Complex Fenestration Thermal Transmission Validation

Radiance Workshop 2017

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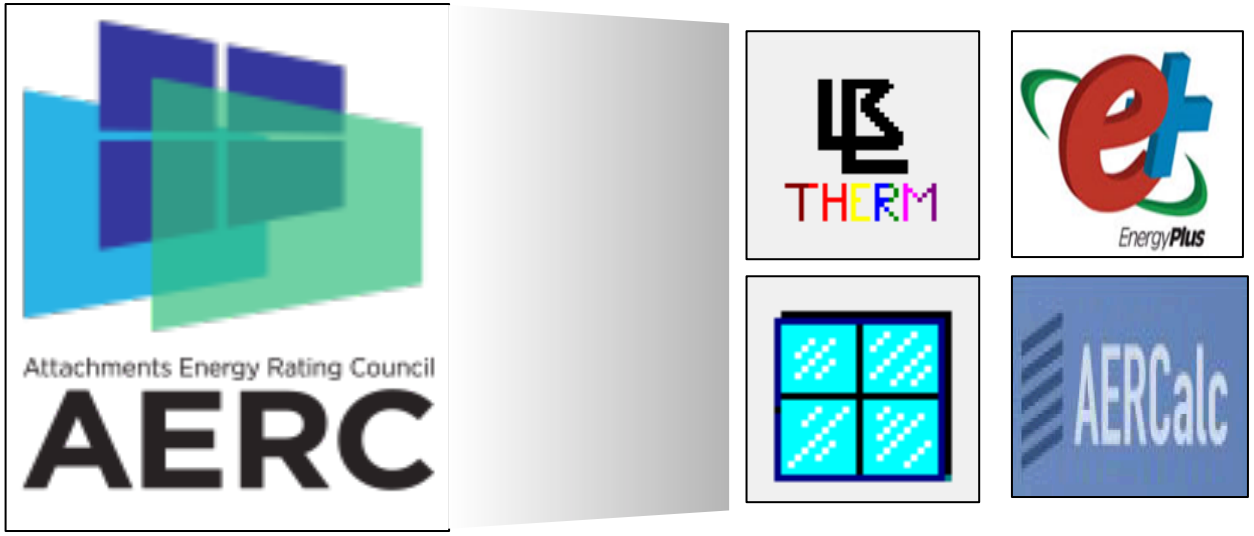
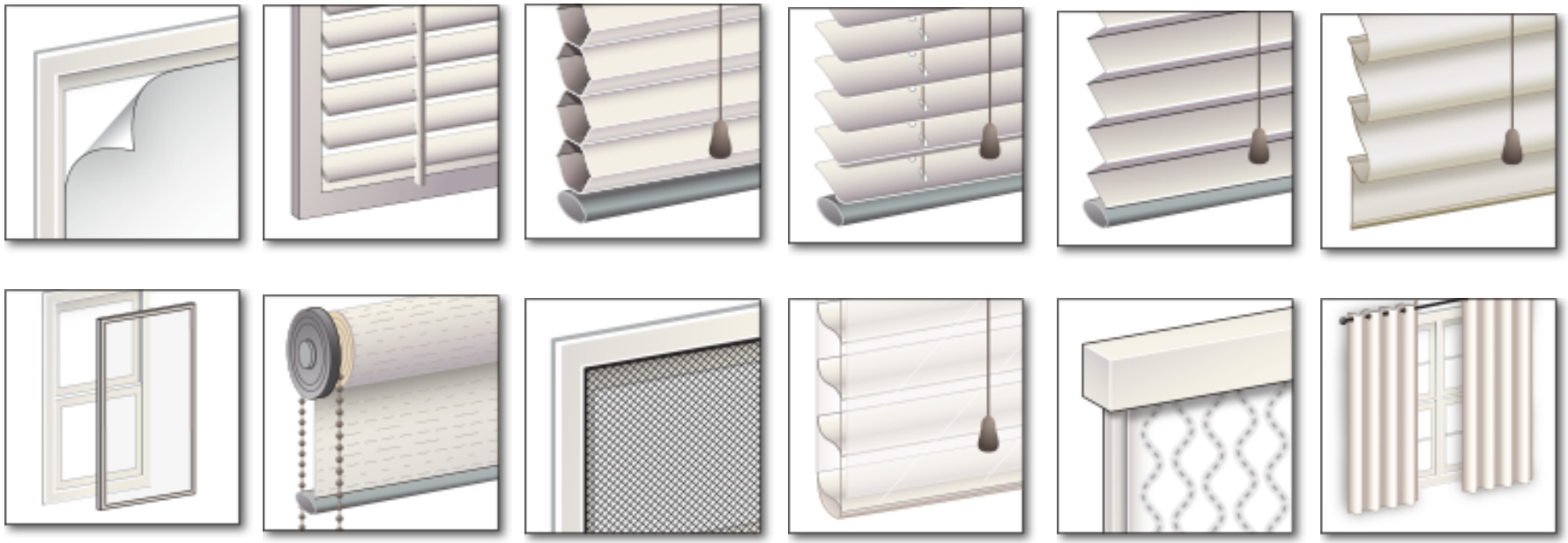
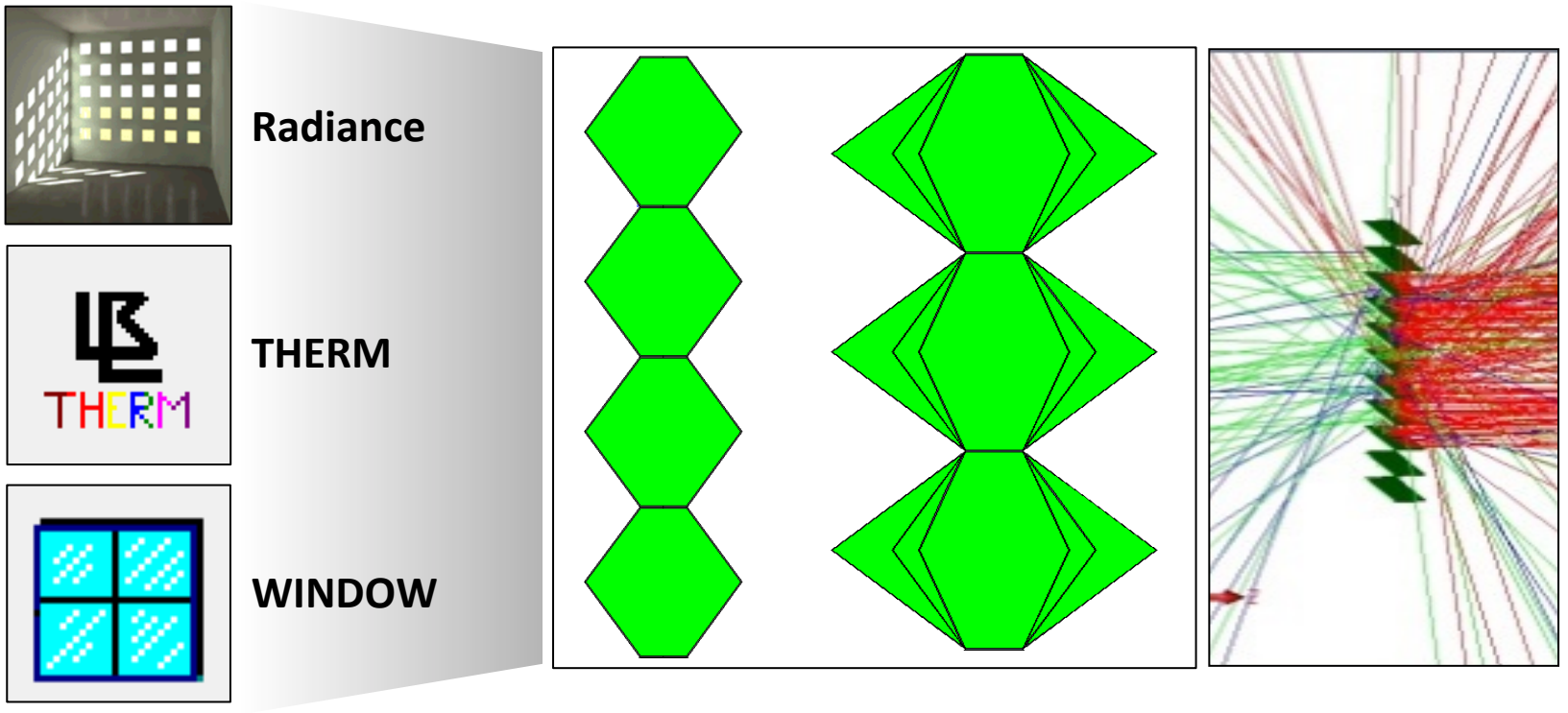
AERC **expands** on principals of NFRC product ratings to include whole building **annual energy** impact relative to baseline windows



Wide range of **Interior, Exterior**, & **between-glass** shading products. **Simulation** method must be **flexible** enough to handle them all.



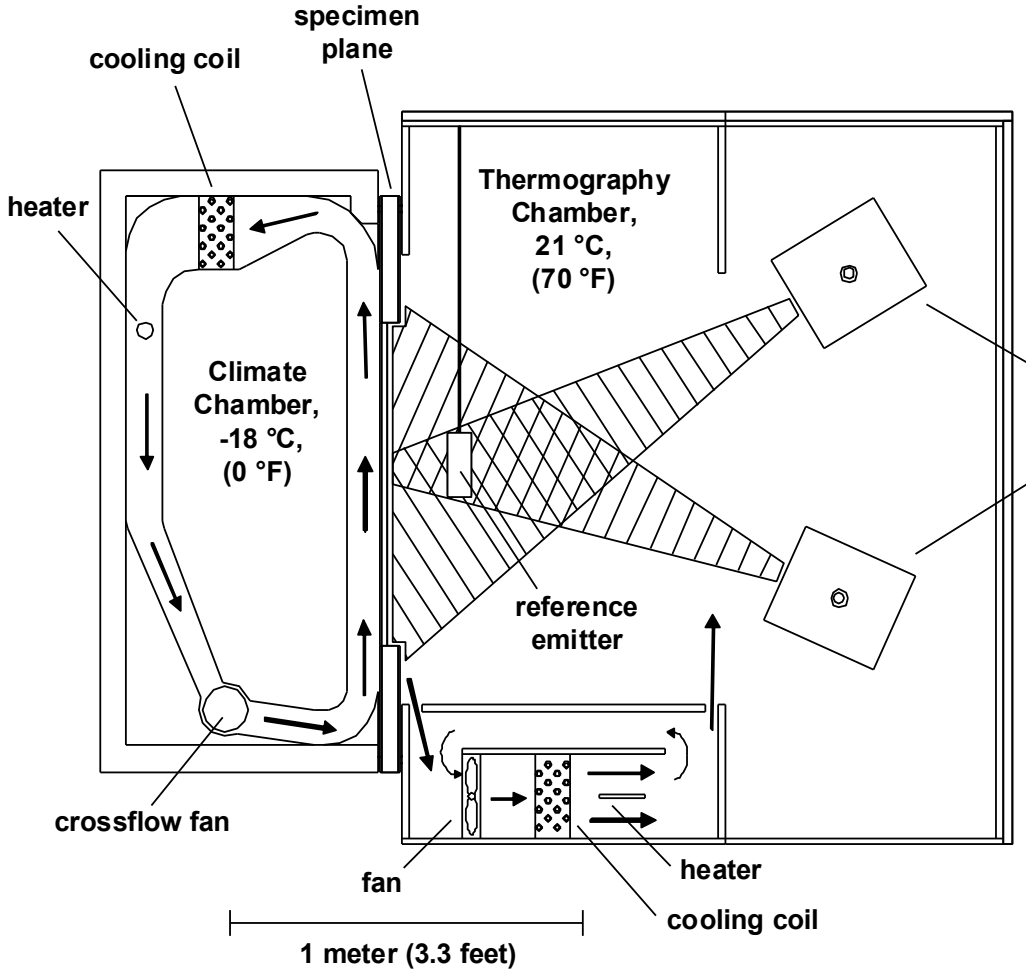
Flexible platform for **any** coplanar shade layer.
Integrates optical **ray tracing** from Radiance and
2D **heat transfer** from THERM



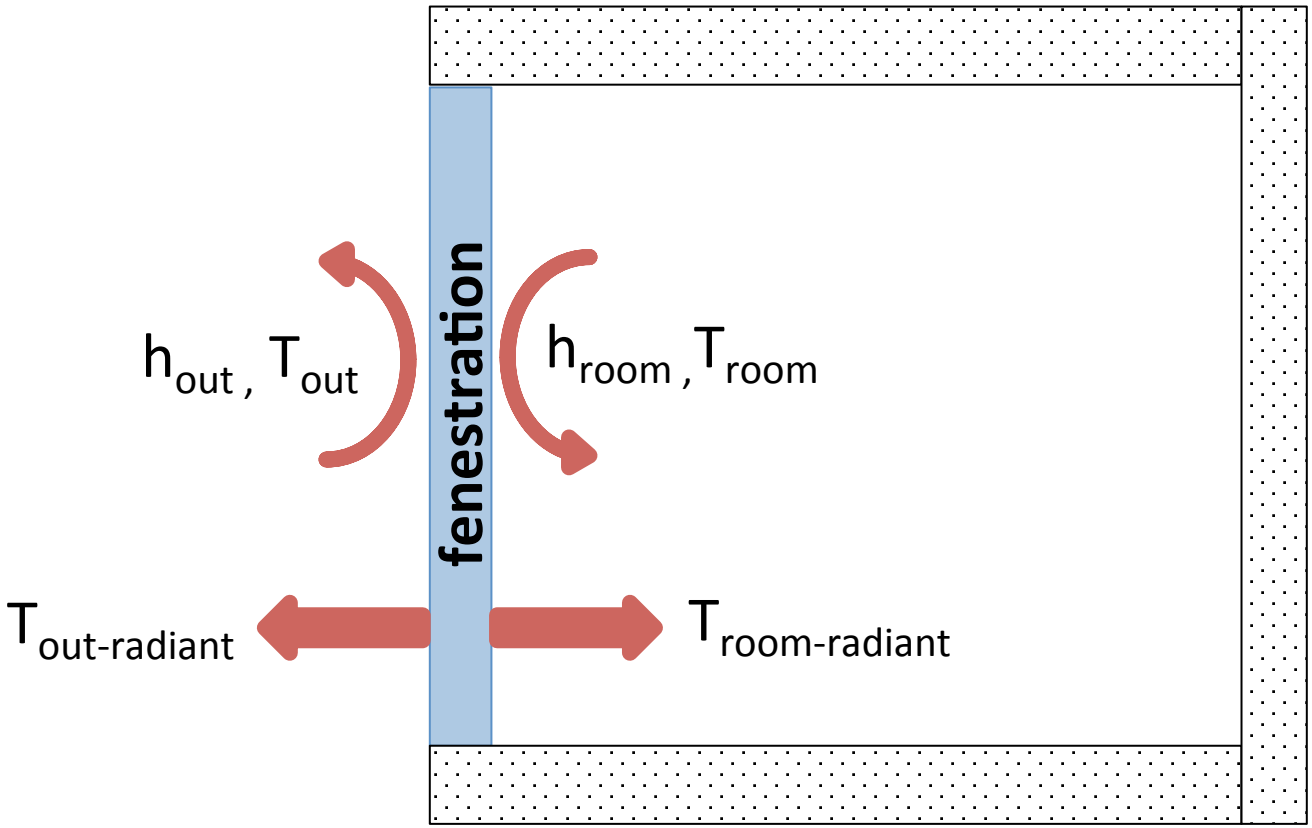
Simulation tool **validation** for net **energy rate** through **fenestration** systems.

Phase 1

Temperature driven heat transfer



energy transfer rate **no** solar load

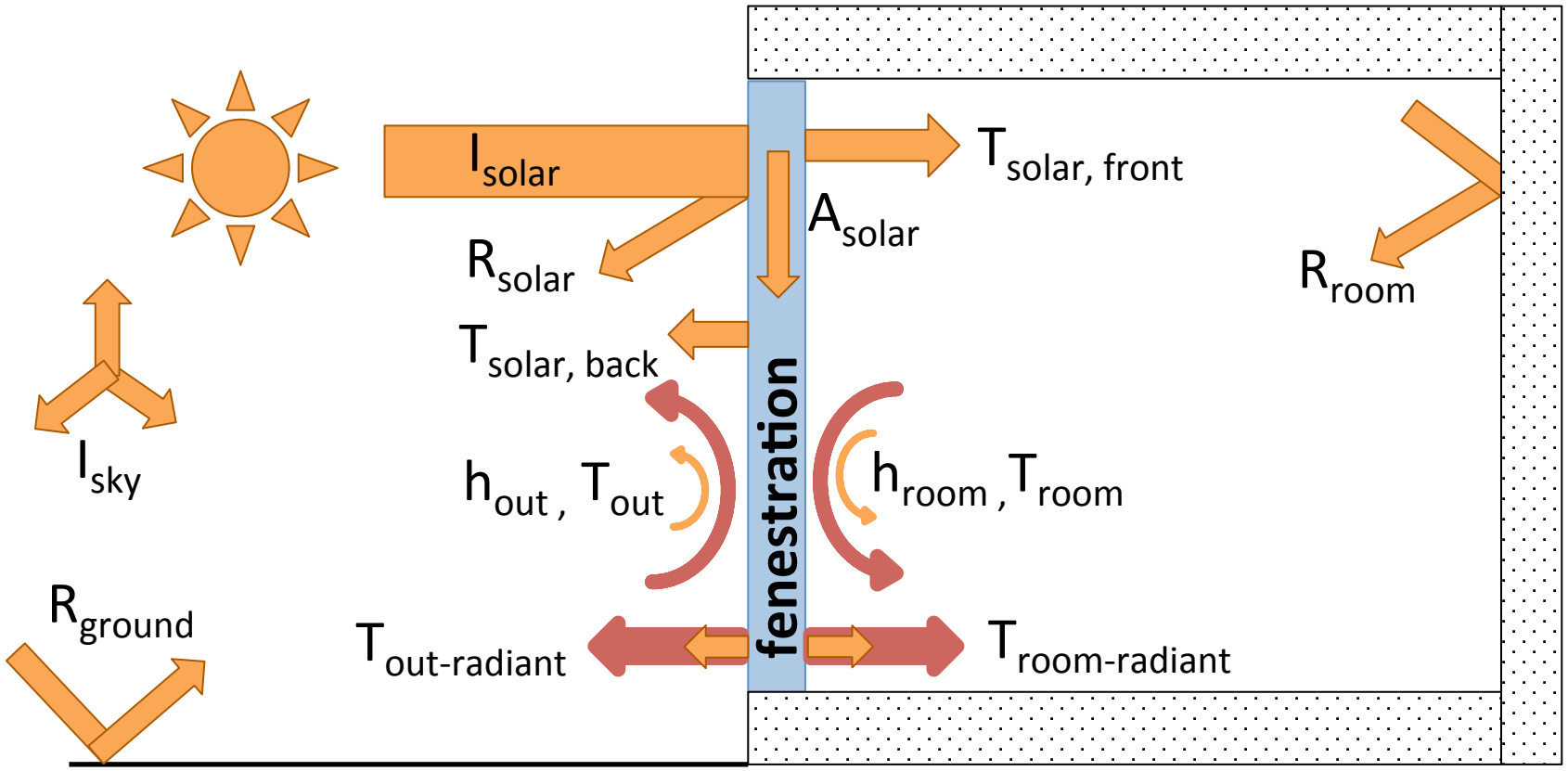


Simulation tool **validation** for net **energy rate** through **fenestration** systems.

Phase 2

Solar driven heat transfer

energy transfer rate **with** solar load



energy transfer rate **with** solar load

Energy rate measurement

THERM

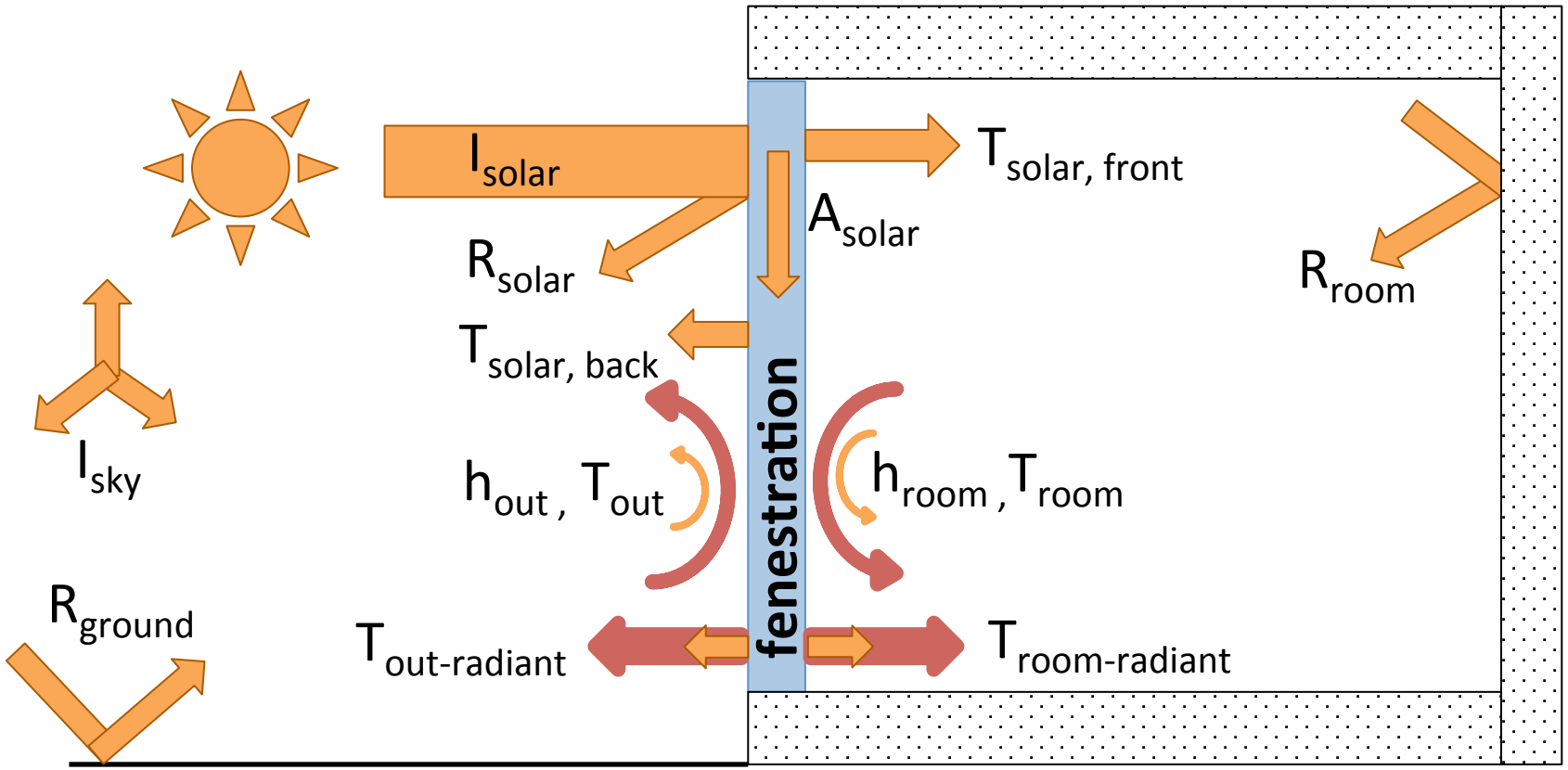
EnergyPlus

Simplified Energy Simulation

THERM

Detailed Energy Simulation

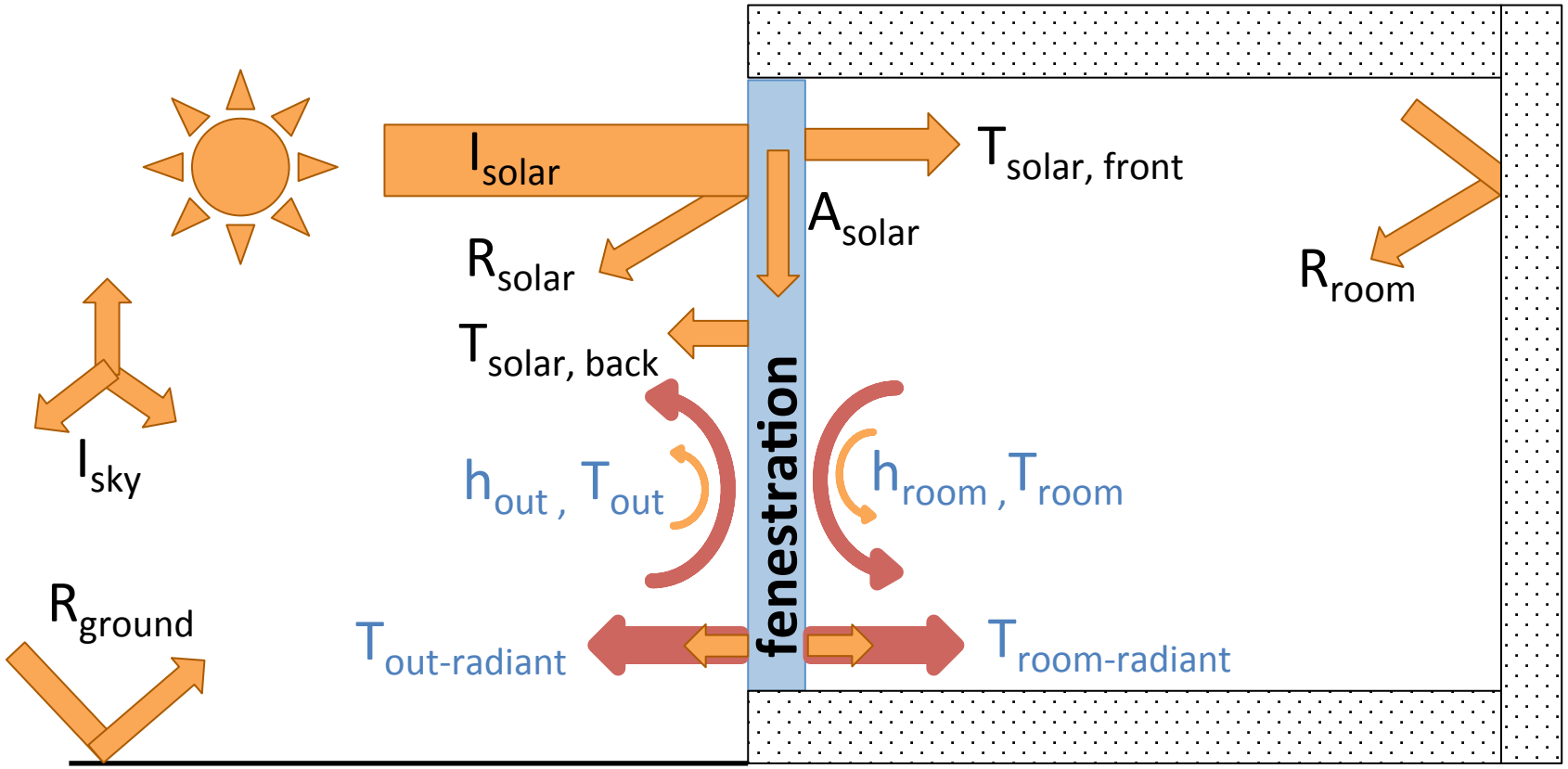
energy transfer rate **with** solar load
EnergyPlus



Simple sky, single reflection → **Fast**

energy transfer rate **with** solar load

Radiance + Berkeley Lab WINDOW



detailed sky & environment, multiple reflections → **Slow**

Measurements

1 minute time step

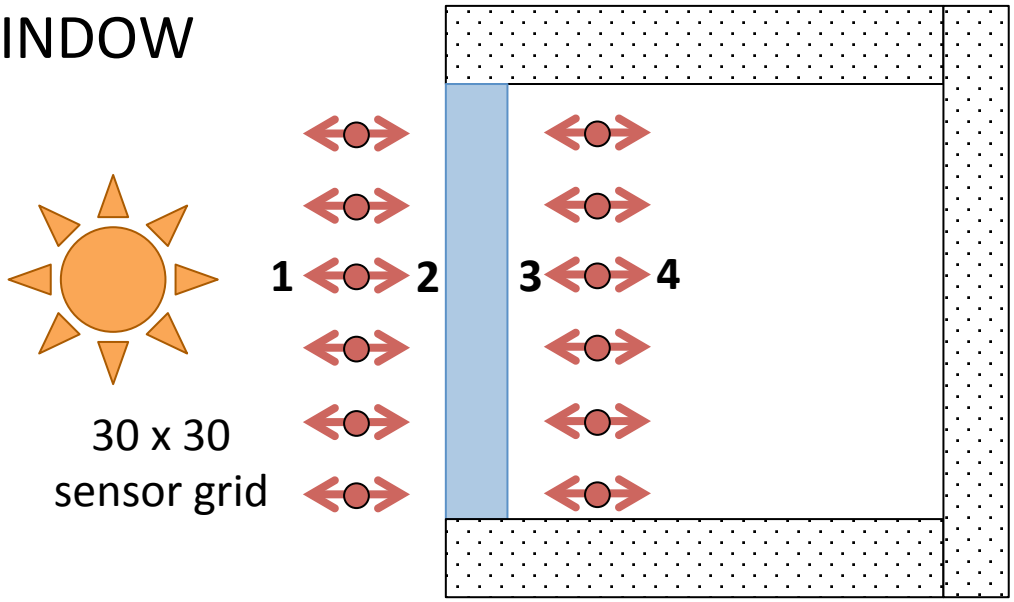
Energy	Environment
Net Cooling	Irradiance, horizontal diffuse
	Irradiance, horizontal global
	Long wave IR radiation (pyrgeometer)
	Temperature – Outdoor dry bulb
	Temperature – Outdoor dew point
	Temperature – Indoor dry bulb
	Wind speed
	Wind direction
	Air pressure

Radiance Methods

Transmission and Reflection DC method

gendaymtx for total and diffuse solar irradiation
oconv for scene with and without ground and room reflections
rfluxmtx to complete scene
dctimestep to compute timestep flux

BSDF from Berkeley Lab WINDOW



Radiance Methods

Transmission and Reflection

Scene	Sky radiation	Direct radiation	Ground reflectance	Room Reflectance
A	X	X	X	X
B	X	X	X	
C	X	X		
D	X			

Radiance Methods

Transmission and Reflection

Metric	Model	Sensor
Total incident irradiance	A	1
Total direct irradiance	A - D	1
Sky diffuse	D	1
Ground diffuse	B - C	1
Solar transmission front	B	3
Solar transmission back	A - B	2

Radiance Methods

Absorption

make_absorb_VMX.bsh with absorptance vectors from WINDOW
rfluxmtx to complete scene
rmtxop to compute timestep flux

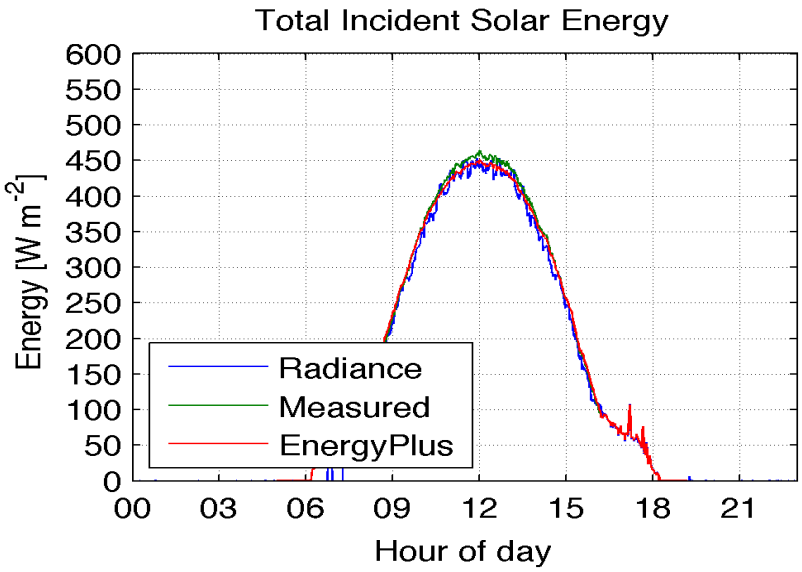
Radiance Methods

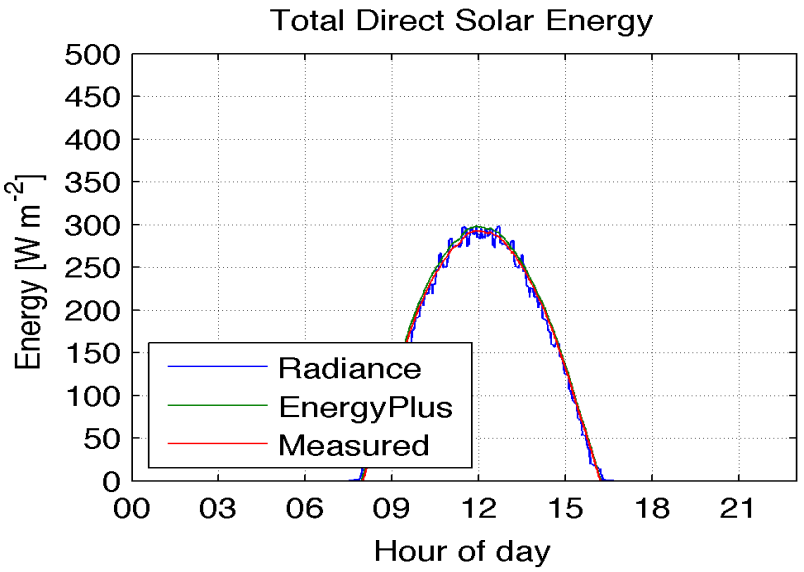
Command list

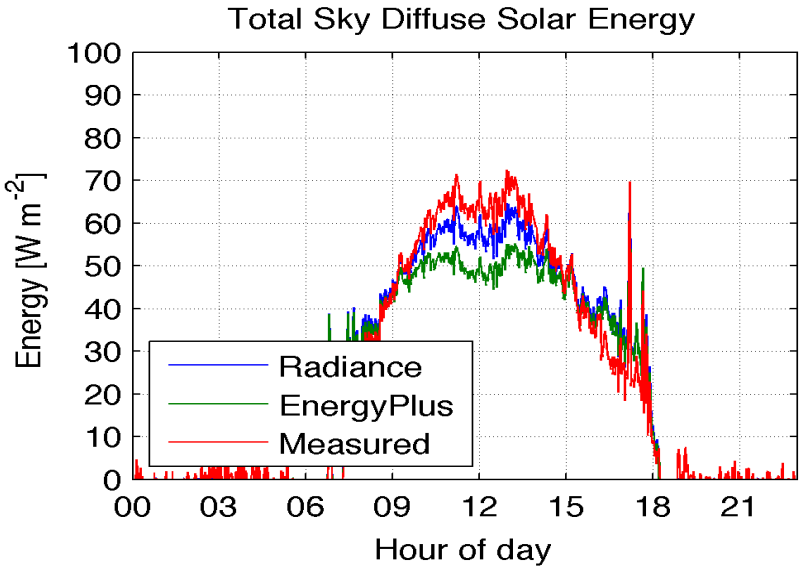
G: ground reflectance
R: room reflectance
S: diffuse sky irradiation
D: direct sky irradiation

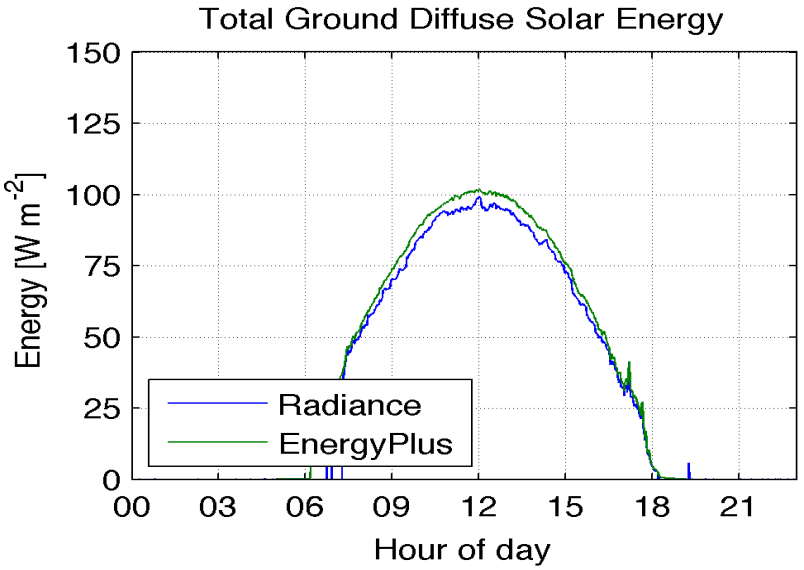
```
gendaymtx -m 4 -c 1 1 1  -O1 skies/DATE.wea > temp/sky_DATE_total.mtx
gendaymtx -s -m 4 -c 1 1 1  -O1 skies/DATE.wea > temp/sky_DATE_sky.mtx

oconv -f window/BSDF_Solar.rad Zone1_GR.rad > temp/BSDF_Solar_GR.oct
oconv -f window/BSDF_Solar.rad Zone1_G.rad > temp/BSDF_Solar_G.oct
oconv -f window/BSDF_Solar.rad Zone1.rad > temp/BSDF_Solar.oct

rfluxmtx -I+ -n 4 -ab 8  -ad 50000 -lw 2e-5 < data/grid.pts -o temp/BSDF_Solar_GR.mtx -y 3600 - skies/sky.rad -i temp/BSDF_Solar_GR.oct
rfluxmtx -I+ -n 4 -ab 8  -ad 50000 -lw 2e-5 < data/grid.pts -o temp/BSDF_Solar_G.mtx -y 3600 - skies/sky.rad -i temp/BSDF_Solar_G.oct
rfluxmtx -I+ -n 4 -ab 8  -ad 50000 -lw 2e-5 < data/grid.pts -o temp/BSDF_Solar.mtx -y 3600 - skies/sky.rad -i temp/BSDF_Solar.oct

dctimestep temp/BSDF_Solar_GR.mtx temp/sky_DATE_total.mtx | rmtxop -fa -c .33 .33 .34 - > results/DATE_SDGR.txt
dctimestep temp/BSDF_Solar_G.mtx temp/sky_DATE_total.mtx | rmtxop -fa -c .33 .33 .34 - > results/DATE_SDG.txt
dctimestep temp/BSDF_Solar.mtx temp/sky_DATE_total.mtx  | rmtxop -fa -c .33 .33 .34 - > results/DATE_SD.txt
dctimestep temp/BSDF_Solar.mtx temp/sky_DATE_sky.mtx | rmtxop -fa -c .33 .33 .34 - > results/DATE_S.txt

bash make_absorb_VMX.bsh nLayers window/WINDOWID_AngularData.csv > window/abs_WINDOWID.mtx

rfluxmtx –n window/WINDOW.rad skies/sky.rad > data/Daylight_G.dmx
rfluxmtx –n window/WINDOW.rad skies/sky.rad > data/Daylight.dmx

rmtxop window/abs_WINDOWID.mtx data/Daylight_SDG.dmx temp/sky_DATE_total.mtx  | rmtxop -c 0.33 0.33 0.34 - > results/DATE_SDG_abs.mtx
rmtxop window/abs_WINDOWID.mtx data/Daylight_SD.dmx temp/sky_DATE_total.mtx  | rmtxop -c 0.33 0.33 0.34 - > results/DATE_SD_abs.mtx
rmtxop window/abs_WINDOWID.mtx data/Daylight_S.dmx temp/sky_DATE_sky.mtx | rmtxop -c 0.33 0.33 0.34 - > results/DATE_S_abs.mtx
```

Incident radiation



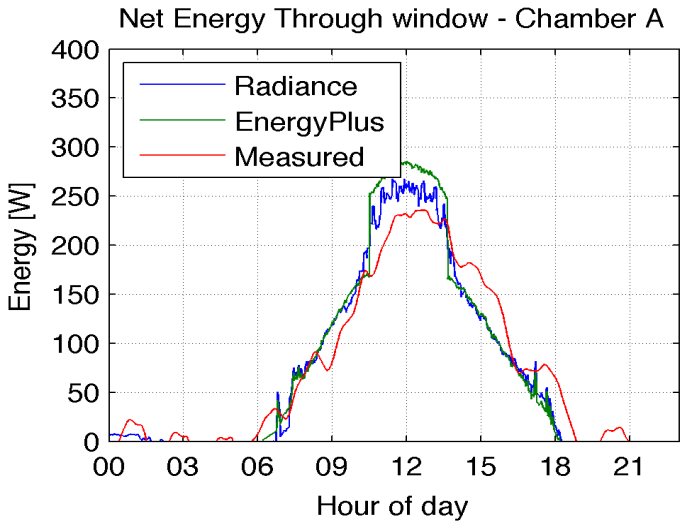


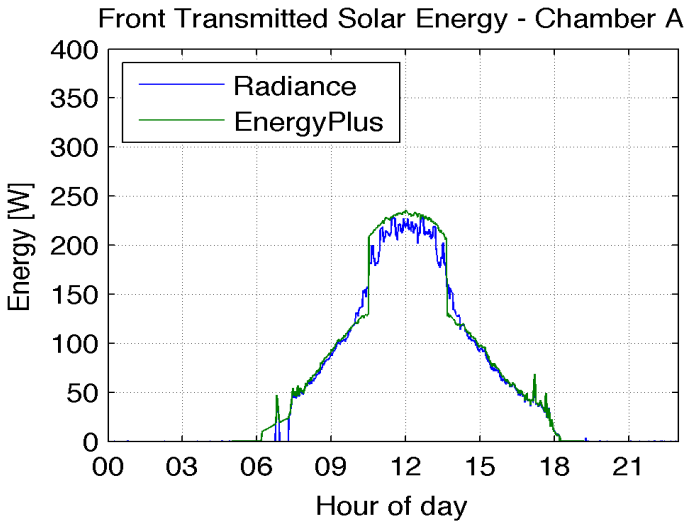


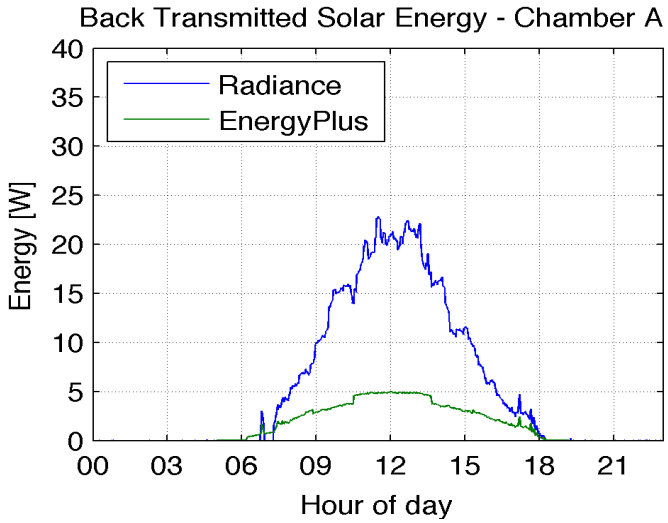


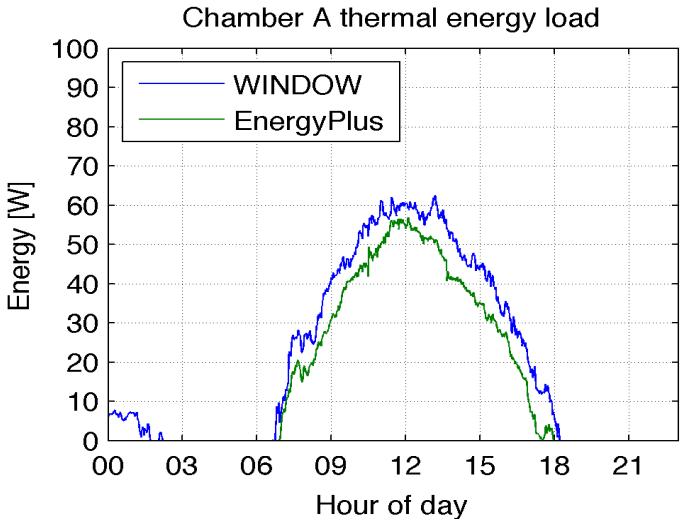
Transmitted Energy

Baseline **Double clear** window



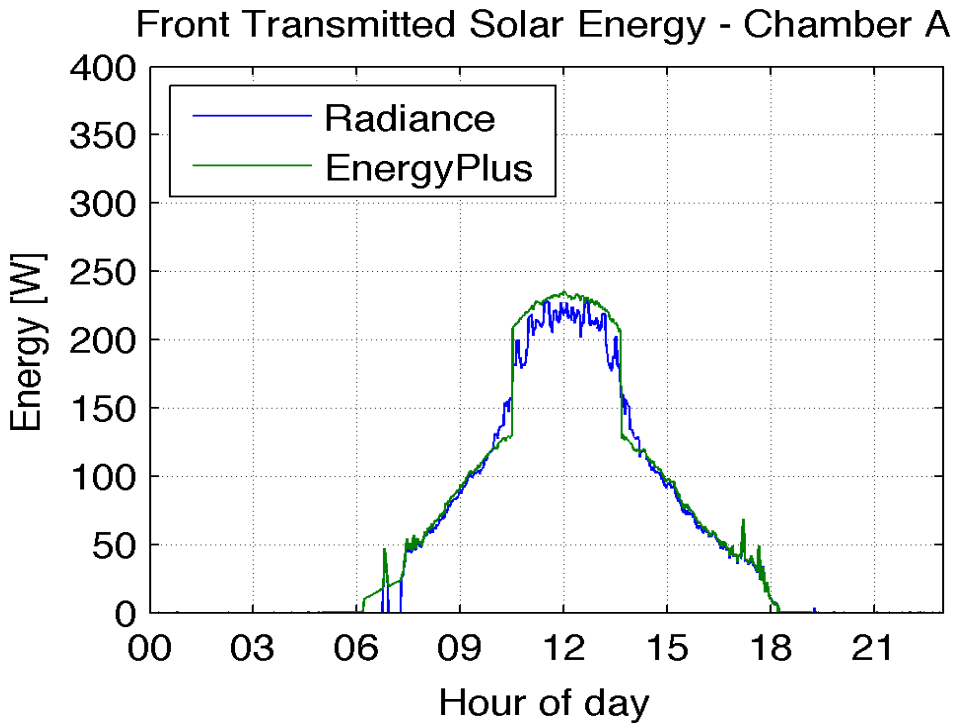


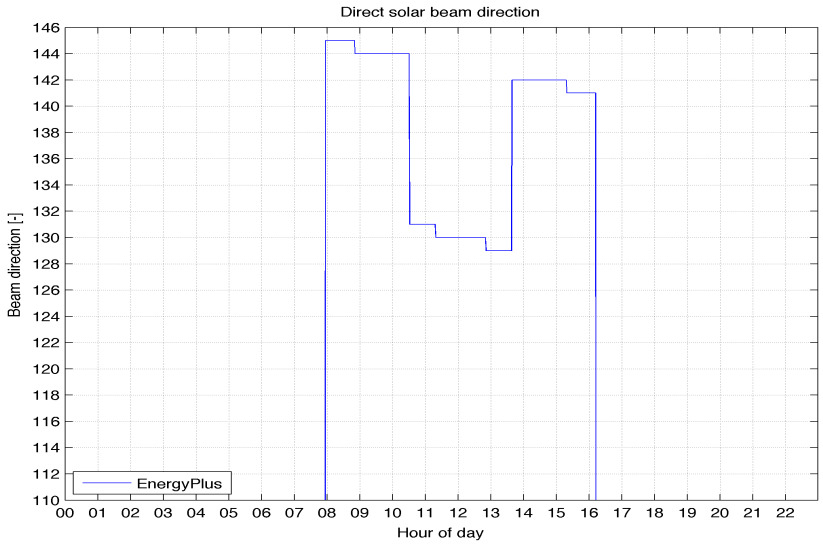


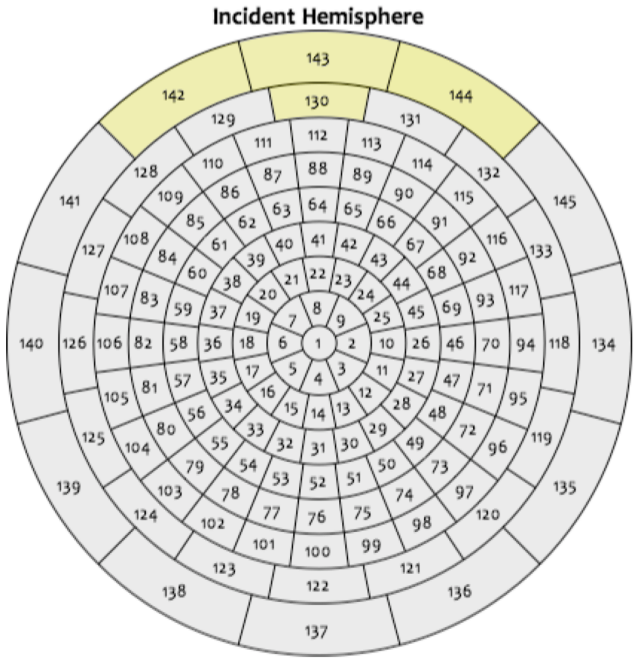


Transmitted Energy

Baseline **Double clear** window







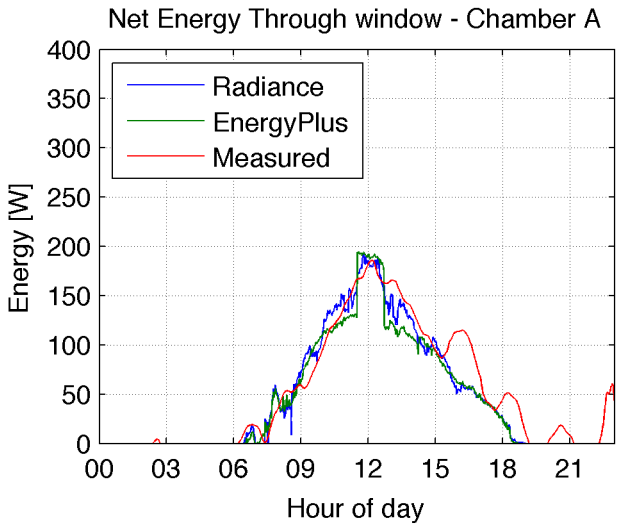
Transmitted Energy

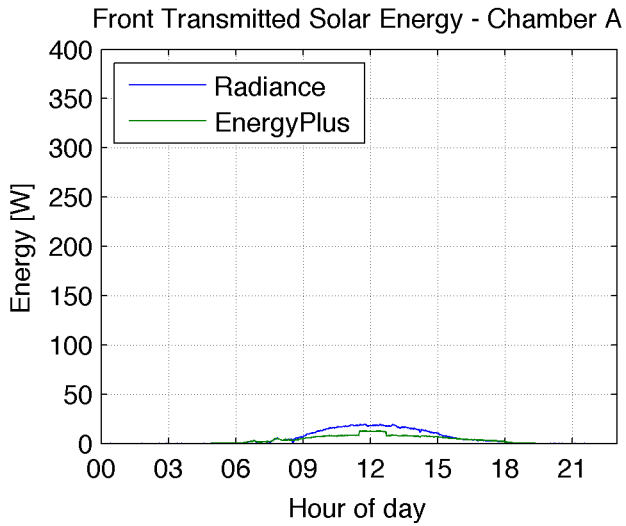
Baseline **Double clear** window

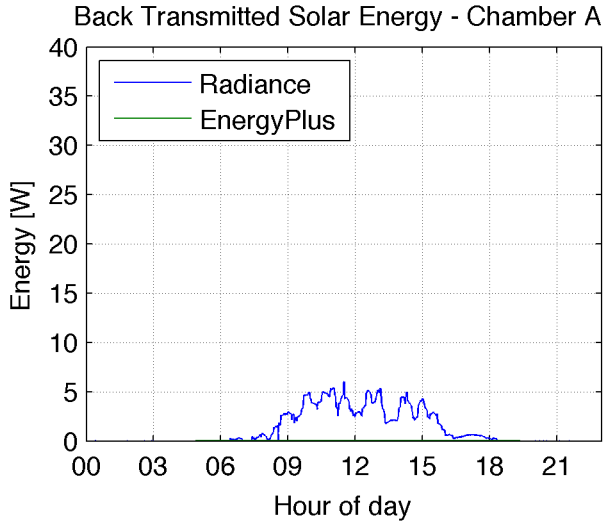
	Net energy rate avg (11:00 - 13:00) [W]		
Date	**Measured**	**Radiance**	**% difference**
5_12_17	227	254	11
5_13_17	222	241	8
5_15_17	219	234	6
5_19_17	230	253	9
5_20_17	239	250	4
5_21_17	230	248	8
6_16_17	163	182	11
6_17_17	170	185	8

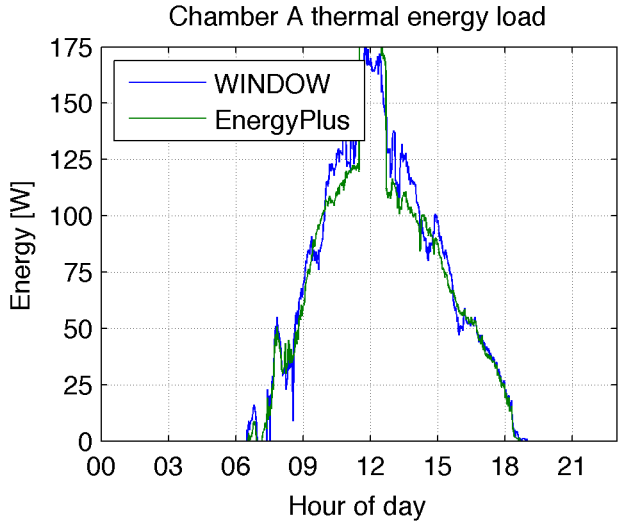
Transmitted Energy

Double clear window + **8%** openness dark **screen**



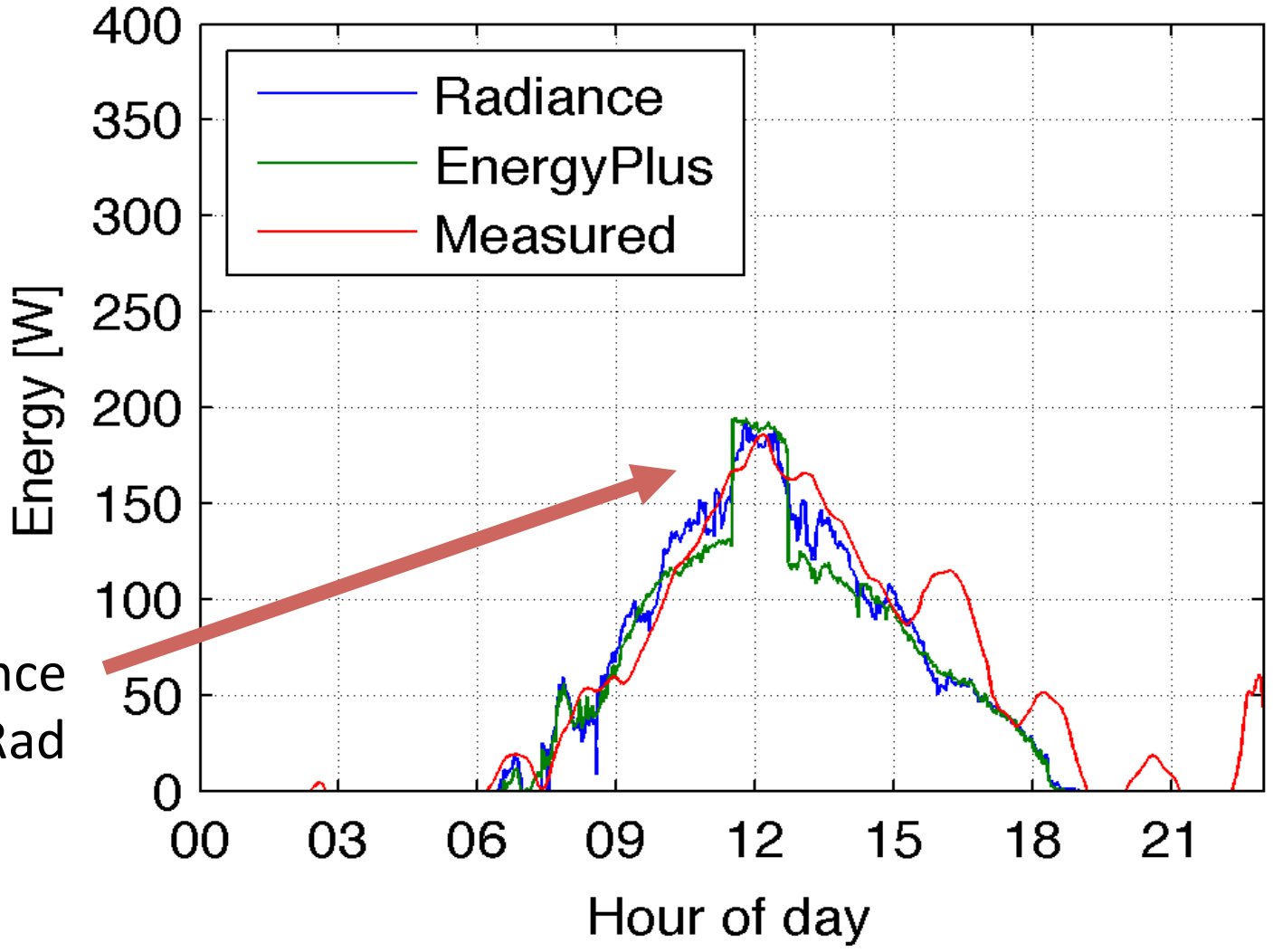






Transmitted Energy

Double clear window + **8%** openness dark **screen**



2% difference
meas. to E+ & Rad

This is a work in progress!

43 unique shading systems being **tested** of all types

Improved **accuracy** of thermal model for all shades

Six (and counting) **bugs** fixed in EnergyPlus and WINDOW relating to complex glazing systems
(most fixes released in next version on EnergyPlus)

Input from the Radiance community on methods to improve our validation techniques is why I'm here

Acknowledgements

DOE as part of AERC development

Giuseppe De Michele

Taoning Wang

Andy McNeil