INSULATION MODULE—ENERGYPLUS EXERCISE INSTRUCTIONS

Exercise Introduction and Objectives

This exercise provides a base file for a two-story building, measuring 104′ x 48′. The building is modeled with core and perimeter zoning for each floor.

The objective of this exercise is to study the effect of insulation on a building's energy use. The same structure is modeled with standard steel stud wall or wood stud wall constructions and different insulation thicknesses to study the difference in energy consumption.

Another simulation is run to study the effect of different types of insulation on the roof.

Note:
These exercise instructions and associated input files have been written to conform with EnergyPlus v5.0.0 format. Use of these instructions and input files with later versions of EnergyPlus may require changes or updates to input objects and location of data sets and weather files.

Building Description

The base file building is modeled with the following construction components:

- **External Walls:** Steel-framed_R-13 + R-7.5 ci_Ext-wall; layers: MAT sheathing + wall insulation + gypsum
- **Roof:** Metal deck roof with mineral fiberboard insulation
- **Floor:** Unheated 8″ slab with carpet
- **Internal Walls:** Gypsum board double layer

Note: About IDF Editor
Users who want a simple way of creating or editing EnergyPlus input data files (IDF) can use the IDF Editor. They can view and edit any EnergyPlus object using a spreadsheet-like grid. A list is provided for inputs with several options. The IDF Editor outputs an EnergyPlus input file with proper syntax and comments to help the user understand the input values. In addition, the IDF Editor converts standard inch-pound units into SI units compatible with EnergyPlus. The IDF Editor does not check inputs for validity, although it highlights some numeric fields that are out of range. For the purpose of this exercise, the IDF editor is a useful input interface.

WALL INSULATION COMPARISONS

Exercise Procedure

New construction objects for external wall surfaces are created with the following layers (outside to inside):

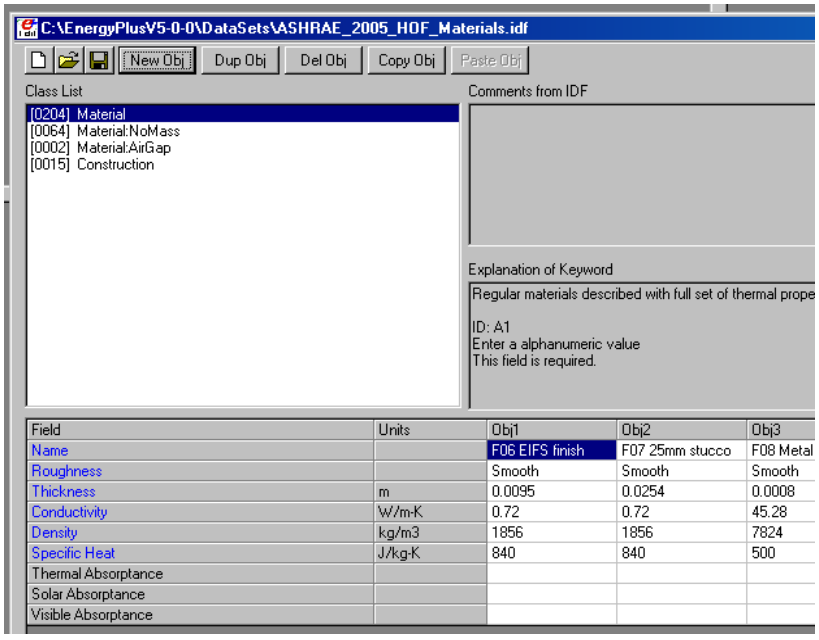
- 100mm brick external face
- 13mm wall air space (1/2″)
- Insulation: expanded polystyrene - molded beads - 32kg/m^3 density (0.5″/ 1″/ 2″ thick)
- Composite 2 x 4 wood stud/steel stud

Simulations are run and energy usage data obtained for analysis.

Wood Stud Wall, 0.5″ EPS Insulation

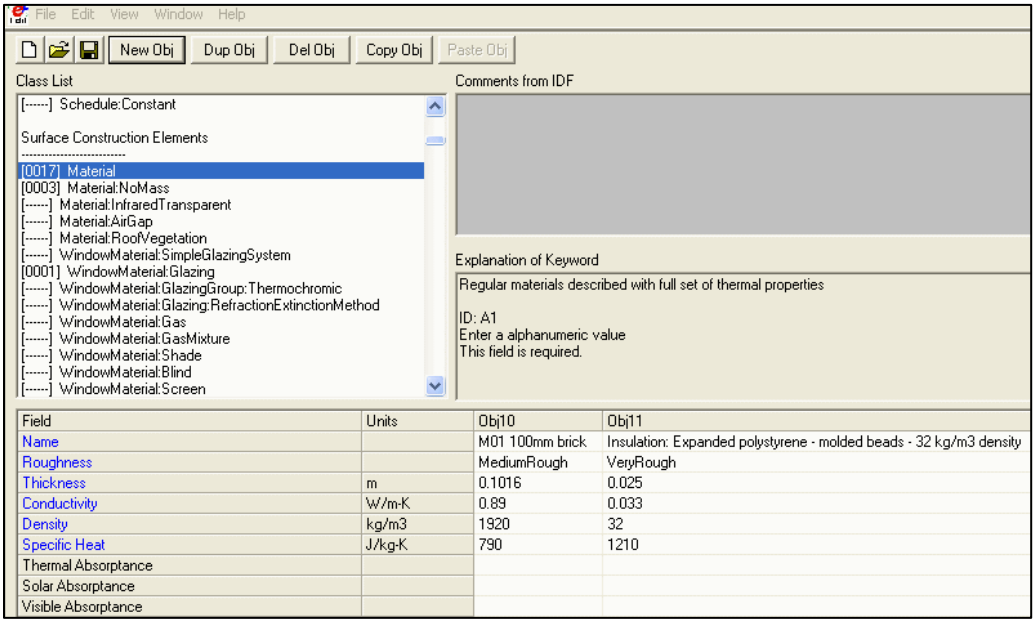
Instructions

1. Start > IDF Editor > File > Open > 1.Insulation_BaseFile.idf
2. Save as > 2.Insulation_WoodStud_0.5in.idf in the destination folder.
3. First step is to import materials for the new construction components:
   a) File > Open Dataset > ASHRAE_2005_HOF_Materials.idf
   b) Open Class List > Material

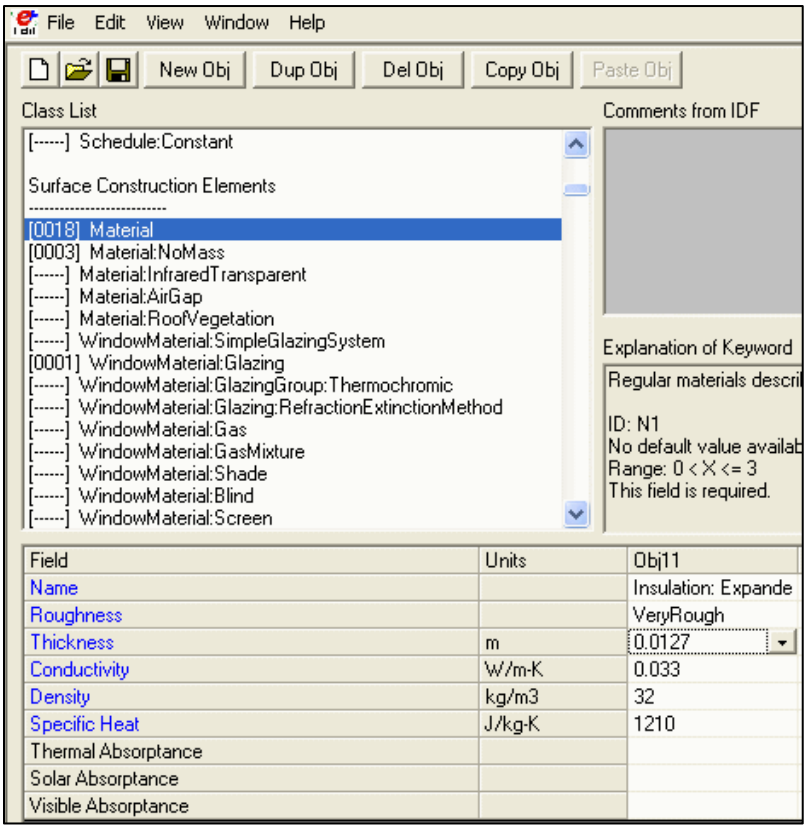


   c) Look for **M01 100mm brick** > Copy Object
   d) Paste object into 2.Insulation_WoodStud_0.5in.idf > Class List > Surface Construction Elements > Material

e) Repeat process with the following material: **Insulation: Expanded polystyrene–molded beads–32kg/m^3 density.**



f) Change thickness of insulation object to 0.0127m (1/2 inch).



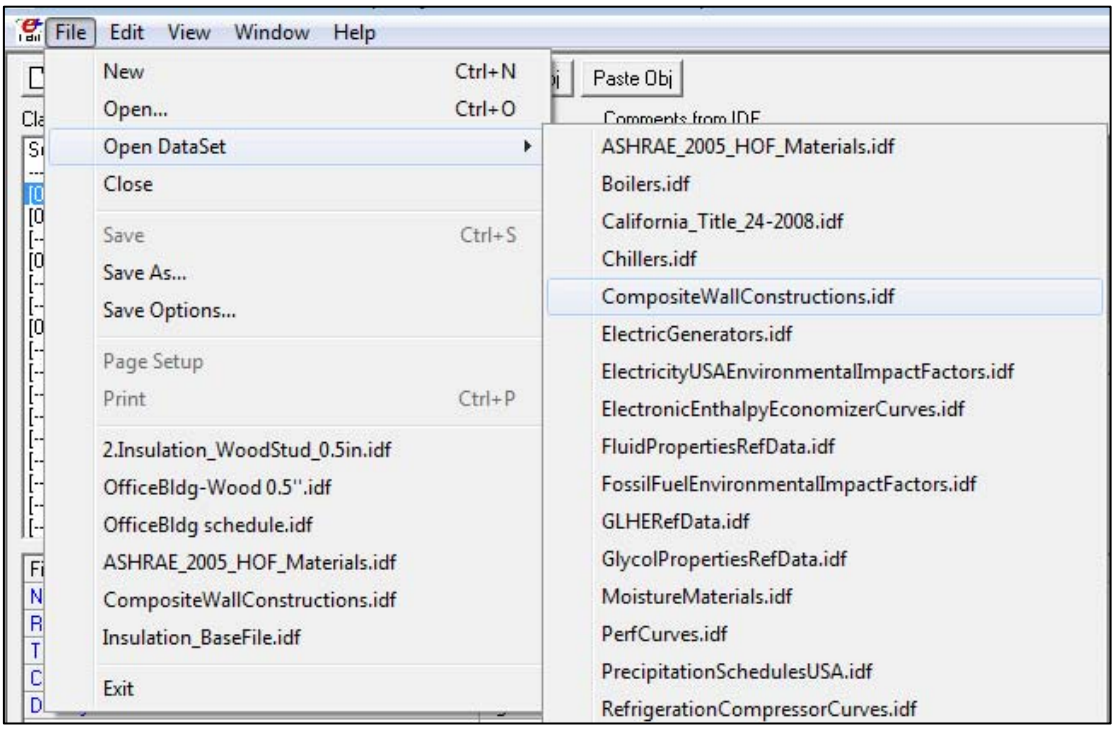
g) We now need to create a material object for the 13mm air space, the data for which is obtained from the 2009 ASHRAE Handbook, Chapter 26, Table 3.
Class List > Surface Construction Elements > Material:AirGap > New Object

Enter the following data:

Name	Air space resistance
Thermal Resistance (m^2-K/W)	0.16

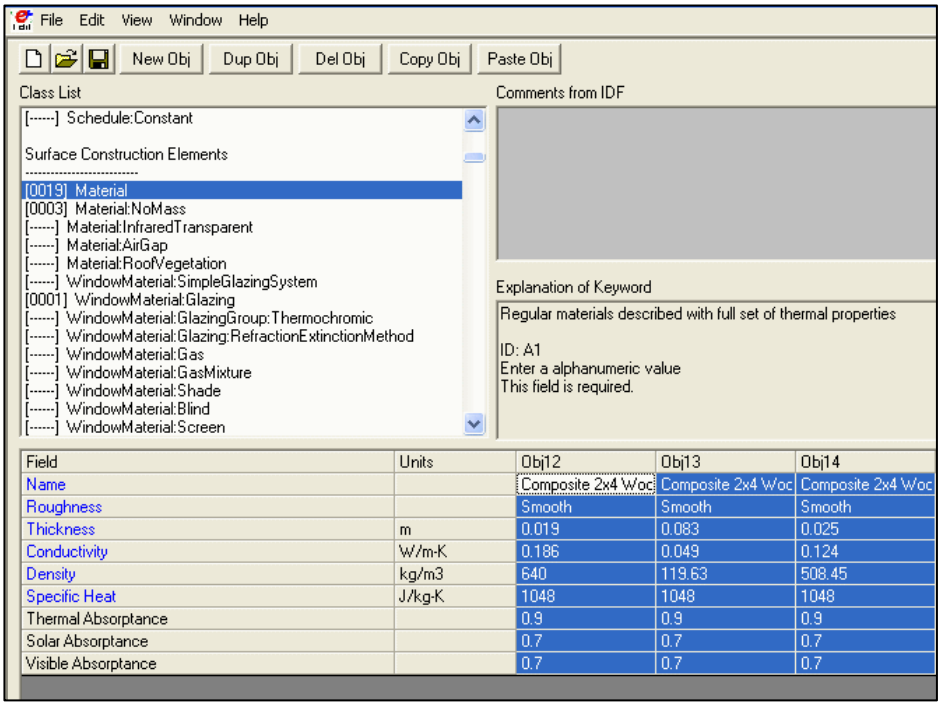
The data selected is for vertical air space - horizontal heat flow, 10˚C mean temperature, 5.6 K temperature difference, $\varepsilon_{eff} = 0.82$

4. We now need to import the composite wall construction for standard 2 x 4 wood stud wall.
   a) File > Open Dataset > CompositeWallConstructions.idf



   b) Look for Class List > Construction > Composite 2 x 4 Wood Stud R11
   The Composite 2 x 4 Wood Stud R11 Construction Object contains three material layers in the order:
   Composite 2 x 4 Wood Stud R11 #3
   Composite 2 x 4 Wood Stud R11 #2
   Composite 2 x 4 Wood Stud R11 #1
   Hence we need to import these three materials into our idf file.
   Class List > Materials > **Composite 2 x 4 Wood Stud R11 #1** > Copy object
   c) Paste into 2.Insulation_WoodStud_0.5in.idf > Class List > Surface Construction Elements > Material

d) Repeat process with materials:
Composite 2 x 4 Wood Stud R11 #2
Composite 2 x 4 Wood Stud R11 #3

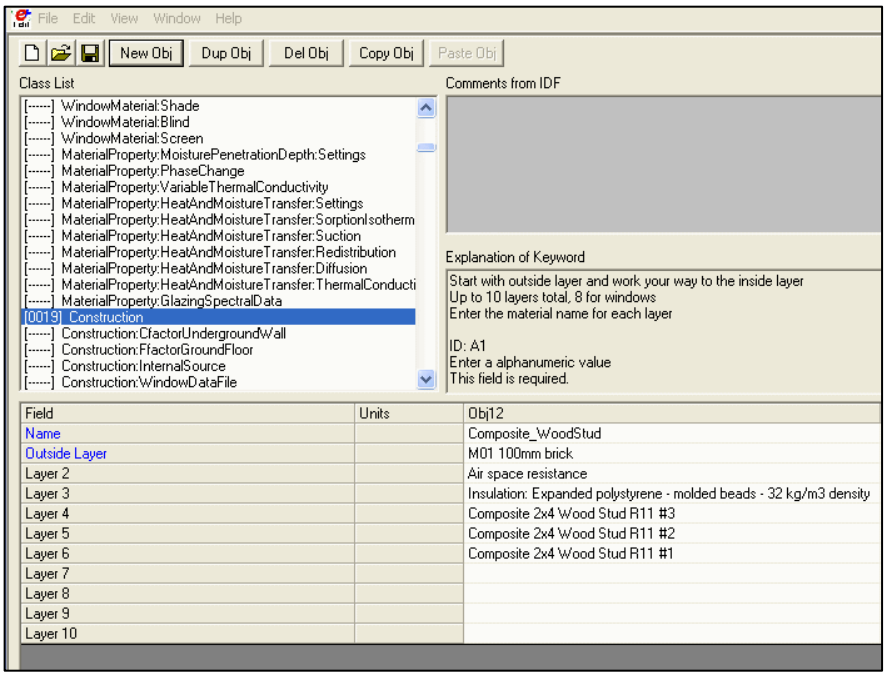


Field	Units	Obj12	Obj13	Obj14
Name		Composite 2x4 Woc	Composite 2x4 Woc	Composite 2x4 Woc
Roughness		Smooth	Smooth	Smooth
Thickness	m	0.019	0.083	0.025
Conductivity	W/m-K	0.186	0.049	0.124
Density	kg/m3	640	119.63	508.45
Specific Heat	J/kg-K	1048	1048	1048
Thermal Absorptance		0.9	0.9	0.9
Solar Absorptance		0.7	0.7	0.7
Visible Absorptance		0.7	0.7	0.7

5. We now need to create the new Composite Wall Construction Object for our external walls with the imported material layers.
Class List > Surface Construction Elements > Construction > New Object

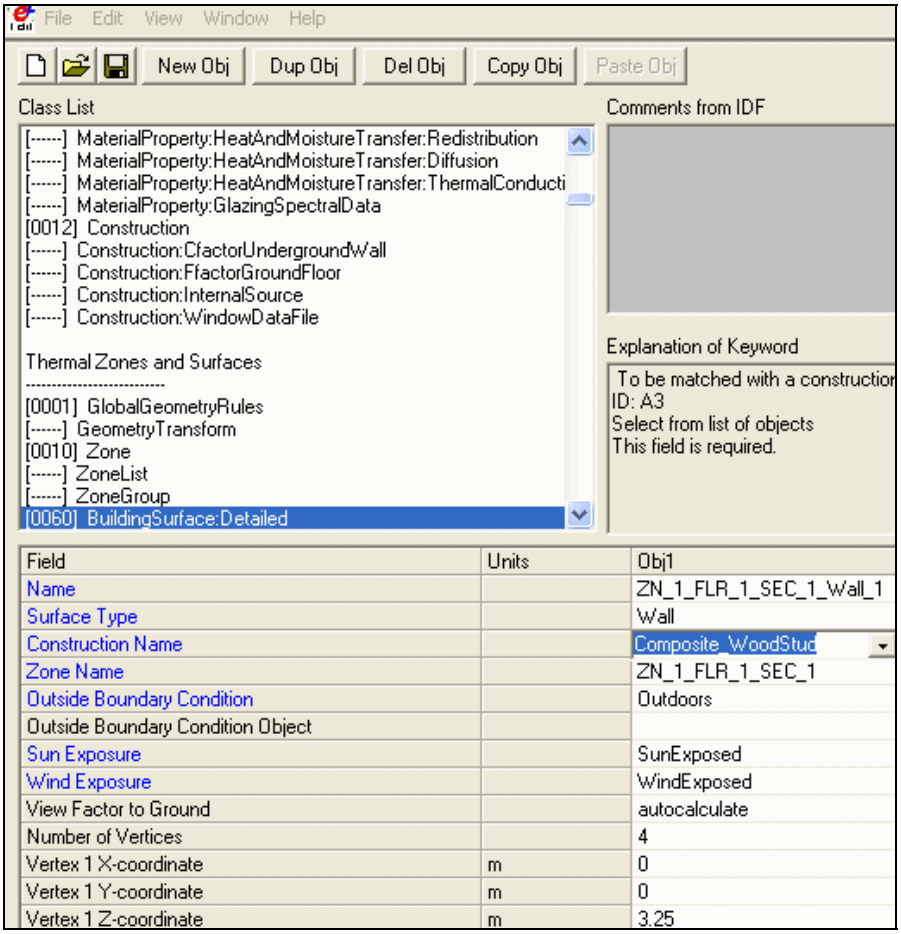
Enter the following data:

Name	Composite_WoodStud
Outside Layer	M01 100mm brick
Layer 2	Air space resistance
Layer 3	Insulation: Expanded polystyrene – molded beads – 32 kg/m3 density
Layer 4	Composite 2 x 4 Wood Stud R11 #3
Layer 5	Composite 2 x 4 Wood Stud R11 #2
Layer 6	Composite 2 x 4 Wood Stud R11 #1



6. We now need to assign this new construction object to all external wall surfaces of our building.
   Class List > Thermal Zones and Surfaces > Building Surface: Detailed
   This object list consists of all surfaces of the building. We need to change the external wall surfaces of all zones (8 surfaces in total) from **Steel-Framed_R-13 + R-7.5 ci_Ext-wall** to **Composite_WoodStud** using the pull-down menu.

   Apply the change to the following objects:
   a) Object 1 > ZN_1_FLR_1_SEC_1_Wall_1
   b) Object 7 >ZN_1_FLR_2_SEC_1_Wall_1
   c) Object 13 > ZN_1_FLR_1_SEC_2_Wall_1
   d) Object 19 > ZN_1_FLR_2_SEC_2_Wall_1
   e) Object 27 > ZN_1_FLR_1_SEC_3_Wall_3
   f) Object 33 > ZN_1_FLR_2_SEC_3_Wall_3
   g) Object 40 > ZN_1_FLR_1_SEC_4_Wall_4
   h) Object 46 > ZN_1_FLR_2_SEC_4_Wall_4



7. All data required for the new composite wall construction is entered into the idf file, which now needs to be set up for required output.

Output Data

The following objects allow standard reports to be defined and utilized in EnergyPlus:

- Output: Table: Time Bins
- Output: Table: Monthly
- Output: Table: Summary Reports
- Output Control: Table: Style

No Output: Meter or Output: Variable objects need to be specified to use the standard reports. A good set of example reports is available in the StandardReports.idf file in the DataSets directory of EnergyPlus.

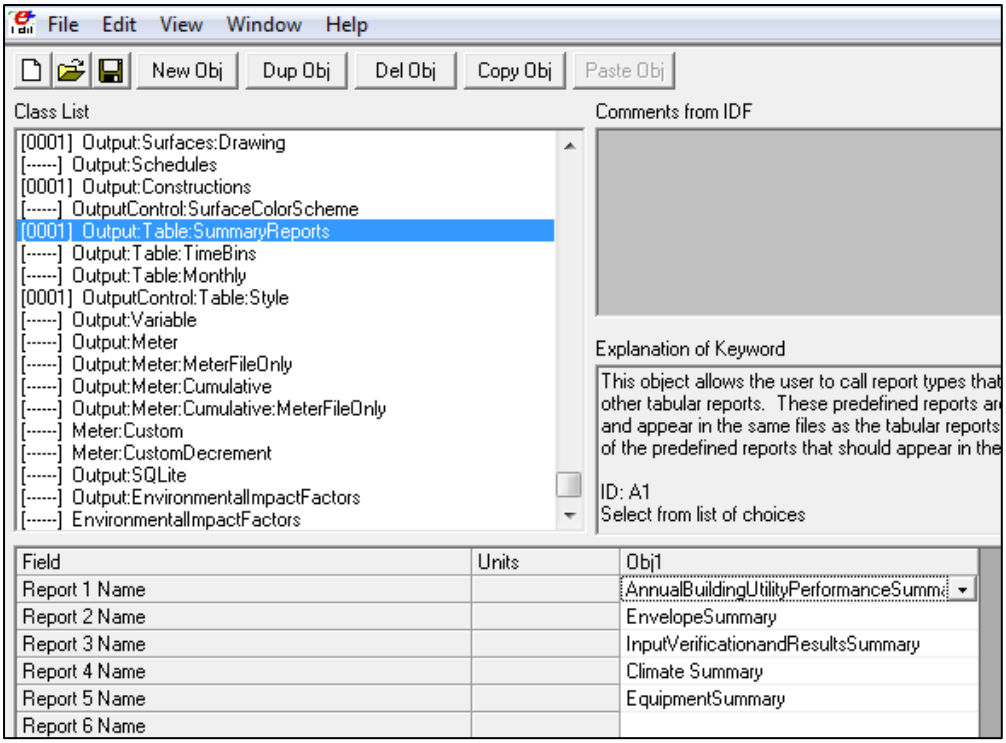
This exercise is limited to creating basic summary reports in html format.

Instructions (continued)

8. Select Class List > Output Reporting > Output: Table: SummaryReports > New Object
   Enter the following data:

Report 1 Name	AnnualBuildingUtilityPerformanceSummary
Report 2 Name	EnvelopeSummary
Report 3 Name	InputVerificationandResultsSummary
Report 4 Name	ClimateSummary
Report 5 Name	EquipmentSummary

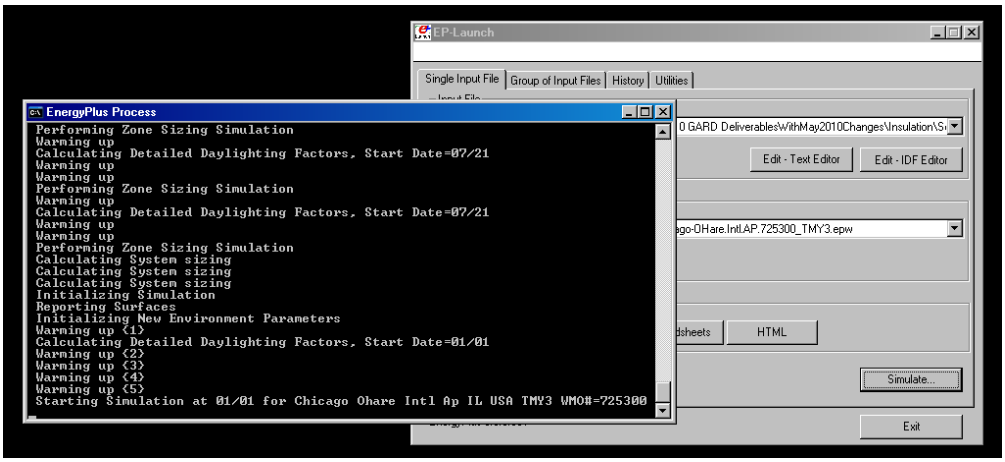
   These are basic reports that allow for a quick analysis of the building's performance. Select more detailed reports from the pull-down menu for in-depth analysis.



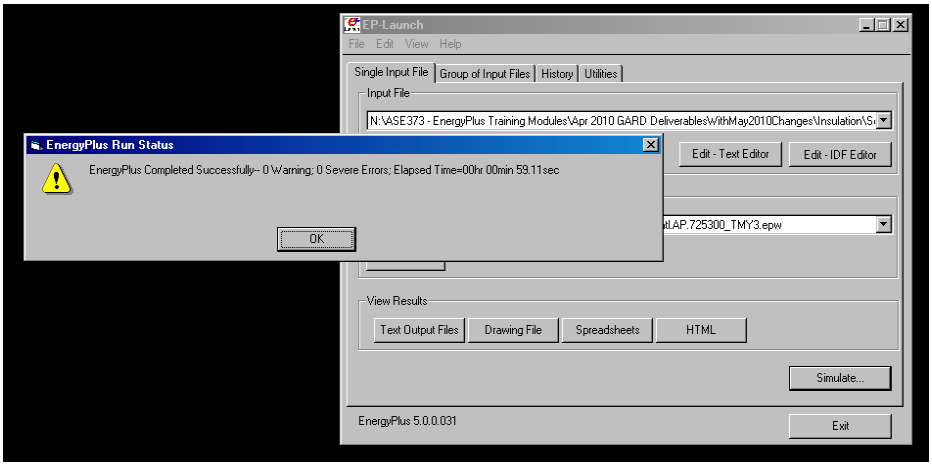
9. Select > Class List > Output Reporting > OutputControl:Table:Style > New Object
   Enter the following data:

Column Separator	HTML

   Other default styles include comma (which works well for importing data into spreadsheet programs such as Microsoft® Excel®), tab (for word processing programs), fixed, etc.
   The idf file is now ready for simulation after saving changes.
10. Start > EP-Launch > Input file > Browse > Select 2.Insulation_WoodStud_0.5in.idf from its destination folder.
11. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
12. Simulate



Simulation in Progress



Simulation Completed

Program Version:**EnergyPlus 5.0.0.031, 5/19/2010 3:17 PM**

Tabular Output Report in Format: **HTML**

Building: **2StoryOfficeBuilding**

Environment: **Chicago Ohare Intl Ap IL USA TMY3 WMO#=725300**

Simulation Timestamp: **2010-05-19 15:17:26**

Report: **AnnualBuildingUtilityPerformanceSummary**

For: **Entire Facility**

Timestamp: **2010-05-19 15:17:26**

Values gathered over 8760.00 hours

Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	379.10	408.72	408.72
Net Site Energy	379.10	408.72	408.72
Total Source Energy	734.19	791.54	791.54
Net Source Energy	734.19	791.54	791.54

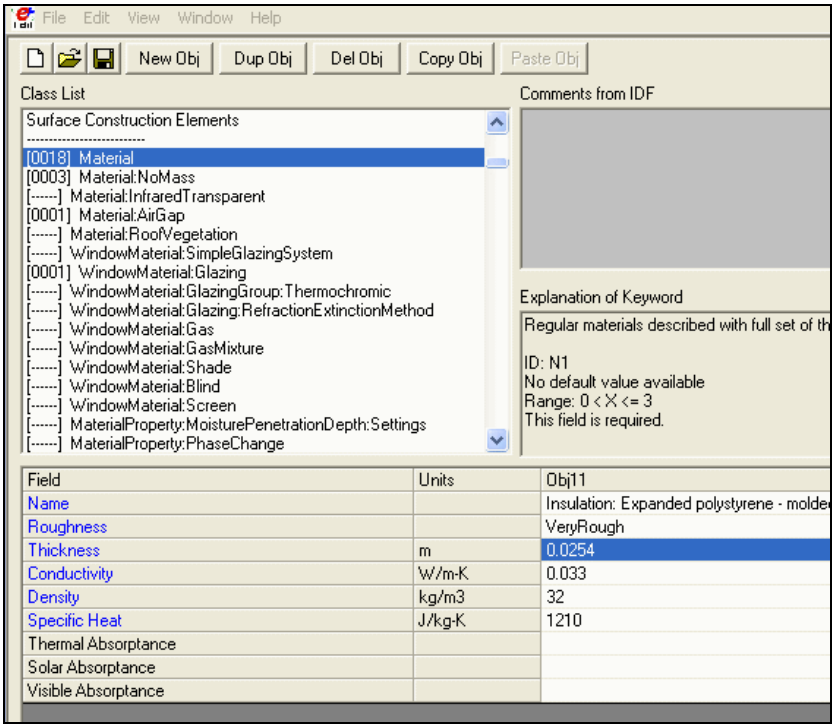
Sample Image of Table Output

Wood Stud Wall, 1″ EPS Insulation

This composite construction only needs a change in the thickness of the insulation layer material from the 0.5-inch wood stud composite construction. Therefore, we can continue working on the idf file we have just created.

Instructions

1. Start > IDF Editor > File > Open > 2.Insulation_WoodStud_0.5in.idf
2. Save as > 3.Insulation_WoodStud_1in.idf in the destination folder
3. Select Class List > Surface Construction Elements > Material **> Insulation: Expanded polystyrene - molded beads - 32 kg/m3 density**
4. Change thickness to 0.0254m (1″).



5. The file is ready to simulate after saving changes.
6. Start > EP-Launch > Input file > Browse > Select 3.Insulation_WoodStud_1in.idf from its destination folder.
7. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
8. Simulate

Wood Stud Wall, 2″ EPS Insulation

Instructions

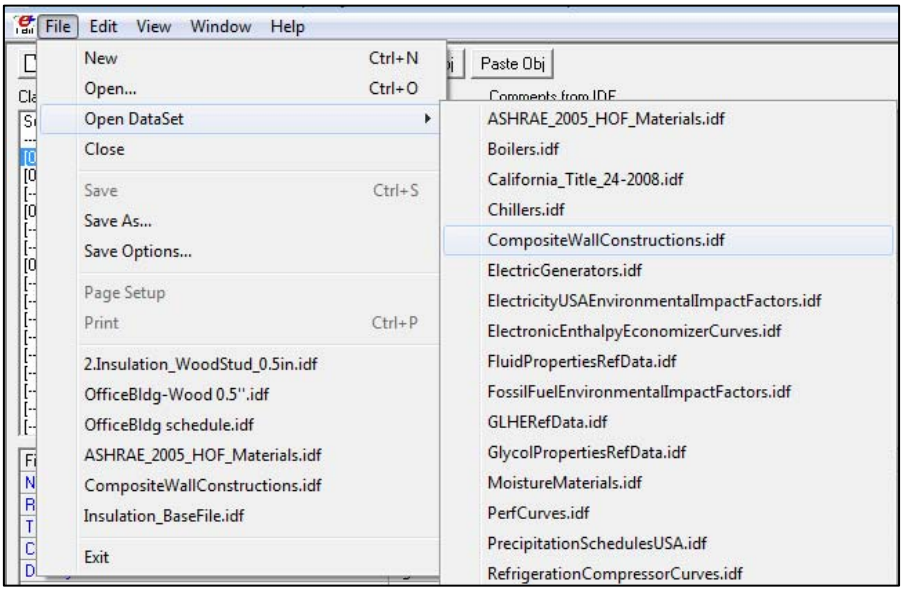
1. Start > IDF Editor > File > Open > 2.Insulation_WoodStud_0.5in.idf
2. Save as > 4.Insulation_WoodStud_2in.idf in the destination folder.
3. Select Class List > Surface Construction Elements > Material > **Insulation: Expanded polystyrene - molded beads - 32 kg/m3 density**
4. Change thickness to 0.0508m (2″).
5. The file is ready to simulate after saving changes.
6. Start > EP-Launch > Input file > Browse > Select > 4.Insulation_WoodStud_2in.idf from its destination folder.
7. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
8. Simulate

Steel Stud Wall, 0.5″ EPS Insulation

This composite construction differs from the 0.5″ wood stud composite construction in the layers of interior wall face construction.

Instructions

1. Start > IDF Editor > File > Open > 2.Insulation_WoodStud_0.5in.idf
2. Save as > 5.Insulation_SteelStud_0.5in.idf in the destination folder.
3. We now need to import the composite wall construction for standard 2 x 4 steel stud wall.
   a) File > Open Dataset > CompositeWallConstructions.idf

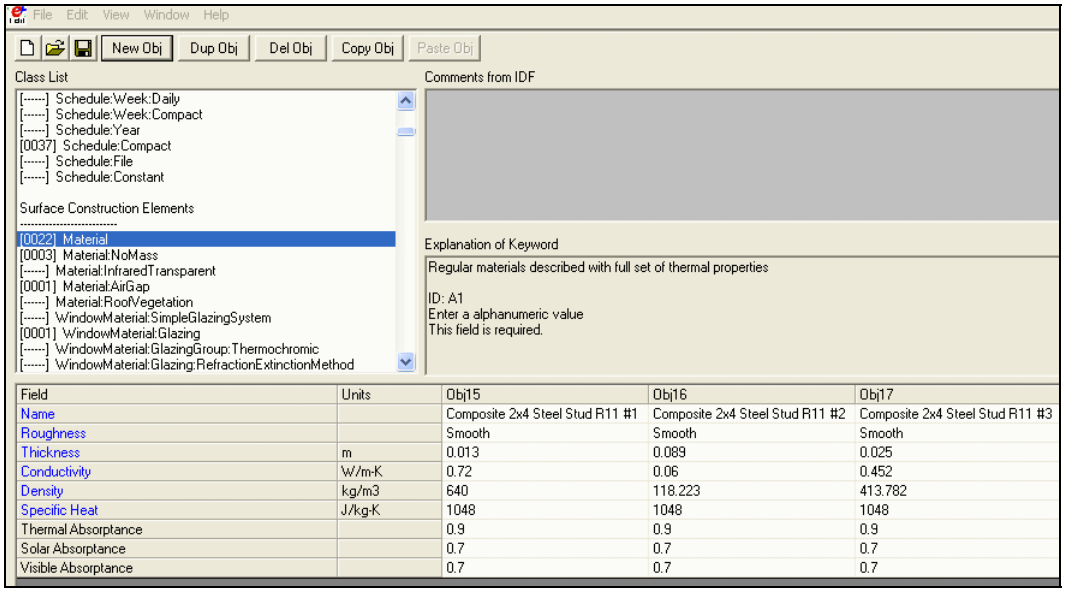


   b) Look for Class List > Construction > Composite 2 x 4 Steel Stud R11
   The Composite 2 x 4 Steel Stud R11 Construction Object contains three material layers in the order:

   Composite 2 x 4 Steel Stud R11 #3
   Composite 2 x 4 Steel Stud R11 #2
   Composite 2 x 4 Steel Stud R11 #1

   Therefore we need to import these three materials into our idf file.
   Class List > Materials > **Composite 2 x 4 Steel Stud R11 #1** > Copy object
   c) Paste into 5.Insulation_SteelStud_0.5in.idf > Class List > Surface Construction Elements > Material
   d) Repeat process with materials:

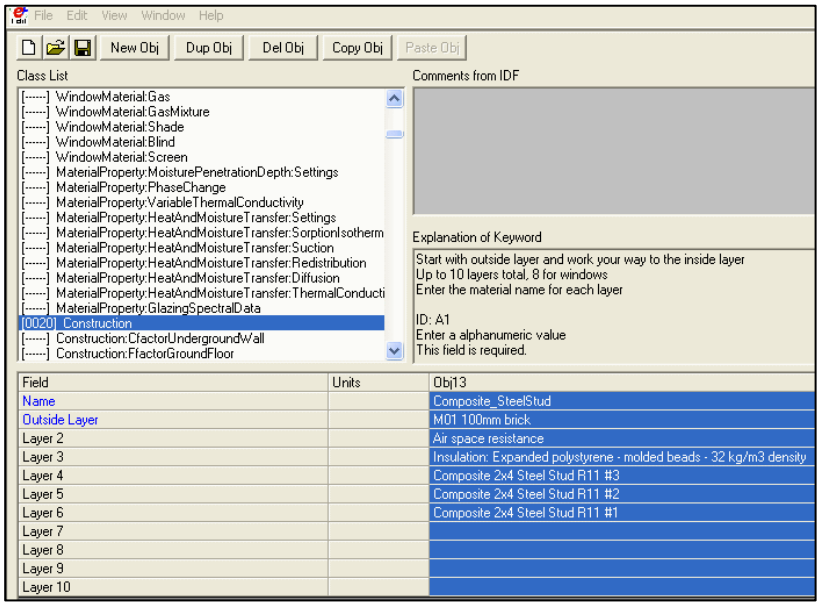
   Composite 2 x 4 Steel Stud R11 #2
   Composite 2 x 4 Steel Stud R11 #3



4. We now need to create the new composite wall construction object for our external walls with the imported material layers.
   Class List > Surface Construction Elements > Construction > New Object

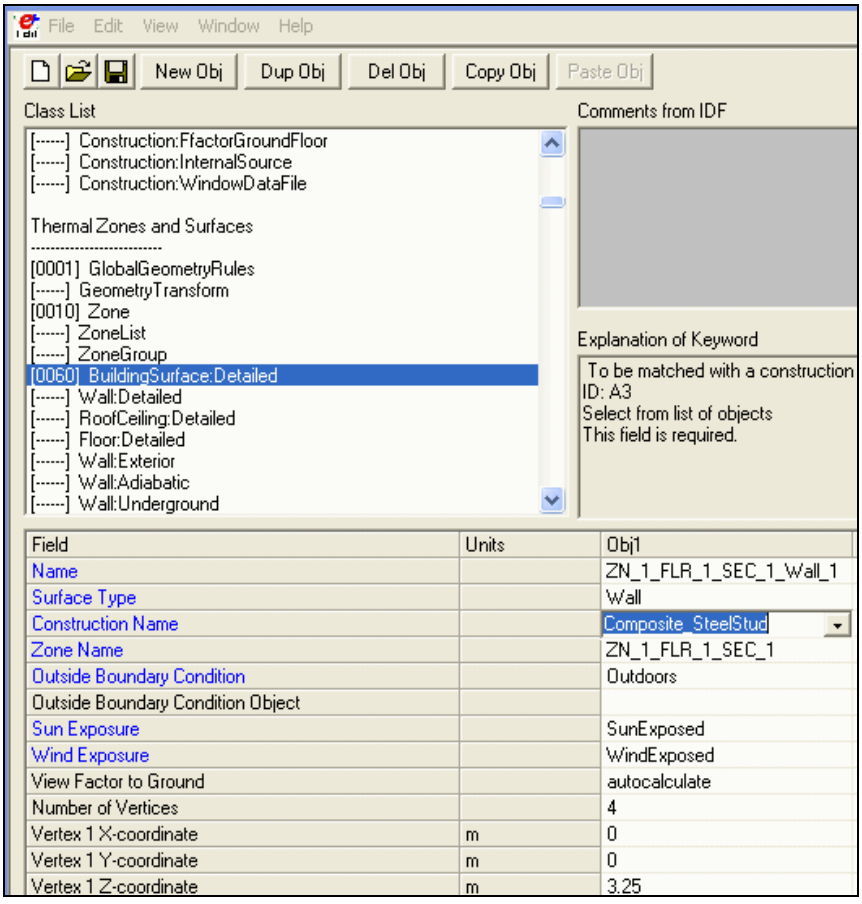
   Enter the following data:

Name	Composite_SteelStud
Outside Layer	M01 100mm brick
Layer 2	Air space resistance
Layer 3	Insulation: Expanded polystyrene – molded beads – 32 kg/m3 density
Layer 4	Composite 2 x 4 Steel Stud R11 #3
Layer 5	Composite 2 x 4 Steel Stud R11 #2
Layer 6	Composite 2 x 4 Steel Stud R11 #1



5. We now need to assign this new construction object to all external wall surfaces of our building.
   Class List > Thermal Zones and Surfaces > Building Surface: Detailed
   This object list consists of all surfaces of the building. We need to change the external wall surfaces of all zones (8 surfaces in total) from **Composite_WoodStud** to **Composite_SteelStud** using the pull-down menu.

   Apply the change to the following objects:
   a) Object 1 > ZN_1_FLR_1_SEC_1_Wall_1
   b) Object 7 >ZN_1_FLR_2_SEC_1_Wall_1
   c) Object 13 > ZN_1_FLR_1_SEC_2_Wall_1
   d) Object 19 > ZN_1_FLR_2_SEC_2_Wall_1
   e) Object 27 > ZN_1_FLR_1_SEC_3_Wall_3
   f) Object 33 > ZN_1_FLR_2_SEC_3_Wall_3
   g) Object 40 > ZN_1_FLR_1_SEC_4_Wall_4
   h) Object 46 > ZN_1_FLR_2_SEC_4_Wall_4



6. All data required for the new composite wall construction is entered into the idf file, which is ready for simulation after saving changes.
7. Start > EP-Launch > Input file > Browse > Select 5.Insulation_SteelStud_0.5in.idf from its destination folder.

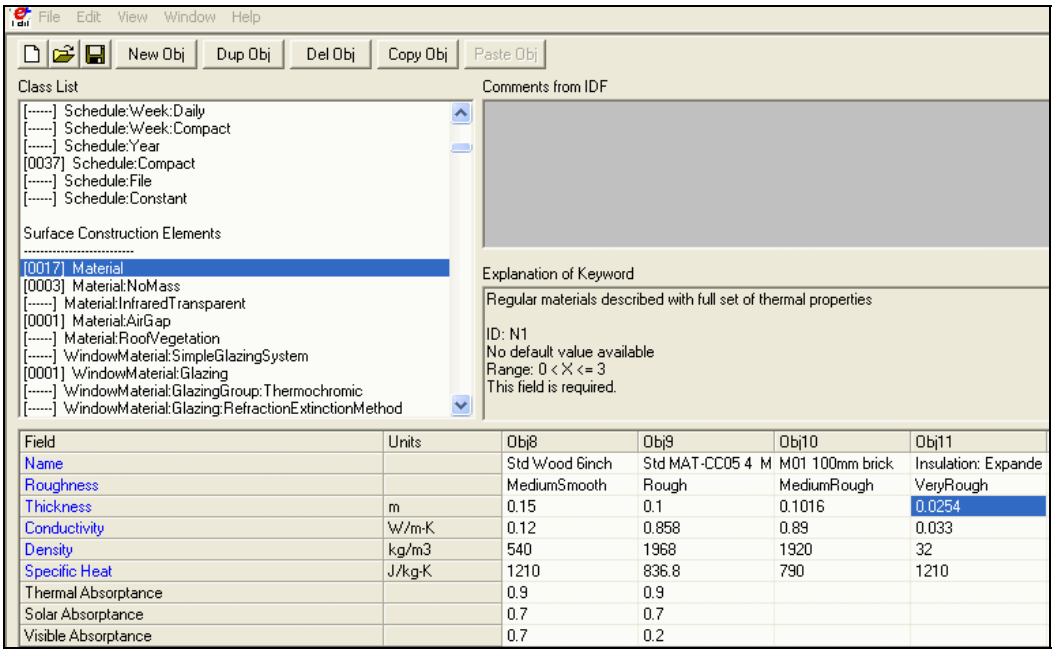
8. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
9. Simulate

Steel Stud Wall, 1″ EPS Insulation

We can repeat the process by changing the material thickness of the insulation layer in Composite Steel Stud construction object.

Instructions

1. Start > IDF Editor > File > Open > 5.Insulation_SteelStud_0.5in.idf
2. Save as > 6.Insulation_SteelStud_1in.idf in the destination folder.
3. Select Class List > Surface Construction Elements > Material > **Insulation: Expanded polystyrene - molded beads - 32 kg/m3 density**
4. Change thickness to 0.0254m (1″).



Field	Units	Obj8	Obj9	Obj10	Obj11
Name		Std Wood 6inch	Std MAT-CC05 4 M	M01 100mm brick	Insulation: Expande
Roughness		MediumSmooth	Rough	MediumRough	VeryRough
Thickness	m	0.15	0.1	0.1016	0.0254
Conductivity	W/m-K	0.12	0.858	0.89	0.033
Density	kg/m3	540	1968	1920	32
Specific Heat	J/kg-K	1210	836.8	790	1210
Thermal Absorptance		0.9	0.9		
Solar Absorptance		0.7	0.7		
Visible Absorptance		0.7	0.2		

5. The file is ready to simulate after saving changes.
6. Start > EP-Launch > Input file > Browse > Select 6.Insulation_SteelStud_1in.idf from its destination folder.
7. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
8. Simulate

Steel Stud Wall, 2″ EPS Insulation

Instructions

1. Start > IDF Editor > File > Open > 5.Insulation_SteelStud_0.5in.idf
2. Save as > 7.Insulation_SteelStud_2in.idf in the destination folder.
3. Select Class List > Surface Construction Elements > Material **> Insulation: Expanded polystyrene - molded beads - 32 kg/m3 density**
4. Change thickness to 0.0508m (2″).
5. The file is ready to simulate after saving changes.
6. Start > EP-Launch > Input file > Browse > Select > 7.Insulation_SteelStud_2in.idf from its destination folder.
7. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
8. Simulate

ROOF INSULATION COMPARISON

Exercise Procedure

The composite construction created in an earlier exercise—steel stud wall, 0.5″ EPS insulation—contains a roof with an overall R-value of R-20.

- Roof = R20

  File name: 5.Insulation_SteelStud_0.5in.idf

  Roof object name: IEAD_R-20 ci_Roof

  Construction details:

Layer Name	**Thickness, t (m)**	**Conductivity, k (W/m-K)**	**R-Value (m^2-K/W)**
Roof Membrane	0.0095	0.16	0.0594
Roof Insulation (13)	0.1673	0.049	3.414
Metal Decking	0.0015	45.006	0.0000333
		Overall Roof R-Value	**3.4737**
		IP Unit Conversion Factor	5.678263
		Overall Roof R-Value	**19.7 (h·ft^2·°F)/Btu**

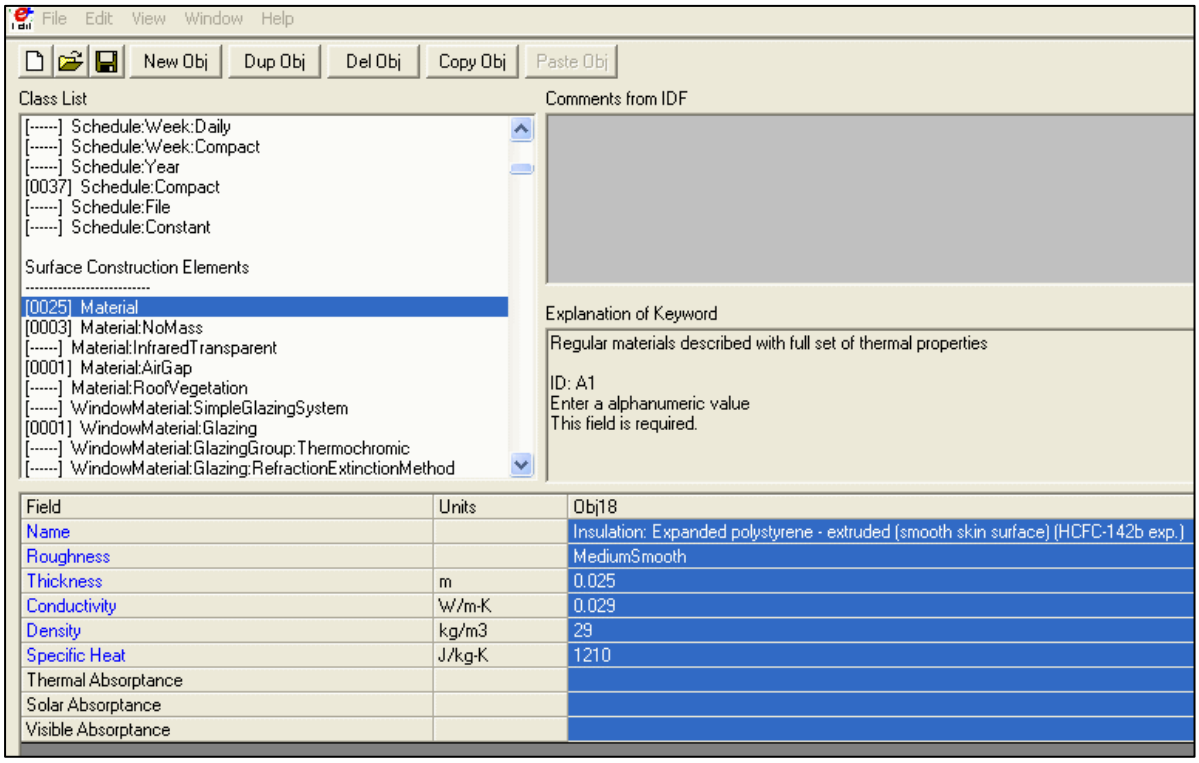
- Roof = R40
  New construction object for the Roof **[R-value=40 (h·ft^2·°F)/Btu]** is created with the following layers:
  a) Roof membrane
  b) Insulation: Expanded polystyrene–extruded (smooth skin surface) (HCFC-142b exp.)–8″ thick
  c) Metal Decking

Simulations are run and energy-usage data obtained for comparison.

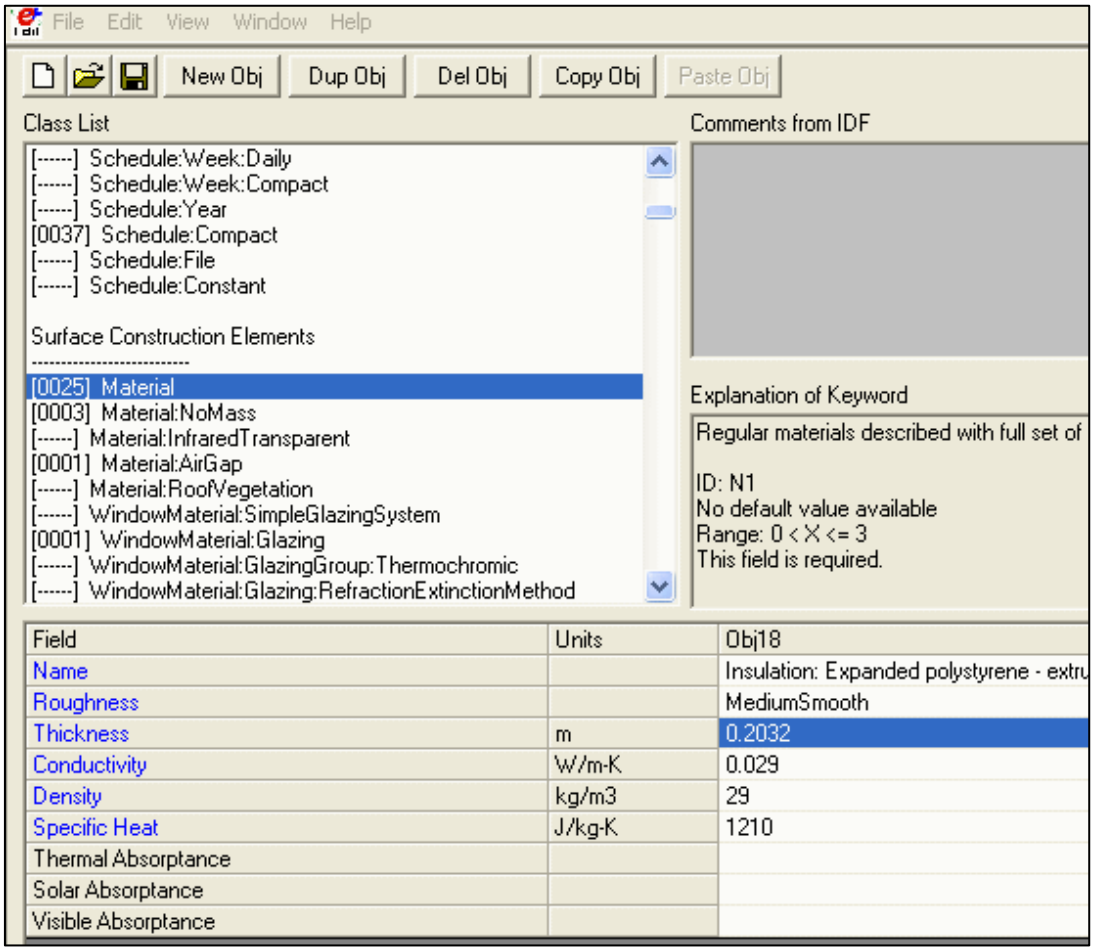
Instructions

1. Start > IDF Editor > File > Open > 5.Insulation_SteelStud_0.5in.idf
2. Save as > 8.Insulation_Roof_R40.idf in the destination folder.
   We will make changes to the roof insulation in this idf file.
3. First step is to import the insulation material for the new roof construction.
   a) File > Open DataSet > ASHRAE_2005_HOF_Materials.idf
   b) Open Class List > Surface Construction Elements > Material
   c) Look for **Insulation: Expanded polystyrene - extruded (smooth skin surface) (HCFC-142b exp.)** > Copy Object

d) Paste object into 8.Insulation_Roof_R40.idf > Class List > Surface Construction Elements > Material

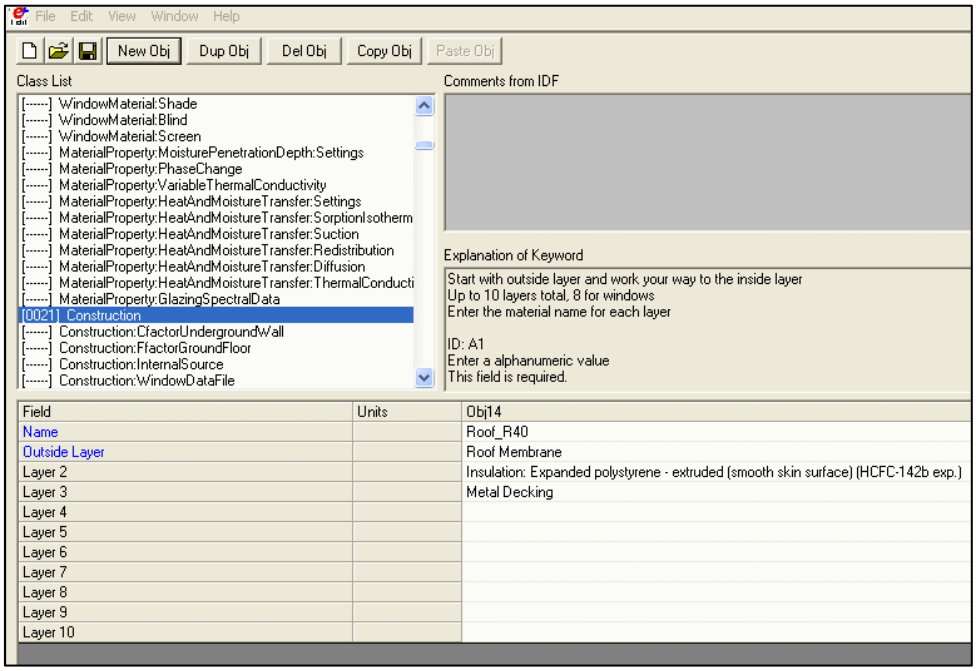


4. Change thickness of imported insulation layer to 0.2032m (8″).



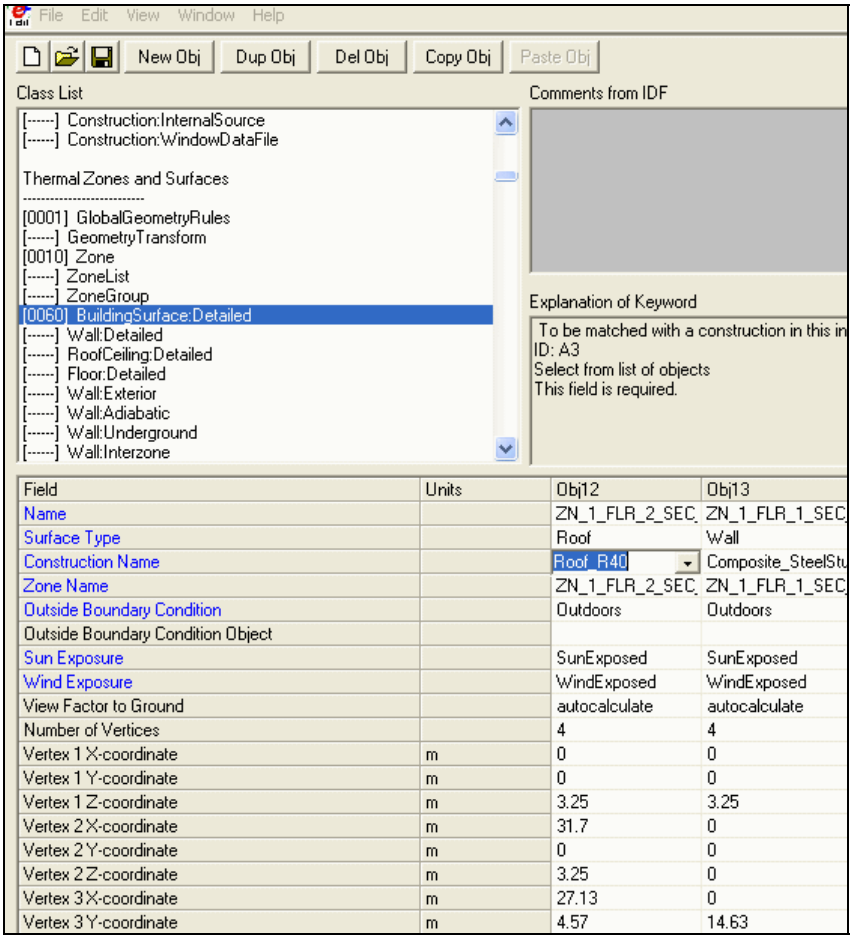
5. We now need to create the new roof construction object with the imported material layer.
   Class List > Surface Construction Elements > Construction > New Object
   Enter the following data:

Name	Roof_R40
Outside Layer	Roof Membrane
Layer 2	Insulation: Expanded polystyrene - extruded (smooth skin surface) (HCFC-142b exp.)
Layer 3	Metal Decking



6. We now need to assign this new construction object to all roof surfaces of the building.
   Class List > Thermal Zones and Surfaces > Building Surface: Detailed
   This object list consists of all surfaces of the building. We need to change the roof surfaces of all zones (5 surfaces in total) from **IEAD_R-20 ci_Roof** to **Roof_R40** using the pull-down menu.

   Apply the change to the following objects:
   a) Object 12 > ZN_1_FLR_2_SEC_1_ Ceiling
   b) Object 24 >ZN_1_FLR_2_SEC_2_ Ceiling
   c) Object 36 > ZN_1_FLR_2_SEC_3_ Ceiling
   d) Object 48 > ZN_1_FLR_2_SEC_4_ Ceiling
   e) Object 60 > ZN_1_FLR_2_SEC_5_Ceiling

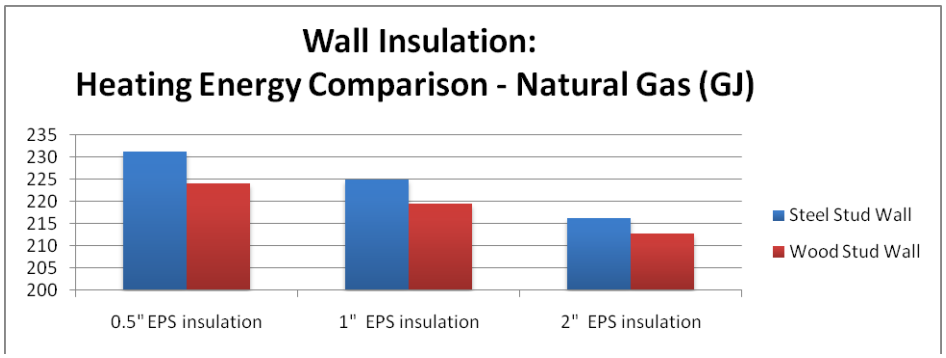


7. All data required for the new roof construction is entered into the idf file, which is ready for simulation after saving changes.
8. Start > EP-Launch > Input file > Browse > Select 8.Insulation_Roof_R40.idf from its destination folder.
9. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
10. Simulate

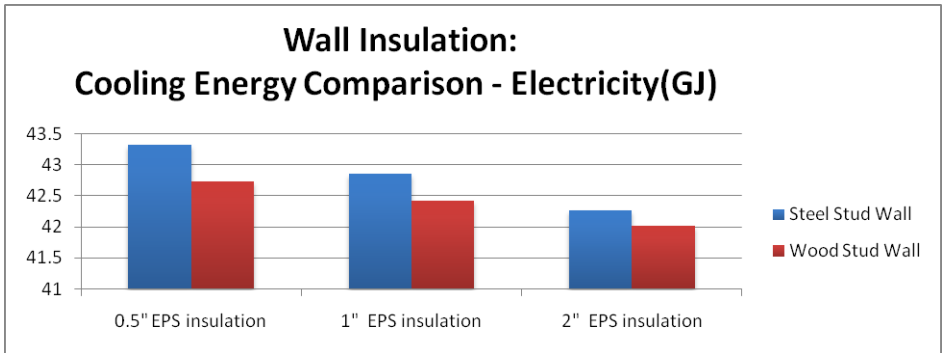
RESULTS

Wall Insulation: Energy End-Use Comparison

The output graphs are created from the output data in the END USES Table in the Annual Building Utility Performance Summary Reports from the html files.



Heating (Natural Gas)	Steel Stud Wall	Wood Stud Wall
0.5″ EPS insulation	231.26	223.92
1″ EPS insulation	224.79	219.35
2″ EPS insulation	216.14	212.64

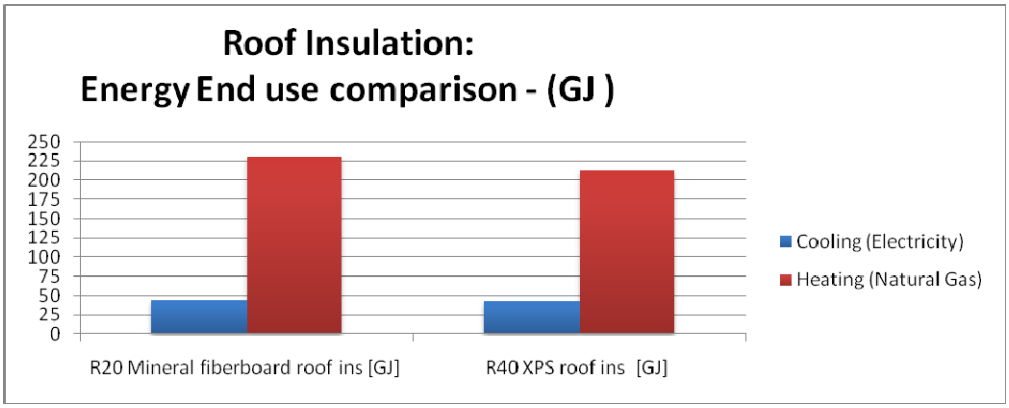


Cooling (Electricity)	Steel Stud Wall	Wood Stud Wall
0.5″ EPS insulation	43.32	42.73
1″ EPS insulation	42.85	42.42
2″ EPS insulation	42.27	42.02

Roof Insulation: Energy End-Use Comparison

The output graph is created from the output data in the END USE Tables in the Annual Building Utility Performance Summary Reports from the following files:

- **R20** = 5.Insulation_SteelStud_0.5in.html
- **R40** = 8.Insulation_Roof_R40.html



	R20 Mineral fiberboard roof ins [GJ]	R40 XPS roof ins [GJ]	% Decrease
Cooling (Electricity)	43.32	42.48	2.0
Heating (Natural Gas)	231.26	213.42	8.4

This material is based upon work supported by the U.S. Department of Energy under Award Number DE-FG26-07NT43330 to the Alliance to Save Energy.