DAYLIGHTING MODULE—ENERGYPLUS EXERCISE INSTRUCTIONS

Exercise Introduction and Objectives

The exercise provides a base file for a single-storied building, measuring 65′ x 15′. The building is modeled with one zone.

The objective of this exercise is to study the effect of daylighting on a building's energy use.

This exercise aims to compare the performance and energy usage of different glazing alternatives and shading strategies. The same sets of simulations are run for Chicago, IL, and Phoenix, AZ, to study the impact of daylighting in different climates.

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.

Exercise Procedure

In the base file, the space is modeled as an office building with a window on the South wall (shorter side—15′), clear glass 3mm thick as glazing material and no lighting controls.

A variety of simulations are generated by making the following changes to controls, glazing material or shading strategies:

1. Base file with clear glass for location of Chicago
2. Addition of automatic lighting controls to Simulation 1 and all further simulations
3. Addition of shading strategy of high reflectivity blinds on 50% of the window area
4. Change of glazing material to Low-E glass (no blinds)
5. Incorporating light shelf into design on South wall

6–7. The building orientation is changed and simulations run so that the light shelf effect can be studied on different directions (South, North and East).

An illuminance level of 500 lux is set as the desired level at a setpoint located centrally in the zone. A 3-stepped lighting control system is chosen for all simulations. Incorporating a lighting control system also allows us to generate illuminance level maps at a grid of maximum 10 x 10 points in the zone. Two points are chosen at desktop height of 0.8m to generate illuminance maps, one 2m from the window and the other 2m from the rear wall. The same sets of simulations are repeated for Phoenix, AZ, importing the weather data from the EnergyPlus datasets.

Note: About IDF Editor
Users who want a simple way of creating or editing EnergyPlus input data files (IDF) can use the IDF Editor. Any EnergyPlus object may be viewed and edited using a spreadsheet-like grid. For inputs with several options, a list is provided. 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 some numeric fields are highlighted if out of range. For the purposes of this exercise, the IDF editor is a useful input interface.

Output Data

Before proceeding to the simulations, we need to set the idf base file for the desired output data and format. This will help make the idf file ready for output right after entering daylighting data so the process does not have to be repeated for every calculation model.

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. The StandardReports.idf file in the DataSets directory of EnergyPlus offers a set of example reports.

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

Instructions

1. Start IDF Editor > File > Open > 0.Daylighting_BaseFile.idf
2. Select Class List > Output Reporting > Output: Table: Summary Reports > New Object
   Enter the following data:

Report 1 Name	AnnualBuildingUtilityPerformanceSummary
Report 2 Name	DaylightingReportMonthly
Report 3 Name	InputVerificationandResultsSummary
Report 4 Name	ClimateSummary
Report 5 Name	EquipmentSummary
Report 6 Name	EnvelopeSummary
Report 7 Name	LightingSummary

   These are basic reports that allow for a quick analysis of the building's performance. More detailed reports can be selected from the pull-down menu.

3. Select > Class List > Output Reporting > Output: Meter > New Object
   Enter the following data:

Name	Reporting Frequency
InteriorLights:Electricity:Zone:ZN_1_FLR_1_SEC_1	Runperiod
InteriorEquipment:Electricity:Zone:ZN_1_FLR_1_SEC_1	Runperiod
Electricity:Zone:ZN_1_FLR_1_SEC_1	Runperiod

4. Select > Class List > Output Reporting > Output: Meter > Output: Meter File Only > New Object
   Enter the following data:

Name	Reporting Frequency
InteriorLights:Electricity:Zone:ZN_1_FLR_1_SEC_1	Hourly
InteriorEquipment:Electricity:Zone:ZN_1_FLR_1_SEC_1	Hourly
Electricity:Zone:ZN_1_FLR_1_SEC_1	Hourly

5. Select > Class List > Output Reporting > Output Control : 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 Excel), tab (for word processing programs), fixed, etc.

6. Save Changes to Base File.

The idf base file is now ready for daylighting data inputs.

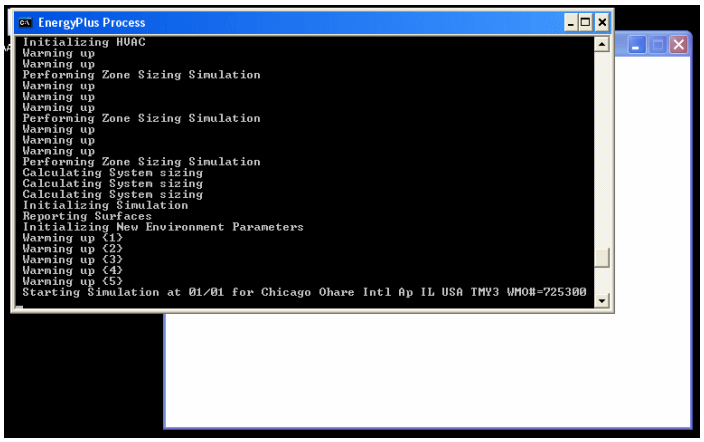
SIMULATIONS FOR LOCATION: CHICAGO

Simulation 1: Base File with Clear Glass

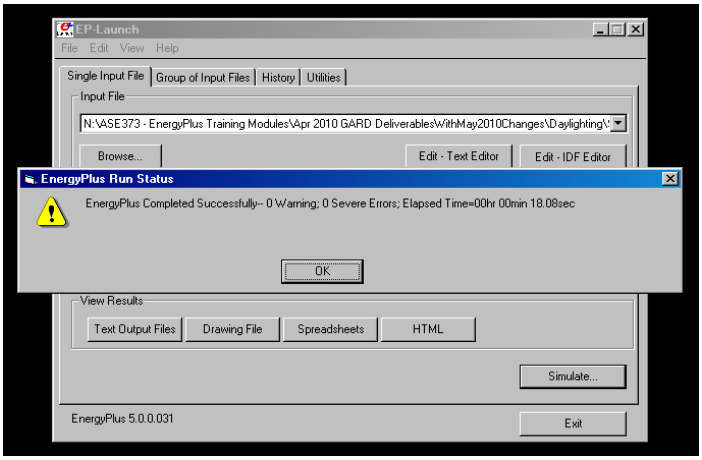
This simulation has the assigned glazing of clear glass to the base file without any lighting controls.

Instructions

1. Start > IDF Editor > File > Open > 0.Daylighting_BaseFile.idf
2. Save as > 1.Daylighting_BaseFile_Chicago.idf in the destination folder
3. Start > EP-Launch > Input file > Browse > Select 1.Daylighting_BaseFile_Chicago.idf from its destination folder.
4. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
5. Simulate



Simulation in Progress



Simulation Completed

Program Version:**EnergyPlus 5.0.0.031, 5/19/2010 3:46 PM**

Tabular Output Report in Format: **HTML**

Building: **Office Building - Daylighting study**

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

Simulation Timestamp: **2010-05-19 15:46:28**

Report: **AnnualBuildingUtilityPerformanceSummary**

For: **Entire Facility**

Timestamp: **2010-05-19 15:46:28**

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	44.45	491.04	491.04
Net Site Energy	44.45	491.04	491.04
Total Source Energy	99.89	1103.36	1103.36
Net Source Energy	99.89	1103.36	1103.36

Sample Image of HTML Output

The meter.csv file generated gives us hourly meter readings for lighting, equipment and overall electricity energy use for the entire run period.

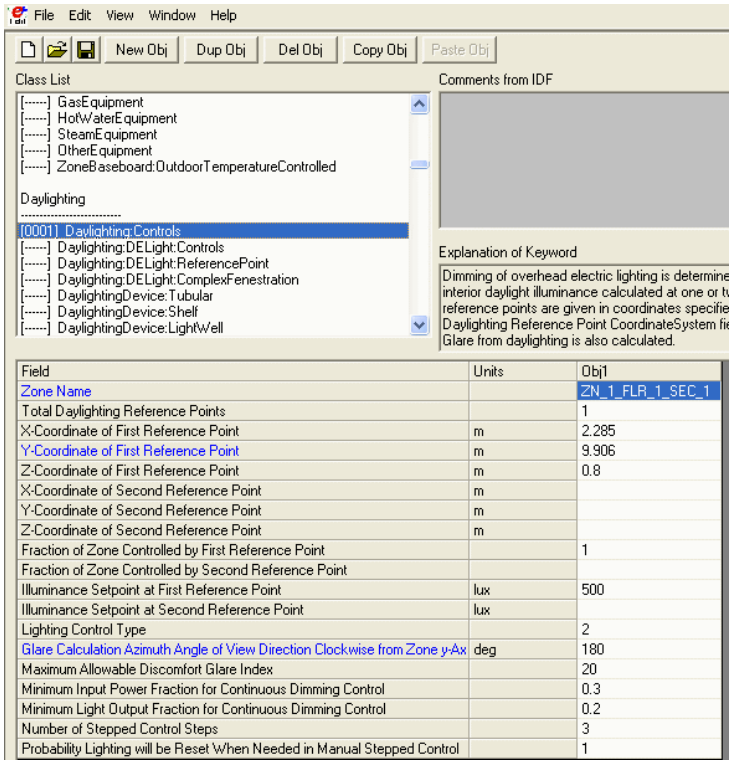
This similar data is further evolved into graphs to better understand and analyze the different glazing alternatives.

Simulation 2: Clear Glass with Lighting Controls
This simulation has the assigned glazing of clear glass to the base file with new lighting controls.

Instructions

1. Start > IDF Editor > File > Open > 1.Daylighting_BaseFile_Chicago.idf
2. Save as > 2.Daylighting_ClearGlass_Chicago.idf in the destination folder.
3. Select > Class List > Daylighting > Daylighting: Controls > New Object
   Enter the following data:

Field	Obj 1
Zone Name	ZN_1_FLR_1_SEC_1
Total Daylighting Reference Points	1
X-Coordinate of First Reference Point	2.285
Y-Coordinate of First Reference Point	9.906
Z-Coordinate of First Reference Point	0.8
Fraction of Zone Controlled by First Reference Point	1
Illuminance Setpoint at First Reference Point	500
Lighting Control Type	2
Glare Calculation Azimuth Angle of View Direction Clockwise from Zone y-Axis	180
Maximum Allowable Discomfort Glare Index	20
Minimum Input Power Fraction for Continuous Dimming Control	0.3
Minimum Light Output Fraction for Continuous Dimming Control	0.2
Number of Stepped Control Steps	3
Probability Lighting will be Reset When Needed in Manual Stepped Control	1

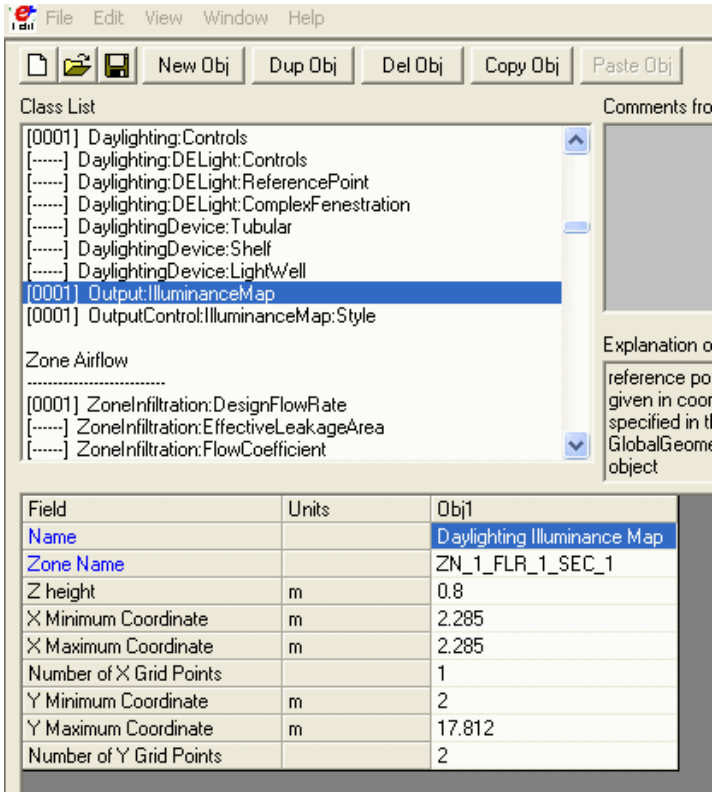


Note: This step helps us set a point in the middle of the zone as reference for measuring illuminance values, the setpoint for which is 500 lux.

The lighting control selected is a 3-stepped system (Type 2:Refer to EnergyPlus Documentation for types) and default minimum fractions are chosen.

4. Select > Class List > Daylighting > Output: Illuminance Map > New Object
   Enter the following data:

Field	Obj 1
Name	Daylighting Illuminance Map
Zone Name	ZN_1_FLR_1_SEC_1
Z Height	0.8
X Minimum Coordinate	2.285
X Maximum Coordinate	2.285
Number of X Grid Points	1
Y Minimum Coordinate	2.285
Y Maximum Coordinate	2.285
Number of Y Grid Points	1



This step allows us to generate an illuminance map for a grid with maximum 10 points on an axis. Here we are creating a map of just 2 points, one 2m from the window and the other 2m from the back wall, both centrally located on the middle longitudinal axis of the zone.

5. Select > Class List > Daylighting > Output Control: Illuminance Map: Style > New Object
   Enter the following data:

Column Separator	Comma

6. Save input file.
7. Start > EP-Launch > Input file > Browse > Select 2.Daylighting_ClearGlass_Chicago.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

The generated map.csv file gives an illuminance map for the entire run period. This data can be further used to generate daylight factor maps.

Simulation 3: Blinds with Lighting Controls
This simulation has the assigned shading strategy of high reflectivity blinds to the base file.

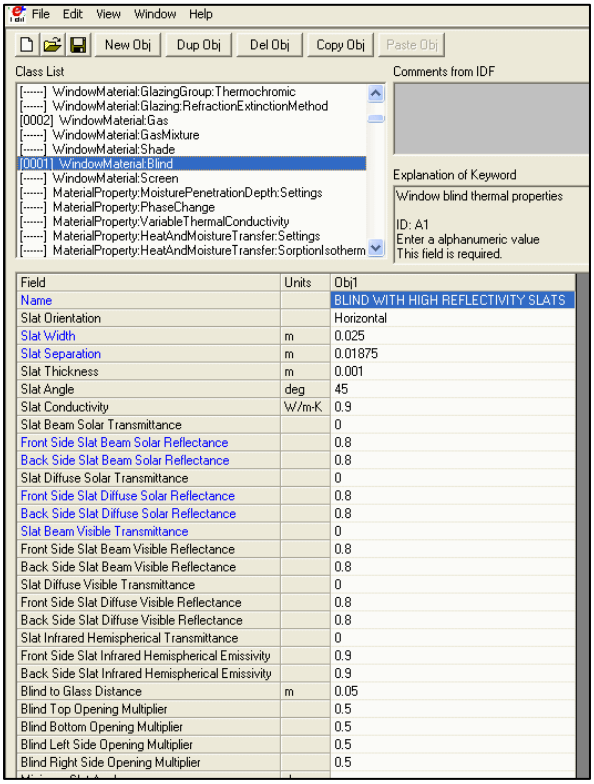
Instructions

1. Start > IDF Editor > File > Open > 2.Daylighting_ClearGlass_Chicago.idf
2. Save as > 3.Daylighting_Blinds_Chicago.idf in the destination folder.
3. Select > Class List > Surface Construction Elements > Window Material: Gas > New Object
   Enter the following data:

Field	Obj 1	Obj 2
Name	AIR GAP 20mm	AIR GAP 40mm
Gas Type	Air	Air
Thickness	0.02	0.004

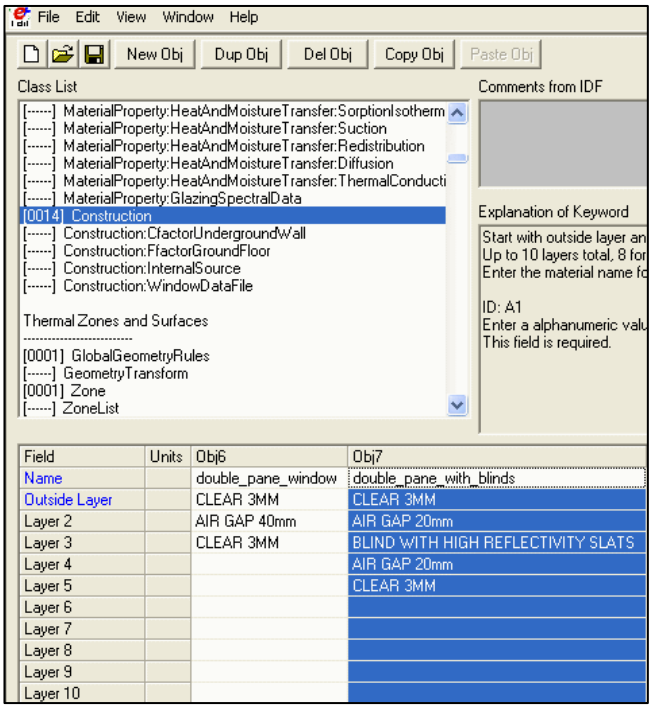
Note: Custom Gas materials can also be imported from Dataset: WindowGasMaterials.idf

4. Import Blind material from dataset
   File > Open Dataset > WindowBlindMaterials.idf > Copy "BLIND WITH HIGH REFLECTIVITY SLATS" and paste into the simulation file.



5. Create new Window Constructions with imported Blinds data and Air Gap
   Select > Class List > Surface Construction Elements > Construction > New Object.
   Enter the following data:

Field	Obj 6	Obj 7
Name	double_pane_window	double_pane_with_blinds
Outside Layer	CLEAR 3MM	CLEAR 3MM
Layer 2	AIR GAP 40mm	AIR GAP 20mm
Layer 3	CLEAR 3MM	BLIND WITH HIGH REFLECTIVITY SLATS
Layer 4	-	AIR GAP 20mm
Layer 5	-	CLEAR 3MM



6. Select Class List > Thermal Zones and Surfaces > Fenestration Surface: Detailed >
   Change Construction name of all 4 windows to the newly created
   “double_pane_window” from the pull-down menu.

7. Select Class List > Thermal Zones and Surfaces > Window Property: Shading Control > New Object
   Enter the following data:

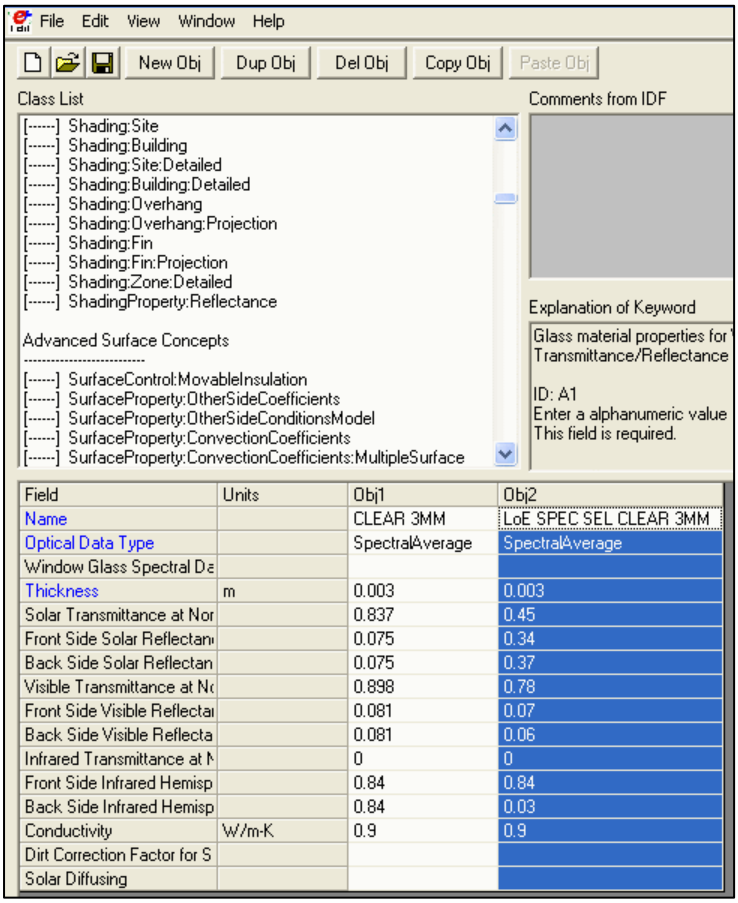
Field	Obj 1
Name	Double Pane Between Glass Blind
Shading Type	Between Glass Blind
Construction with Shading Name	double_pane_with_blinds
Shading Control type	AlwaysOn
Shading Control Is Scheduled	No
Glare Control is Active	No
Type of Slat Angle Control for Blinds	FixedSlatAngle

   The file is now ready for simulation. Save input file before simulation.
8. Start > EP-Launch > Input file > Browse > Select 3.Daylighting_Blinds_Chicago.idf from its destination folder.
10. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
11. Simulate

Simulation 4: Low-E Glass with Lighting Controls
This simulation shows how to change the glass material from the base file.

Instructions

1. Start > IDF Editor > File > Open > 2.Daylighting_ClearGlass_Chicago.idf
2. Save as > 4.Daylighting_LoEGlass_Chicago.idf in the destination folder.
3. File > Open Dataset > WindowGlassMaterials.idf > Copy "LoE SPEC SEL CLEAR 3MM" into current idf file.



4. Select Class List > Surface Construction Elements > Construction > South_wall_window > Change glass material to "LoE SPEC SEL CLEAR 3MM"
5. Save input file.
6. Start > EP-Launch > Input file > Browse > Select 4.Daylighting_LoEGlass_Chicago.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

Simulation 5: Light Shelf on South wall (Low-E Glass) with Lighting Controls
This simulation shows how to model light shelves.

Instructions

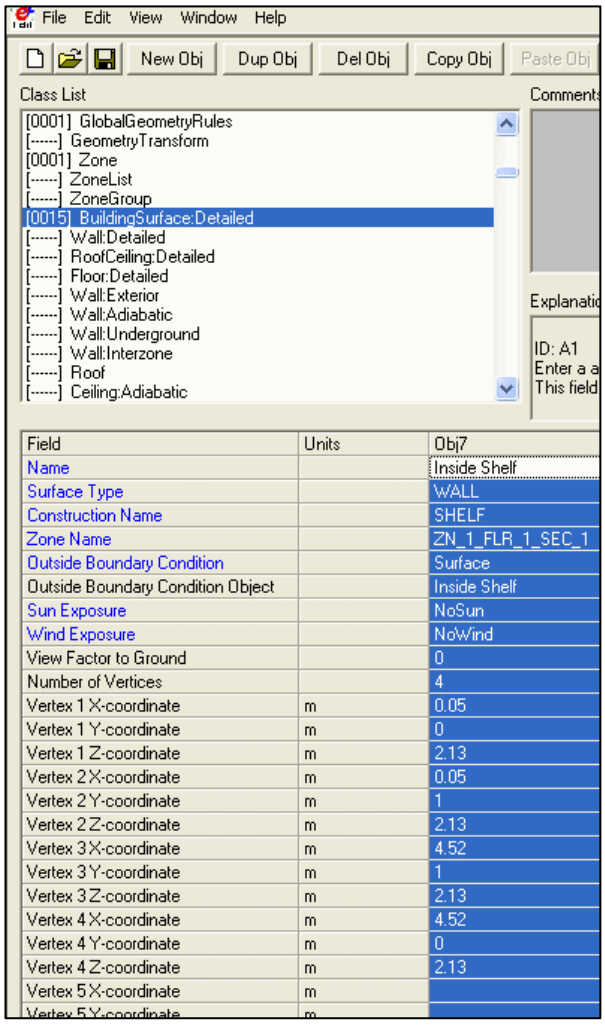
1. Start > IDF Editor > File > Open > 4.Daylighting_LoEGlass_Chicago.idf
2. Save as > 5.Daylighting_LightShelf_Southwall_Chicago.idf in the destination folder.
3. File > Open Dataset > ASHRAE_2005_HOF_Materials.idf > Copy "C12-2 IN HW CONCRETE – PAINTED WHITE" into current idf file.
4. Select Class List > Surface Construction Elements > Construction > New Obj
   Enter the following data:

Field	Obj 9
Name	SHELF
Outside Layer	C12-2 IN HW CONCRETE – PAINTED WHITE

5. Select Class List > Thermal Zones and Surfaces > Building Surface: Detailed > New Obj
   Enter the following data:

Field	Obj 7
Name	Inside Shelf
Surface Type	WALL
Construction Name	SHELF
Zone Name	ZN_1_FLR_1_SEC_1
Outside Boundary Condition	Surface
Outside Boundary Condition Object	Inside Shelf
Sun Exposure	NoSun
Wind Exposure	NoWind
View Factor to Ground	0
Number of vertices	4
Vertex 1 X-coordinate	0.05
Vertex 1 Y-coordinate	0
Vertex 1 Z-coordinate	2.13
Vertex 2 X-coordinate	0.05
Vertex 2 Y-coordinate	1
Vertex 2 Z-coordinate	2.13
Vertex 3 X-coordinate	4.52

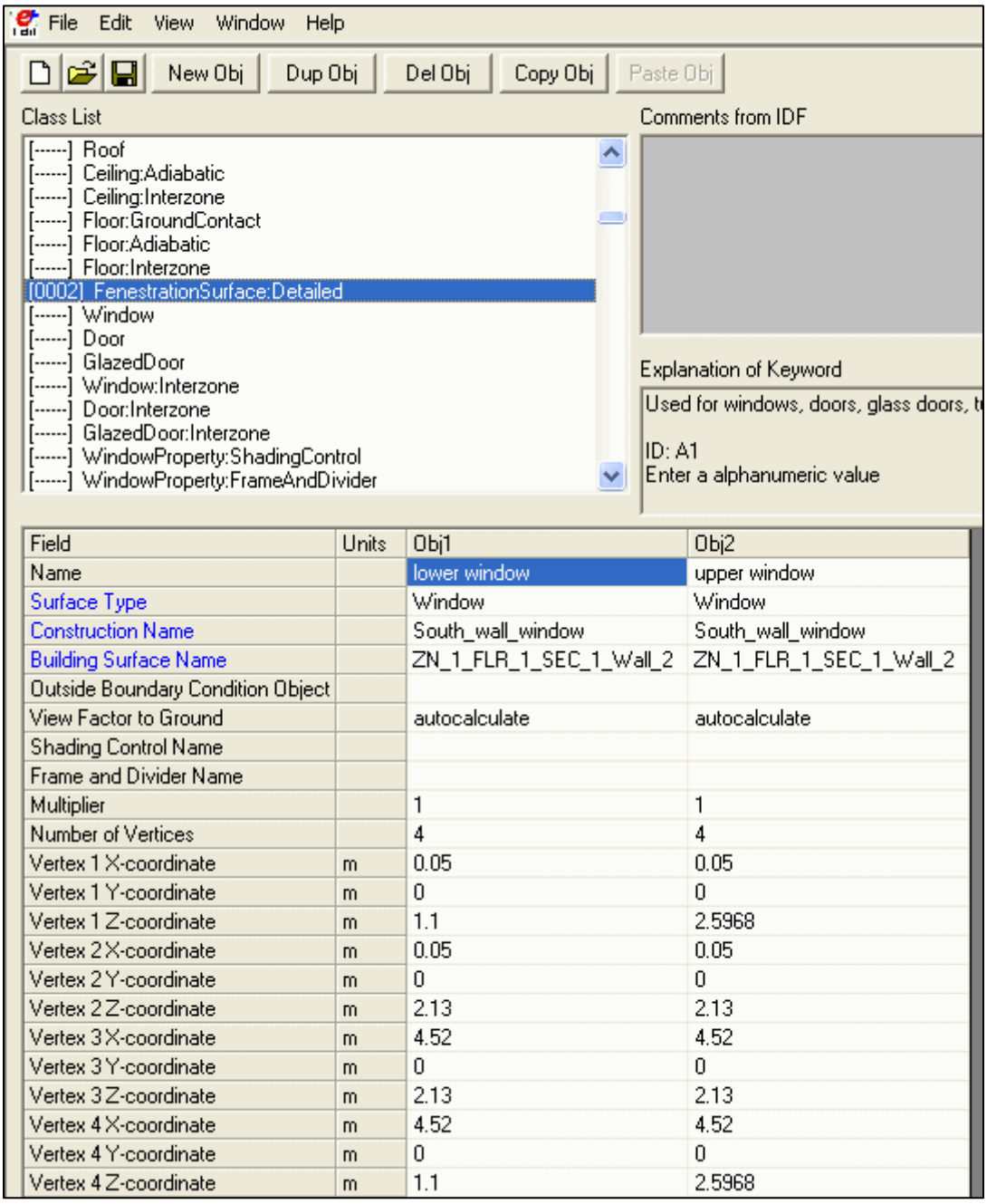
Vertex 3 Y-coordinate	1
Vertex 3 Z-coordinate	2.13
Vertex 4 X-coordinate	4.52
Vertex 4 Y-coordinate	0
Vertex 4 Z-coordinate	2.13



6. Select Class List > Thermal Zones and Surfaces > Fenestration Surface: Detailed > Delete Obj.1 and Obj.2
   We need to create new fenestration surfaces: Lower Window and Upper Window

7. Select Class List > Thermal Zones and Surfaces > Fenestration Surface: Detailed > New Obj
   Enter the following data:

Field	Obj 1	Obj 2
Name	lower window	upper window
Surface Type	Window	Window
Construction Name	South_wall_window	South_wall_window
Building Surface Name	ZN_1_FLR_1_SEC_1_Wall_2	ZN_1_FLR_1_SEC_1_Wall_2
View Factor to Ground	Autocalculate	0
Multiplier	1	1
Number of vertices	4	4
Vertex 1 X-coordinate	0.05	0.05
Vertex 1 Y-coordinate	0	0
Vertex 1 Z-coordinate	2.13	2.5968
Vertex 2 X-coordinate	0.05	0.05
Vertex 2 Y-coordinate	0	0
Vertex 2 Z-coordinate	1.1	2.13
Vertex 3 X-coordinate	4.52	4.52
Vertex 3 Y-coordinate	0	0
Vertex 3 Z-coordinate	1.1	2.13
Vertex 4 X-coordinate	4.52	4.52
Vertex 4 Y-coordinate	0	0
Vertex 4 Z-coordinate	2.13	2.5968

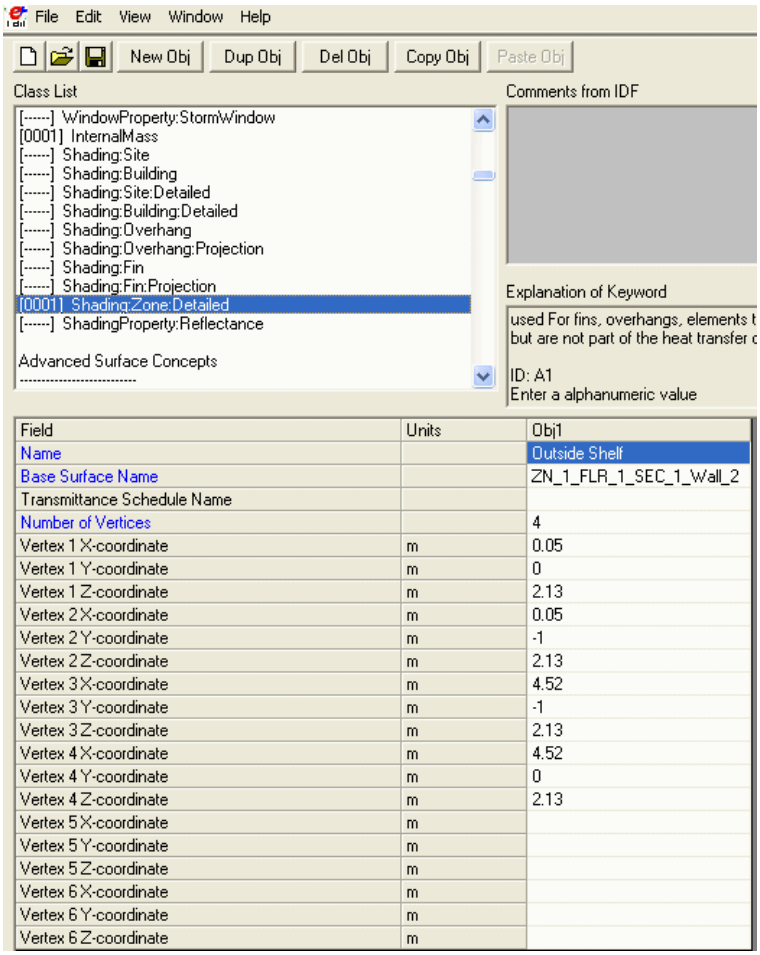


Field	Units	Obj1	Obj2
Name		lower window	upper window
Surface Type		Window	Window
Construction Name		South_wall_window	South_wall_window
Building Surface Name		ZN_1_FLR_1_SEC_1_Wall_2	ZN_1_FLR_1_SEC_1_Wall_2
Outside Boundary Condition Object			
View Factor to Ground		autocalculate	autocalculate
Shading Control Name			
Frame and Divider Name			
Multiplier		1	1
Number of Vertices		4	4
Vertex 1 X-coordinate	m	0.05	0.05
Vertex 1 Y-coordinate	m	0	0
Vertex 1 Z-coordinate	m	1.1	2.5968
Vertex 2 X-coordinate	m	0.05	0.05
Vertex 2 Y-coordinate	m	0	0
Vertex 2 Z-coordinate	m	2.13	2.13
Vertex 3 X-coordinate	m	4.52	4.52
Vertex 3 Y-coordinate	m	0	0
Vertex 3 Z-coordinate	m	2.13	2.13
Vertex 4 X-coordinate	m	4.52	4.52
Vertex 4 Y-coordinate	m	0	0
Vertex 4 Z-coordinate	m	1.1	2.5968

8. Select Class List > Thermal Zones and Surfaces > Shading: Zone: Detailed > New Obj
   Enter the following data:

Field	Obj 1
Name	Outside Shelf
Base Surface Name	ZN_1_FLR_1_SEC_1_Wall_2
Number of vertices	4
Vertex 1 X-coordinate	0.05
Vertex 1 Y-coordinate	0

Vertex 1 Z-coordinate	2.13
Vertex 2 X-coordinate	0.05
Vertex 2 Y-coordinate	-1
Vertex 2 Z-coordinate	2.13
Vertex 3 X-coordinate	4.52
Vertex 3 Y-coordinate	-1
Vertex 3 Z-coordinate	2.13
Vertex 4 X-coordinate	4.52
Vertex 4 Y-coordinate	0
Vertex 4 Z-coordinate	2.13



9. Save input file.
10. Start > EP-Launch > Input file > Browse > Select 5.Daylighting_LightShelf_Southwall_Chicago.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 6: Light Shelf on North wall (Low-E Glass) with Lighting Controls
This simulation shows how to change orientation of light shelves.

Instructions

1. Start > IDF Editor > File > Open > 5.Daylighting_LightShelf_Southwall_Chicago.idf
2. Save as > 6.Daylighting_LightShelf_Northwall_Chicago.idf in the destination folder.
3. Select > Class List > Simulation Parameters > Building > Change North Axis to "180" deg.
4. Save input file.
5. Start > EP-Launch > Input file > Browse > Select 6.Daylighting_LightShelf_Northwall_Chicago.idf from its destination folder.
6. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
7. Simulate

Simulation 7: Light Shelf on East wall (Low E-Glass) with Lighting Controls

Instructions

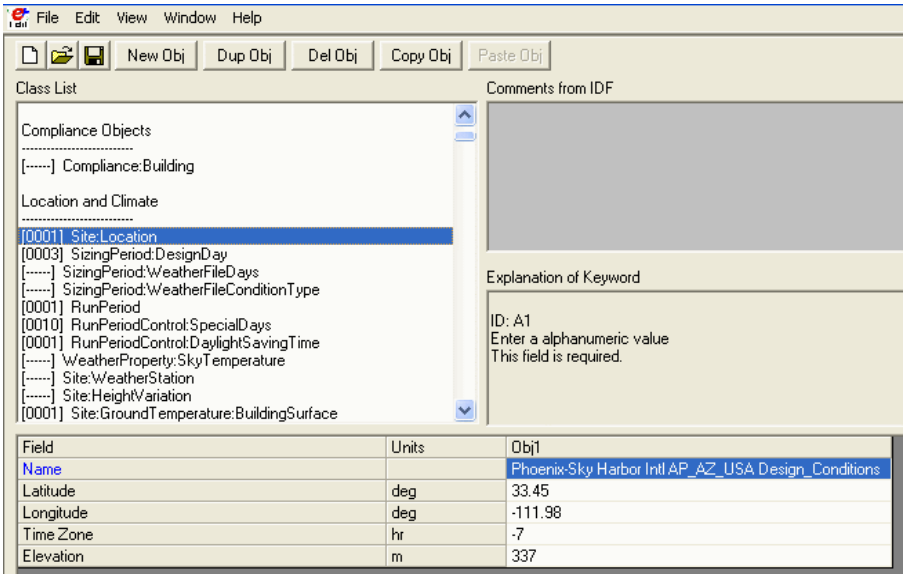
1. Start > IDF Editor > File > Open > 5.Daylighting_LightShelf_Southwall_Chicago.idf
2. Save as > 7.Daylighting_LightShelf_Eastwall_Chicago.idf in the destination folder.
3. Select > Class List > Simulation Parameters > Building > Change North Axis to "-90" deg.
4. Save input file.
5. Start > EP-Launch > Input file > Browse > Select 7.Daylighting_LightShelf_Eastwall_Chicago.idf from its destination folder.
6. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
7. Simulate

SIMULATIONS FOR LOCATION: PHOENIX
Simulations 8–14: Same as above with change of location

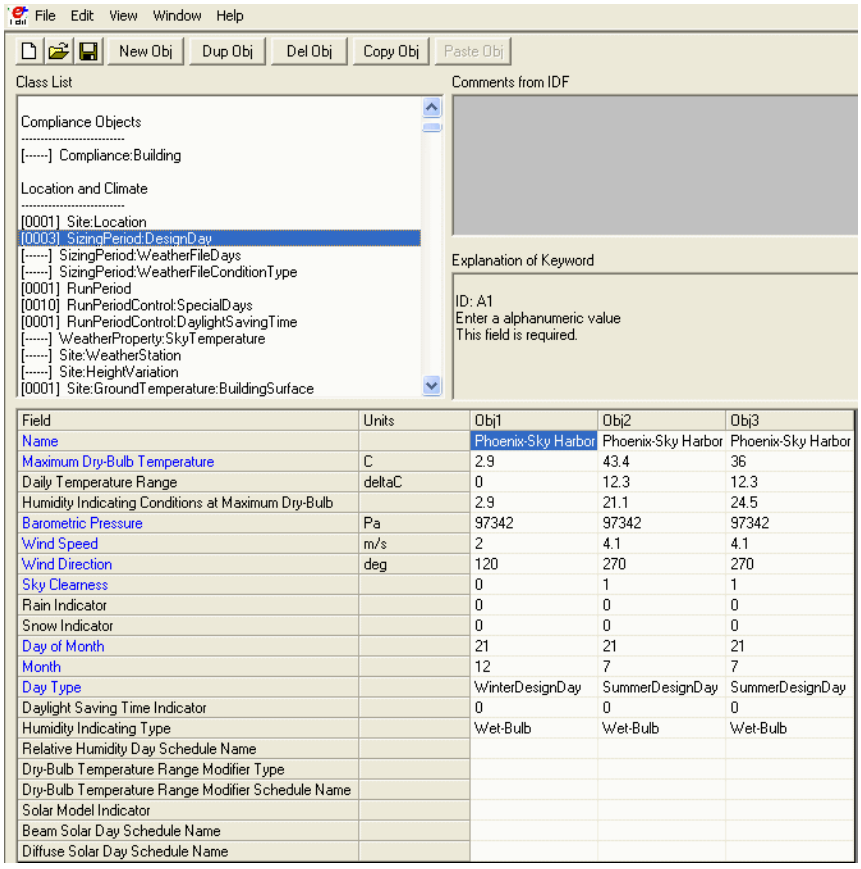
Weather data for more than 2,100 locations are now available in EnergyPlus weather format — 1,042 locations in the United States, 71 locations in Canada and more than 1,000 locations in 100 other countries. The weather data are arranged by World Meteorological Organization region and country.

Instructions

1. Download weather data for Phoenix from the EnergyPlus website (zip file from the following link) http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region=4_north_and_central_america_wmo_region_4/country=1_usa/cname=USA#AZ
2. Extract data from zip file and save .epw file in EnergyPlusV5-0-0 folder in Program Files.
3. Replace Location and Design Day data from the .ddy file into the idf's.
   Select > Class List > Location and Climate > Site: Location



Select > Class List > Location and Climate > Sizing Period: Design Day



Field	Units	Obj1	Obj2	Obj3
Name		Phoenix-Sky Harbor	Phoenix-Sky Harbor	Phoenix-Sky Harbor
Maximum Dry-Bulb Temperature	C	2.9	43.4	36
Daily Temperature Range	deltaC	0	12.3	12.3
Humidity Indicating Conditions at Maximum Dry-Bulb		2.9	21.1	24.5
Barometric Pressure	Pa	97342	97342	97342
Wind Speed	m/s	2	4.1	4.1
Wind Direction	deg	120	270	270
Sky Clearness		0	1	1
Rain Indicator		0	0	0
Snow Indicator		0	0	0
Day of Month		21	21	21
Month		12	7	7
Day Type		WinterDesignDay	SummerDesignDay	SummerDesignDay
Daylight Saving Time Indicator		0	0	0
Humidity Indicating Type		Wet-Bulb	Wet-Bulb	Wet-Bulb
Relative Humidity Day Schedule Name				
Dry-Bulb Temperature Range Modifier Type				
Dry-Bulb Temperature Range Modifier Schedule Name				
Solar Model Indicator				
Beam Solar Day Schedule Name				
Diffuse Solar Day Schedule Name				

4. Repeat the same process for all simulations done above using the new weather file: Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_AZ_Phoenix-Sky.Harbor.Intl.AP.722780_TMY3\USA_AZ_Phoenix-Sky.Harbor.Intl.AP.722780_TMY3.epw

Simulation 15: Illuminance Map — Low-E Glass with Lighting Controls
This simulation is to illustrate how to generate an illuminance map over grid points.

Instructions

1. Start > IDF Editor > File > Open > 4.Daylighting_LoEGlass_Chicago.idf
2. Save as > 15.Daylighting_LoEGlass_Chicago_Illuminance Map.idf in the destination folder.
3. Select > Class List > Daylighting > Output: Illuminance Map > Change to update the following data
   Enter the following data:

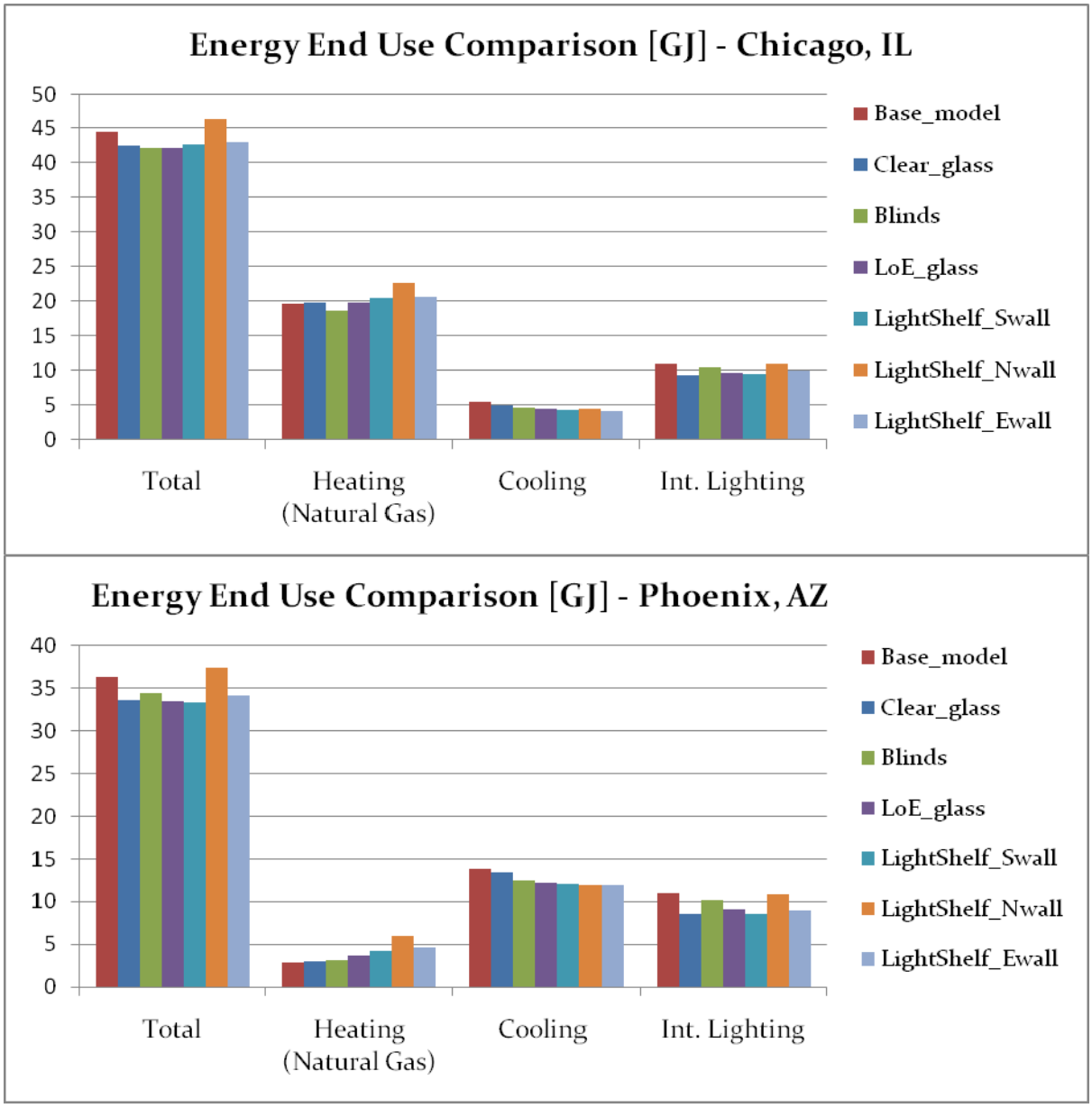
Field	Obj 1
Name	Daylighting Illuminance Map
Zone Name	ZN_1_FLR_1_SEC_1
Z Height	0.8
X Minimum Coordinate	0.5
X Maximum Coordinate	4.5
Number of X Grid Points	5
Y Minimum Coordinate	1
Y Maximum Coordinate	19
Number of Y Grid Points	10

Note: Max. Grid Points allowable = 10 x 10 points

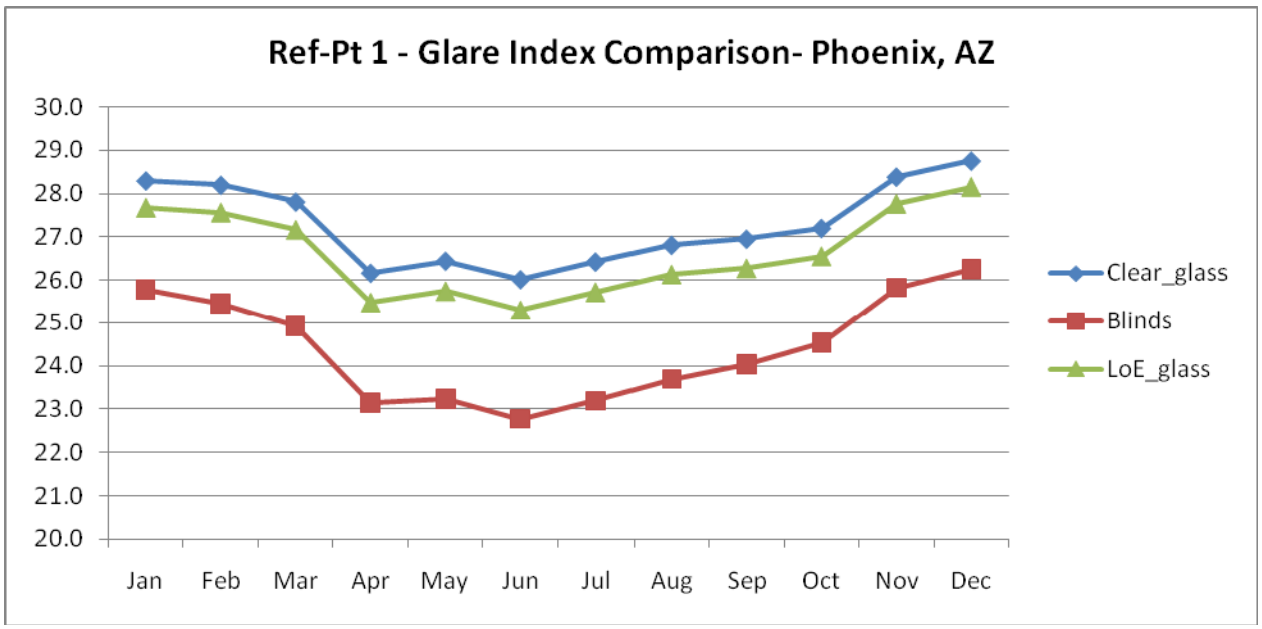
4. Save input file.
5. Start > EP-Launch > Input file > Browse > Select 15.Daylighting_LoEGlass_Chicago_Illuminance Map.idf from its destination folder.
6. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
7. Simulate

RESULTS

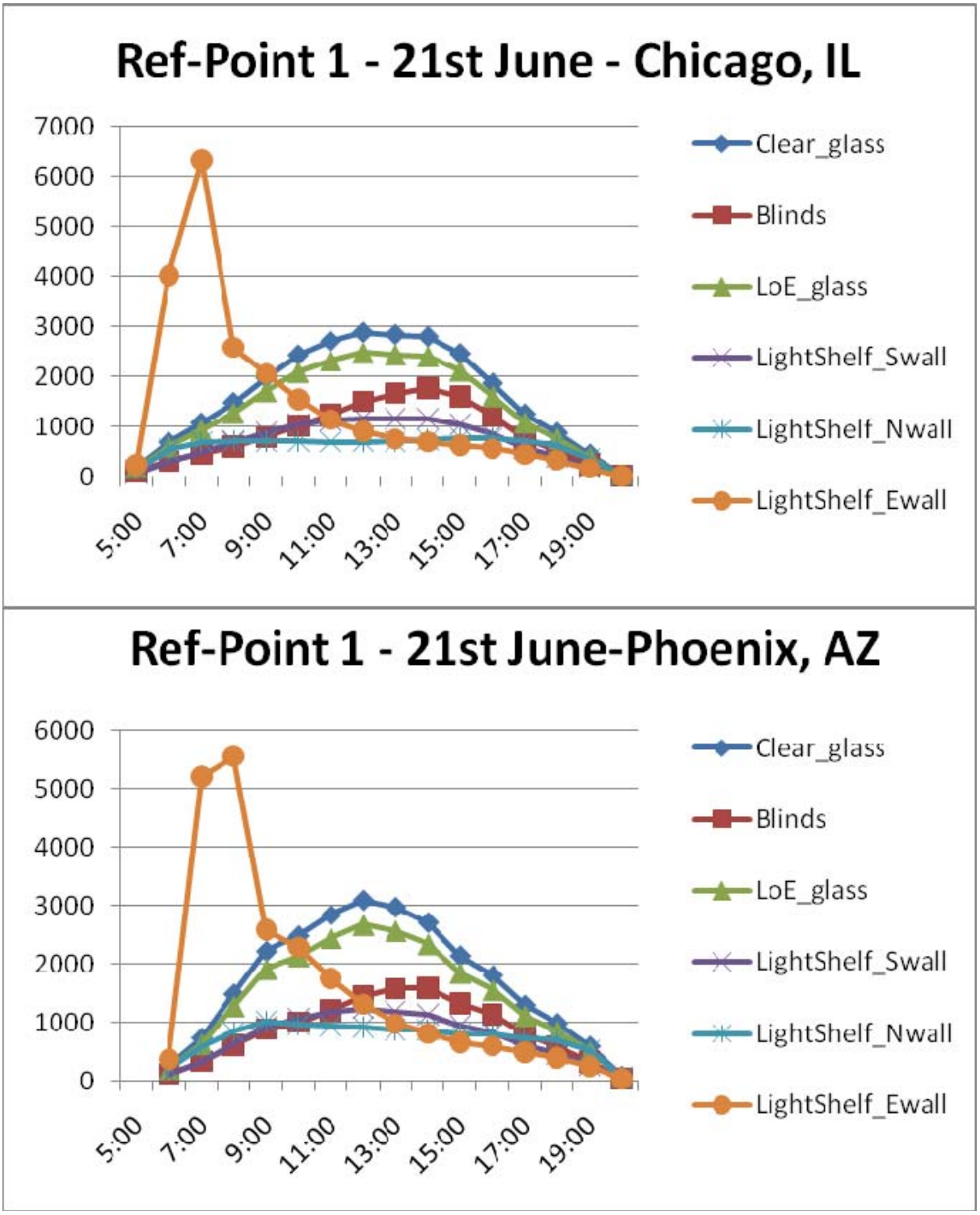
1. ENERGY END USE COMPARISON

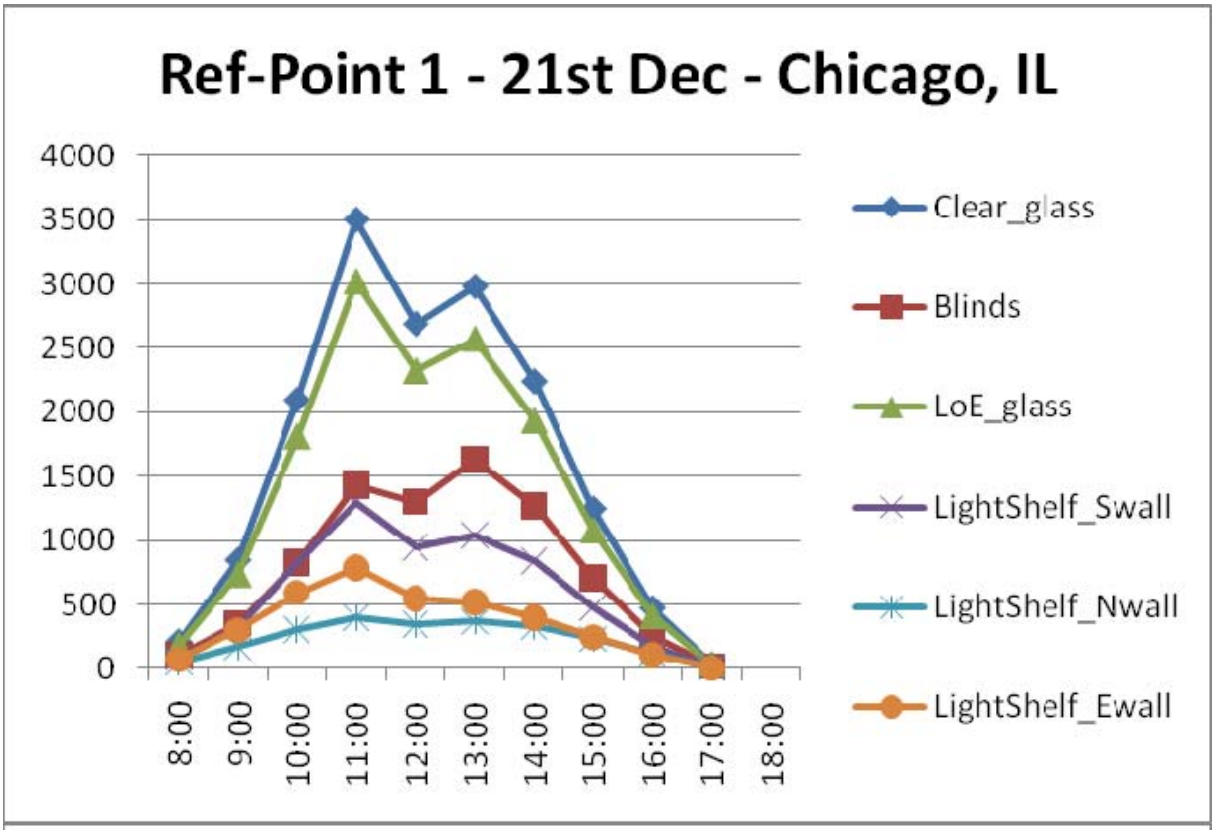


2. GLARE INDEX COMPARISON



3. ILLUMINANCE LEVEL (LUX) COMPARISONS




Ref-Point 1 - 21st Dec - Chicago, IL
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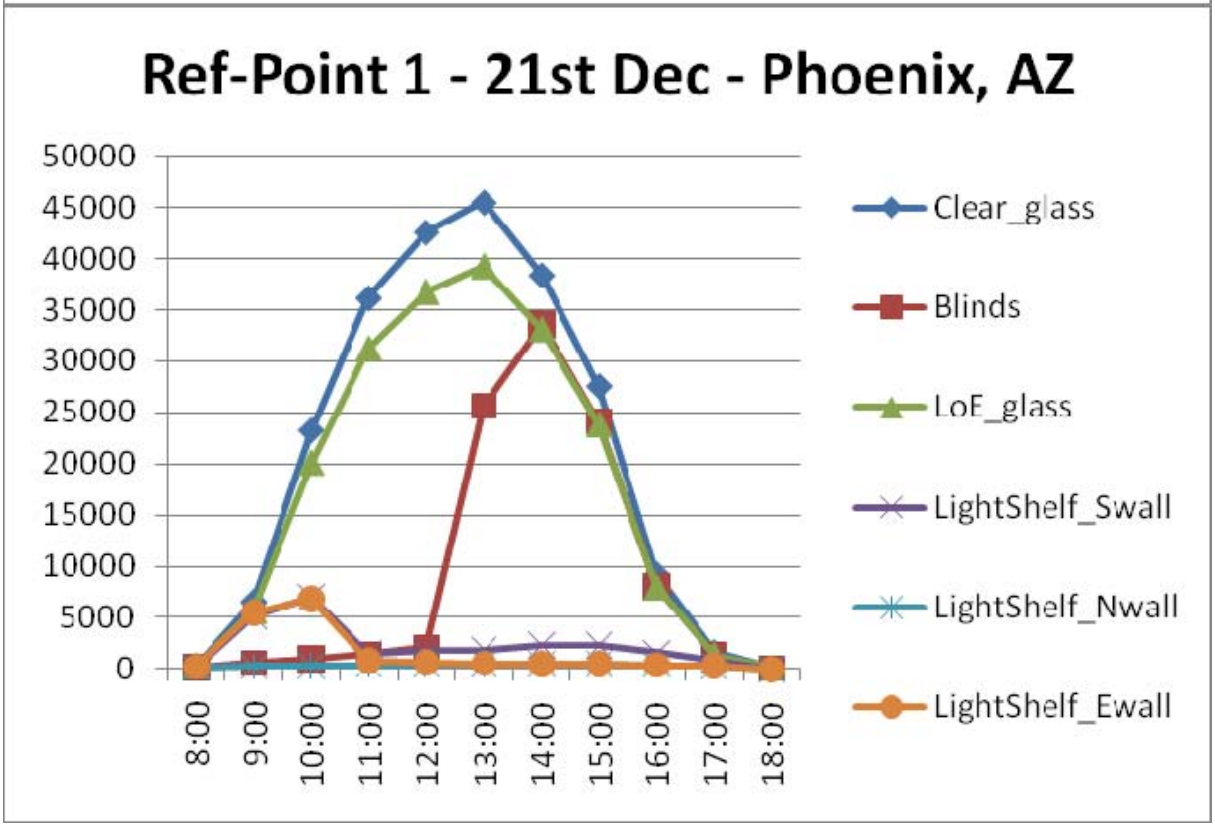
3500
3000
2500
2000
1500
1000
500
0
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
Clear_glass
Blinds
LoE_glass
LightShelf_Swall
LightShelf_Nwall
LightShelf_Ewall


Ref-Point 1 - 21st Dec - Phoenix, AZ
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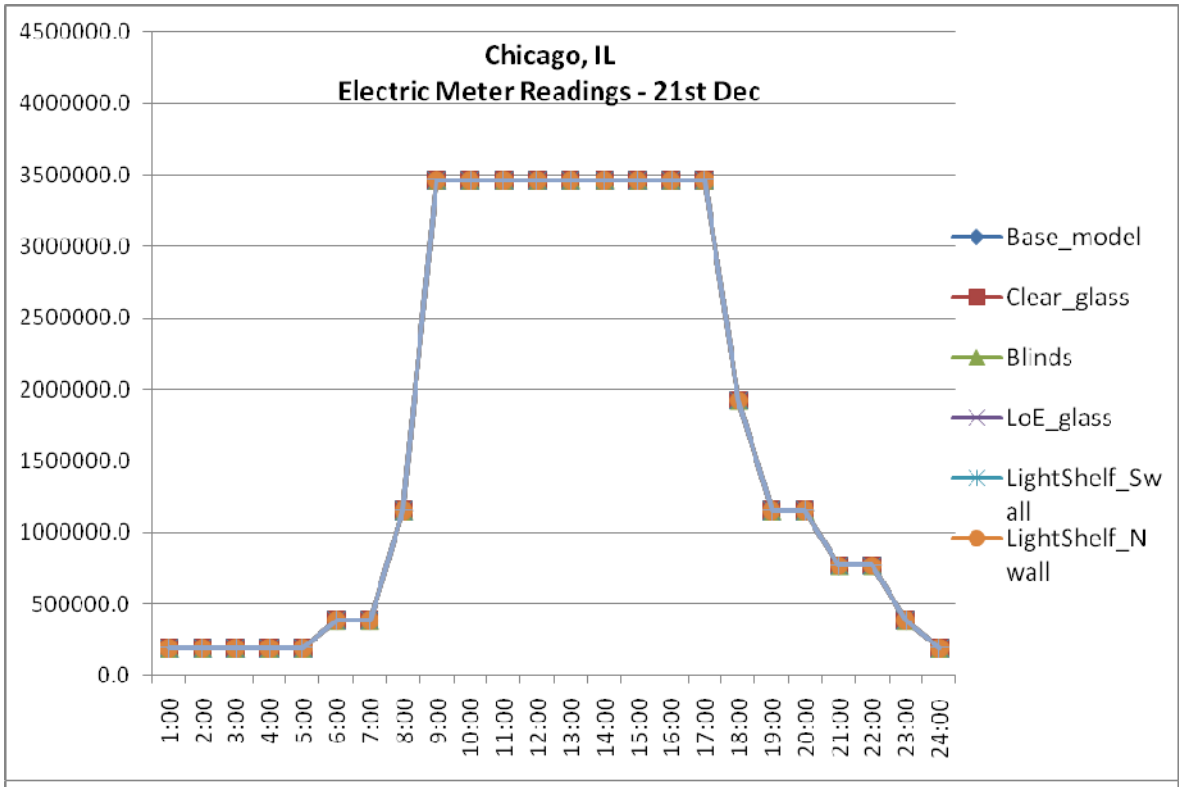
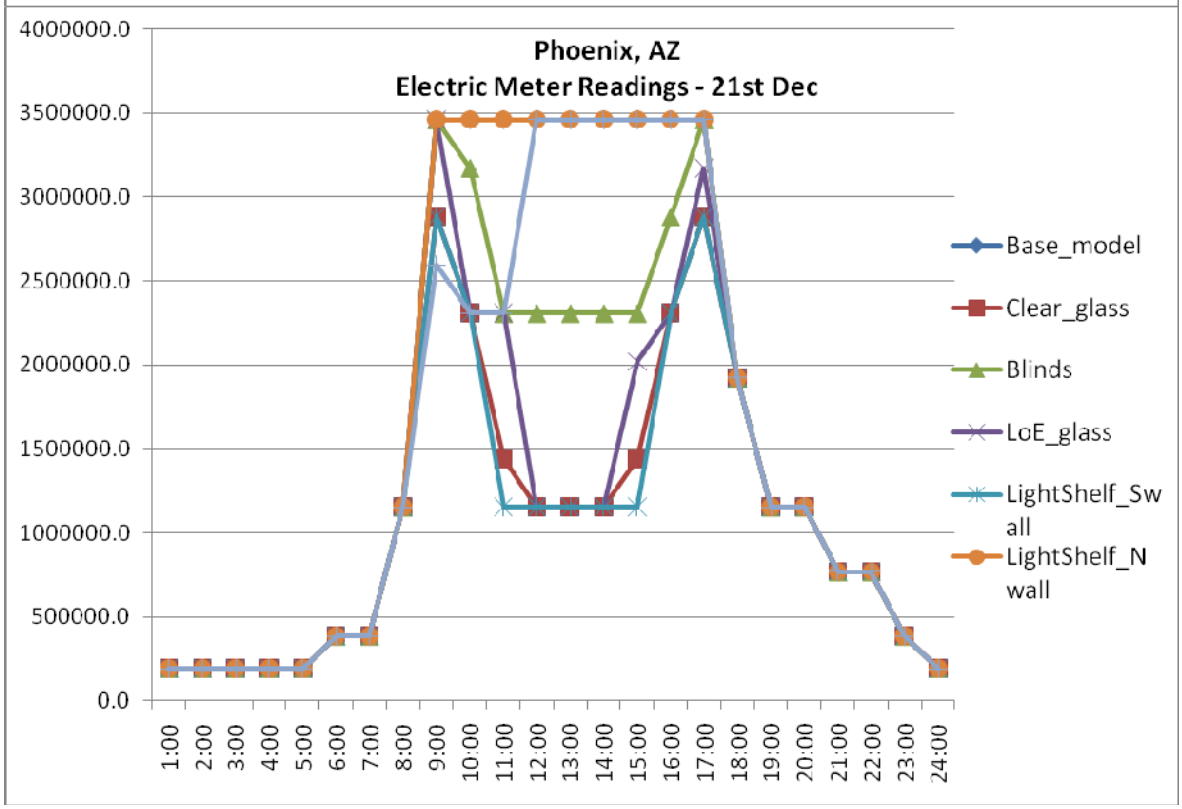
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
Clear_glass
Blinds
LoE_glass
LightShelf_Swall
LightShelf_Nwall
LightShelf_Ewall

4. ELECTRIC METER READINGS COMPARISON





5. ILLUMINANCE MAP AND DAYLIGHT FACTOR MAP

Image showing Illuminance Map Outputs for simulation with Low-E Glass at Chicago on March 21.

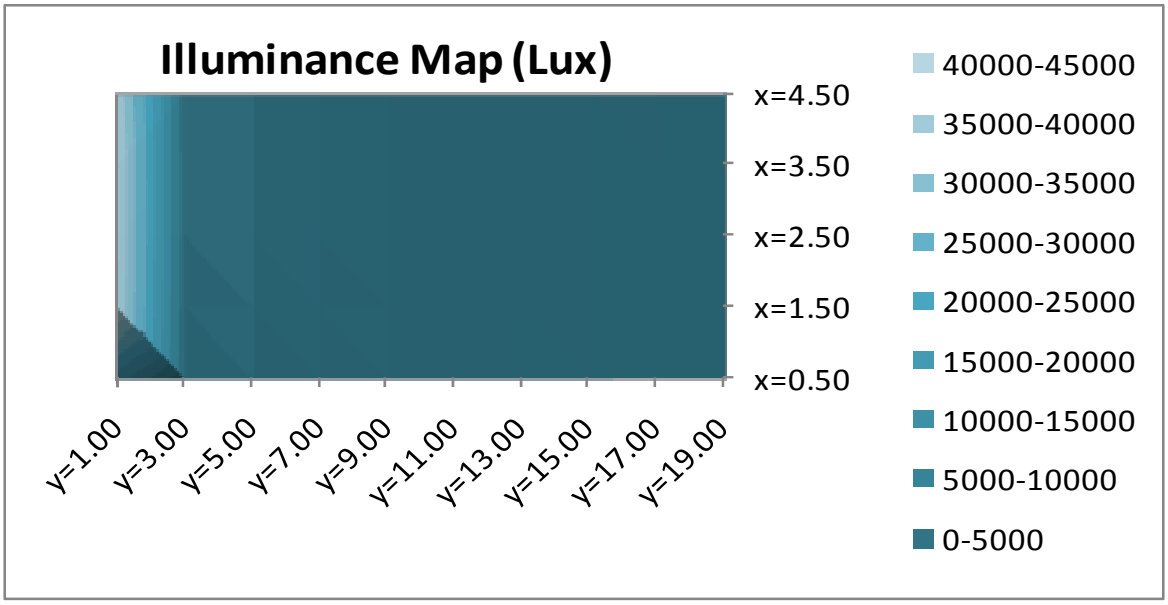
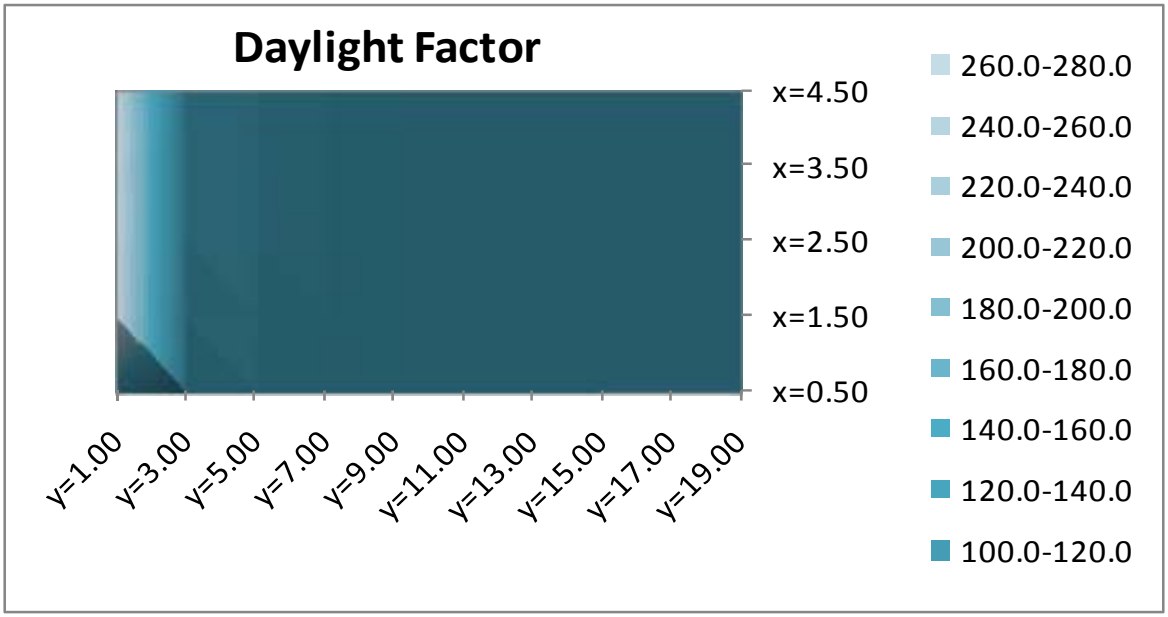


Image showing Daylight Factor Map for simulation with Low-E Glass at Chicago on March 21.



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