Berkeley Lab

California Public Interest Energy Research (PIER)

U.S. Department of Energy

Radiance Related Activities at LBNL

Andrew McNeil
Building Technologies Department
Lawrence Berkeley National Laboratory

Eleanor Lee, Stephen Selkowitz, Joseph Klems, Robert Clear, Dariush Arasteh, Mike Rubin, Phil Haves, Michael Wetter, Jacob Jonssen, Tianzhen Hong, Christian Kohler, Robin Mitchell, Mehry Yazdanian, Kyle Konis

Goals

1. Enable accurate annual assessments of innovative daylighting technologies
2. Enable users of all abilities to simulate complex fenestration with Radiance

Outline

Part 1: Overview of Radiance related activities at LBNL

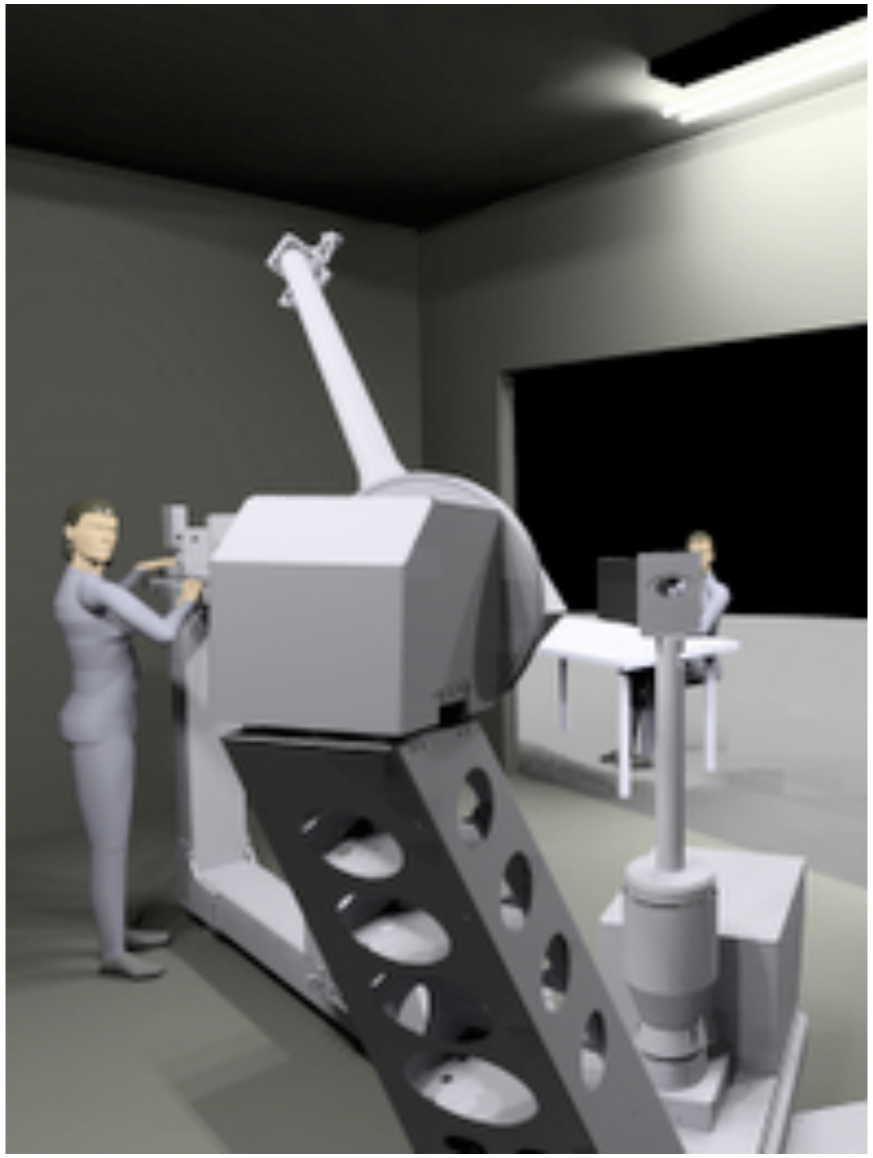
Part 2: Applying new Radiance tools to perform an annual assessments of complex fenestration systems

Radiance Related Activities At LBNL

- Optical Measurements
- Window6 BSDF integration
- COMFEN - Radiance Integration
- Building Controls Virtual Test Bed (BCVTB)
- Increased Support of Radiance Community

Measurements of Optically Complex Fenestration Layers

- Measured ~200 devices!
- Working on a way to make data available (some kind of robust database).

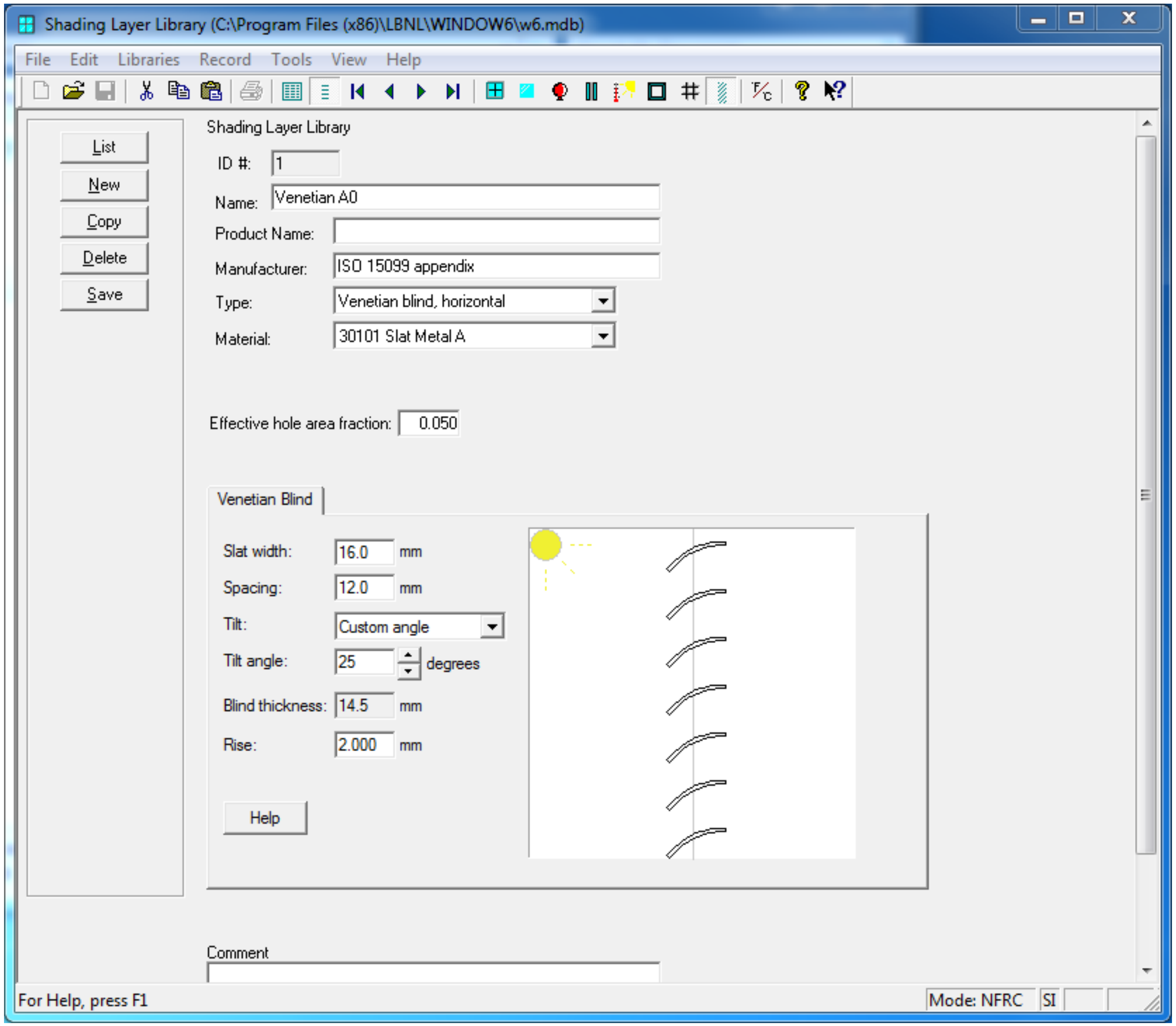


pab-opto goniophotometer

Window6

- Includes non-specular window components
- Writes a BSDF file for glazing + shading
- Working to include MGF data for mkillum renderings.

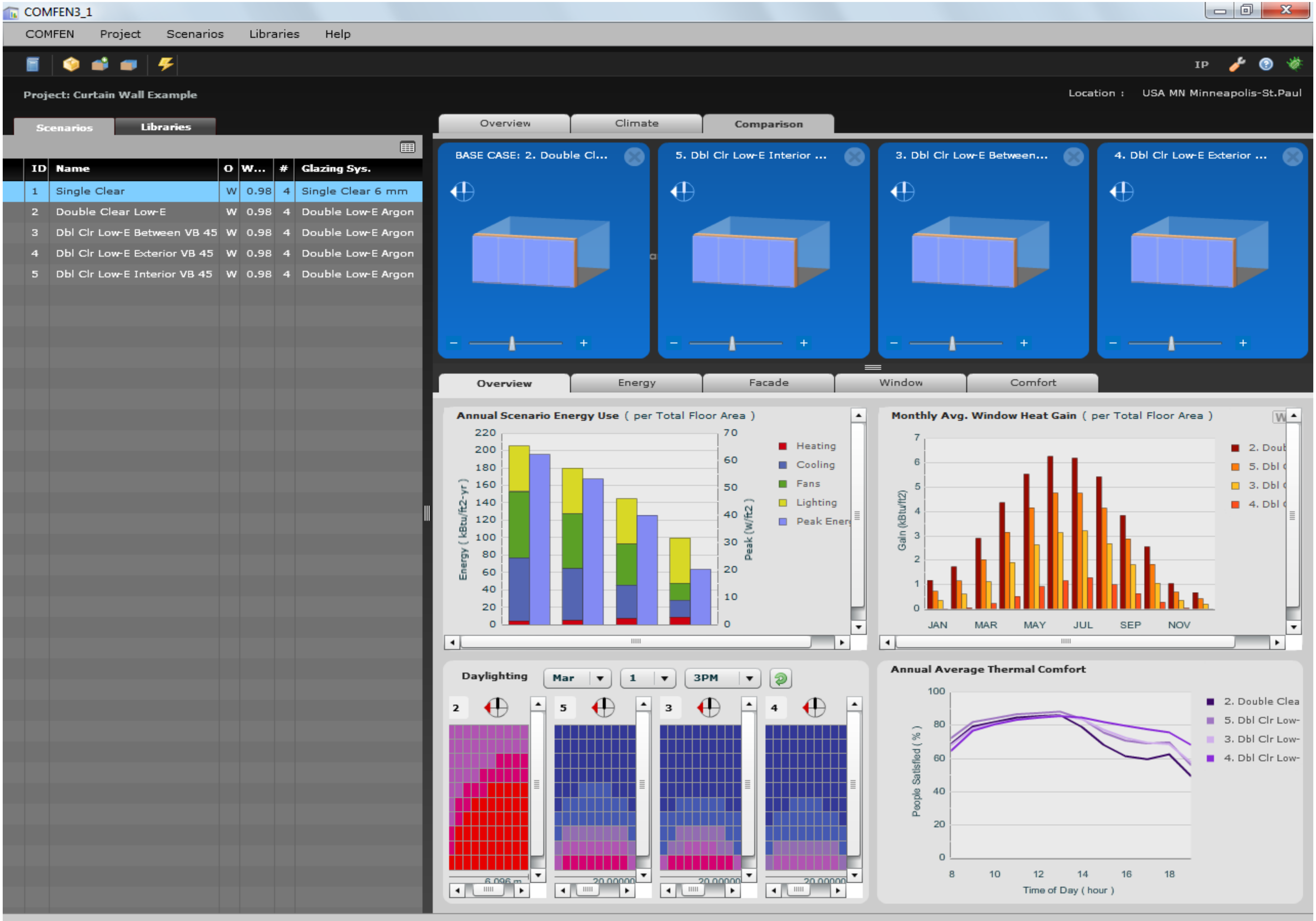
Window 6

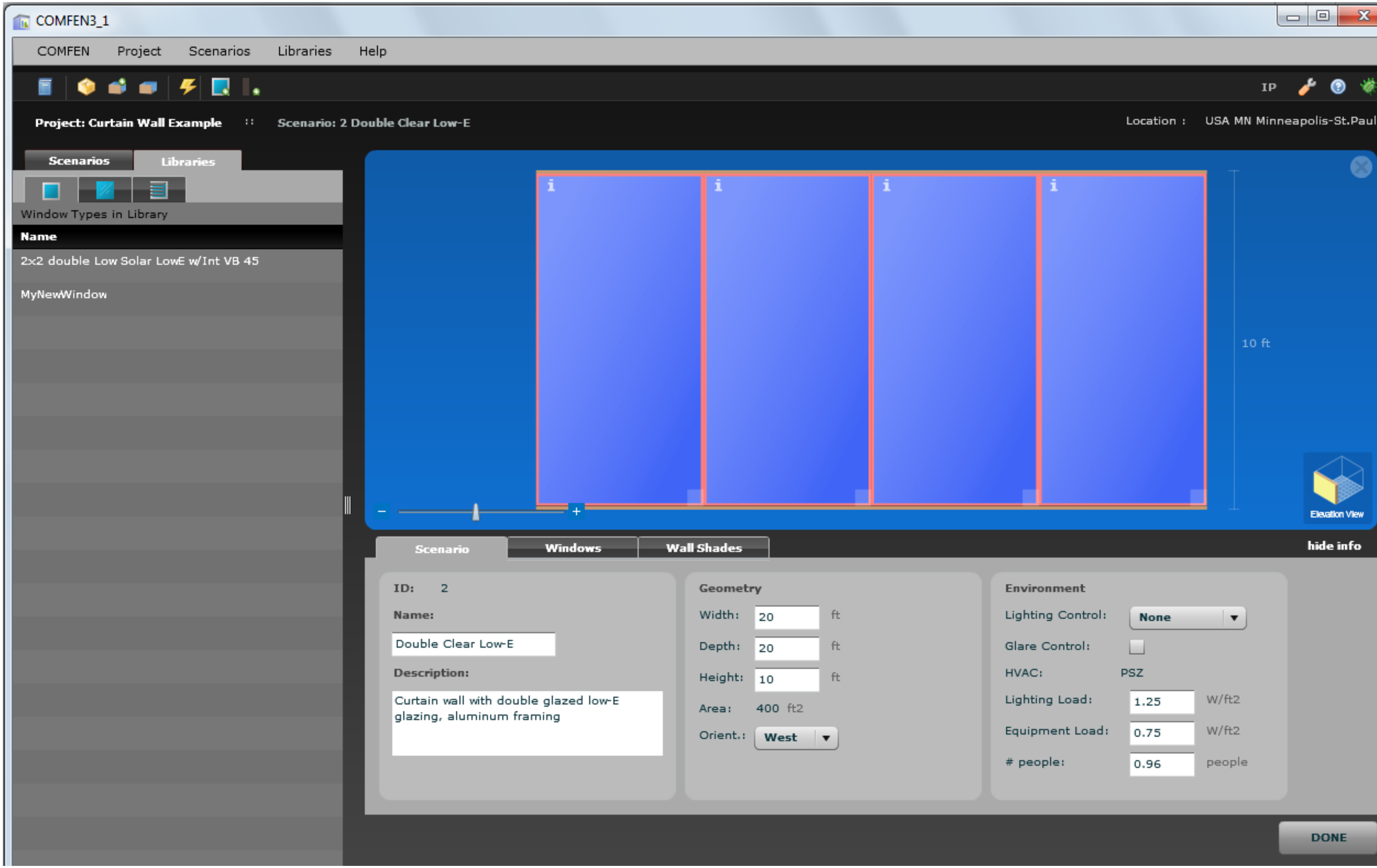


- Venetian Blind
- Homogeneous Diffusing Shade
- Woven Shade
- Frit
- BSDF import

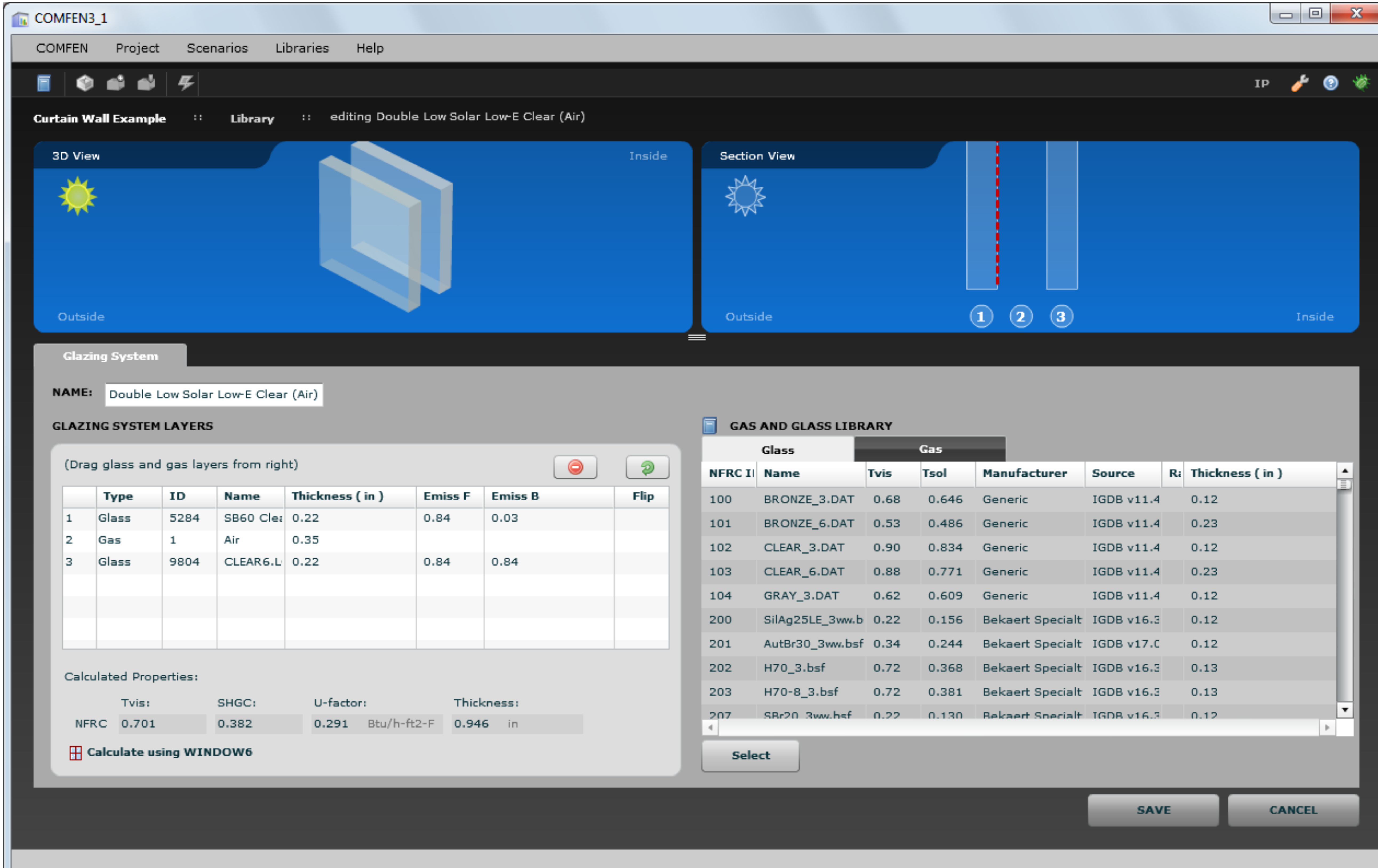
COMFEN

- Commercial Fenestration Design Tool for conceptual/ preliminary design
- For architects, engineers, building industry professionals
- Provides comparative results between façade design options and their impact on the perimeter zone
- Multiple glazing and shading options on each façade.
- EnergyPlus simulation engine
- **Not** whole building analysis.

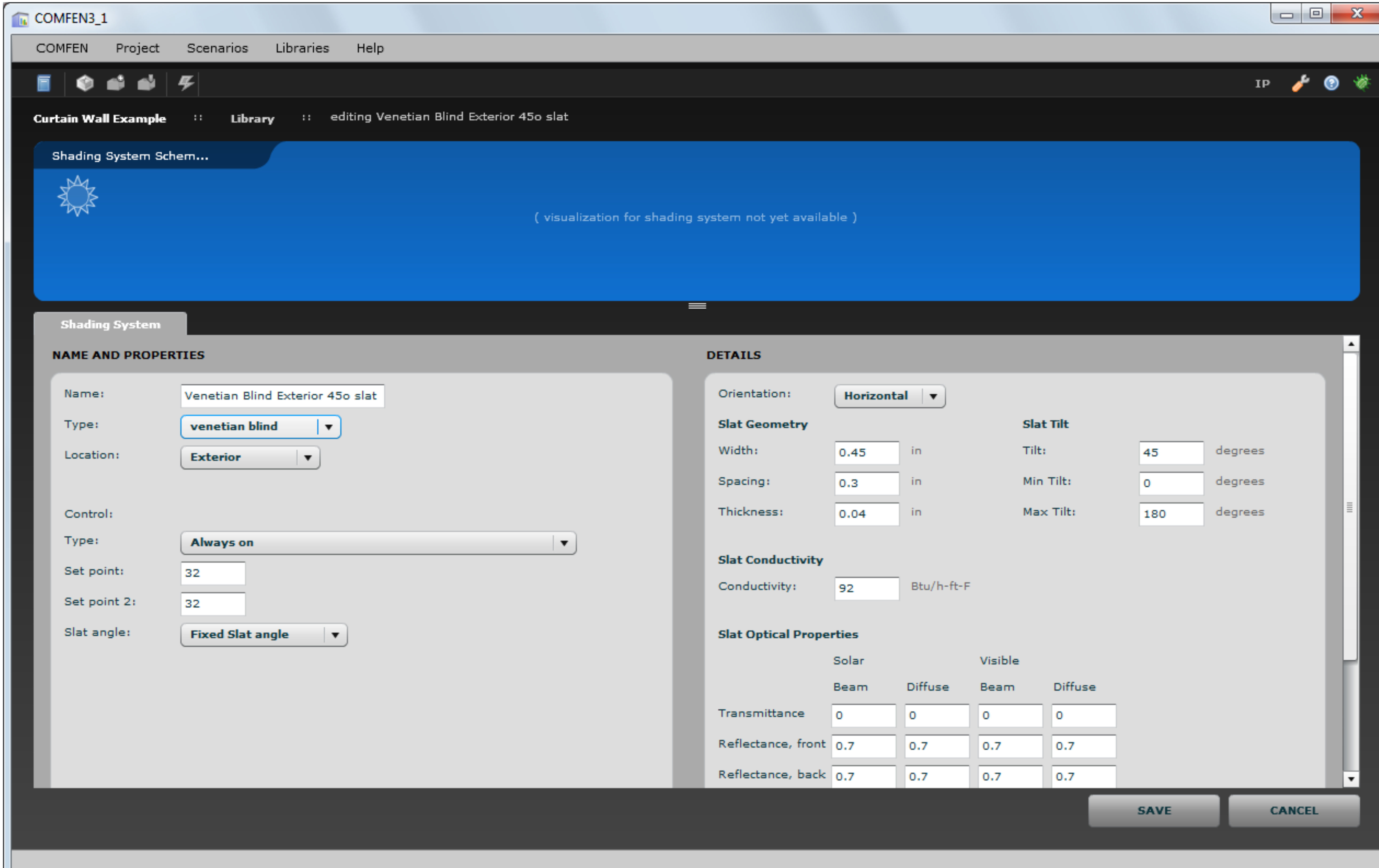

COMFEN3_1
COMFEN
Project
Scenarios
Libraries
Help
IP
Project: Curtain Wall Example
Location : USA MN Minneapolis-St.Paul
Scenarios
Libraries
ID
Name
O
W...
#
Glazing Sys.
1 Single Clear W 0.98 4 Single Clear 6 mm
2 Double Clear Low-E W 0.98 4 Double Low-E Argon
3 Dbl Clr Low-E Between VB 45 W 0.98 4 Double Low-E Argon
4 Dbl Clr Low-E Exterior VB 45 W 0.98 4 Double Low-E Argon
5 Dbl Clr Low-E Interior VB 45 W 0.98 4 Double Low-E Argon
Overview
Climate
Comparison
BASE CASE: 2. Double Cl...
5. Dbl Clr Low-E Interior ...
3. Dbl Clr Low-E Between...
4. Dbl Clr Low-E Exterior ...
Overview
Energy
Facade
Window
Comfort
Annual Scenario Energy Use (per Total Floor Area)
Energy (kBtu/ft2-yr)
Peak (W/ft2)
Heating
Cooling
Fans
Lighting
Peak Energ
Monthly Avg. Window Heat Gain (per Total Floor Area)
Gain (kBtu/ft2)
JAN
MAR
MAY
JUL
SEP
NOV
2. Doub
5. Dbl
3. Dbl
4. Dbl
Daylighting
Mar
1
3PM
Annual Average Thermal Comfort
People Satisfied (%)
Time of Day (hour)
2. Double Clea
5. Dbl Clr Low-
3. Dbl Clr Low-
4. Dbl Clr Low-


COMFEN3_1
COMFEN Project Scenarios Libraries Help
IP
Project: Curtain Wall Example
Scenario: 2 Double Clear Low-E
Location : USA MN Minneapolis-St.Paul
Scenarios
Libraries
Window Types in Library
Name
2x2 double Low Solar LowE w/Int VB 45
MyNewWindow
10 ft
Elevation View
Scenario
Windows
Wall Shades
hide info
ID: 2
Name:
Double Clear Low-E
Description:
Curtain wall with double glazed low-E glazing, aluminum framing
Geometry
Width: 20 ft
Depth: 20 ft
Height: 10 ft
Area: 400 ft2
Orient.: West
Environment
Lighting Control: None
Glare Control:
HVAC: PSZ
Lighting Load: 1.25 W/ft2
Equipment Load: 0.75 W/ft2
people: 0.96 people
DONE

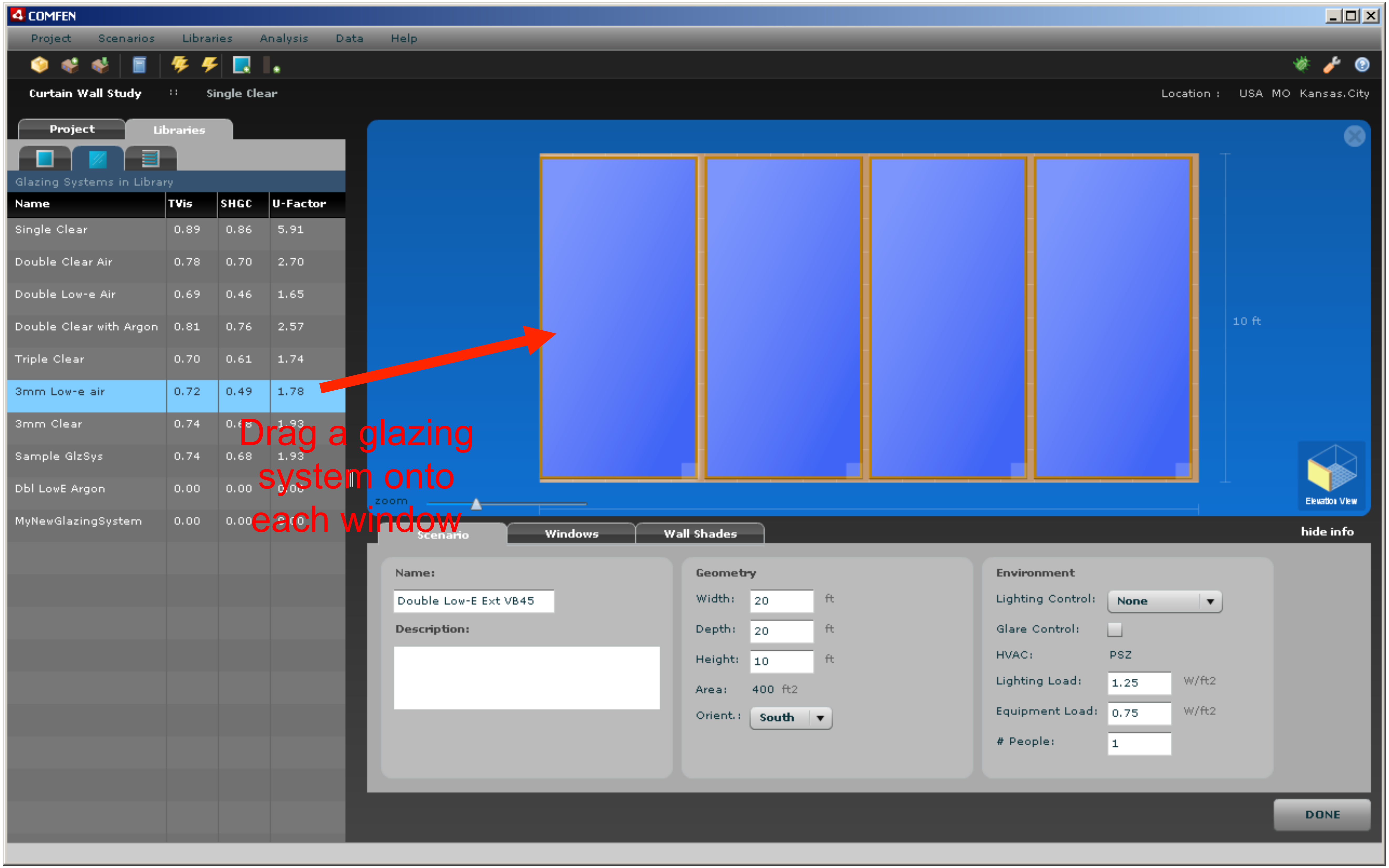
Define a glazing system for a window (glass + gas components).



Include shades, blinds, drapes, external shading devices, etc.



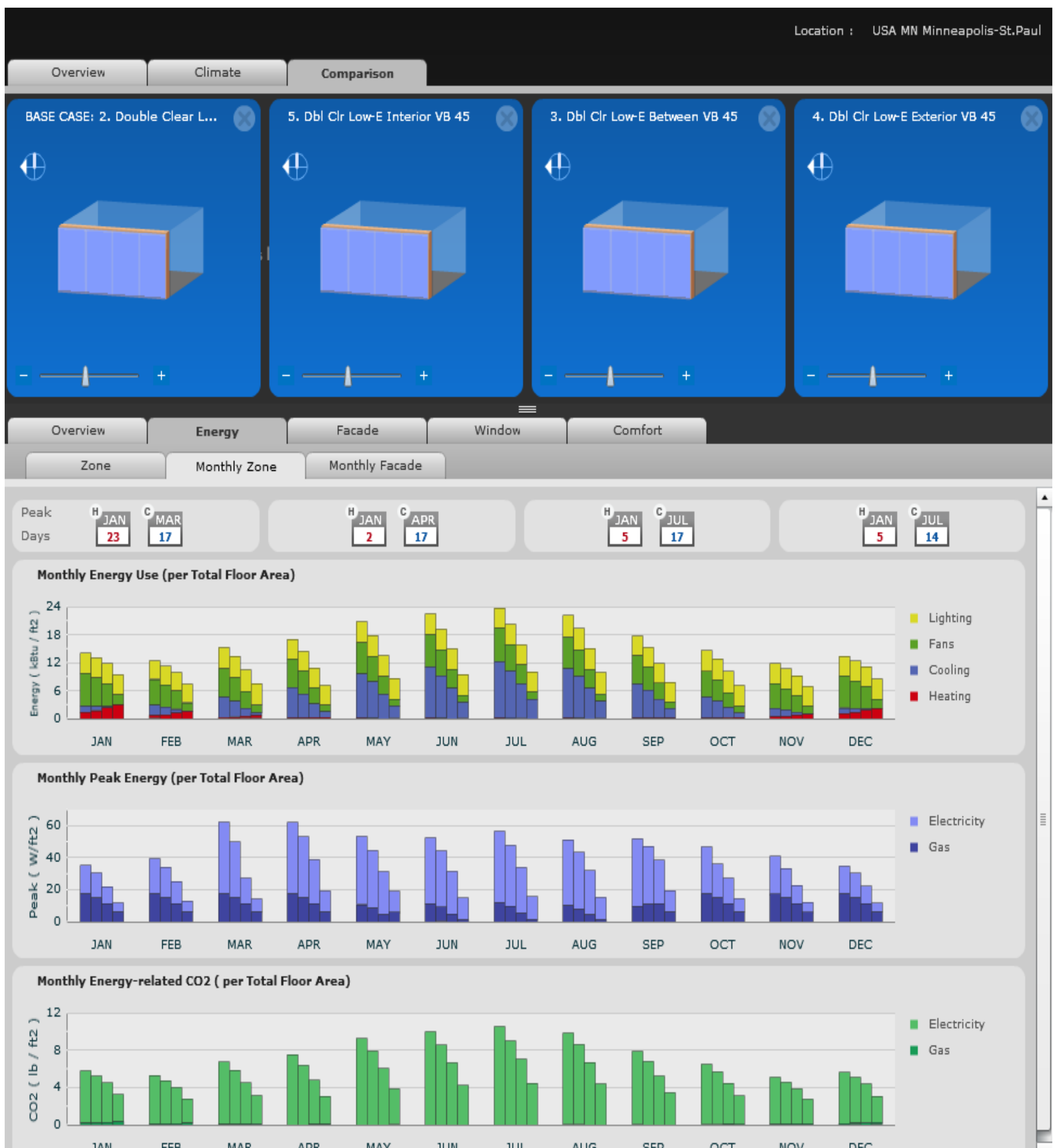
Assign glazing systems to windows in model.



COMFEN Annual Energy Results

Monthly Zone Results

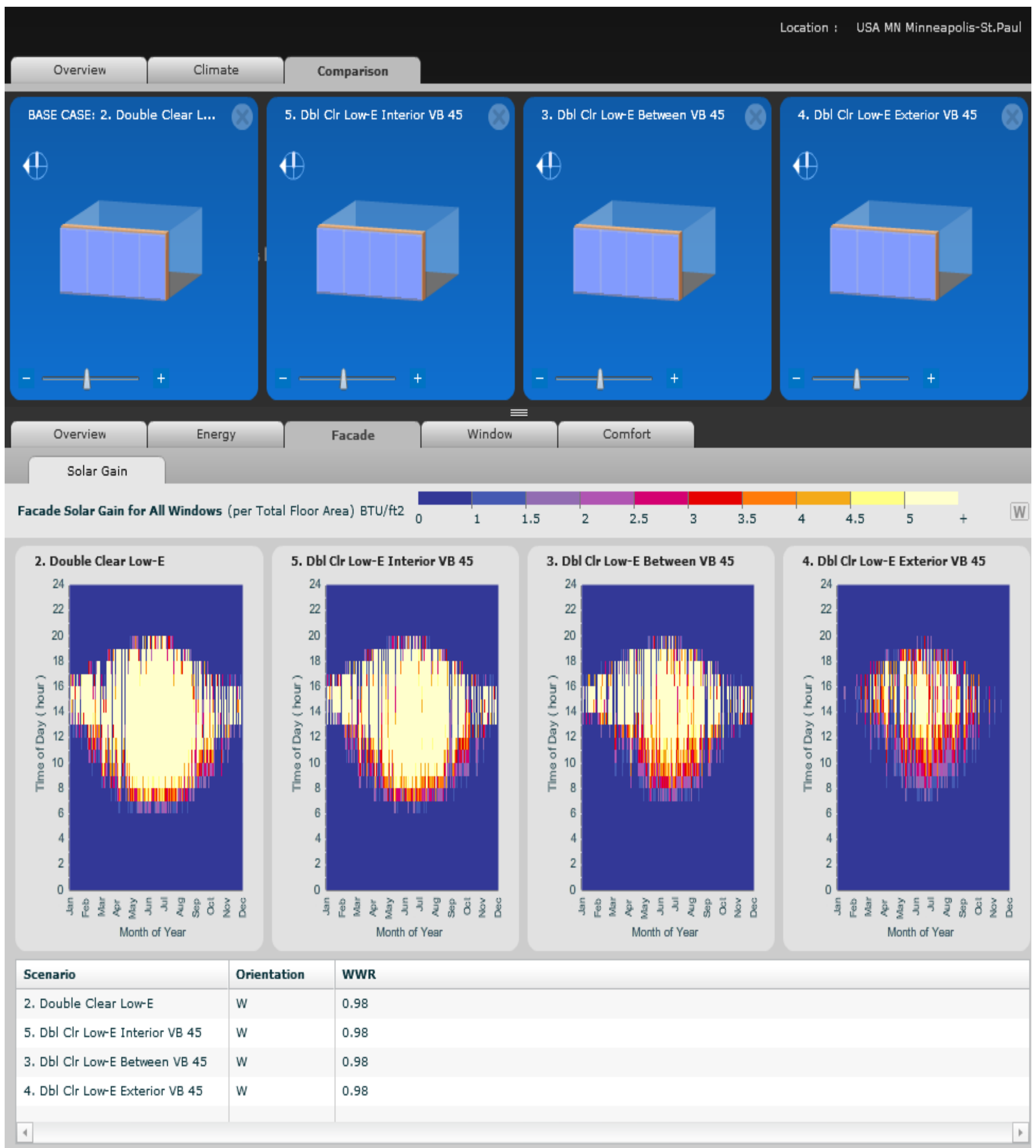
Energy-use + Peak



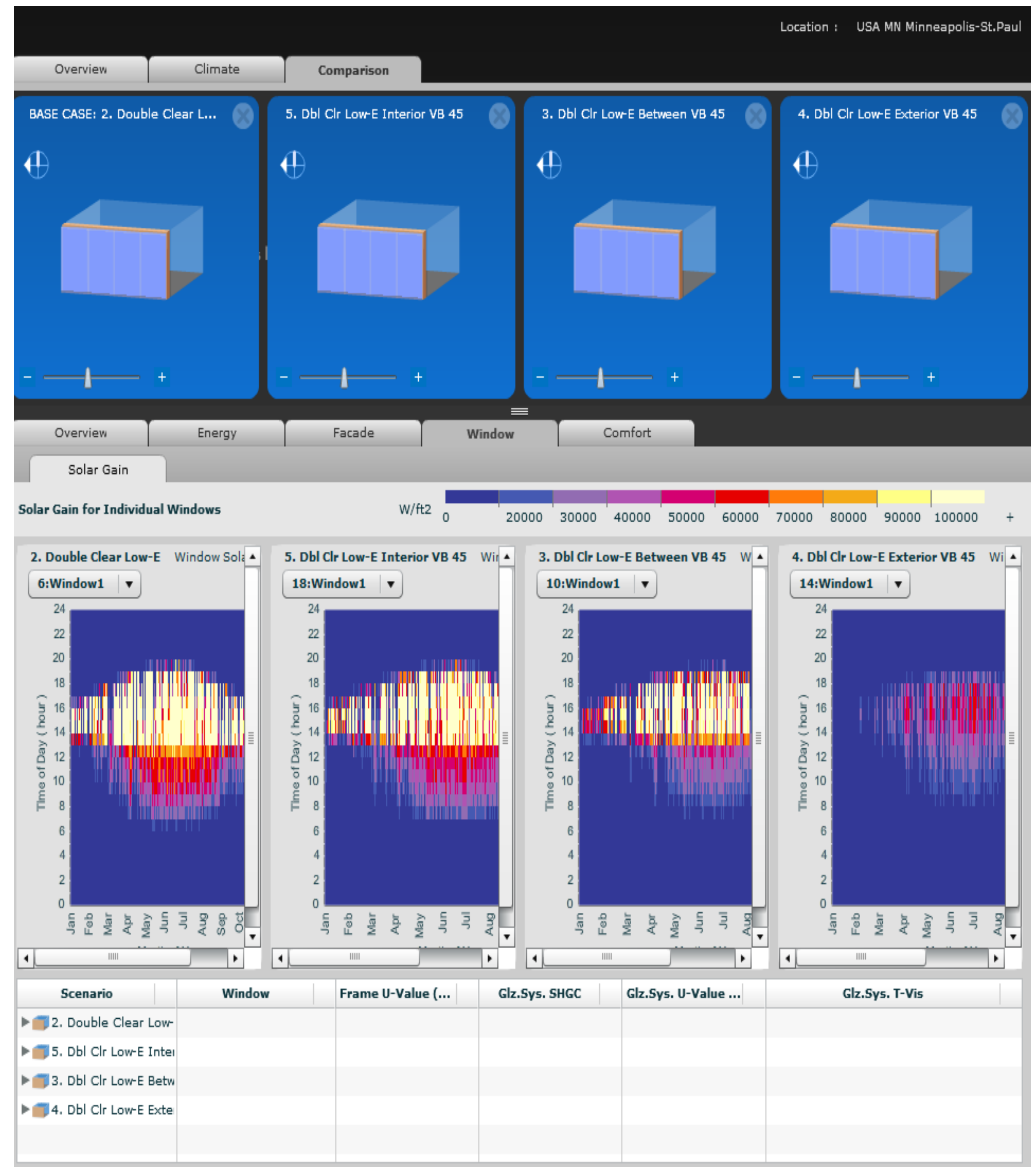
Facade-energy (load)

Solar Gain

Facade Gain



Window Gain



Radiance Integration with COMFEN

- Clean & Easy Radiance integration for modeling complex fenestration using BSDF.
  - Stage One - static renderings using mkillum I+ option with BSDF file (October 2010)
  - Stage Two - more realistic renderings using mkillum I- option and using detailed geometry incorporated in BSDF file.
  - Stage Three - Annual Daylight Calculations with Radiance?

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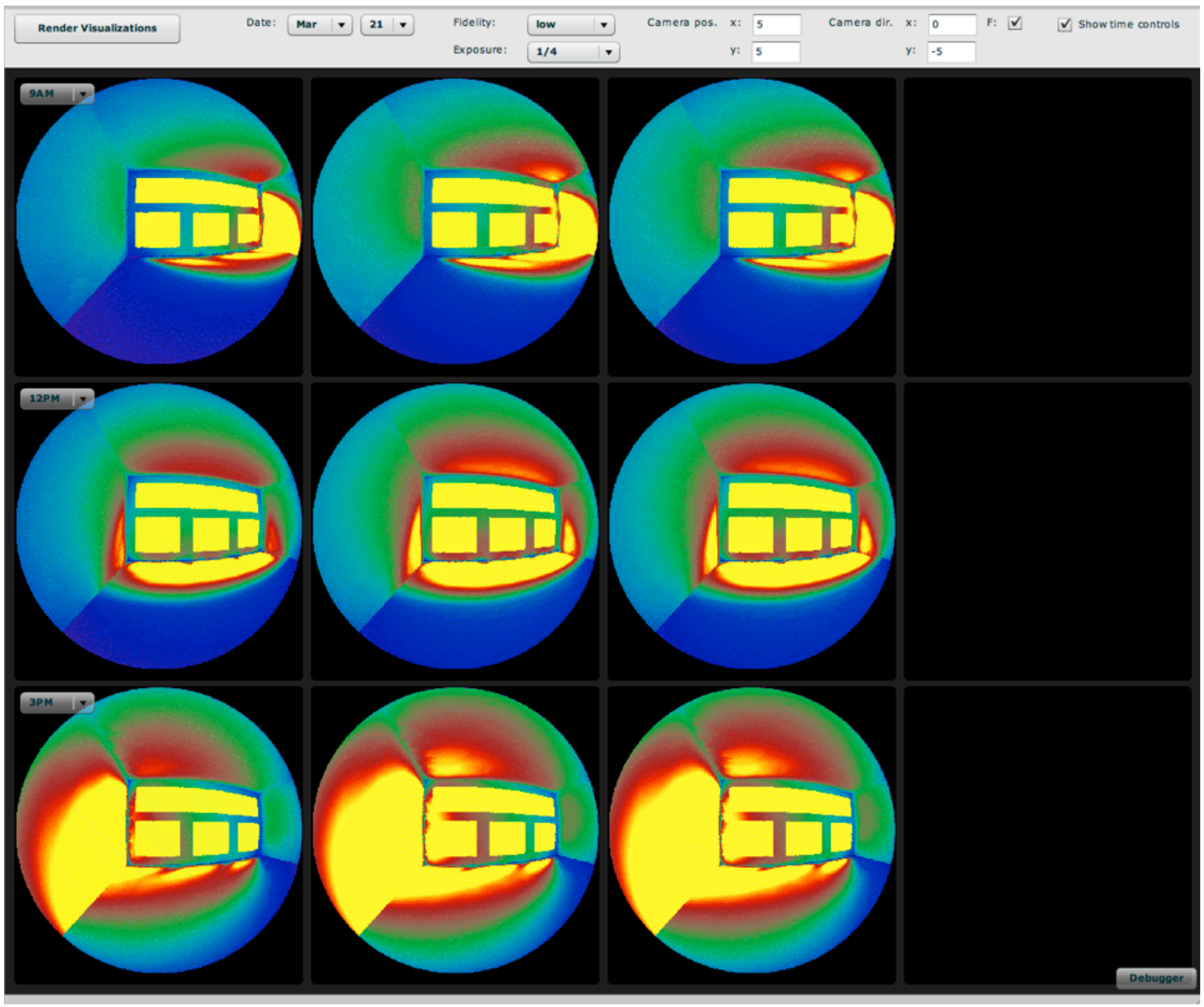
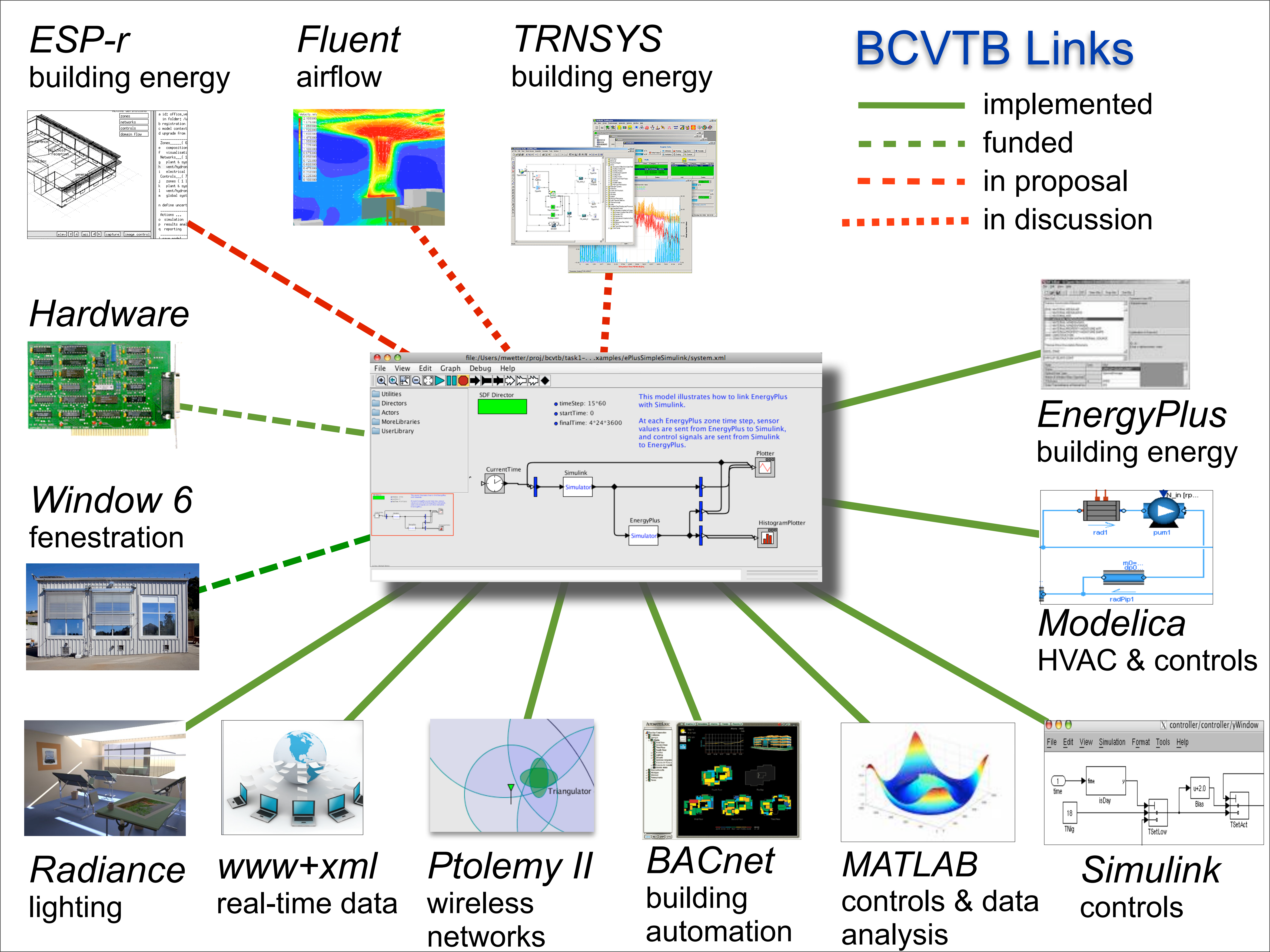
Radiance Integration with COMFEN



Building Controls Virtual Test Bed (BCVTB)

- allows users to easily connect simulation programs & share data between programs.
- provides an opportunity to simulate interaction between building systems
- gives the ability to test control semantics

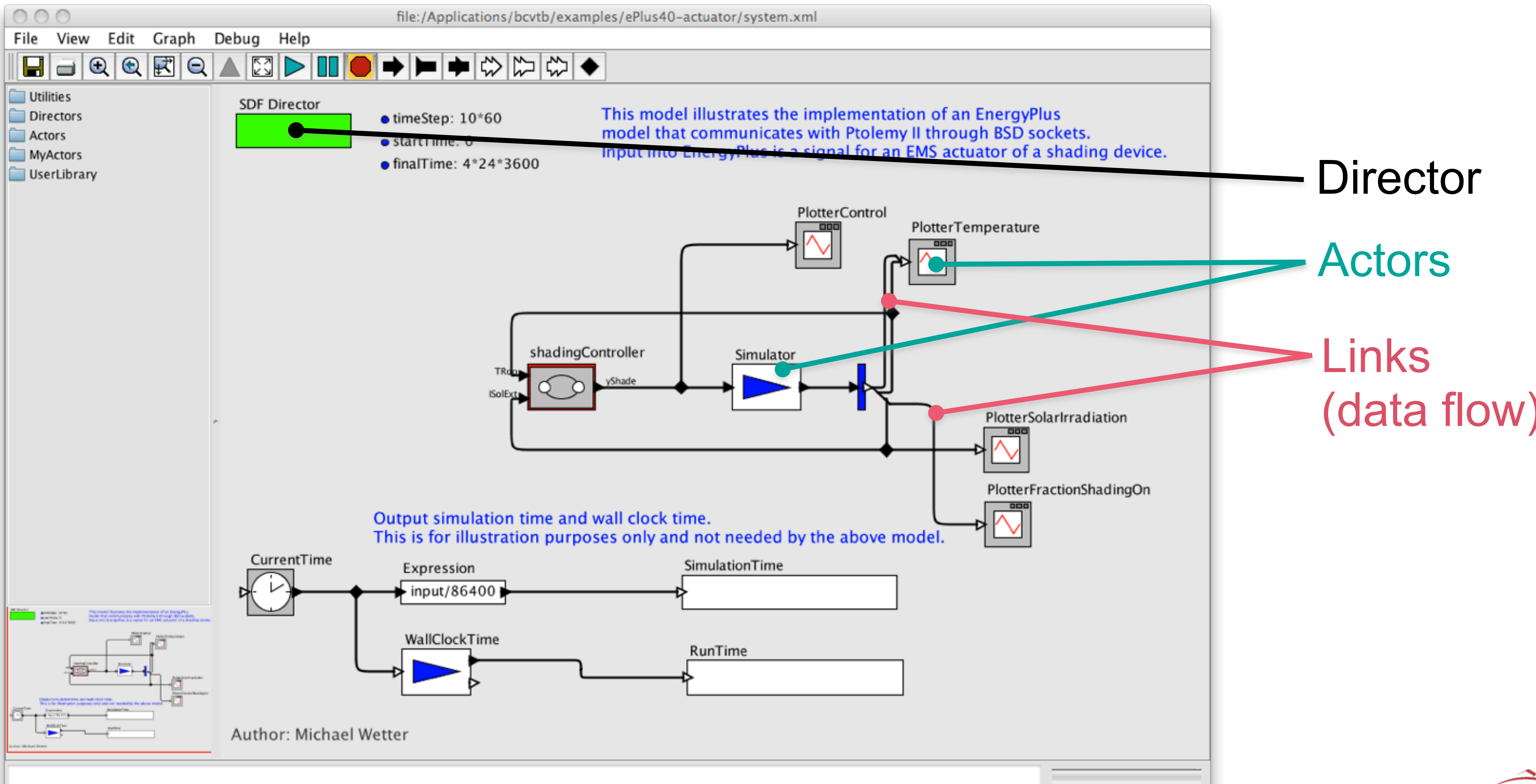


BCVTB Links
implemented
funded
in proposal
in discussion
ESP-r
building energy
Fluent
airflow
TRNSYS
building energy
Hardware
Window 6
fenestration
EnergyPlus
building energy
Modelica
HVAC & controls
Radiance
lighting
www+xml
real-time data
Ptolemy II
wireless
networks
BACnet
building
automation
MATLAB
controls & data
analysis
Simulink
controls
file:/Users/mwetter/proj/bcvtb/task1-. . .xamples/ePlusSimpleSimulink/system.xml
File View Edit Graph Debug Help
Utilities
Directors
Actors
MoreLibraries
UserLibrary
SDF Director
timeStep: 15*60
startTime: 0
finalTime: 4*24*3600
This model illustrates how to link EnergyPlus with Simulink.
At each EnergyPlus zone time step, sensor values are sent from EnergyPlus to Simulink, and control signals are sent from Simulink to EnergyPlus.
CurrentTime
Simulink
Simulator
EnergyPlus
Simulator
Plotter
HistogramPlotter
rad1
pum1
radPip1
Triangulator
controller/controller/yWindow
File Edit View Simulation Format Tools Help
time
isDay
TNig
TSetLow
Bias
TSetAct

BCVTB is

- Based on Ptolemy framework
- Actor-oriented framework for concurrent simulation
- UC Berkeley EECS department
- Java
- Has a graphical user interface - Vergil
- Open Source

BCVTB GUI


file:/Applications/bcvtb/examples/ePlus40-actuator/system.xml
File View Edit Graph Debug Help
Utilities
Directors
Actors
MyActors
UserLibrary
SDF Director
timeStep: 10*60
startTime: 0
finalTime: 4*24*3600
This model illustrates the implementation of an EnergyPlus
model that communicates with Ptolemy II through BSD sockets.
Input into EnergyPlus is a signal for an EMS actuator of a shading device.
Director
PlotterControl
PlotterTemperature
Actors
shadingController
yShade
Simulator
Links
(data flow)
PlotterSolarIrradiation
PlotterFractionShadingOn
Output simulation time and wall clock time.
This is for illustration purposes only and not needed by the above model.
CurrentTime
Expression
input/86400
SimulationTime
WallClockTime
RunTime
Author: Michael Wetter

Support Radiance User Community

- We're working to secure funding for a new website.
- We want to host Radiance Workshop in 2011

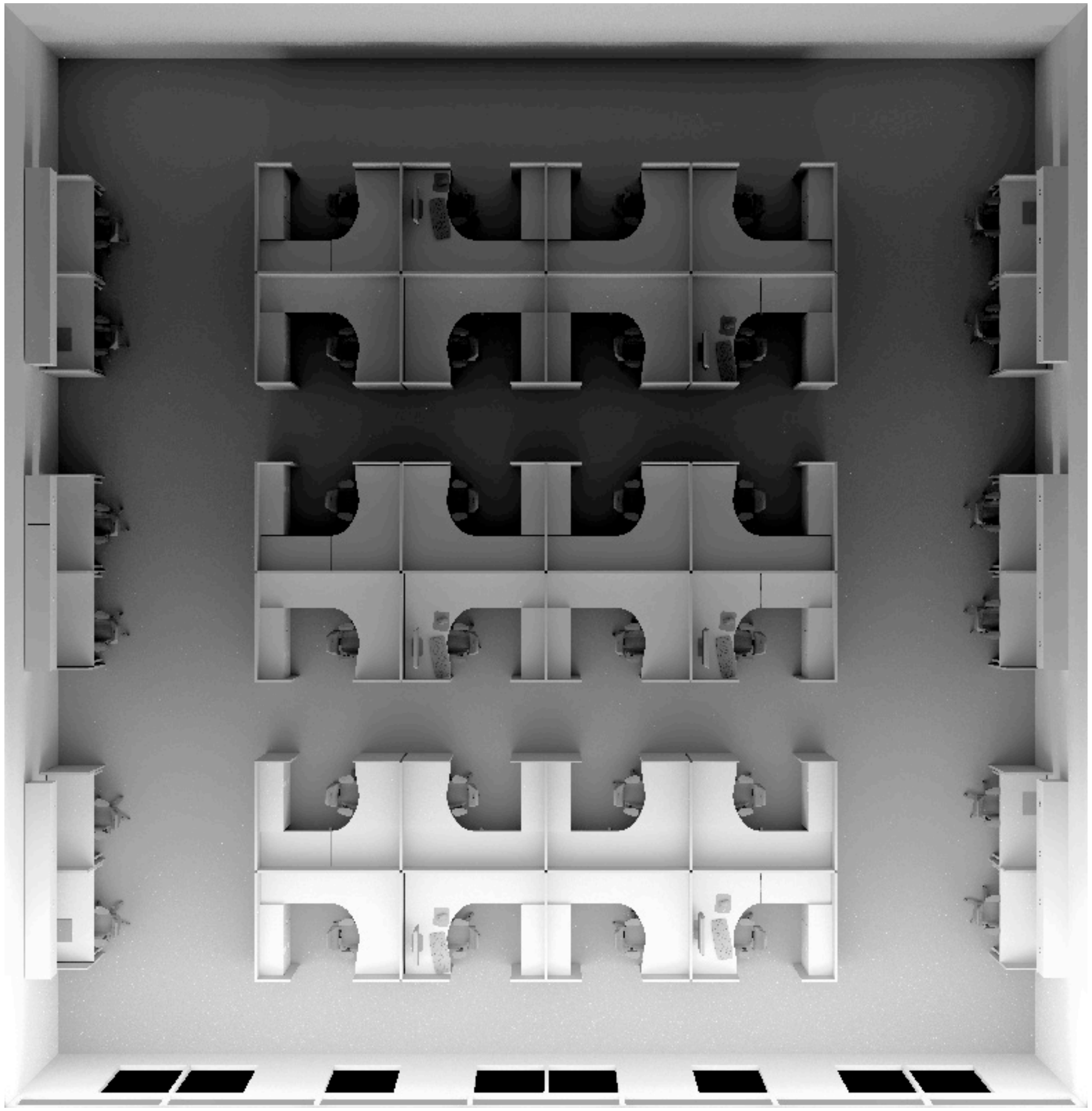
Website Wish List

- Organized process for pre-release testing. (volunteers for platform testing needed!)
- Anonymous CVS access (via mirror or git)
- Organized library of tutorials, references and documentation.
- Material repository with some sort of trusted user rating system.
- Improved browsing and searching of the mailing list (forum with subscription)?
- Anything else?

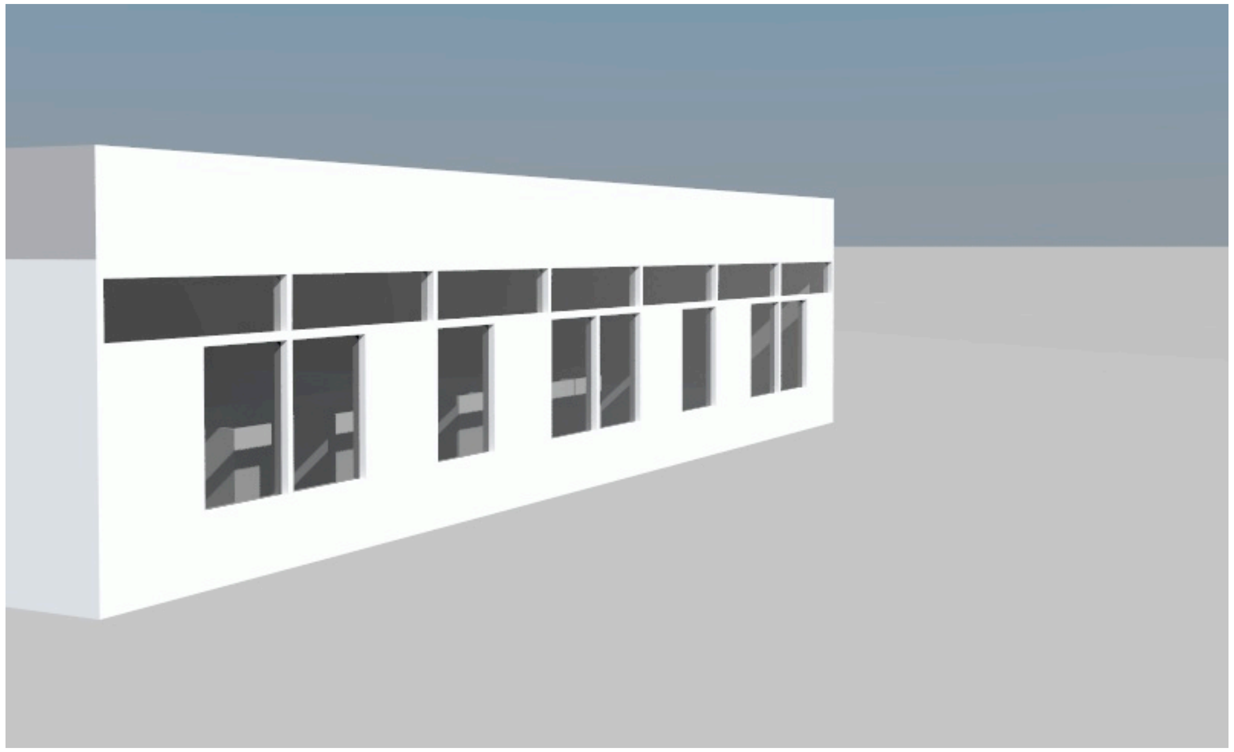
Annual Assessment of Optically Complex Fenestration

Applying new Radiance BSDF tools

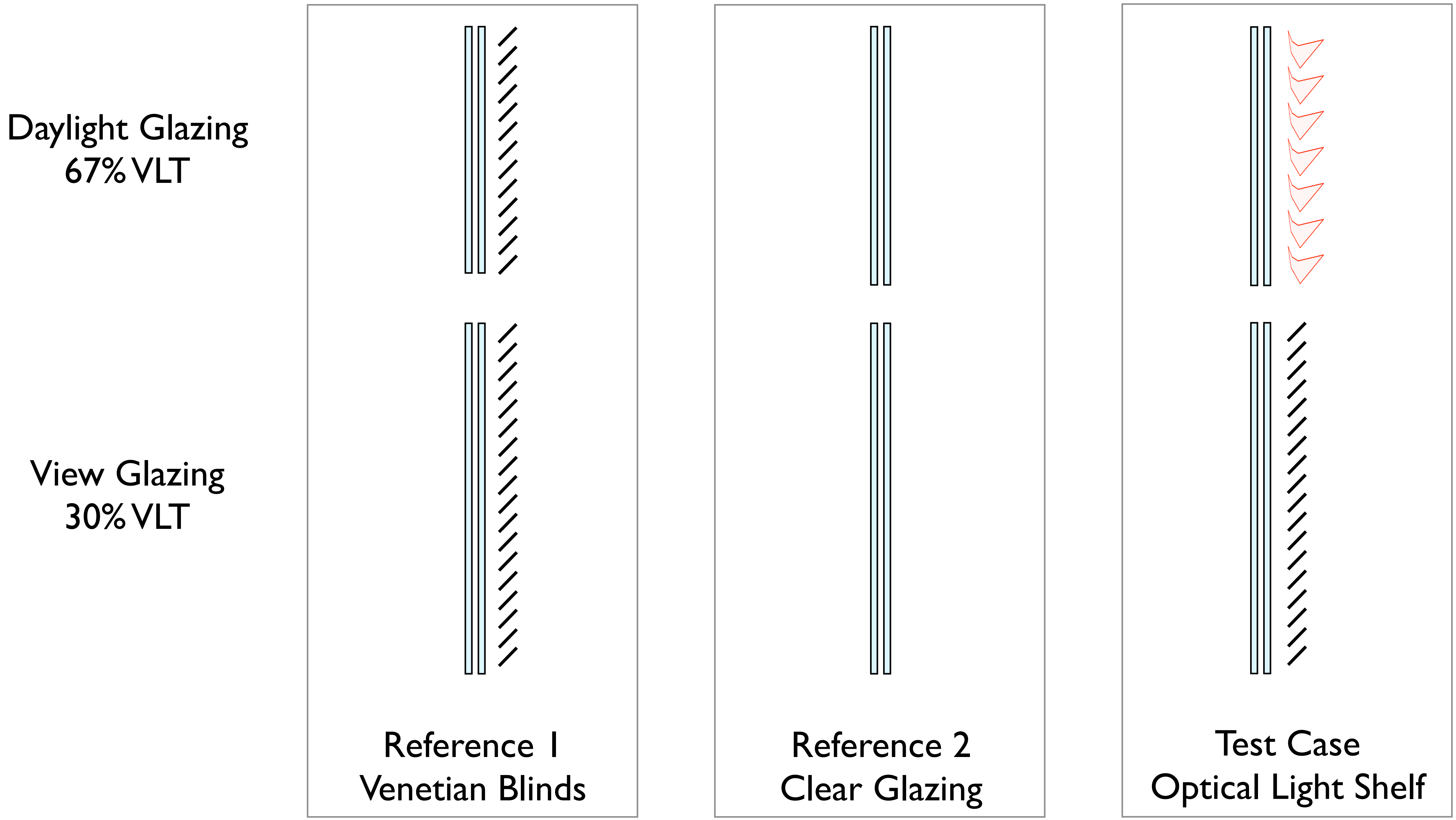
Open Plan Office Space



- The space is extra deep for testing daylight redirection systems
- The fenestration consists of upper daylight windows and lower view windows



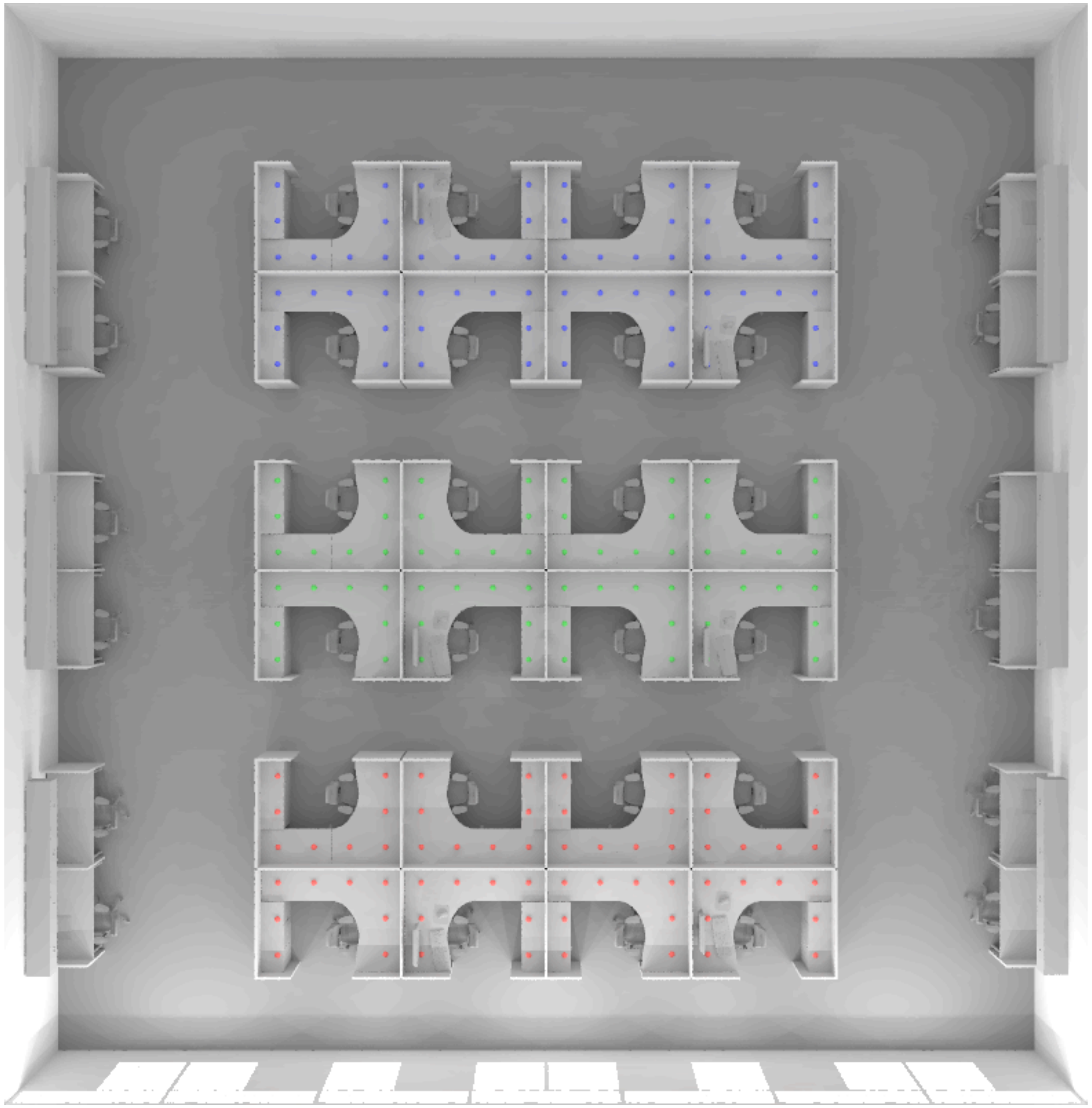
Fenestration Systems



View Matrices

- Illuminance sensor points for daylight sufficiency
- Luminance renderings for visual comfort

Illuminance View Matrix



Zone 3

Zone 2

Zone 1

Illuminance View Matrix

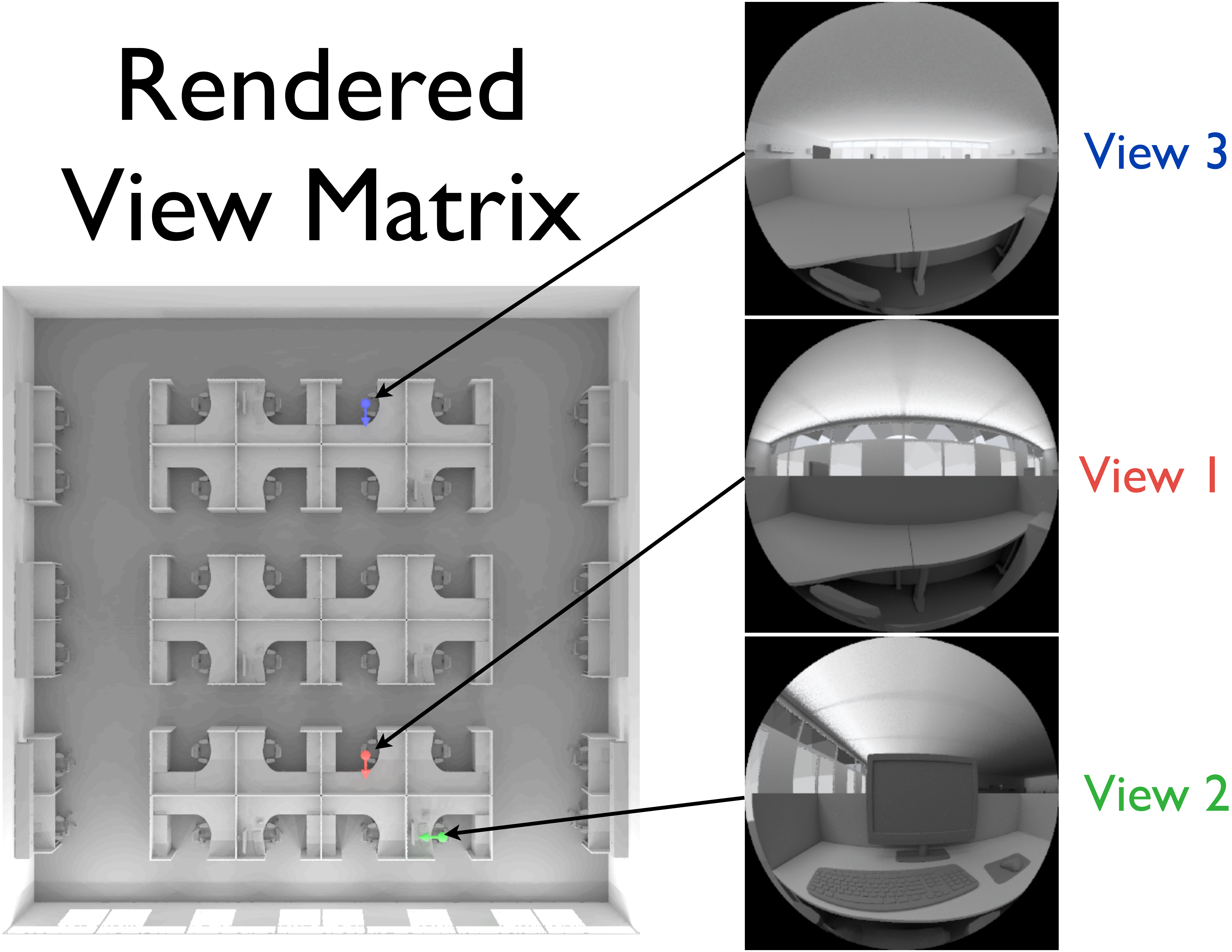
rtcontrib settings	
-ab	5
-ad	10000
-as	0
-aa	0
-lw	1.00E-12
-ds	0.06

Computation Time:

1.25 CPU*Hours

(1) 2.66 GHz Processor

Rendered View Matrix



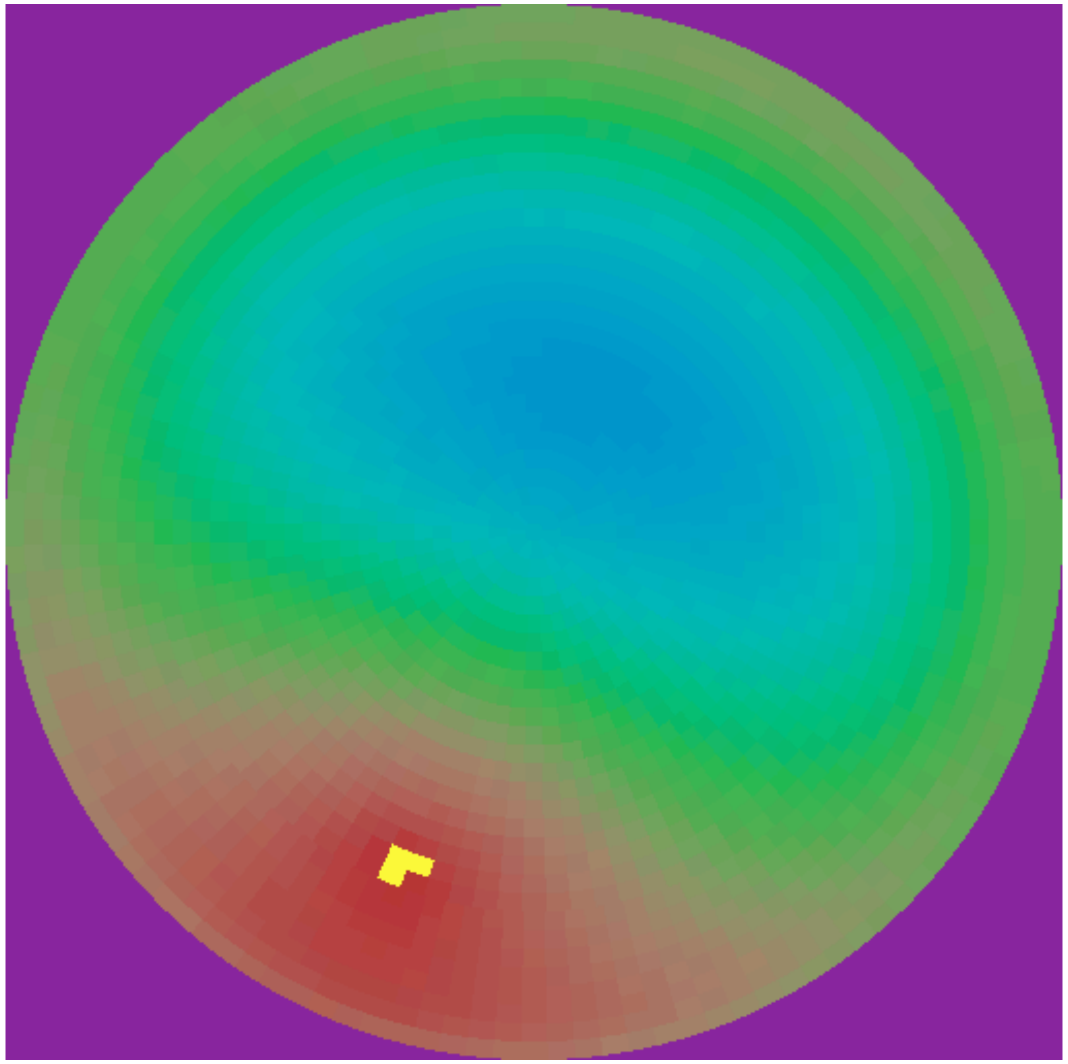
Rendered View Matrix

rtcontrib settings	
-ab	5
-ad	10000
-as	0
-aa	0
-lw	1.00E-12
-ds	0.06

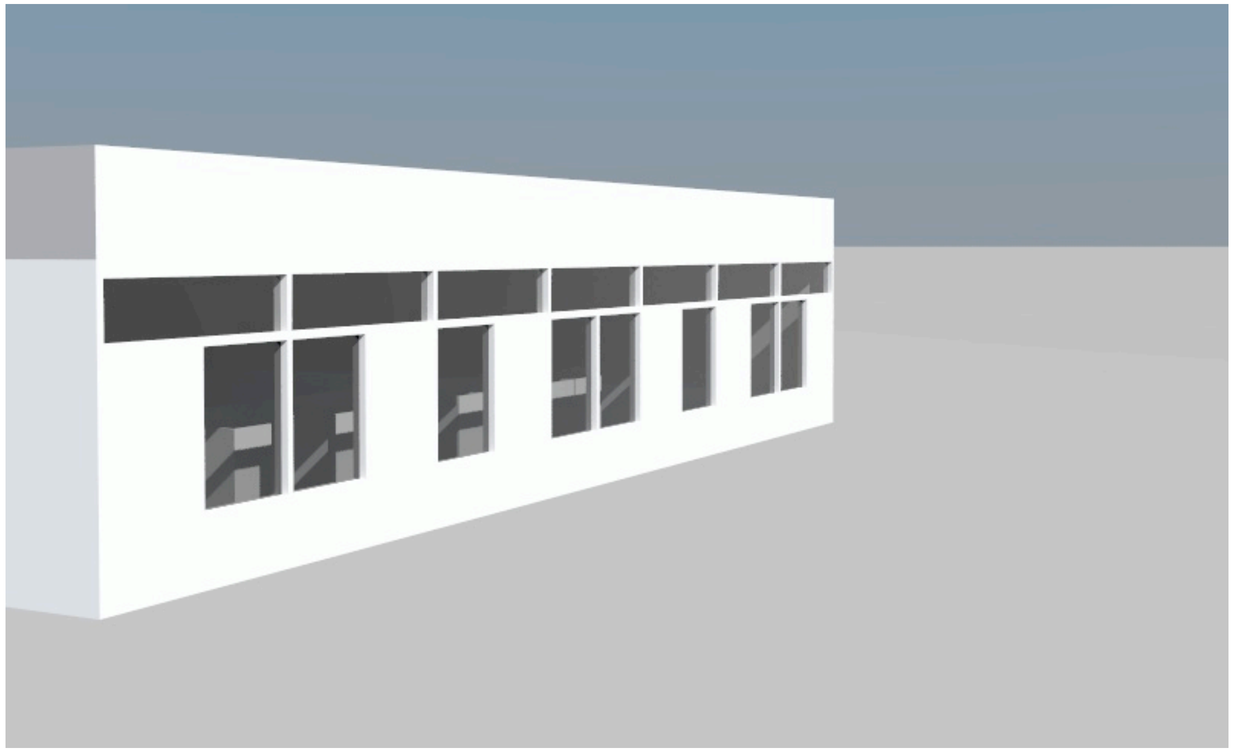
Computation Time:

- 4013 CPU*Hours
- (64) 2.66 GHz Processor
- 62 Hours (wall time)

Daylight Matrix



Reinhart MF:4 sky
(2305 divisions)



No External Obstructions

Computation Time:

1.25 CPU*Hours

S Matrix

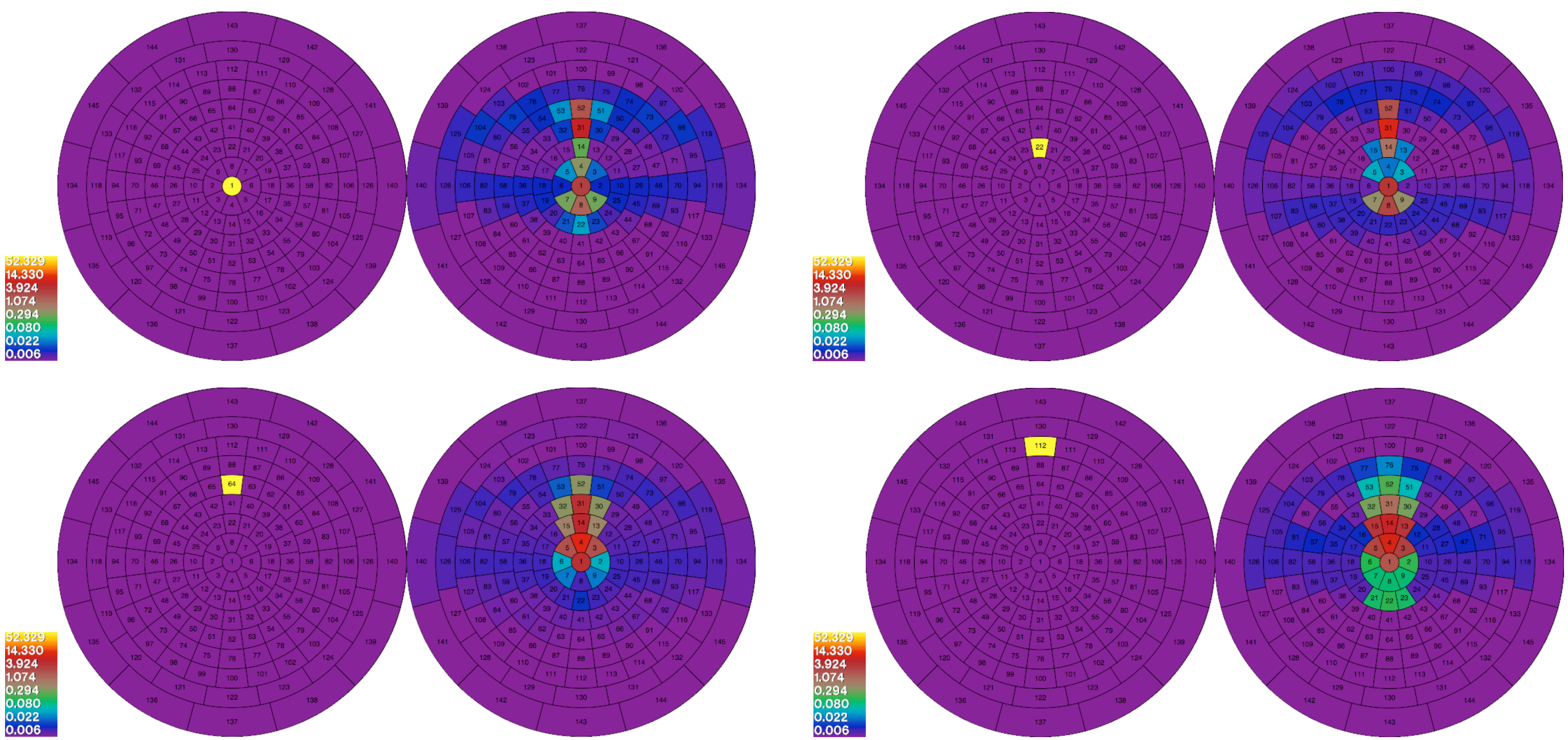
- Sky vectors were pre-computed and zipped to reduce repetitive generation of the same sky vectors.

  gendaylit [options] | genskyvec -m 4 | gzip > m_d_t.svec.gz

- gensky was used when gendaylit failed (assumed a static sun and sky efficacy).
- Computation time: 1.0 CPU hours

T-Matrix (BTDF)

- Generated a BTDF using radiance genklemsamp and rtcontrib.



Prelude Calculation Times

- V Matrix: 1.25 hours for Illuminance

  62 hours for a Rendering

- D Matrix: 1 hour
- T matrix: 1 hour with genBSDF

  0.05 hours with Window6

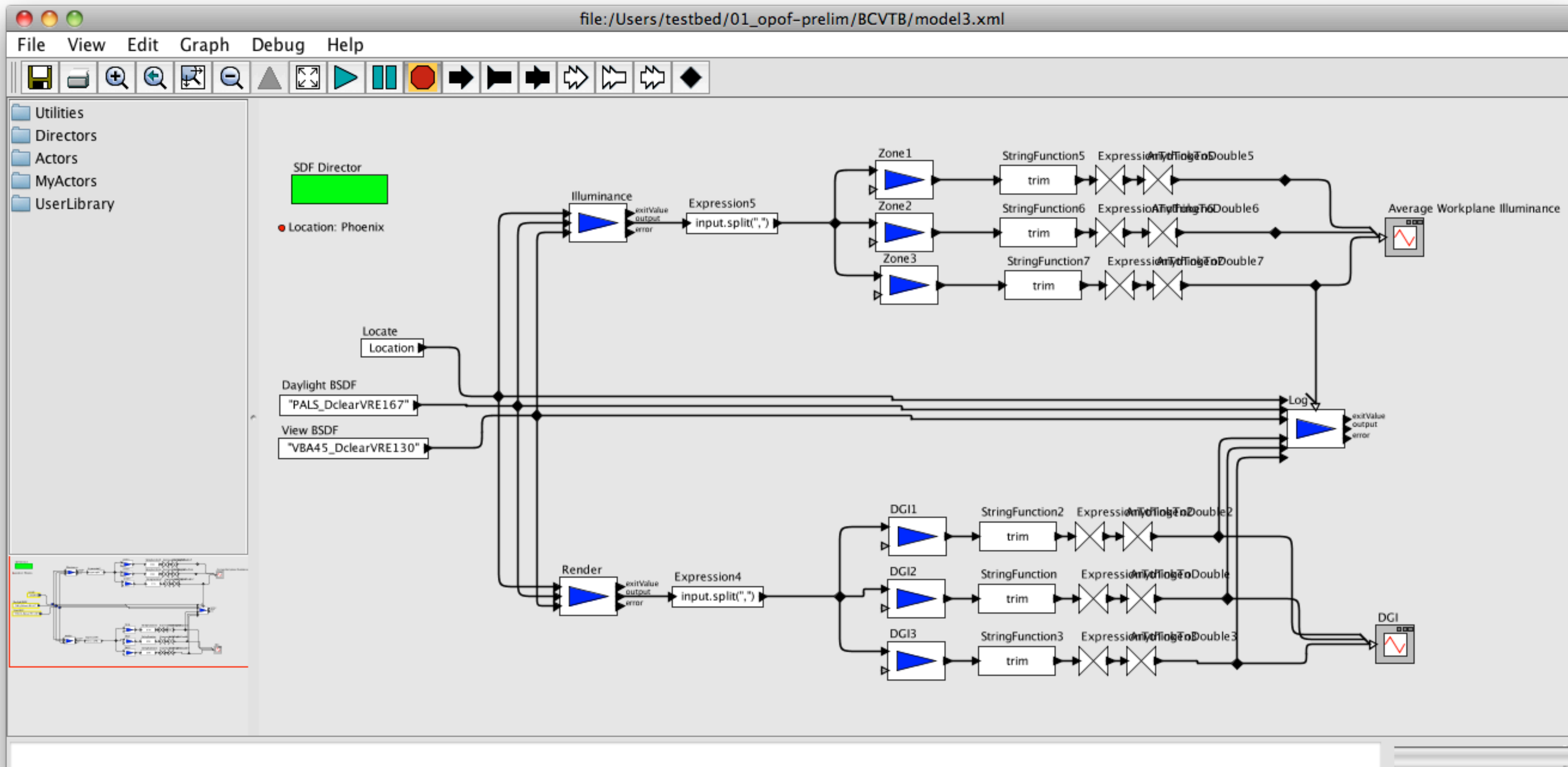
- S matrix: 1 hour

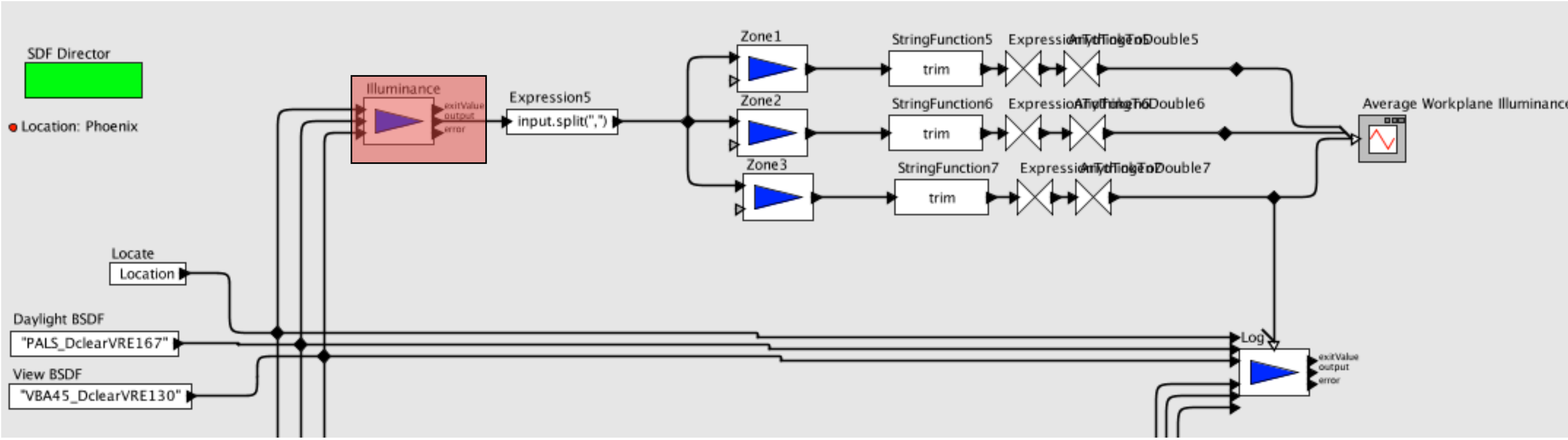
Now we can start our annual simulations!

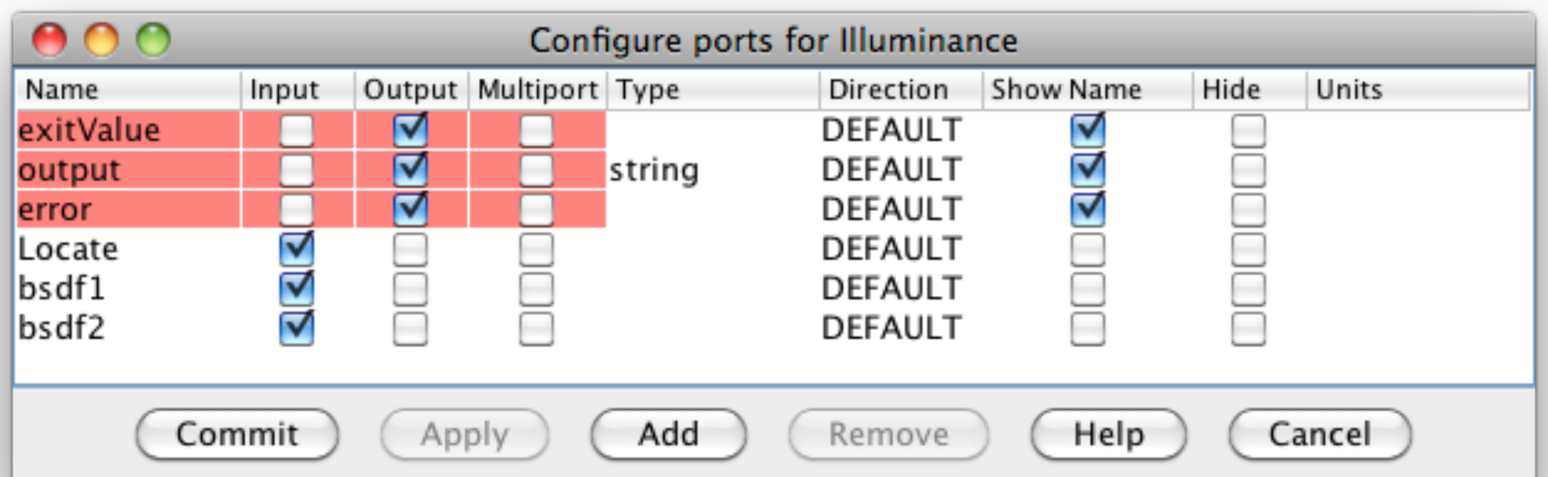
Annual Runs

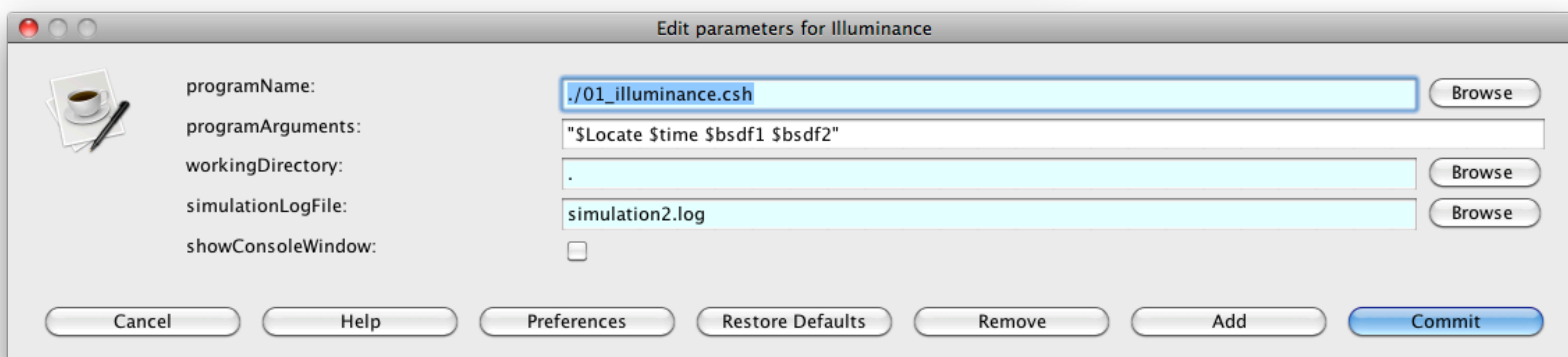
- dctimestep for illuminance zones
    - Illuminances processed for UDI, CDA and lighting energy use.
    - computation takes 2.5 hours
- dctimestep for rendered views
    - Images analyzed for DGI
    - computation takes 12.5 hours (smaller images would speed this up)

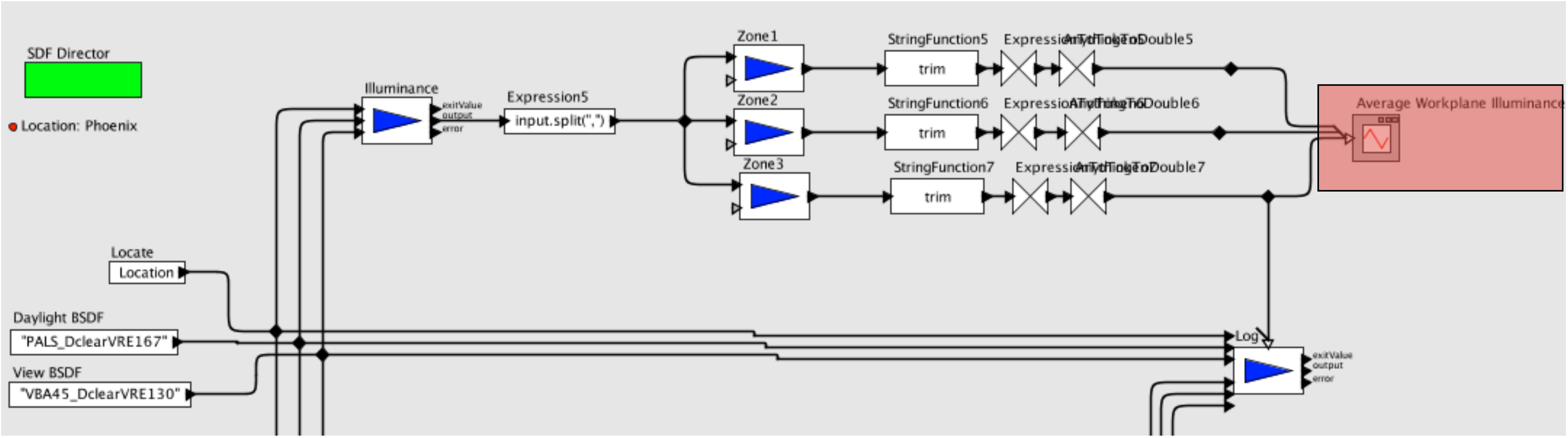
BCVTB Model for Annual Daylight Simulation

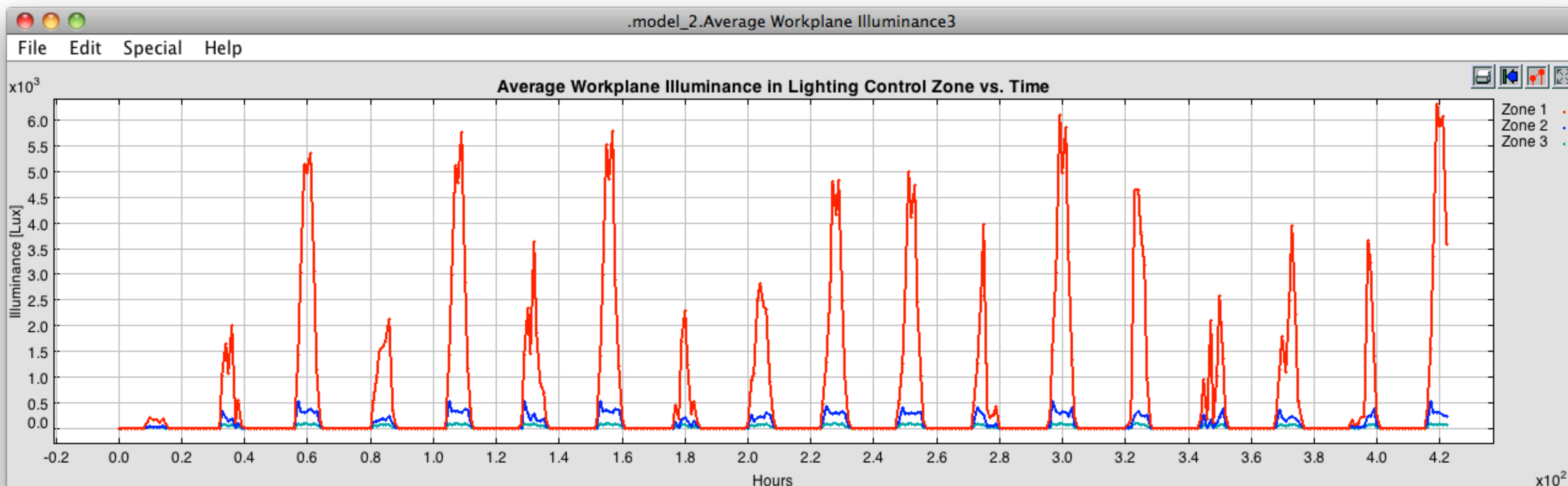


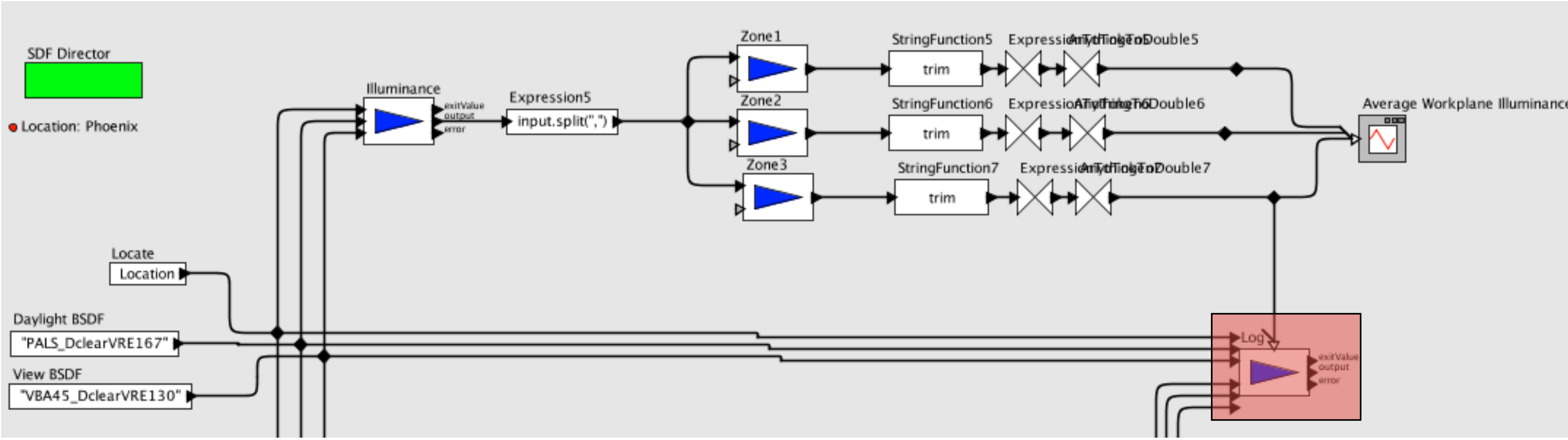

SDF Director
Location: Phoenix
Illuminance
exitValue
output
error
Expression5
input.split(",")
Zone1
Zone2
Zone3
StringFunction5
StringFunction6
StringFunction7
trim
trim
trim
Average Workplane Illuminance
Locate
Location
Daylight BSDF
"PALS_DclearVRE167"
View BSDF
"VBA45_DclearVRE130"
Log
exitValue
output
error


Configure ports for Illuminance
Name
Input
Output
Multiport
Type
Direction
Show Name
Hide
Units
exitValue
DEFAULT
output
string
DEFAULT
error
DEFAULT
Locate
DEFAULT
bsdf1
DEFAULT
bsdf2
DEFAULT
Commit
Apply
Add
Remove
Help
Cancel


Edit parameters for Illuminance
programName:
./01_illuminance.csh
Browse
programArguments:
"$Locate $time $bsdf1 $bsdf2"
workingDirectory:
.
Browse
simulationLogFile:
simulation2.log
Browse
showConsoleWindow:
Cancel
Help
Preferences
Restore Defaults
Remove
Add
Commit


SDF Director
Location: Phoenix
Illuminance
Expression5
input.split(",")
Zone1
Zone2
Zone3
StringFunction5
StringFunction6
StringFunction7
trim
Average Workplane Illuminance
Locate
Location
Daylight BSDF
"PALS_DclearVRE167"
View BSDF
"VBA45_DclearVRE130"
Log


.model_2.Average Workplane Illuminance3
File Edit Special Help
Average Workplane Illuminance in Lighting Control Zone vs. Time
x10^3
Illuminance [Lux]
Hours
x10^2
Zone 1
Zone 2
Zone 3



Phoenix_llouver_DclearVRE167_VBA45_DclearVRE130_summary.txt

1,	1,	00.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	01.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	02.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	03.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	04.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	05.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	06.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	07.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	08.5,	17.0,	12.7,	17.6,	110.1,	8.5,	472.6,	266.7,	89.6,	472.6,	48.1,	15.2,	112.4,	15.4,	8.5,	30.9
1,	1,	09.5,	13.8,	19.3,	19.3,	268.6,	17.9,	1272.3,	662.0,	251.7,	1272.3,	105.0,	34.9,	197.8,	38.7,	17.9,	83.8
1,	1,	10.5,	13.8,	21.6,	20.7,	383.8,	26.8,	1874.6,	960.1,	402.0,	1874.6,	137.0,	54.9,	276.7,	54.3,	26.8,	84.3
1,	1,	11.5,	21.5,	23.5,	22.1,	519.0,	65.0,	2189.7,	1254.7,	639.0,	2189.7,	211.0,	105.6,	355.8,	91.2,	65.0,	123.1
1,	1,	12.5,	25.0,	23.8,	22.4,	509.9,	74.7,	2330.4,	1240.8,	570.8,	2330.4,	191.1,	101.9,	376.0,	97.9,	74.7,	132.4
1,	1,	13.5,	21.5,	23.9,	24.3,	533.3,	63.3,	2228.1,	1293.1,	652.8,	2228.1,	214.1,	109.7,	357.1,	92.7,	63.3,	123.6
1,	1,	14.5,	13.7,	21.2,	25.6,	364.0,	33.5,	1645.8,	897.8,	372.1,	1645.8,	136.6,	59.7,	250.2,	57.7,	33.5,	94.1
1,	1,	15.5,	15.3,	11.5,	23.6,	136.3,	15.0,	690.7,	322.8,	130.1,	690.7,	60.5,	24.0,	114.5,	25.7,	15.0,	49.4
1,	1,	16.5,	16.9,	12.2,	20.9,	109.2,	11.3,	488.6,	257.5,	98.2,	488.6,	51.3,	18.6,	108.4,	18.9,	11.3,	37.0
1,	1,	17.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	18.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	19.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	20.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	21.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	22.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	1,	23.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	00.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	01.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	02.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	03.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	04.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	05.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	06.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	07.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	08.5,	15.6,	7.6,	20.6,	31.7,	4.4,	123.9,	72.3,	29.8,	123.9,	16.1,	6.4,	31.4,	6.8,	4.4,	12.0
1,	2,	09.5,	15.3,	13.0,	20.3,	195.5,	17.3,	879.7,	471.0,	187.4,	879.7,	82.6,	29.8,	155.7,	32.8,	17.3,	64.3
1,	2,	10.5,	13.1,	20.6,	21.2,	323.1,	27.3,	1519.0,	791.7,	335.7,	1519.0,	125.4,	50.7,	249.9,	52.2,	27.3,	83.5
1,	2,	11.5,	13.4,	20.6,	22.5,	361.4,	50.1,	1480.6,	857.8,	434.1,	1480.6,	155.7,	77.0,	269.8,	70.6,	50.1,	99.8
1,	2,	12.5,	14.5,	10.3,	22.6,	162.2,	29.5,	644.0,	370.5,	181.2,	644.0,	77.2,	39.9,	145.3,	39.0,	29.5,	58.6
1,	2,	13.5,	14.1,	10.3,	22.4,	163.6,	26.7,	640.2,	374.7,	183.4,	640.2,	78.0,	39.2,	143.2,	38.0,	26.7,	59.1
1,	2,	14.5,	15.0,	10.6,	22.4,	163.2,	21.5,	674.3,	382.7,	171.1,	674.3,	73.2,	33.3,	136.5,	33.8,	21.5,	56.3
1,	2,	15.5,	13.6,	7.5,	21.0,	38.3,	6.3,	148.1,	88.0,	43.5,	148.1,	18.3,	9.1,	32.8,	8.5,	6.3,	13.1
1,	2,	16.5,	16.7,	11.6,	21.1,	102.6,	11.0,	448.5,	240.6,	92.8,	448.5,	48.8,	17.9,	101.3,	18.4,	11.0,	35.9
1,	2,	17.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	18.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	19.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	20.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	21.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0
1,	2,	22.5,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0,	0.0

Why Use BCVTB?

BCVTB is not necessary for annual simulations with Radiance.

We used BCVTB because of our future needs:

- Ability to easily incorporate control algorithms when we simulate dynamic systems
- Ability to add Energy Plus to the model to simulate HVAC energ.
- Ability to connect manufacturer's control hardware to test systems without the need to reveal proprietary algorithms

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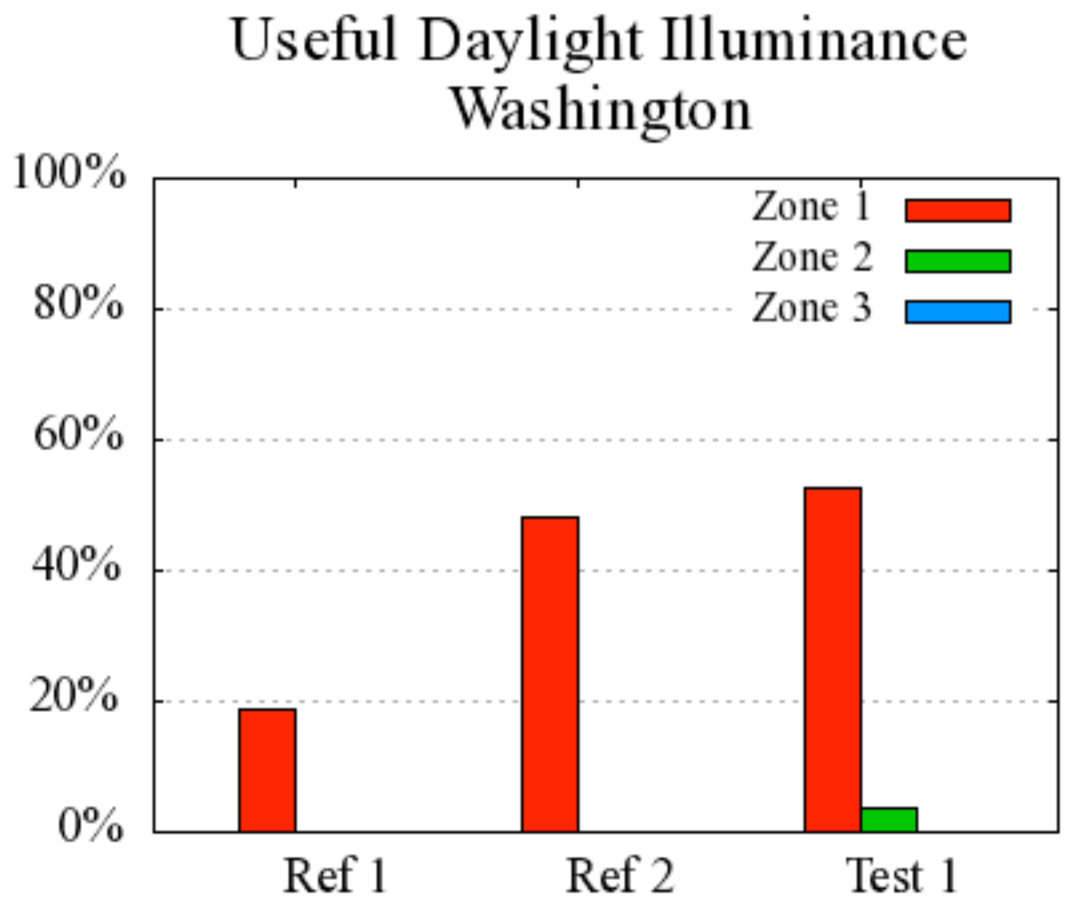
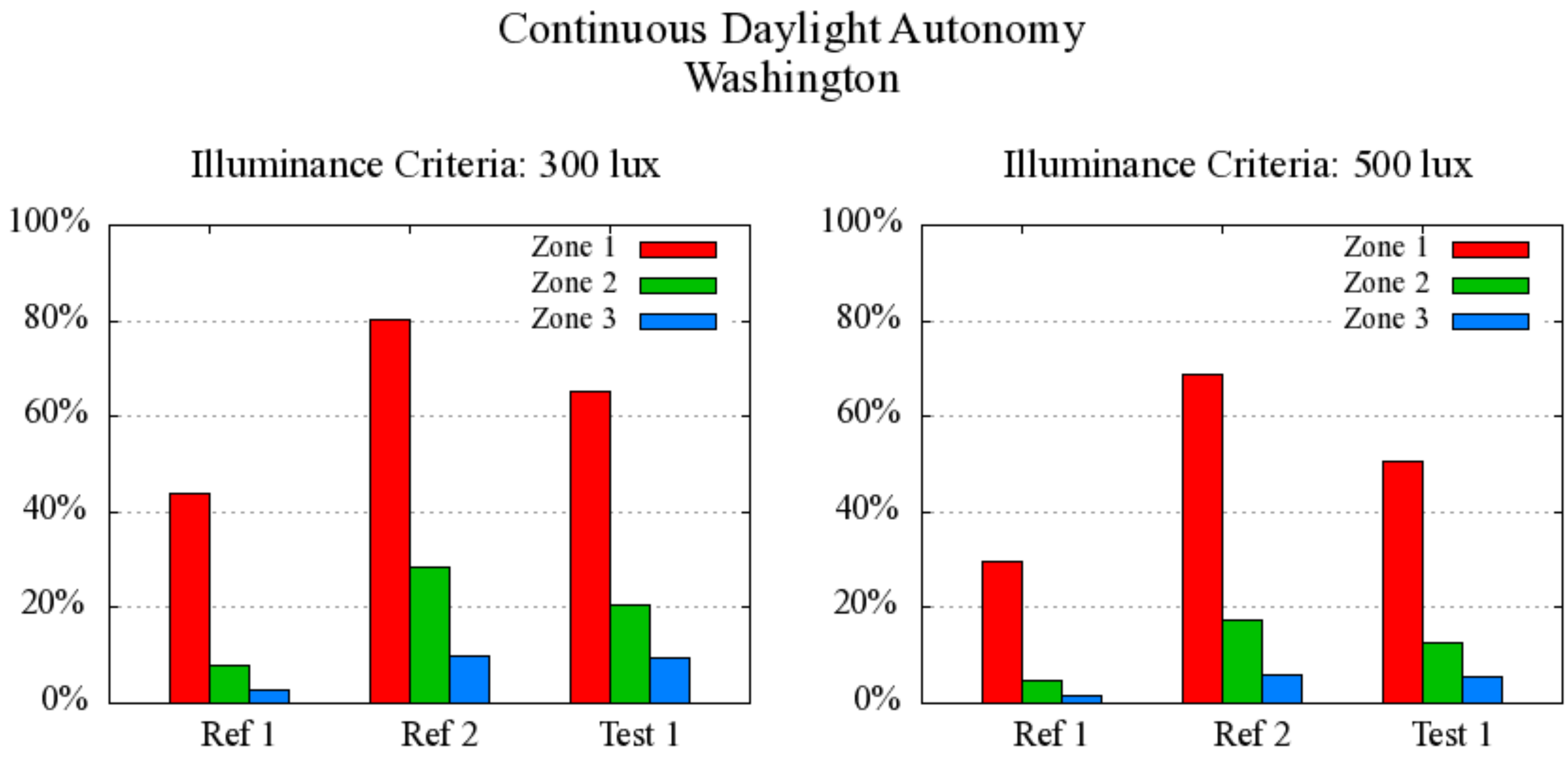
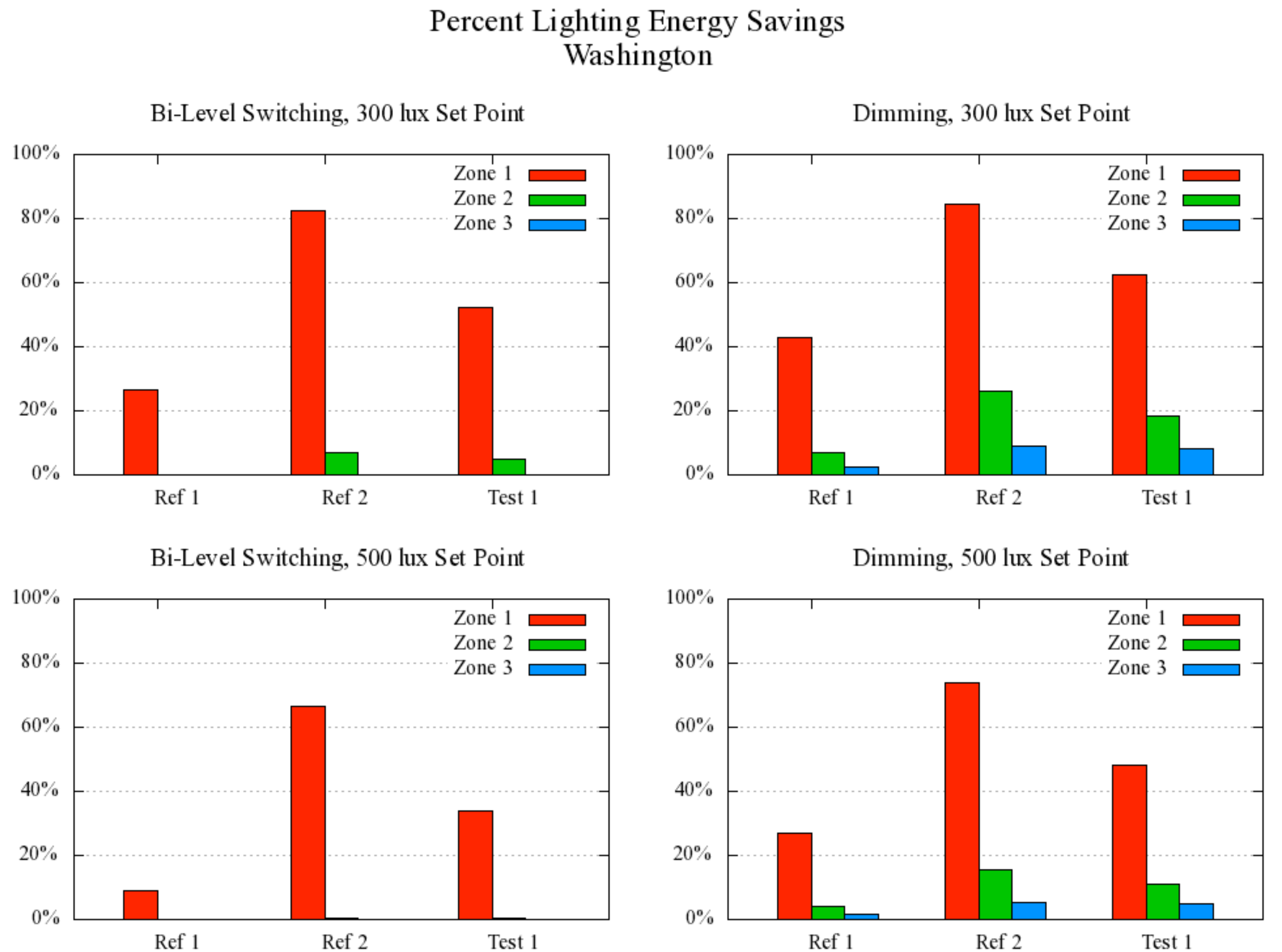
Useful Daylight Illuminance

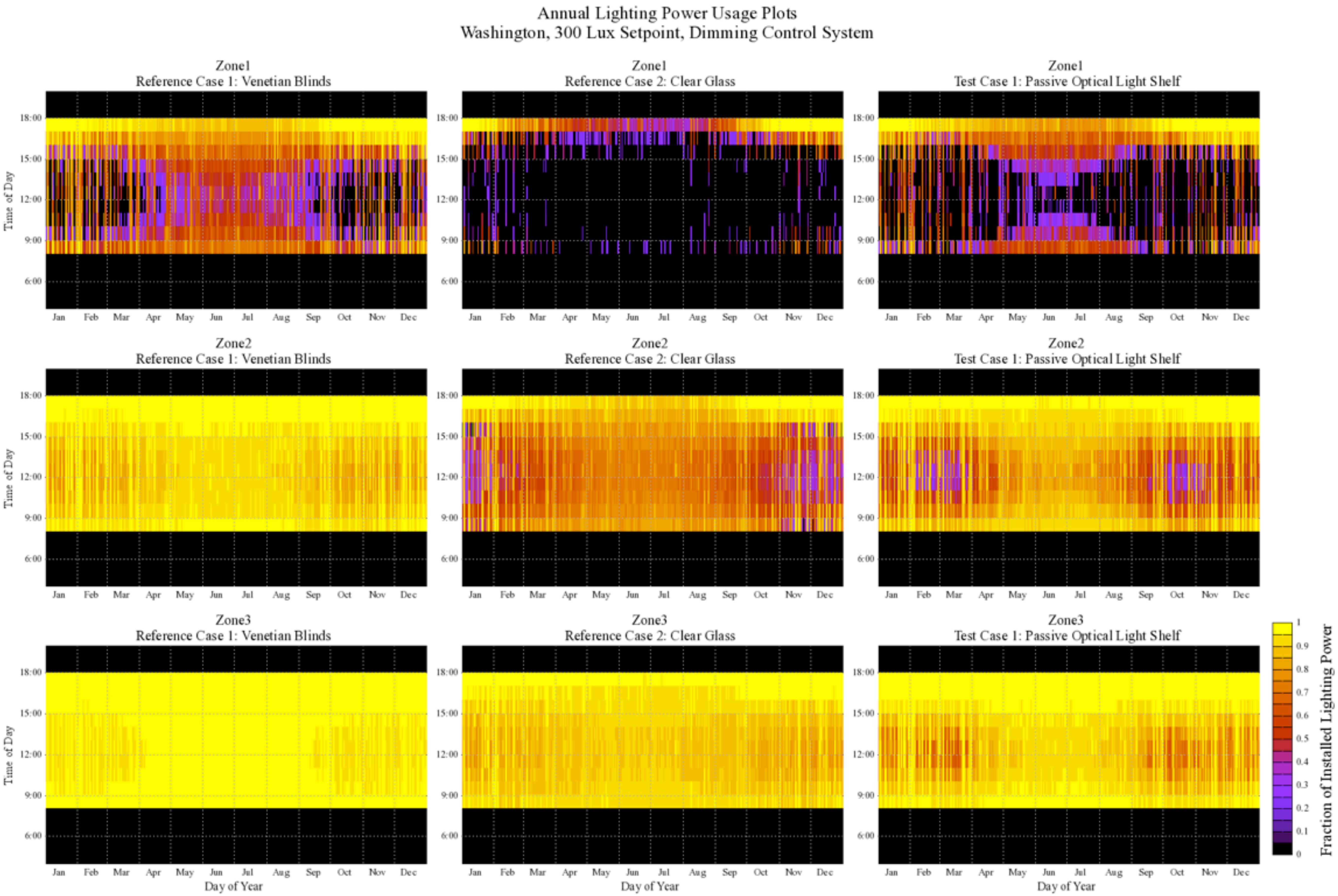


Continuous Daylight Autonomy

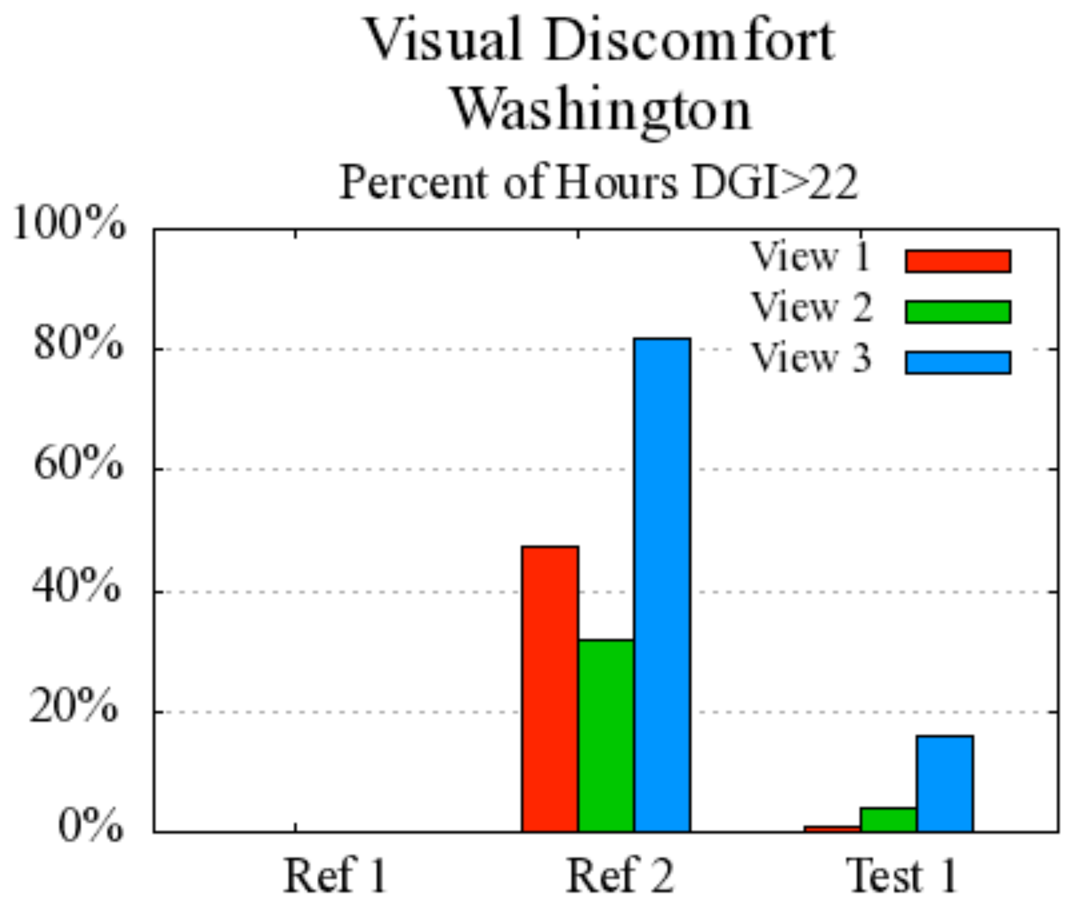


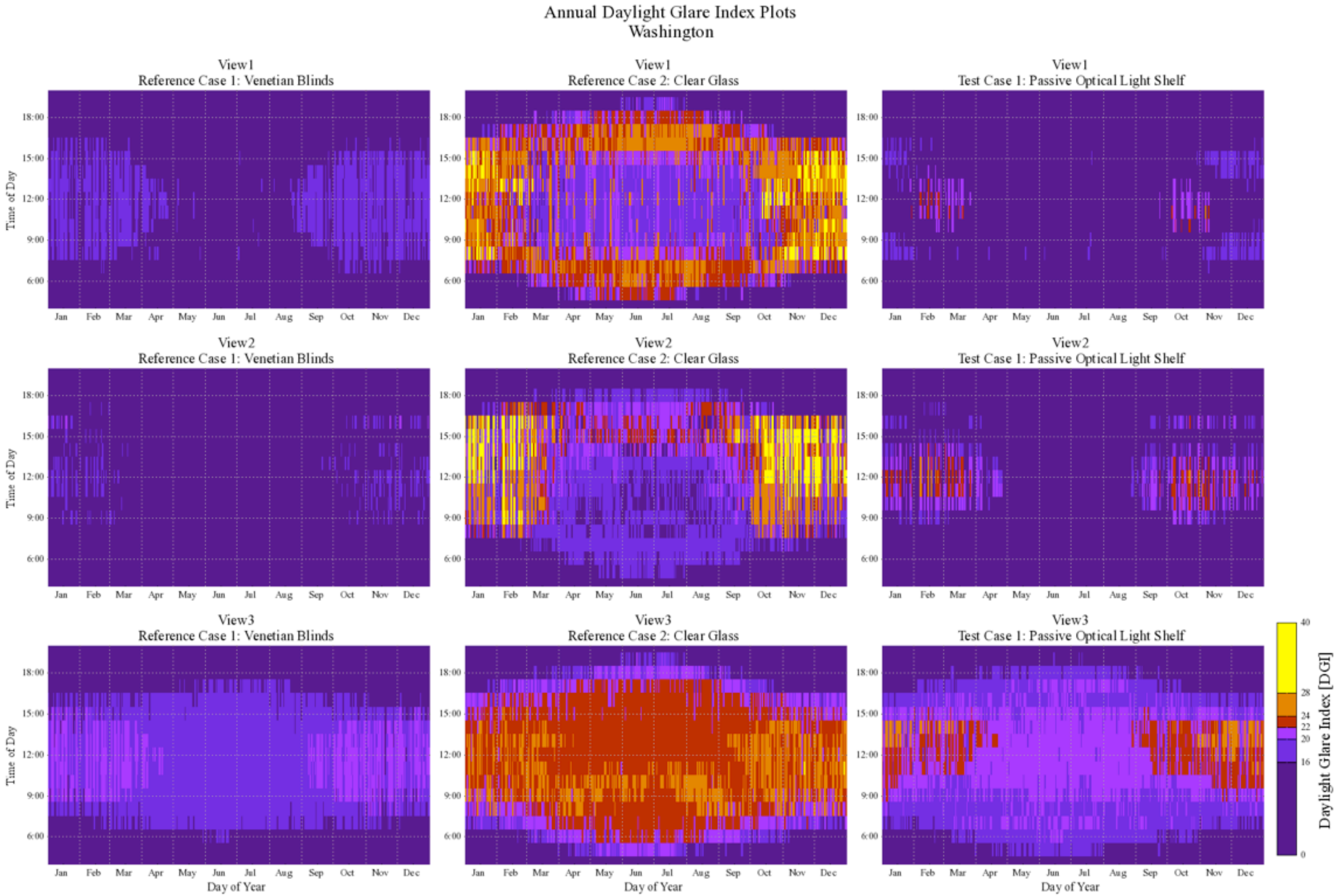


Percent Lighting Energy Savings
Washington
Bi-Level Switching, 300 lux Set Point
Dimming, 300 lux Set Point
Bi-Level Switching, 500 lux Set Point
Dimming, 500 lux Set Point
Zone 1
Zone 2
Zone 3
0%
20%
40%
60%
80%
100%
Ref 1
Ref 2
Test 1


Annual Lighting Power Usage Plots
Washington, 300 Lux Setpoint, Dimming Control System
Zone1
Reference Case 1: Venetian Blinds
Zone1
Reference Case 2: Clear Glass
Zone1
Test Case 1: Passive Optical Light Shelf
Zone2
Reference Case 1: Venetian Blinds
Zone2
Reference Case 2: Clear Glass
Zone2
Test Case 1: Passive Optical Light Shelf
Zone3
Reference Case 1: Venetian Blinds
Zone3
Reference Case 2: Clear Glass
Zone3
Test Case 1: Passive Optical Light Shelf
Time of Day
18:00
15:00
12:00
9:00
6:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Day of Year
Fraction of Installed Lighting Power
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Daylight Glare Index




Annual Daylight Glare Index Plots
Washington
View1
Reference Case 1: Venetian Blinds
View1
Reference Case 2: Clear Glass
View1
Test Case 1: Passive Optical Light Shelf
View2
Reference Case 1: Venetian Blinds
View2
Reference Case 2: Clear Glass
View2
Test Case 1: Passive Optical Light Shelf
View3
Reference Case 1: Venetian Blinds
View3
Reference Case 2: Clear Glass
View3
Test Case 1: Passive Optical Light Shelf
Time of Day
18:00
15:00
12:00
9:00
6:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Day of Year
Daylight Glare Index [DGI]
40
28
24
22
20
16
0

Who Would Do This?

- Manufacturers
  - Test products in a prototype stage
  - Test products in various climates
  - Test control algorithms for motorized products.
- Lighting Consultants
  - Simulate performance of various systems for a specific project
  - Evaluate design of custom shading systems

What do users need to do this?

- Illuminance only - relatively fast:

  a desktop computer

  half a day (for computation - not including model prep.)

- Renderings - slower:

  Could be sped up by using lower resolution images and reduced rendering parameters. Could still be done with a desktop computer but would need to run overnight. A small cluster doesn't hurt though.

BERKELEY LAB

California Public Interest Energy Research (PIER)

U.S. Department of Energy

Windows and Daylighting Group
Building Technologies Department
Lawrence Berkeley National Laboratory
Building 90-3111
Berkeley, CA 94720
Email: amcneil@lbl.gov

<u>More Info:</u>

Window 6
http://windows.lbl.gov/software/window/6

High performance commercial building facades
http://lowenergyfacades.lbl.gov

Acknowledgments
US Department of Energy
California Energy Commission
Public Interest Energy Research (PIER)