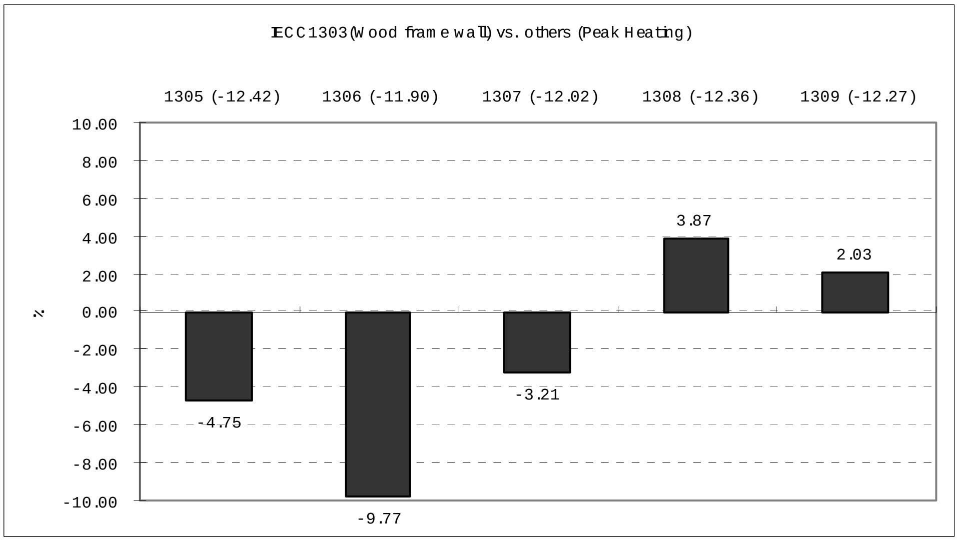


Figure 3-22. The comparison of peak heating load between IECC1105 and others.

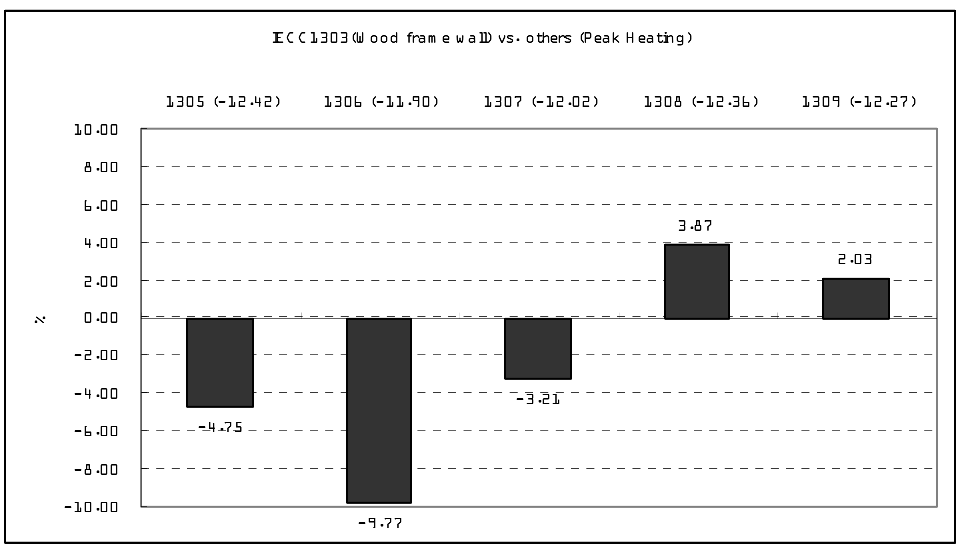
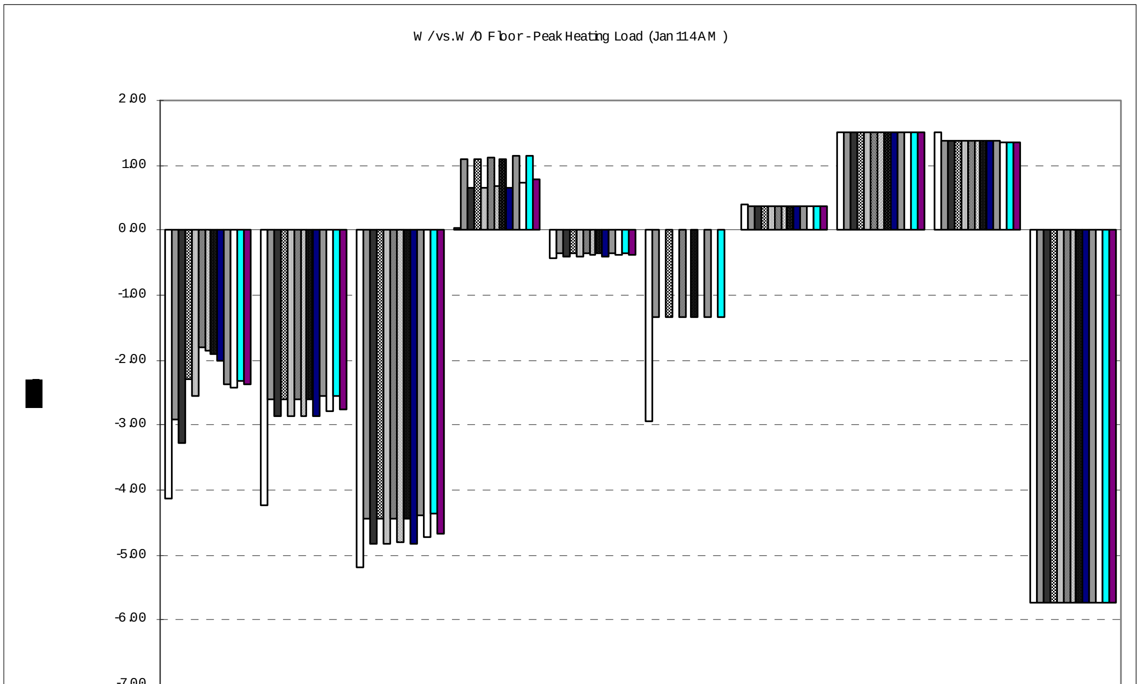


Figure 3-23. The comparison of IECC1303 (Wood frame wall) with others.

Peak Heating Load (January 11 4AM) of With vs. Without Floor



	WALL CONDUCTION	ROOF CONDUCTION	WINDOW GLASS+FRM COND	WINDOW GLASS SOLAR	DOOR CONDUCTION	UNDERGROUND SURF COND	OCCUPANTS TO SPACE	LIGHT TO SPACE	EQUIPMENT TO SPACE	INFILTRATION
1105 (-19.21)	-4.13	-4.24	-5.19	0.03	-0.42	-2.93	0.40	1.50	1.50	-5.73
1303 (-13.04)	-2.91	-2.60	-4.45	1.10	-0.36	-1.34	0.37	1.50	1.38	-5.73
1304 (-13.19)	-3.27	-2.86	-4.83	0.65	-0.39	0.00	0.37	1.50	1.39	-5.73
1305 (-12.42)	-2.29	-2.60	-4.45	1.10	-0.36	-1.34	0.37	1.50	1.38	-5.73
1305f (-12.46)	-2.55	-2.86	-4.83	0.65	-0.39	0.00	0.37	1.50	1.39	-5.73
1306 (-11.90)	-1.79	-2.60	-4.44	1.11	-0.35	-1.34	0.37	1.50	1.38	-5.73
1306f (-11.72)	-1.86	-2.85	-4.80	0.68	-0.39	0.00	0.37	1.50	1.38	-5.73
1307 (-12.02)	-1.90	-2.60	-4.44	1.10	-0.35	-1.34	0.37	1.50	1.38	-5.73
1307f (-11.91)	-2.00	-2.86	-4.82	0.65	-0.39	0.00	0.37	1.50	1.38	-5.73
1308 (-12.36)	-2.36	-2.56	-4.39	1.14	-0.35	-1.33	0.36	1.50	1.37	-5.73
1308f (-12.07)	-2.42	-2.78	-4.72	0.74	-0.38	0.00	0.36	1.50	1.37	-5.73
1309 (-12.27)	-2.31	-2.56	-4.37	1.15	-0.35	-1.33	0.36	1.50	1.37	-5.73
1309f (-11.90)	-2.36	-2.76	-4.68	0.78	-0.38	0.00	0.36	1.50	1.37	-5.73

Figure 3-24. Peak heating load of with and without floor.

In regard to peak heating load between with and without floor, the results show that the glass solar heat gain through the window is the most sensitive factor as the peak cooling load.

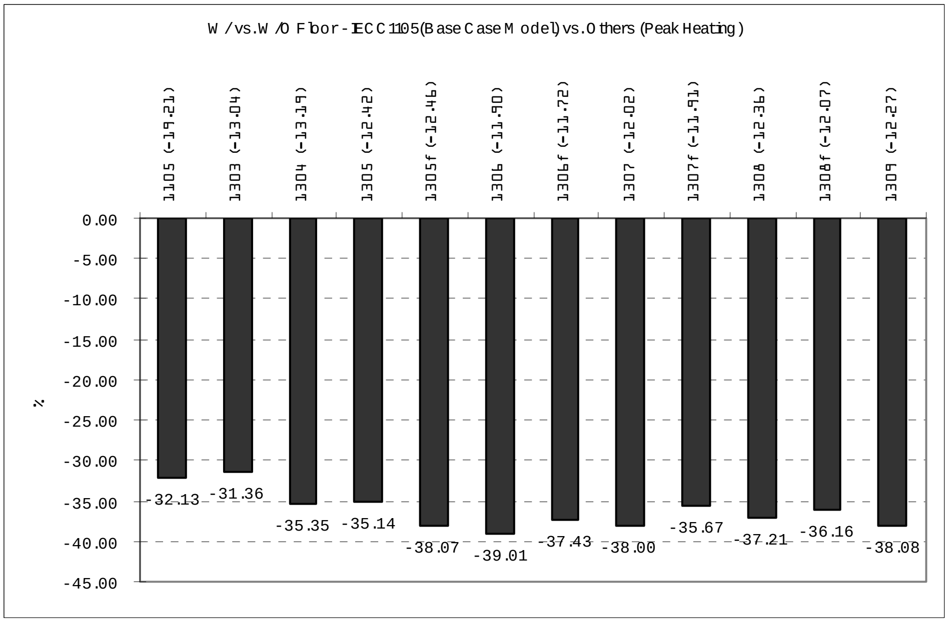


Figure 3-25. The comparison of peak heating load of with and without floor.

Peak day total electricity use (kWh/day) – August 26

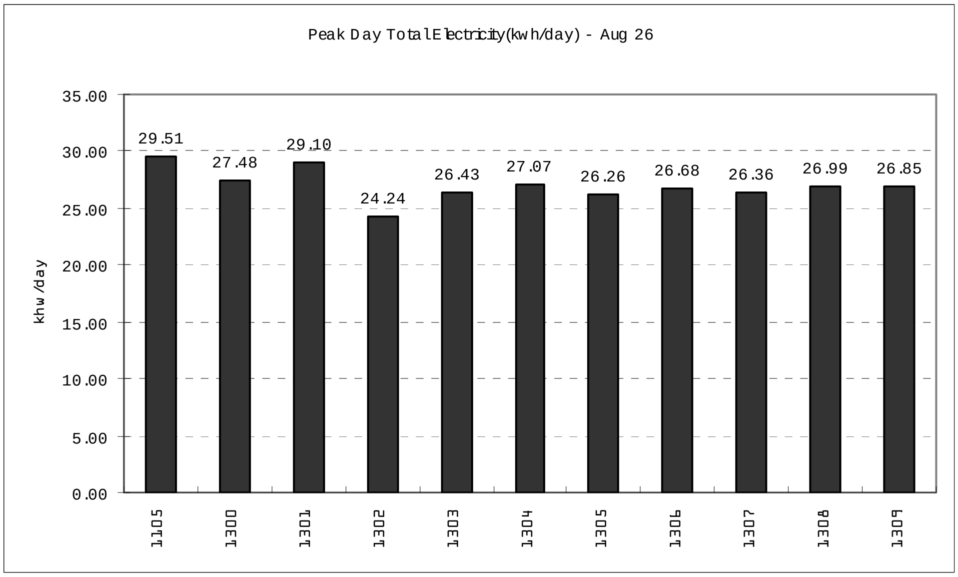


Figure 3-26. Peak day total electricity use.

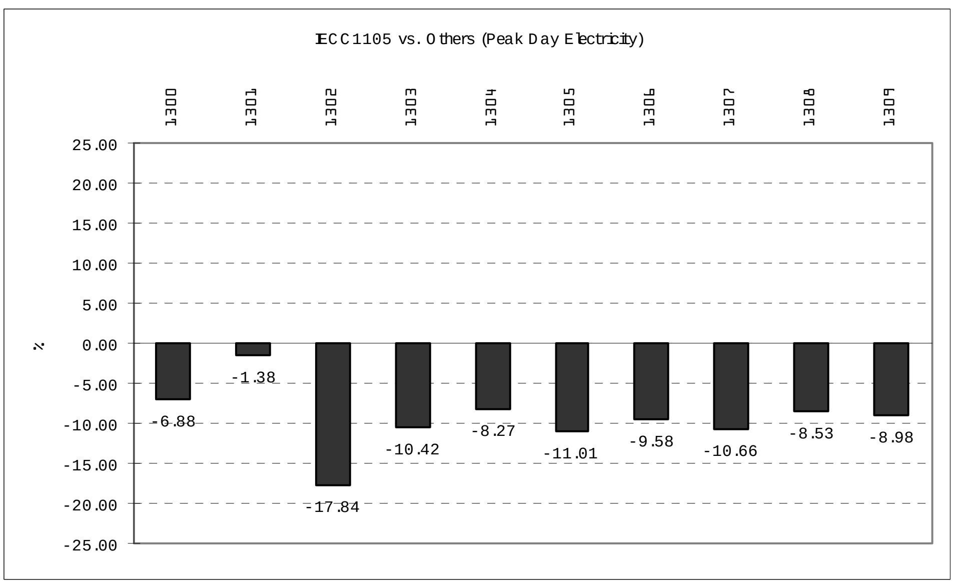


Figure 3-27. The comparison of total electricity use.

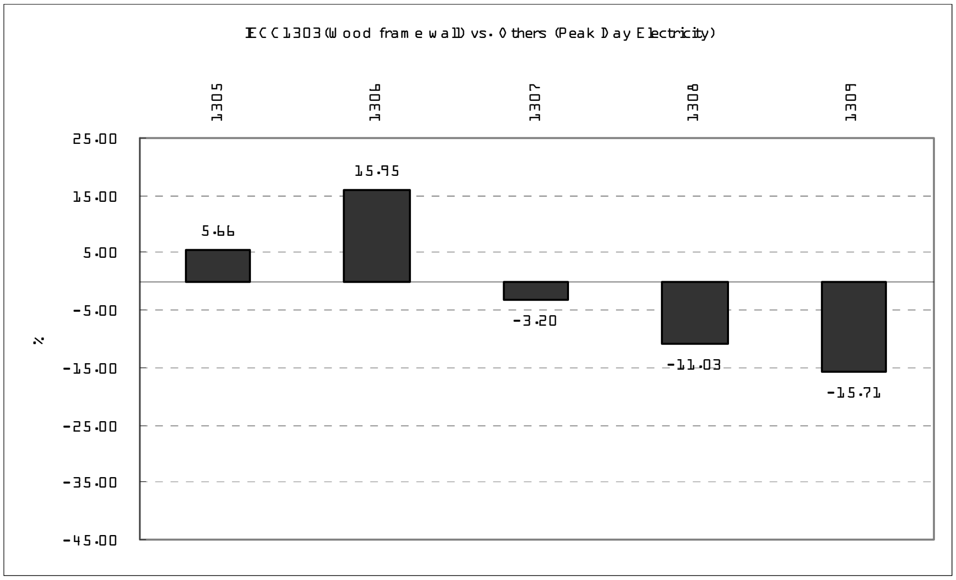


Figure 3-28. The comparison of IECC1303 (Wood frame wall) with others.

The highest electricity use occurred on August 26 at IECC1105 base case input file. In order to compare the peak day total electricity use (kWh/day) with other input files, the total electricity use of August 26 of other input files (from IECC1300 to 1309) was recalculated using the DOE-2 hourly report. The results from IECC1305.inp (3" Face Brick wall) were selected as the lowest electricity energy use after LBNL ground method was applied.

Summary of the simulation results

Table 3-8. The summary of the simulation results. * ( ): Results of without floor.

Name	Annual Energy Use MBtu	Total Peak Cooling KBtu/hr	Total Peak Heating KBtu/hr	Electricity Use kWh/day
IECC1105	65.4	24.81	-19.21	29.51
IECC1300	62.7	20.85	-18.95	27.48
IECC1301	62.5	16.72	-13.57	29.10
IECC1302	63.6	14.97	-14.62	24.24
IECC1303	**61.4** (65.9)	16.01 (16.99)	-13.03 (-13.19)	26.43
IECC1305	**61.2** (65.3)	15.19 (15.92)	-12.42 (-12.46)	**26.26**
IECC1306	61.6 (65.0)	**15.04** (15.66)	**-11.90** (-11.72)	26.68
IECC1307	61.6 (65.2)	**15.14** (15.81)	**-12.02** (-11.91)	**26.36**
IECC1308	62.7 (65.7)	15.94 (16.45)	-12.36 (-12.07)	26.99
IECC1309	62.6 (65.3)	15.99 (16.53)	-12.27 (-11.90)	26.85

From the results of annual energy use, total peak cooling and heating, and electricity energy use, the IECC1305 (3” face brick, interior insulation, R-value=11.25) reduced the annual energy use most from 65.4 to 61.2 MBtu (a 6.4% reduction). In regard to peak cooling and peak heating energy, the IECC1306 (8” block with perlite fill, interior insulation, R-value=11.50) reduced the peak cooling load from 24.81 to 15.04 KBtu/hr (a 39.4% reduction) and the peak heating load from 19.21 to 11.90 KBtu/hr (a 38.1% reduction).

4 Simulation conditions according to the types of the real block walls

There are several kinds of block walls that are used at the real residential houses. In this research, four types of block walls are modeled to perform the simulation; and, in order to select the proper block code from the DOE library, the real block is measured to know the exact weight and size.

- Weight: 41lb
- Volume = $(15.5*7.5*7.5)/12^3 = 0.50ft^3$
- Density = weight(lb) / volume(ft^3)
  = 81.26 lb/ ft^3

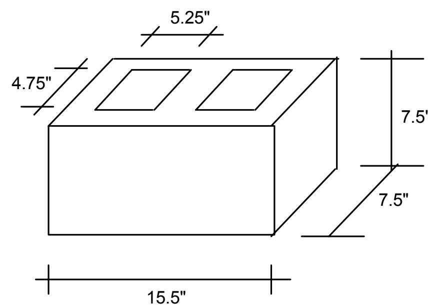


Figure 4-1. The measurement of the real block.

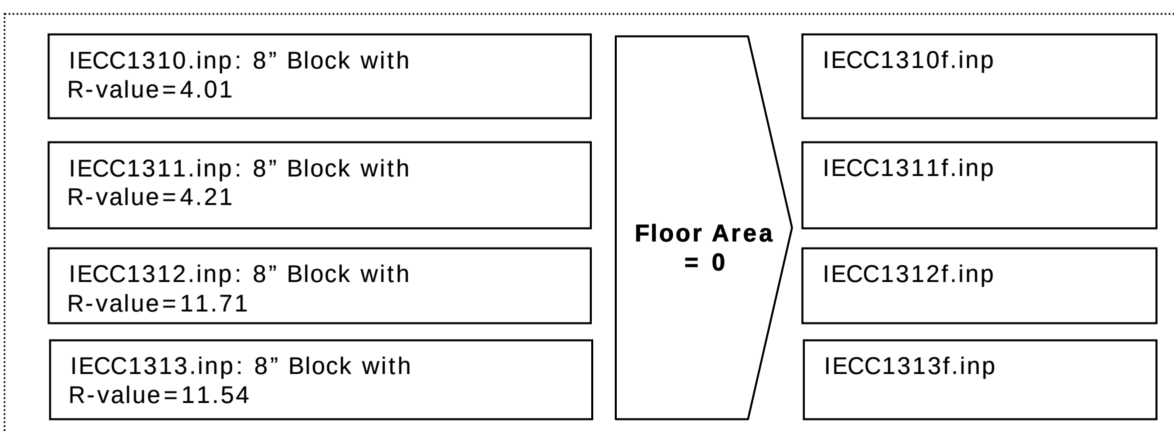
The following table is the concrete block density (hollow, 8”) from the DOE-2 Library.

Table 4-1. The concrete block of the DOE-2 Library.

DOE code	Density (lb/ $ft^{3})$
CB11 (Heavy Weight)	69
CB31 (Medium Weight)	53
CB51 (Light Weight)	45

According to the measurement of the real block, the heavy weight concrete (CB11) is decided for the standard block for this simulation.

<u>Simulation Procedure</u>



Wall description of each simulation

Table 4-2. Summary of wall description of each simulation.

Name	R-value h. ft^2.□/Btu	Uw Btu/ h. ft^2.□	Heat Capacity Btu/ft^2.□	Insulation	Description
IECC1310	4.01	0.249	9.75	-	Perlite Block (8”) + Air (3/4”) + Gypsum Board (1/2”)
IECC1310f	4.01	0.249	9.75	-	Perlite Block (8”) + Air (3/4”) + Gypsum Board (1/2”) w/o floor area
IECC1311	4.21	0.238	12.52	-	Stucco (1”) + Perlite Block (8”) + Air (3/4”) + Gypsum Board (1/2”)
IECC1311f	4.21	0.238	12.52	-	Stucco (1”) + Perlite Block (8”) + Air (3/4”) + Gypsum Board (1/2”) w/o floor area
IECC1312	11.03	0.09	9.84	Inside	Perlite Block (8”) + Insulation (1.8”) + Gypsum Board (1/2”): Heavy weight concrete
IECC1312f	11.03	0.09	9.84	Inside	Perlite Block (8”) + Insulation (1.8”) + Gypsum Board (1/2”): Heavy weight concrete w/o floor area
IECC1313	7.60	0.13	12.60	Outside	Stucco (1”) + Insulation (0.78”) + Perlite Block (8”) + Air (3/4”) + Gypsum Board (1/2”)
IECC1313f	7.60	0.13	12.60	Outside	Stucco (1”) + Insulation (0.78”) + Perlite Block (8”) + Air (3/4”) + Gypsum Board (1/2”) w/o floor area
IECC1314	1.10	0.909	9.20	-	Hollow Block: Heavy weight concrete
IECC1314f	1.10	0.909	9.20	-	Hollow Block: Heavy weight concrete w/o floor area
IECC1315	2.93	0.341	9.33	-	Block with perlite fill: Heavy weight concrete
IECC1315f	2.93	0.341	9.33	-	Block with perlite fill: Heavy weight concrete w/o floor area

4.1 Block wall – Type 1 (IECC1310.inp)

The following table and figure describe the thermal properties and other dimensions that are used for type 1 block wall.

Table 4-3. Thermal properties of type 1 block wall (IECC1310.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Heavy weight concrete block with perlite fill	0.6667	0.2272	2.93	70	0.2	CB13
2	Air layer			0.89			AL21
3	Gypsum Board	0.0417	0.0926	0.45	50	0.20	GP01
Tot				4.01 (0.249)			

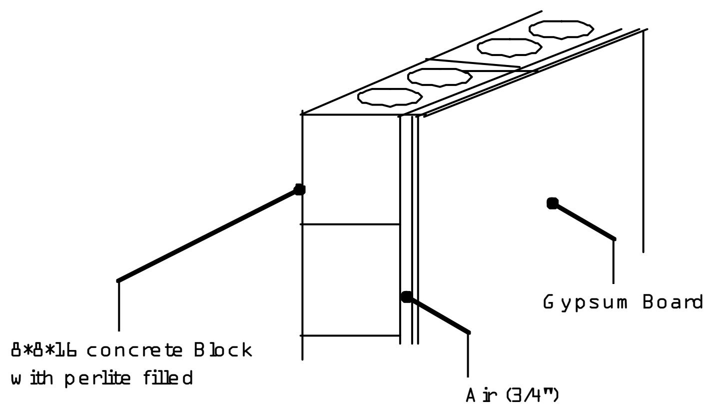


Figure 4-2. Description of type 1 block wall (IECC1310.inp).

The heat capacity is 9.75 Btu/ft^2·°F; this value agrees with high mass material (6 Btu/ft^2·°F).

<u>The wall part of DOE code of IECC1310.inp</u>

```
WA-3 = LAYERS
       MATERIAL = (BLOCK-CB13, AIR-AL21, GYPSUM-BOARD)  ..
              $ BLOCK-CB33 - PERLITE FILL CONCRETE BLCOK, HEAVY WEIGHT
$ AIR-AL21 - AIR LAYER, 3/4 INCH TO 4 INCH, VERTICAL WALLS
              $ GYPSUM-BOARD = Gypsum Board 1/2"
```

4.2 Block wall – Type 2 (IECC1311.inp)

The following table and figure describe the thermal properties and other dimensions that are used for type 2 block wall.

Table 4-4. Thermal properties of type 2 block wall (IECC1311.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Stucco	0.0833	1.042	0.08	166	0.20	SC01
2	Heavy weight concrete block with perlite fill	0.6667	0.2272	2.93	70	0.20	CB13
3	Air layer			0.89			AL21
4	Gypsum Board	0.0417	0.0926	0.45	50	0.20	GP01
Tot				4.21 (0.238)			

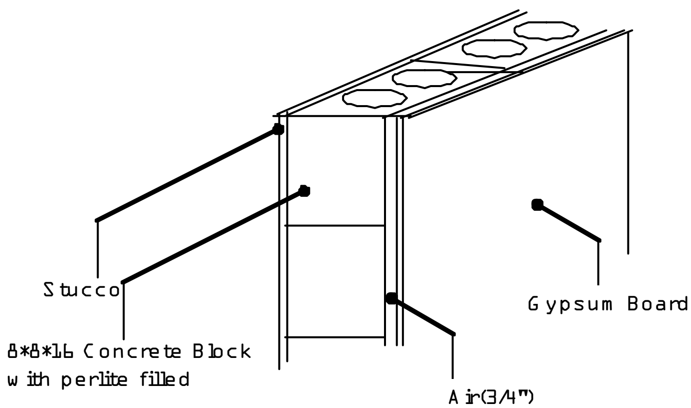


Figure 4-3. Description of type 2 block wall (IECC1311.inp).

The heat capacity is 12.52 Btu/ft^2·°F; this value agrees with high mass material (6 Btu/ft^2·°F).

<u>The wall part of DOE code of IECC1311.inp</u>

```
WA-3 = LAYERS
       MATERIAL = (STUCCO-SC01, BLOCK-CB13, AIR-AL21, GYPSUM-BOARD)  ..
              $ BLOCK-CB35 - CONCRETE AND PERLITE FILL, HEAVY WEIHGT
              $ AIR-AL21 - AIR LAYER, 3/4 INCH TO 4 INCH, VERTICAL WALLS
             $ GYPSUM-BOARD - Gypsum Board 1/2"
```

Figure 4-4. DOE code of type 3 block wall (IECC1311.inp).

4.3 Block wall – Type 3 (IECC1312.inp)

The following table and figure describe the thermal properties and other dimensions that are used for type 3 block wall.

Table 4-5. Thermal properties of type 3 block wall (IECC1312.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Heavy weight concrete block with perlite fill	0.6667	0.2272	2.93	70	0.20	CB13
2	Polystyrene insulation	0.1667	0.02	8.33	1.8	0.29	IN35
3	Gypsum Board	0.0417	0.0926	0.45	50	0.20	GP01
Tot				11.71 (0.0854)			

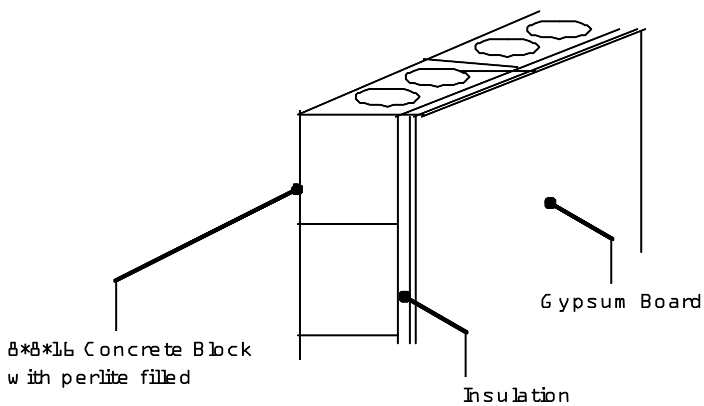


Figure 4-5. Description of type 3 block wall (IECC1312.inp).

The heat capacity is 9.84 Btu/ft^2·°F; this value agrees with high mass material (6 Btu/ft^2·°F).

<u>The wall part of DOE code of IECC1312.inp</u>

```
WA-3 = LAYERS
       MATERIAL = (BLOCK-CB13, INSULATION-IN35, GYPSUM-BOARD)  ..
              $ BLOCK-CB35 - CONCRETE AND PERLITE FILL, HEAVY WEIHGT
              $ INSULATON-IN35 - R8.33
            $ GYPSUM-BOARD = Gypsum Board 1/2"
```

Figure 4-6 DOE code of type 3 block wall (IECC1312.inp)

4.4 Block wall – Type 4 (IECC1313.inp)

The following table and figure describe the thermal properties and other dimensions that are used for type 4 block wall.

Table 4-6. Thermal properties of type 4 block wall (IECC1313.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Stucco	0.0833	1.042	0.08	166	0.20	SC01
2	Polystyrene insulation	0.1667	0.02	8.33	1.8	0.29	IN35
3	Heavy weight concrete block with perlite fill	0.6667	0.2272	2.93	70	0.20	CB13
4	Air layer			0.89			AL21
5	Gypsum Board	0.0417	0.0926	0.45	50	0.20	GP01
Tot				11.54 (0.0867)			

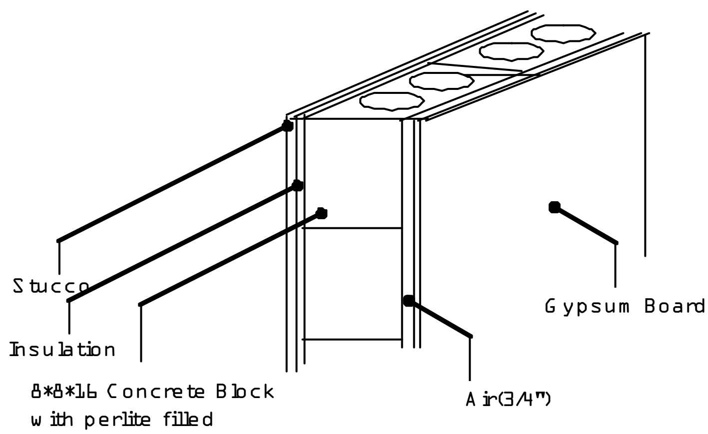


Figure 4-7. Description of type 4 block wall (IECC1313.inp).

The heat capacity is 12.60 Btu/ft^2·°F; this value agrees with high mass material (6 Btu/ft^2·°F).

<u>The wall part of DOE code of IECC1313.inp</u>

```
WA-3 = LAYERS
       MATERIAL = (STUCCO-SC01, INSULATION-IN35,
                   BLOCK-CB13, AIR-AL21, GYPSUM-BOARD)  ..
$ BLOCK-CB35 - CONCRETE AND PERLITE FILL, HEAVY WEIHGT
$ INSULATON-IN35 - R8.33
$ AIR-AL21 - AIR LAYER, 3/4 INCH TO 4 INCH, VERTICAL WALLS
$ GYPSUM-BOARD = Gypsum Board 1/2"
```

Figure 4-8. DOE code of type 4 block wall (IECC1313.inp).

4.5 Block wall – Type 5 (IECC1314.inp)

The following table and figure describe the thermal properties and other dimensions that are used for type 5 block wall.

Table 4-7. Thermal properties of type 5 block wall (IECC1314.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Hollow heavy weight concrete block	0.6667	0.6060	1.10	69.0	0.2	CB11
Tot				1.10 (0.909)			

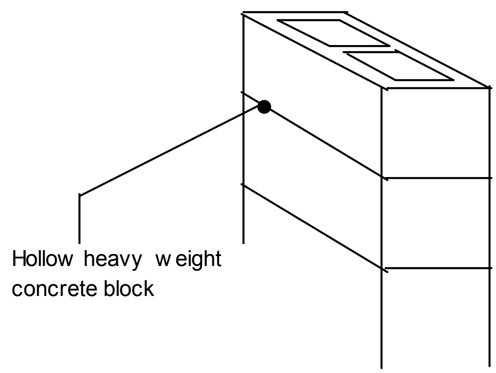


Figure 4-9. Description of type 5 block wall (IECC1314.inp).

The heat capacity is 9.20 Btu/ft^2·°F; this value agrees with high mass material (6 Btu/ft^2·°F).

<u>The wall part of DOE code of IECC1314.inp</u>

```
WA-3 = LAYERS
       MATERIAL = (BLOCK-CB11)  ..
             $ BLOCK-CB11 - HOLLOW CONCRETE BLCOK
```

Figure 4-10. DOE code of type 5 block wall (IECC1314.inp).

4.6 Block wall – Type 6 (IECC1315.inp)

The following table and figure describe the thermal properties and other dimensions that are used for type 6 block wall.

Table 4-8. Thermal properties of type 6 block wall (IECC1315.inp).

No	Name	Thickness (ft)	Conductivity (Btu-ft/hr-ft2-F)	R (Uw)	Density (lb/ft^3)	Specific Heat (Btu/Lb.F)	DOE Code
1	Heavy weight concrete block with perlite fill	0.6667	0.2272	2.93	70	0.2	CB13
Tot				2.93 (0.341)			

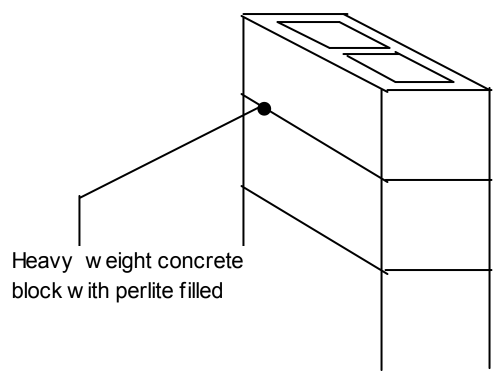


Figure 4-11. Description of type 6 block wall (IECC1315.inp).

The heat capacity is 9.33 Btu/ft^2·°F; this value agrees with high mass material (6 Btu/ft^2·°F).

<u>The wall part of DOE code of IECC1315.inp</u>

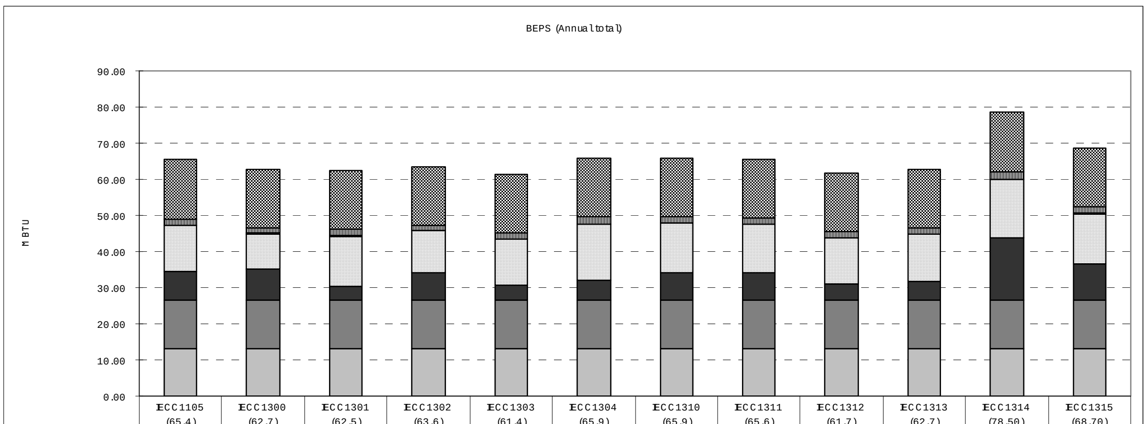
```
WA-3 = LAYERS
       MATERIAL = (BLOCK-CB13)  ..
            $ BLOCK-CB13 - CONCRETE BLCOK WITH PERLITE FILL
```

Figure 4-12. DOE code of type 6 block wall (IECC1315.inp).

4.7 Results

Results of this report also consist of annual energy use (BEPS DOE Report), peak cooling / heating load (LS-C DOE Report), and peak day electricity use (PS-F DOE Report) like the previous results of Chapter 3. IECC1314 and IECC1315 are excluded from the analysis because of the rare used wall type.

BEPS (Annual Total)



	IECC1105 (65.4)	IECC1300 (62.7)	IECC1301 (62.5)	IECC1302 (63.6)	IECC1303 (61.4)	IECC1304 (65.9)	IECC1310 (65.9)	IECC1311 (65.6)	IECC1312 (61.7)	IECC1313 (62.7)	IECC1314 (78.50)	IECC1315 (68.70)
DOMHOT WATER	16.30	16.30	16.30	16.30	16.30	16.30	16.30	16.30	16.30	16.30	16.30	16.30
VENT FANS	1.70	1.20	1.70	1.40	1.50	1.90	1.60	1.60	1.50	1.50	2.10	1.70
PUMPS & MISC	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
SPACE COOL	12.80	9.80	14.10	11.70	12.80	15.40	13.50	13.50	12.80	12.90	16.00	14.00
SPACE HEAT	8.00	8.80	3.80	7.60	4.20	5.70	7.90	7.60	4.50	5.40	17.50	10.10
MISC EQUIPMT	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20
AREA LIGHTS	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20

Figure 4-13. BEPS (Annual Total) Report.

As analyzed in Chapter 3, the space cooling and space heating are the most changeable among other energy consumption category. Of 6 models (IECC1105, IECC1303, IECC1310, IECC1311, IECC1312, IECC1313, IECC1314, and IECC1315), IECC1312 (8” block with R-value=11.03) predicts the lowest energy consumption in this simulation according to the types of the real block walls.

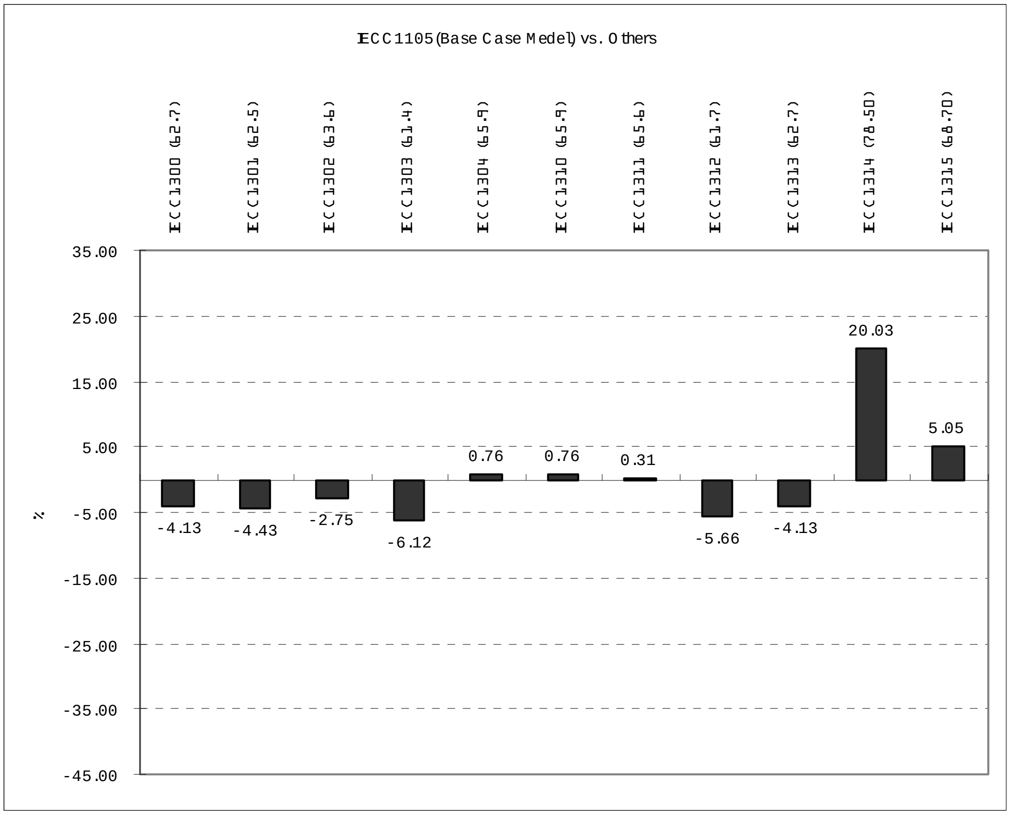


Figure 4-14. The comparison of IECC1105 (base case model) with others.

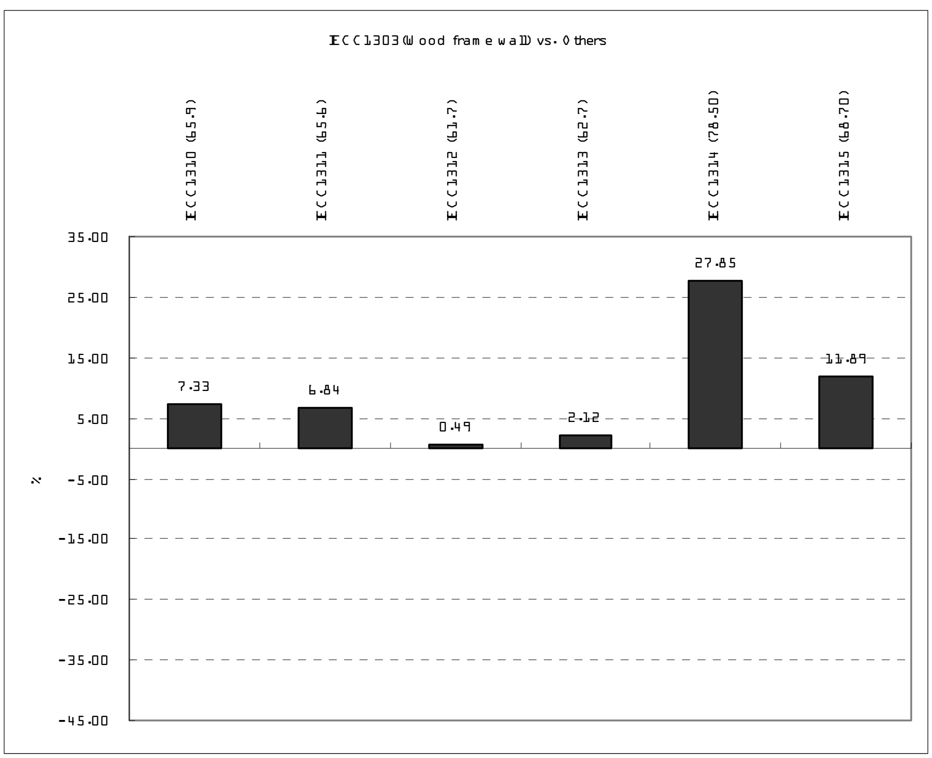
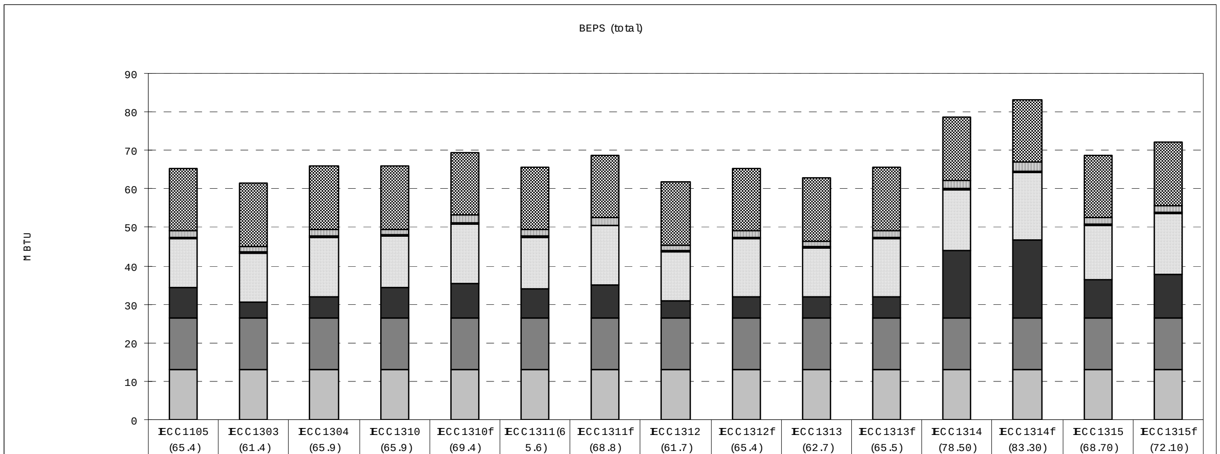


Figure 4-15. The comparison of IECC1303 (Wood frame wall) with others.

<u>BEPS (Annual Total) of With vs. Without Floor</u>



	IECC1105 (65.4)	IECC1303 (61.4)	IECC1304 (65.9)	IECC1310 (65.9)	IECC1310f (69.4)	IECC1311(65.6)	IECC1311f (68.8)	IECC1312 (61.7)	IECC1312f (65.4)	IECC1313 (62.7)	IECC1313f (65.5)	IECC1314 (78.50)	IECC1314f (83.30)	IECC1315 (68.70)	IECC1315f (72.10)
DOMHOT WATER	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.30	16.3	16.3
VENT FANS	1.7	1.5	1.9	1.6	1.9	1.6	1.9	1.5	1.8	1.5	1.8	2.1	2.40	1.7	2.0
PUMPS & MISC	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.20	0.2	0.2
SPACE COOL	12.8	12.8	15.4	13.5	15.5	13.5	15.4	12.8	15.3	12.9	15.1	16.0	17.60	14.0	15.7
SPACE HEAT	8	4.2	5.7	7.9	9.1	7.6	8.6	4.5	5.4	5.4	5.7	17.5	20.40	10.1	11.5
MISC EQUIPMT	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.20	13.2	13.2
AREA LIGHTS	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.20	13.2	13.2

Figure 4-16. BEPS (Annual Total) Report of with and without floor.

Just like the simulation in Chapter 3, all input files have the same input files, whose floor area is 0, to investigate the effect of floor area. The result shows that if the floor area is eliminated in the simulation, the annual energy consumption is increased.

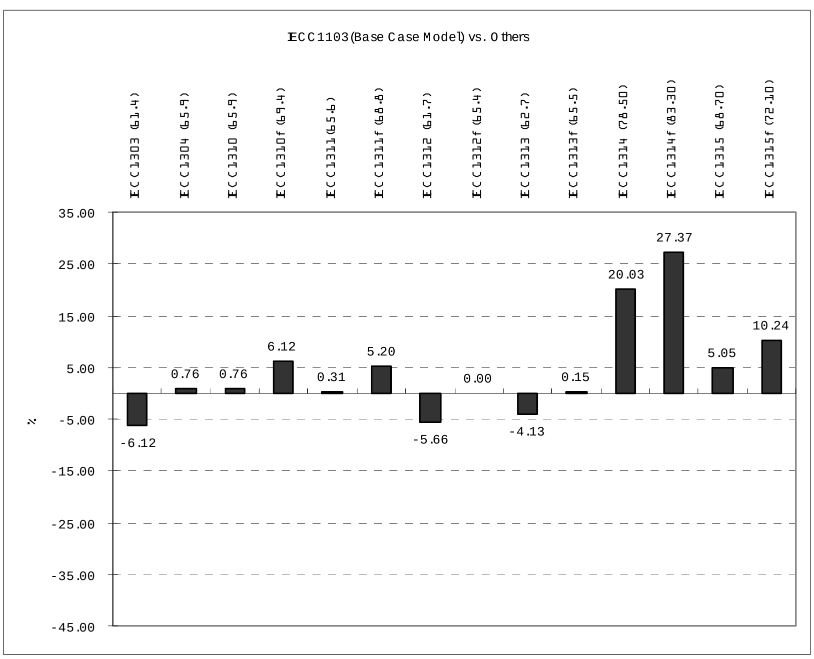
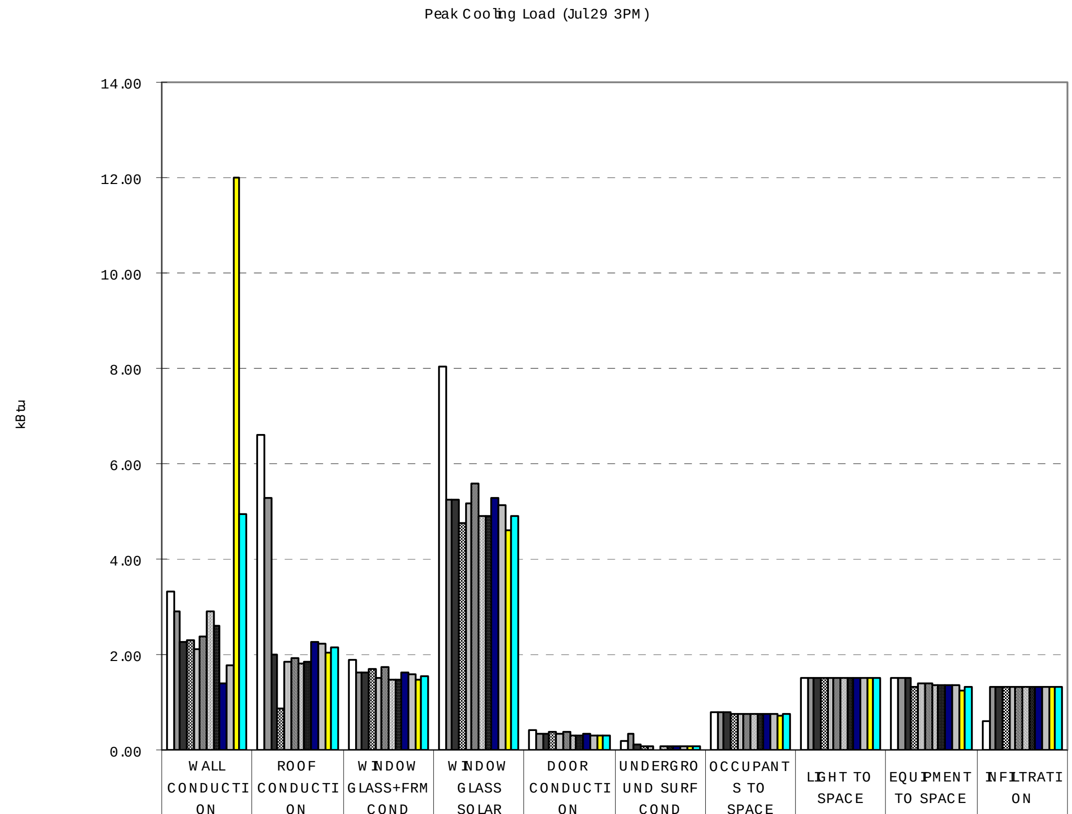


Figure 4-17. The comparison of IECC1105 with others of with and without floor.

Peak Cooling Load (Jul 29 3PM)



	WALL CONDUCTION	ROOF CONDUCTION	WINDOW GLASS+FRM COND	WINDOW GLASS SOLAR	DOOR CONDUCTION	UNDERGROUND SURF COND	OCCUPANTS TO SPACE	LIGHT TO SPACE	EQUIPMENT TO SPACE	INFILTRATION
1105 (24.81)	3.30	6.60	1.88	8.02	0.40	0.19	0.80	1.50	1.50	0.61
1300 (20.85)	2.89	5.29	1.61	5.25	0.36	0.34	0.80	1.50	1.50	1.32
1301 (16.72)	2.27	2.01	1.61	5.25	0.36	0.10	0.80	1.50	1.50	1.32
1302 (14.97)	2.30	0.86	1.69	4.77	0.36	0.09	0.76	1.50	1.33	1.32
1303 (16.01)	2.11	1.86	1.50	5.16	0.33	0.09	0.77	1.50	1.38	1.32
1304 (16.99)	2.38	1.92	1.75	5.60	0.37	0.00	0.77	1.50	1.39	1.32
1310 (16.44)	2.91	1.83	1.46	4.92	0.32	0.09	0.76	1.50	1.35	1.32
1311 (16.13)	2.59	1.83	1.46	4.92	0.32	0.09	0.76	1.50	1.35	1.32
1312 (15.92)	1.39	2.25	1.61	5.30	0.32	0.09	0.77	1.50	1.38	1.31
1313 (16.01)	1.76	2.22	1.58	5.12	0.32	0.09	0.76	1.50	1.37	1.31
1314 (25.33)	12.01	2.05	1.48	4.61	0.30	0.08	0.73	1.50	1.25	1.31
1315 (21.82)	4.95	2.14	1.53	4.91	0.31	0.08	0.75	1.50	1.33	1.31

Figure 4-18. Peak cooling load.

From this figure, the simulation results indicate that the largest reductions are attributable to the window glass solar gain and heat conduction through the roof, as are the results in Chapter 3. In terms of peak cooling load, IECC1312 (8” Block wall with R-11.03) was the most energy conservative materials from the simulation results, according to the types of the real block walls, after the LBNL ground method was applied.

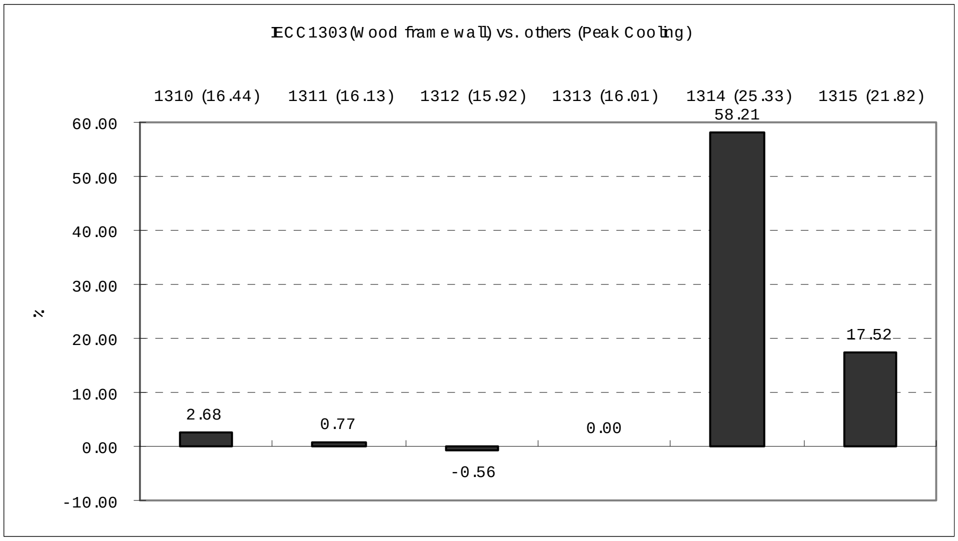


Figure 4-19. The comparison of peak cooling load between IECC1105 and others.

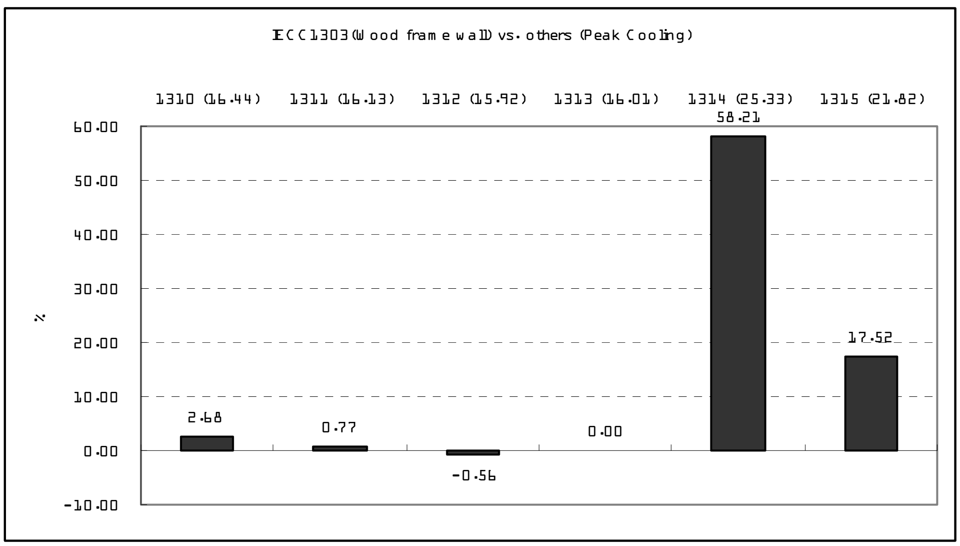
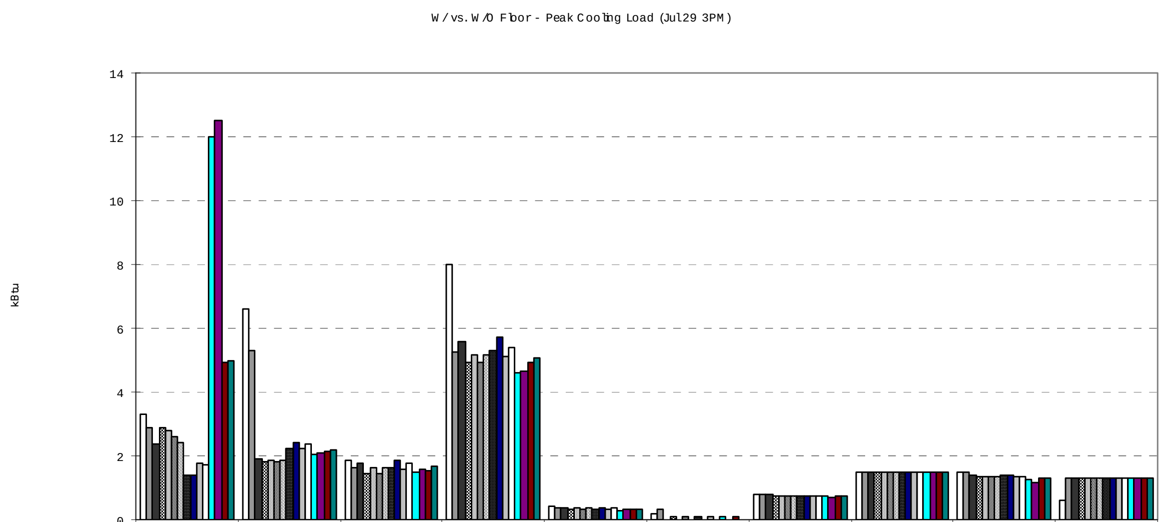


Figure 4-20. The comparison of peak cooling load between IECC1303 (Wood frame wall) and others.

Peak Cooling Load (Jul 29 3PM) of With vs. Without Floor



	WALL CONDUCTION	ROOF CONDUCTION	WINDOW GLASS+FRM COND	WINDOW GLASS SOLAR	DOOR CONDUCTION	UNDERGROUND SURF COND	OCCUPANTS TO SPACE	LIGHT TO SPACE	EQUIPMENT TO SPACE	INFILTRATION
1105 (24.81)	3.303	6.603	1.8773	8.021	0.404	0.19	0.8	1.502	1.502	0.611
1300 (20.85)	2.89	5.286	1.61	5.253	0.356	0.337	0.8	1.501	1.501	1.318
1304 (16.99)	2.377	1.92	1.748	5.599	0.374	0	0.769	1.501	1.385	1.318
1310 (16.44)	2.91	1.83	1.46	4.92	0.32	0.09	0.76	1.50	1.35	1.32
1310f (16.74)	2.79	1.86	1.65	5.18	0.35	0.00	0.75	1.50	1.33	1.32
1311 (16.13)	2.59	1.83	1.46	4.92	0.32	0.09	0.76	1.50	1.35	1.32
1311f (16.38)	2.42	1.87	1.65	5.19	0.35	0.00	0.75	1.50	1.33	1.32
1312 (15.92)	1.39	2.25	1.61	5.30	0.32	0.09	0.77	1.50	1.38	1.31
1312f (16.74)	1.38	2.43	1.86	5.74	0.37	0.00	0.77	1.50	1.38	1.31
1313 (16.01)	1.76	2.22	1.58	5.12	0.32	0.09	0.76	1.50	1.37	1.31
1313f (16.54)	1.71	2.36	1.77	5.41	0.35	0.00	0.76	1.50	1.36	1.31
1314 (25.33)	12.01	2.05	1.48	4.61	0.30	0.08	0.73	1.50	1.25	1.31
1314f (25.89)	12.53	2.07	1.60	4.65	0.32	0.00	0.72	1.50	1.19	1.31
1315 (21.82)	4.949	2.139	1.534	4.909	0.309	0.084	0.752	1.501	1.325	1.314
1315f (19.14)	4.989	2.199	1.692	5.069	0.339	0	0.745	1.501	1.295	1.314

Figure 4-21. Peak cooling load of with and without floor.

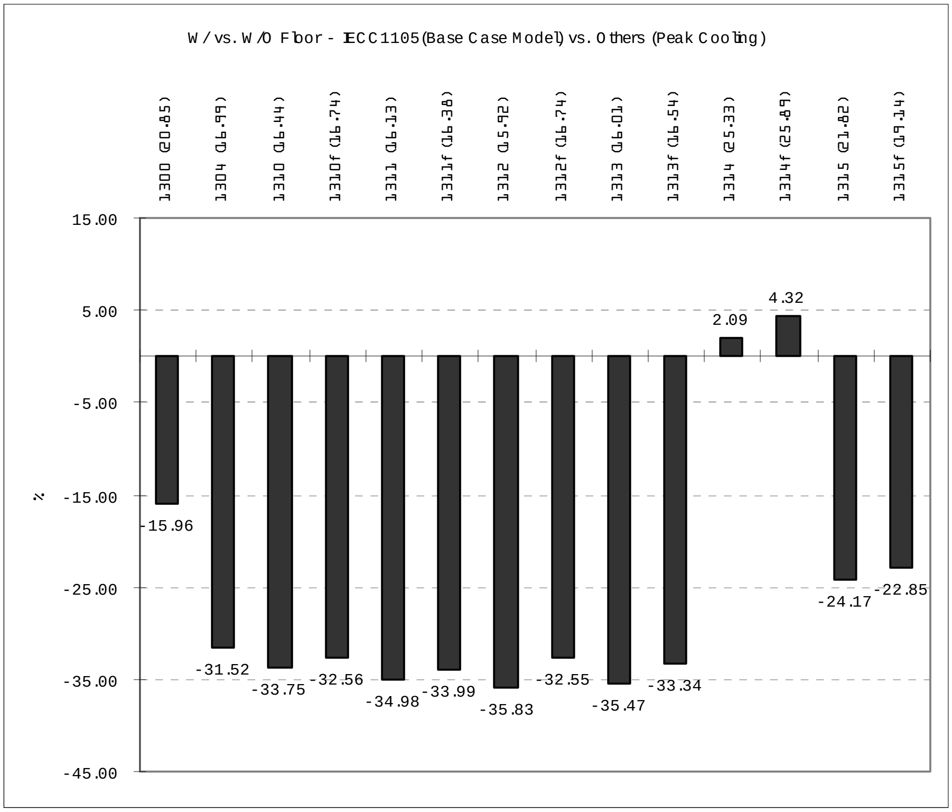
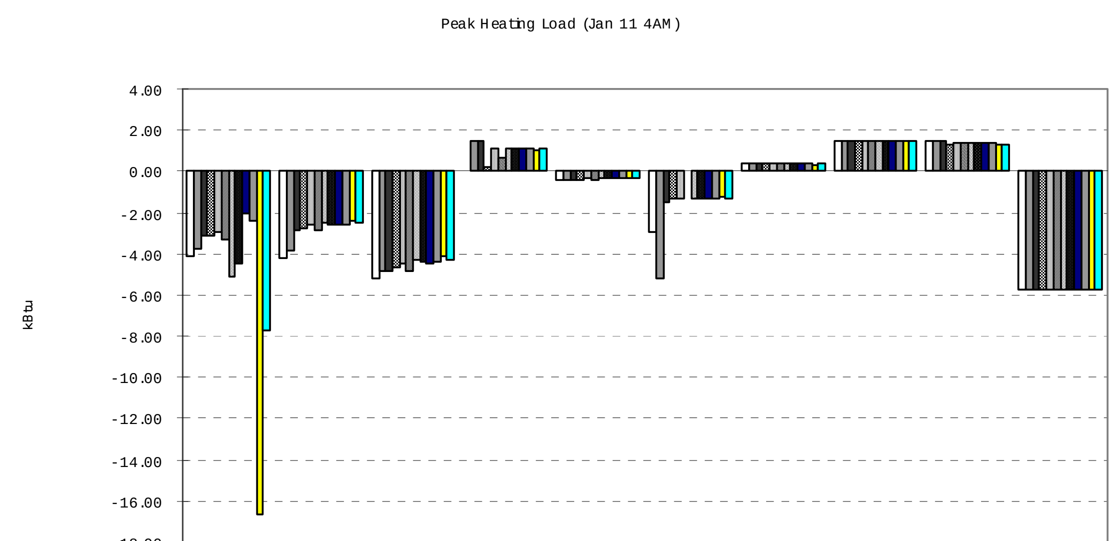


Figure 4-22. The comparison of peak cooling load of with and without floor.

Peak Heating Load (January 11 4AM)



	WALL CONDUCTION	ROOF CONDUCTION	WINDOW GLASS+FRM COND	WINDOW GLASS SOLAR	DOOR CONDUCTION	UNDERGROUND SURF COND	OCCUPANTS TO SPACE	LIGHT TO SPACE	EQUIPMENT TO SPACE	INFILTRATION
1105 (-19.21)	-4.13	-4.24	-5.19	0.03	-0.42	-2.93	0.40	1.50	1.50	-5.73
1300 (-18.95)	-3.78	-3.86	-4.86	1.46	-0.39	-5.19	0.40	1.50	1.50	-5.73
1301 (-13.57)	-3.16	-2.81	-4.86	1.46	-0.39	-1.48	0.40	1.50	1.50	-5.73
1302 (-14.62)	-3.16	-2.76	-4.67	0.23	-0.38	-1.34	0.36	1.50	1.33	-5.73
1303 (-13.04)	-2.91	-2.60	-4.45	1.10	-0.36	-1.34	0.37	1.50	1.38	-5.73
1304 (-13.19)	-3.27	-2.86	-4.83	0.65	-0.39	0.00	0.37	1.50	1.39	-5.73
1310 (-15.07)	-5.12	-2.54	-4.34	1.11	-0.35	-1.31	0.36	1.50	1.35	-5.73
1311 (-14.40)	-4.44	-2.54	-4.34	1.11	-0.35	-1.32	0.36	1.50	1.35	-5.73
1312 (-12.15)	-2.03	-2.60	-4.44	1.10	-0.35	-1.34	0.37	1.50	1.38	-5.73
1313 (-12.37)	-2.42	-2.56	-4.37	1.15	-0.35	-1.33	0.36	1.50	1.37	-5.73
1314 (-26.37)	-16.66	-2.39	-4.11	1.00	-0.33	-1.23	0.33	1.50	1.25	-5.73
1315 (-17.53)	-7.69	-2.48	-4.27	1.11	-0.34	-1.30	0.35	1.50	1.33	-5.73

Figure 4-23. Peak heating load.

In terms of the peak heating load, the largest change occurred at window glass solar after the custom floor weight factor was calculated by DOE-2 and underground surface after using real floor material. The results show that IECC1312 (8" Block wall with R-11.03) was the most energy conservative materials in this simulation results according to the types of the real block walls.

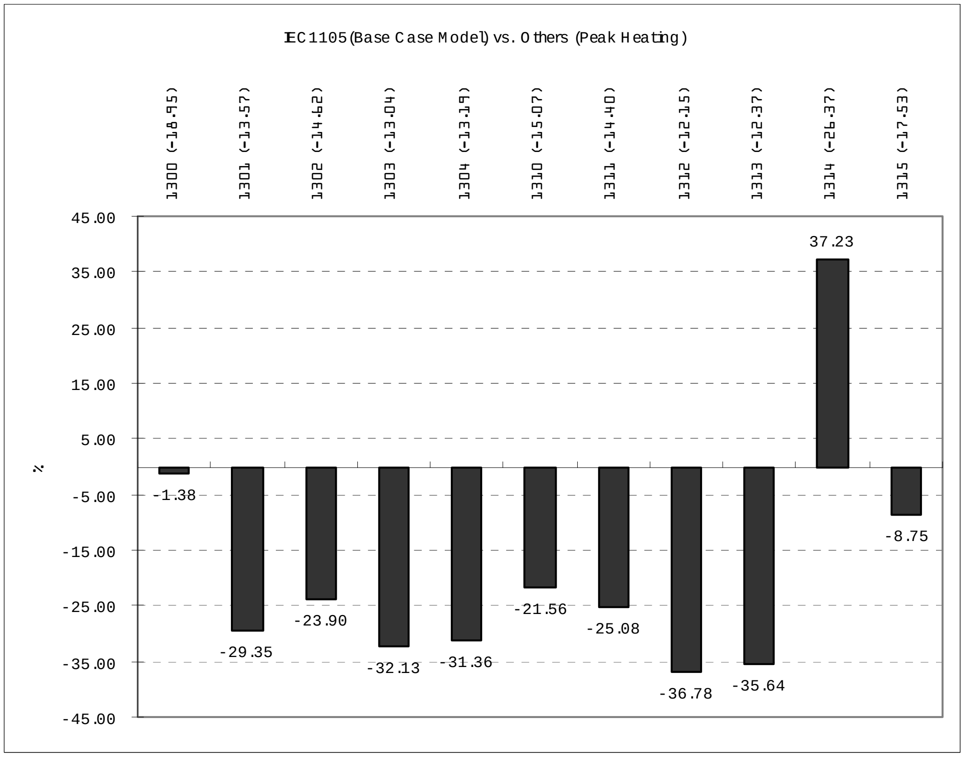


Figure 4-24. The comparison of peak heating load between IECC1105 and others.

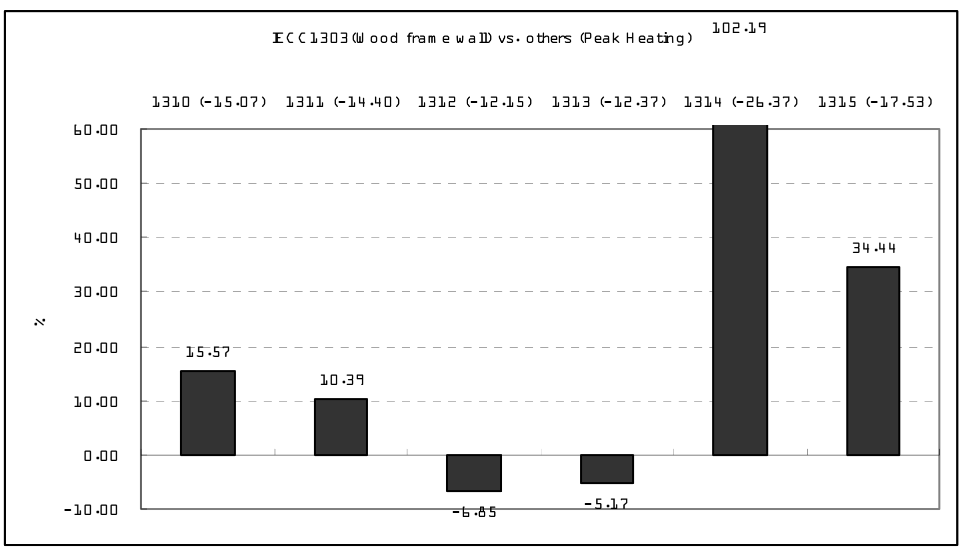
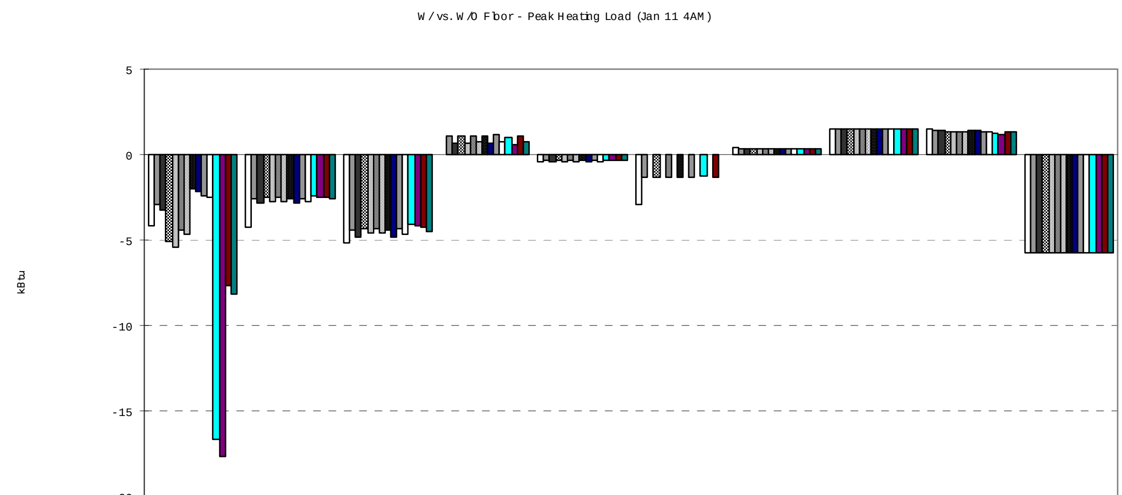


Figure 4-25. The comparison of peak heating load between IECC1303 (Wood frame wall) and others.

Peak Heating Load (January 11 4AM) of With vs. Without Floor



	WALL CONDUCTION	ROOF CONDUCTION	WINDOW GLASS+FRM COND	WINDOW GLASS SOLAR	DOOR CONDUCTION	UNDERGROUND SURF COND	OCCUPANTS TO SPACE	LIGHT TO SPACE	EQUIPMENT TO SPACE	INFILTRATION
1105 (-19.21)	-4.13	-4.238	-5.192	0.033	-0.424	-2.932	0.4	1.501	1.501	-5.733
1303 (-13.04)	-2.91	-2.60	-4.45	1.10	-0.36	-1.34	0.37	1.50	1.38	-5.73
1304 (-13.19)	-3.27	-2.86	-4.83	0.65	-0.39	0.00	0.37	1.50	1.39	-5.73
1310 (-15.07)	-5.12	-2.54	-4.34	1.11	-0.35	-1.31	0.36	1.50	1.35	-5.73
1310f (-15.00)	-5.44	-2.73	-4.62	0.71	-0.38	0.00	0.35	1.50	1.33	-5.73
1311 (-14.40)	-4.44	-2.54	-4.34	1.11	-0.35	-1.32	0.36	1.50	1.35	-5.73
1311f (-14.22)	-4.66	-2.73	-4.62	0.72	-0.38	0.00	0.35	1.50	1.33	-5.73
1312 (-12.15)	-2.03	-2.60	-4.44	1.10	-0.35	-1.34	0.37	1.50	1.38	-5.73
1312f (-12.05)	-2.15	-2.86	-4.81	0.65	-0.39	0.00	0.37	1.50	1.38	-5.73
1313 (-12.37)	-2.42	-2.56	-4.37	1.15	-0.35	-1.33	0.36	1.50	1.37	-5.73
1313f (-12.01)	-2.47	-2.76	-4.68	0.79	-0.38	0.00	0.36	1.50	1.36	-5.73
1314 (-26.37)	-16.66	-2.39	-4.11	1.00	-0.33	-1.23	0.33	1.50	1.25	-5.73
1314f (-26.75)	-17.63	-2.47	-4.20	0.62	-0.34	0.00	0.32	1.50	1.19	-5.73
1315 (-17.53)	-7.694	-2.484	-4.272	1.109	-0.34	-1.296	0.352	1.501	1.325	-5.733
1315f (-17.50)	-8.17	-2.624	-4.489	0.737	-0.364	0	0.345	1.501	1.295	-5.733

Figure 4-26. Peak heating load of with and without floor.

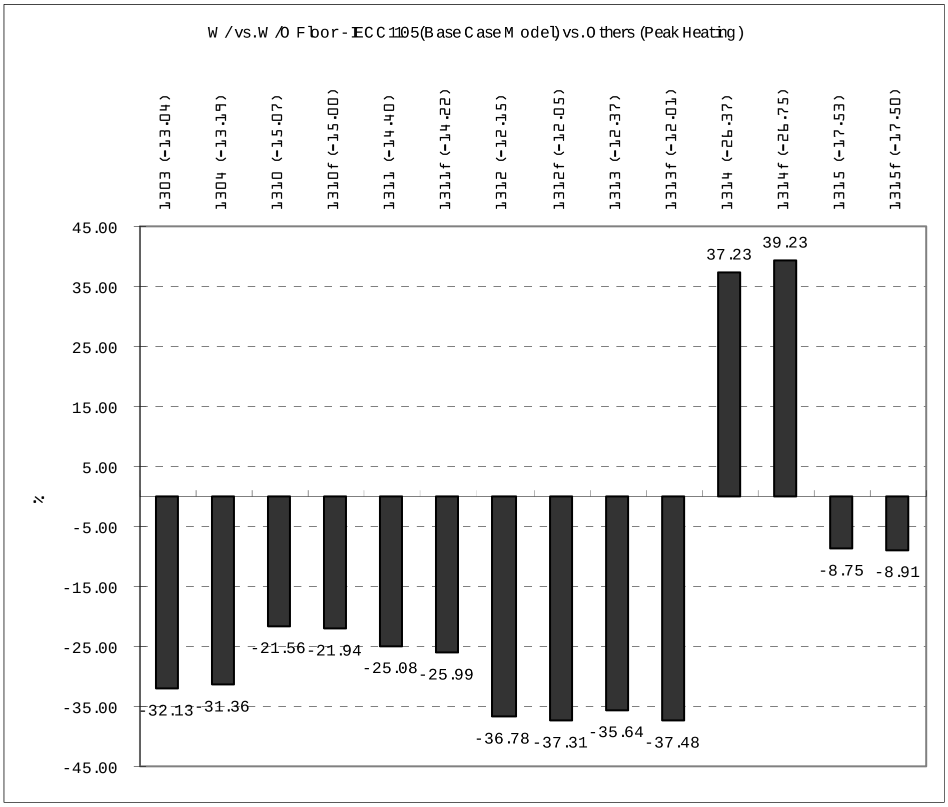


Figure 4-27. The comparison of peak heating load of with and without floor.

Peak day total electricity use (kWh/day) – August 26

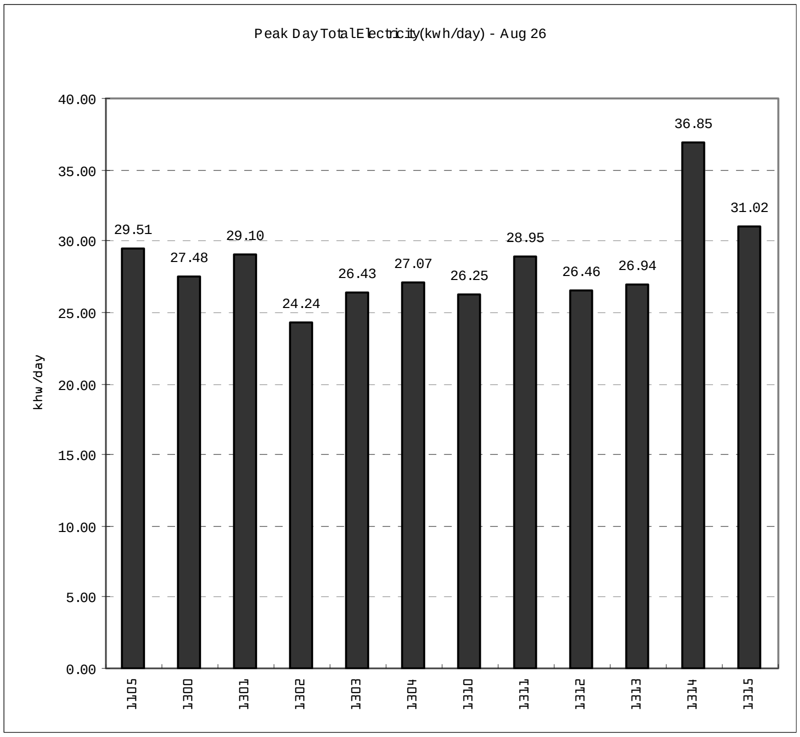


Figure 4-28. Peak day total electricity use.

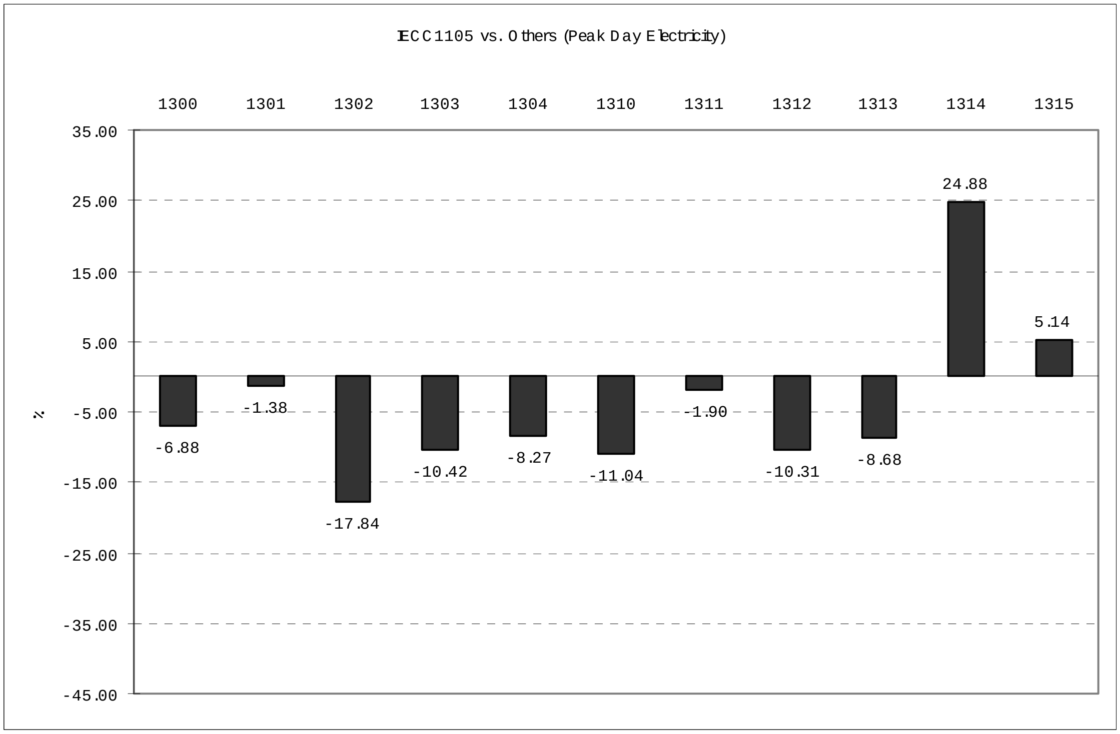


Figure 4-29. The comparison of total electricity use.

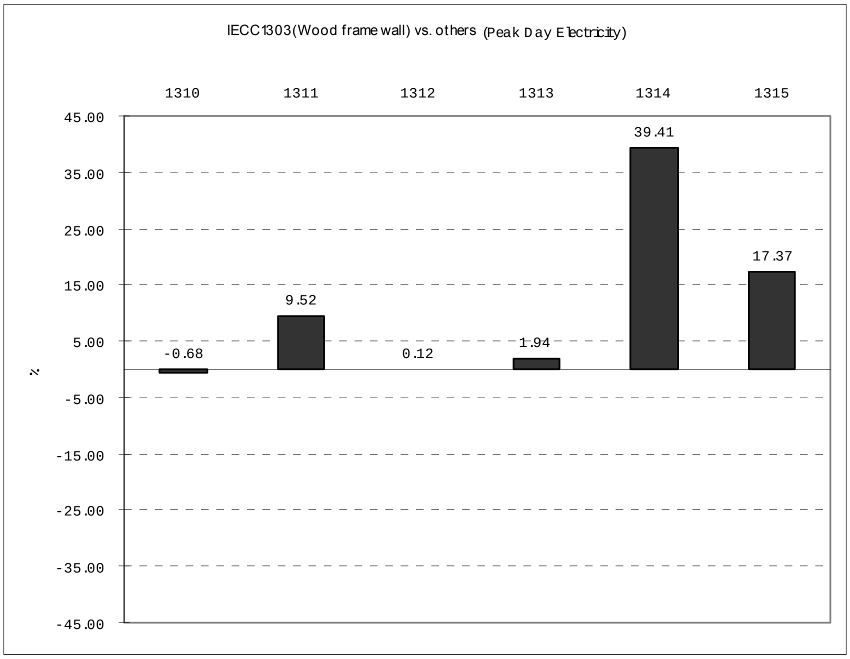


Figure 4-30. The comparison of total electricity use between IECC1303 (Wood frame wall) and others.

In order to investigate the difference of the peak day total electricity use (kWh/day), the total electricity use of August 26 of other input files (from IECC1310 to 1313) was recalculated using the DOE-2 hourly report. Results from IECC1310.inp were selected as the lowest electricity energy use after the LBNL ground method was applied.

Summary of the simulation results

Table 4-9. The summary of the simulation results. * ( ): Results of without floor.

Name	Annual Energy Use MBtu	Total Peak Cooling KBtu/hr	Total Peak Heating KBtu/hr	Electricity Use kWh/day
IECC1105	65.4	24.81	-19.21	29.51
IECC1300	62.70	20.85	-18.95	27.48
IECC1301	62.50	16.72	-13.57	29.10
IECC1302	63.60	14.97	-14.62	24.24
IECC1303	61.40 (65.90)	16.01 (16.99)	-13.04 (-13.19)	26.43
IECC1310	65.90 (69.40)	16.44 (16.74)	-15.07 (-15.00)	26.25
IECC1311	65.60 (68.80)	16.13 (16.38)	-14.40 (-14.22)	28.95
IECC1312	**61.70** (65.40)	**15.92** (16.74)	**-12.15** (-12.05)	**26.46**
IECC1313	**62.70** (65.50)	**16.01** (16.54)	**-12.37** (-12.01)	**26.94**
IECC1314	78.50 (83.30)	25.33 (25.89)	-26.37 (-26.75)	36.85
IECC1315	68.70 (72.10)	21.82 (19.14)	-17.53 (-17.50)	31.02

From the results of annual energy use, total peak cooling and heating, and electricity energy use, the IECC1312 (8" block with R-value=11.03) reduced annual energy use most from 65.40 to 61.70 MBtu (5.6% reduction). In regard to peak cooling and peak heating energy, the IECC1312 also reduced peak cooling load from 24.81 to 15.92 KBtu/hr (a 35.8 % reduction) and peak heating load from 19.21 to 12.15 KBtu/hr (a 36.8% reduction).

APPENDIX A

4.8 Simulation File Name List:

On the accompanying CD, each of the following names are associated with one input and one output file.

IECC1105
IECC1301
IECC1302
IECC1303
IECC1304
IECC1305
IECC1305f
IECC1306
IECC1306f
IECC1307
IECC1307f
IECC1308
IECC1308f
IECC1309
IECC1309f
IECC1310
IECC1310f
IECC1311
IECC1311f
IECC1312
IECC1312f
IECC1313
IECC1313f
IECC1314
IECC1314f
IECC1315
IECC1315f