



Bifacial_Radiance Training Part 1

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NREL Webinar
October 17, 2019

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- This webinar is being recorded.
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 - We will answer as many questions as possible at several point during the webinar.



bifacial_radiance

Open Source toolkit for working with RADIANCE for the
ray-trace modeling of Bifacial Photovoltaics

Available on: https://github.com/NREL/bifacial_radiance

Documentation: <https://bifacial-radiance.readthedocs.io>

Installation: <https://youtu.be/4A9GocfHKyM>

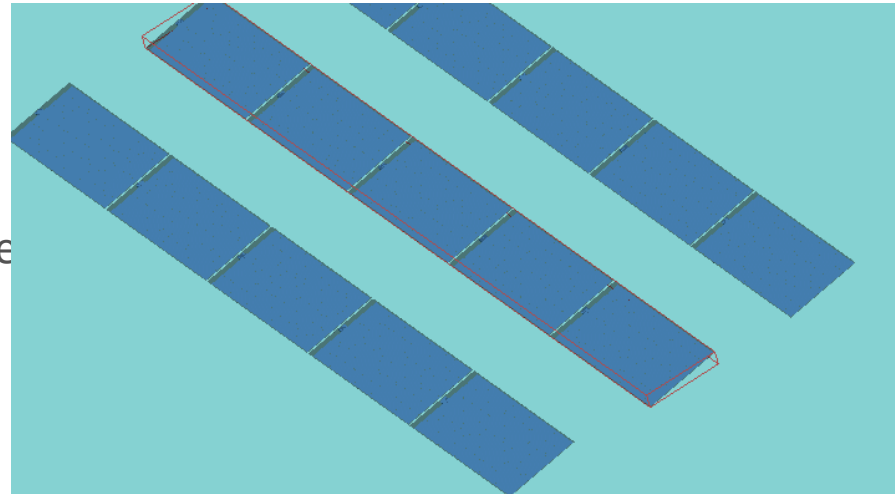
V. 0.3.3.1 (10/16/19)

Radiance

Radiance is a ray-trace software – a suite of tools for performing lighting simulation.
Developed in 1985, by Greg Ward at Lawrence Berkeley National Laboratory
Underlying simulation engine for many packages.
Homepage: <https://floyd.lbl.gov/radiance/HOME.html>

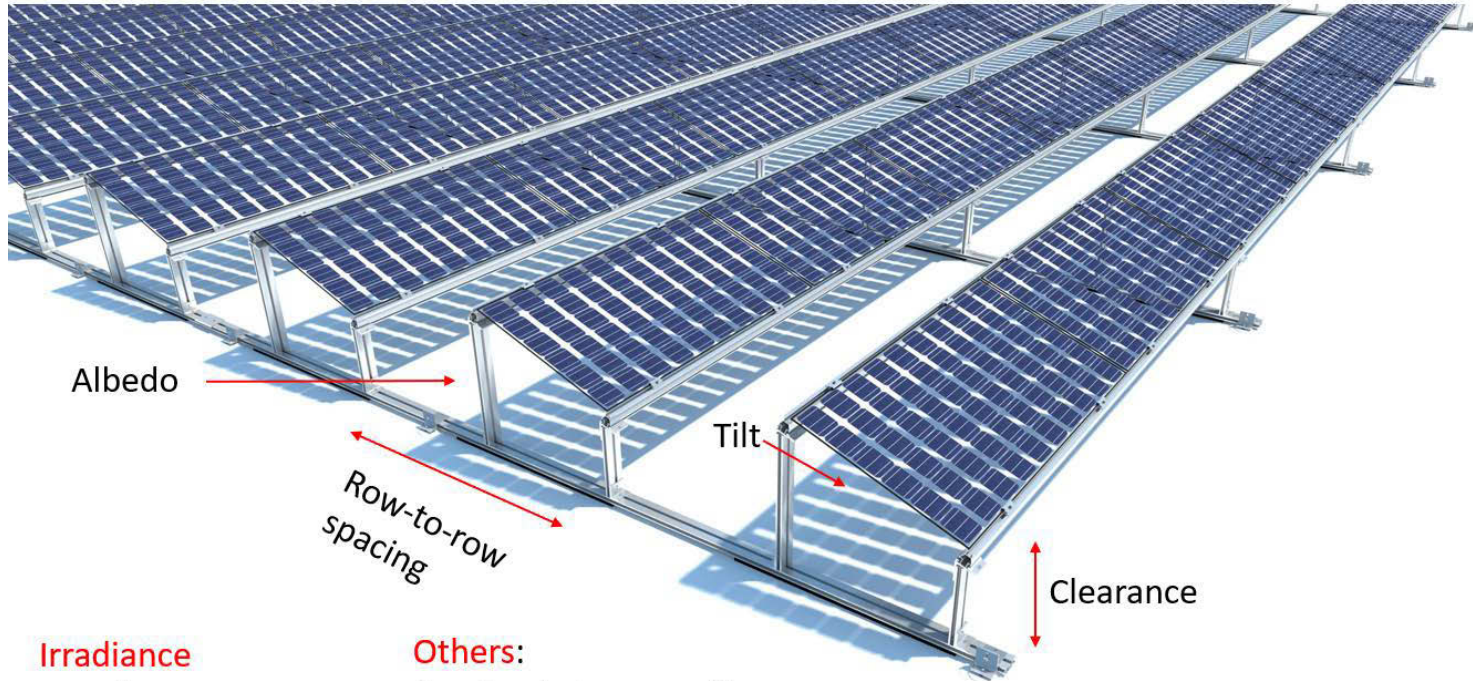
Modules << Sky

We use **backward ray-trace** to evaluate the irradiance (W/m^2) at the modules
Reduces complexity and run-time.



Bifacial Challenge: accurate modelling of rear irradiance

Image courtesy of Opsun trackers, via Francois Gilles-Gagnon



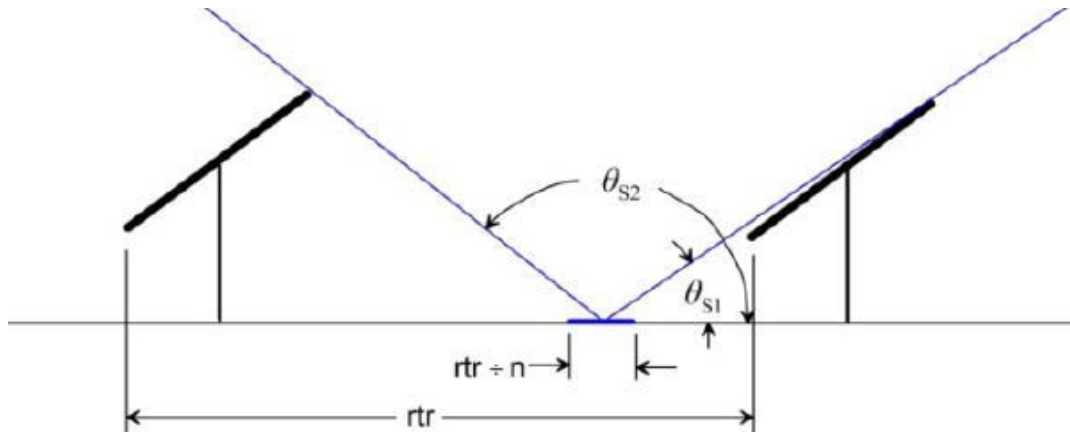
Irradiance

Location
Weather
Sky Diffuse

Others:

Spacing between cells
#rows, #panels
Mounting Structure
Other scene elements

View Factor Model for Rear Irradiance



Simple

basic
geometry

Fast

computationally
inexpensive

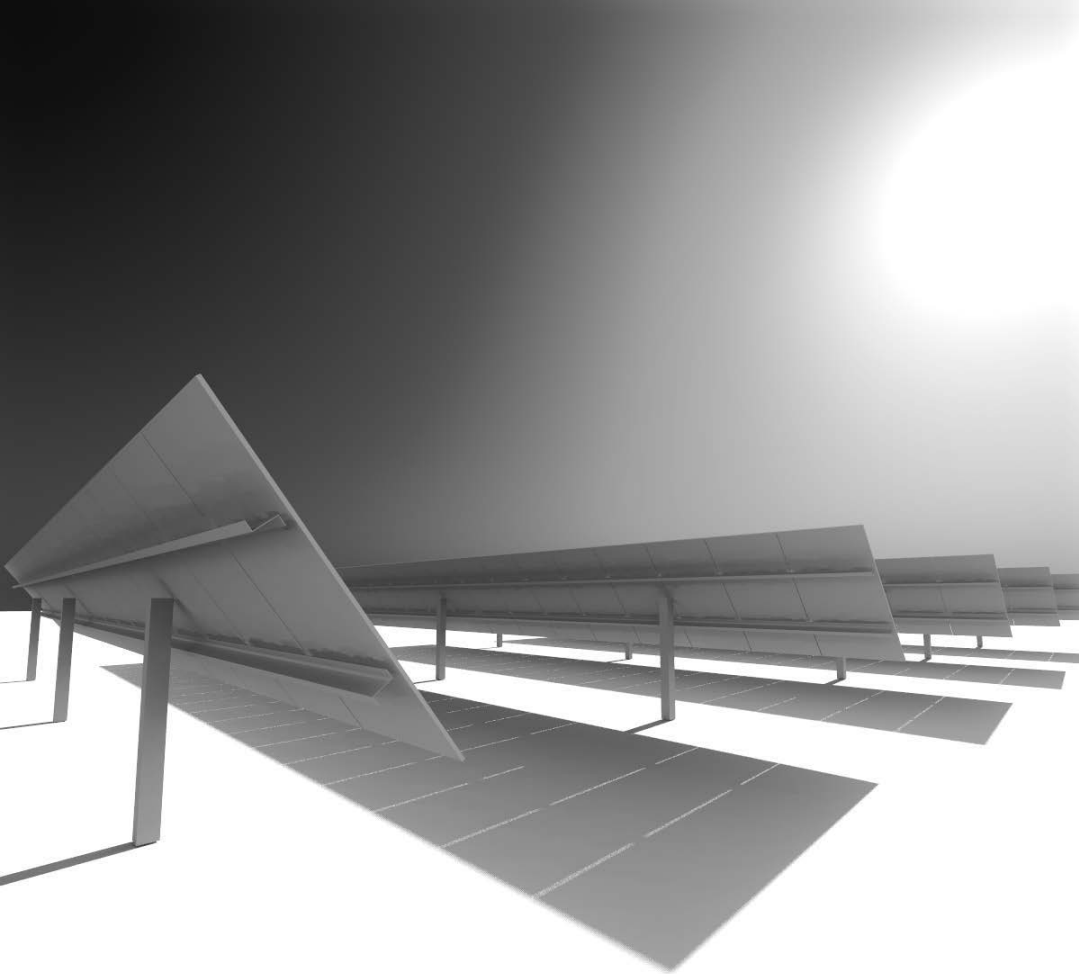
Common

Behind

SAM, Pvsyst, bifacialvf
and others

Simple

basic
geometry

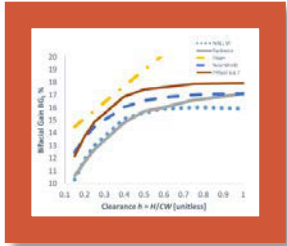


Raytrace benefits:

- Any size array
- Sample any module
- Evaluate edge effects
- Complicated geometries
 - Modules
 - Racking
 - Obstructions
- Evaluate shading
- Evaluate electrical mismatch
- Open source
- Dedicated visual interface
- Validated

Cons:

- Complexity ← Visual interface
- Run-times ← Training
- ← HPC integration
- ← Simplified models



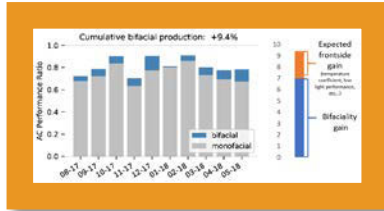
2017

Comparison of models and validation with test-bed data

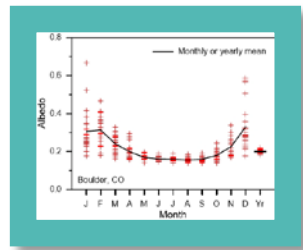


Single-axis tracking model

2018



Framework to calculate bifacial gain with field data
Validation with 2 100kW fields



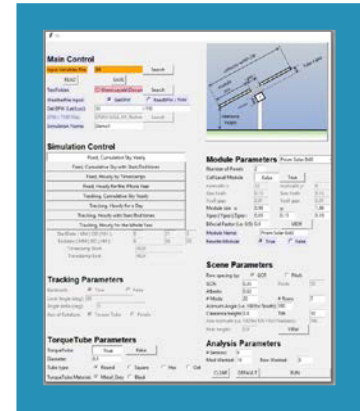
2019

Albedo assessment and database at Duramat

Standards for bifacial rating
Capacity testing



Assess system performance impact from rear irradiance shading and electrical mismatch



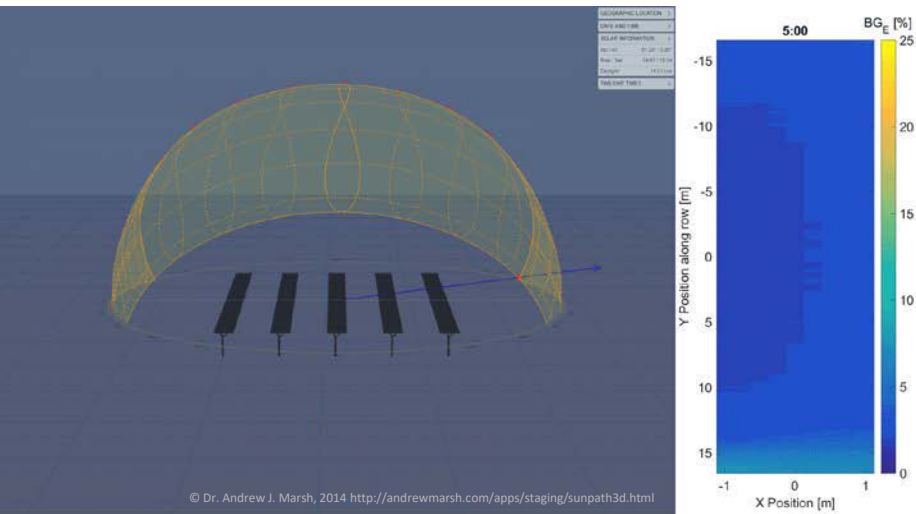
Publications

S. Ayala Pelaez, C. Deline, et al “Comparison of bifacial solar irradiance model predictions with field validation,” IEEE J. Photovoltaics, vol. 9, no. 1, pp. 82–88, 2019. <https://ieeexplore.ieee.org/abstract/document/8534404>

S. Ayala Pelaez, C. Deline, et al “Model and Validation of Single-Axis Tracking with Bifacial PV” IEEE J. Photovoltaics, 2019. <https://ieeexplore.ieee.org/abstract/document/8644027> <https://www.nrel.gov/docs/fy19osti/72039.pdf>

S. Ayala Pelaez, C. Deline, et al “Effect of Torque-Tube Parameters on Rear-Irradiance and Rear-Shading Loss for Bifacial PV Performance on Single-Axis Tracking Systems”, 46th PVSC. <https://www.nrel.gov/docs/fy20osti/73203.pdf>

Deline, C., et al “Bifacial PV Mismatch Loss Estimation and Parameterization”. 36th EUPVSEC <https://www.nrel.gov/docs/fy20osti/73541.pdf>
*Submitted as extended journal to PinPV



Complete list of publications: https://github.com/NREL/bifacial_radiance/wiki

Bifacial_radiance Training Part 1

1 Why/how we raytrace

2 Geometry

3 Skies

4 Github

5 Demo 1: Tutorial 1 in Jupyter Journal

6 Other Tutorials

7 Demo 2: GUI



20 minutes



10 minutes



10 minutes

Why | How we
raytrace?

Components

Sky

Source Properties

“Scene”

Modules

Racks

Obstructions

etc..

Materials

Properties

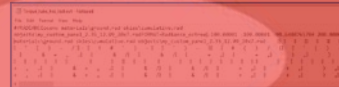
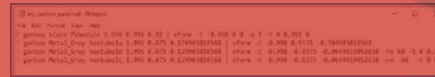
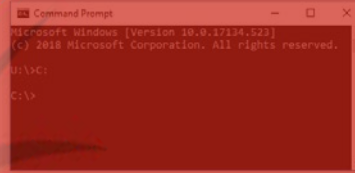
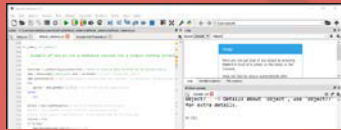


What does bifacial_radiance do?

bifacial_radiance



bifacial_radiance is a python wrapper for calling and using Radiance, with specific functions to generate geometry (text files) related to bifacial pv systems

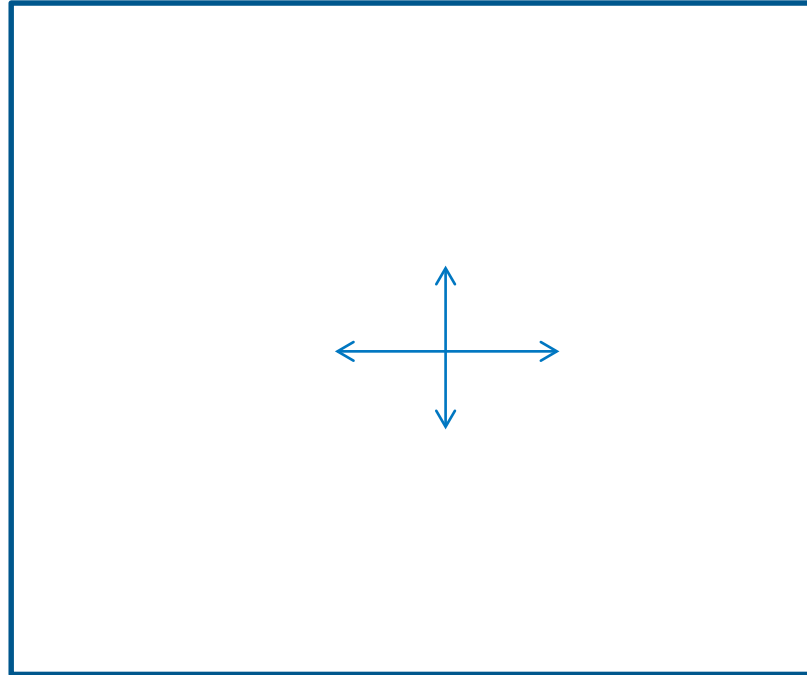


How a full example might look like

```
In [ ]: ▶ 1 from bifacial_radiance import *
2 demo = RadianceObj()
3 demo.setGround(0.62)
4 epwfile = demo.getEPW(37.5, -77.6)
5 metdata = demo.readWeatherFile(epwfile)
6 demo.gendaylight(metdata, 4020)
7 demo.makeModule("My_panel",x=1,y=2)
8 sceneDict={'tilt':30, 'pitch':3, 'clearance_height':0.5, 'azimuth':180, 'nMods':10, 'nRows':4}
9 scene = demo.makeScene("My_panel", sceneDict)
10 octfile=demo.makeOct()
11 analysis = AnalysisObj(octfile, demo.name)
12 frontscan, backscan = analysis.moduleAnalysis(scene)
13 analysis.analysis(octfile, demo.name, frontscan, backscan)
```

MAIN STEPS / INSTRUCTIONS

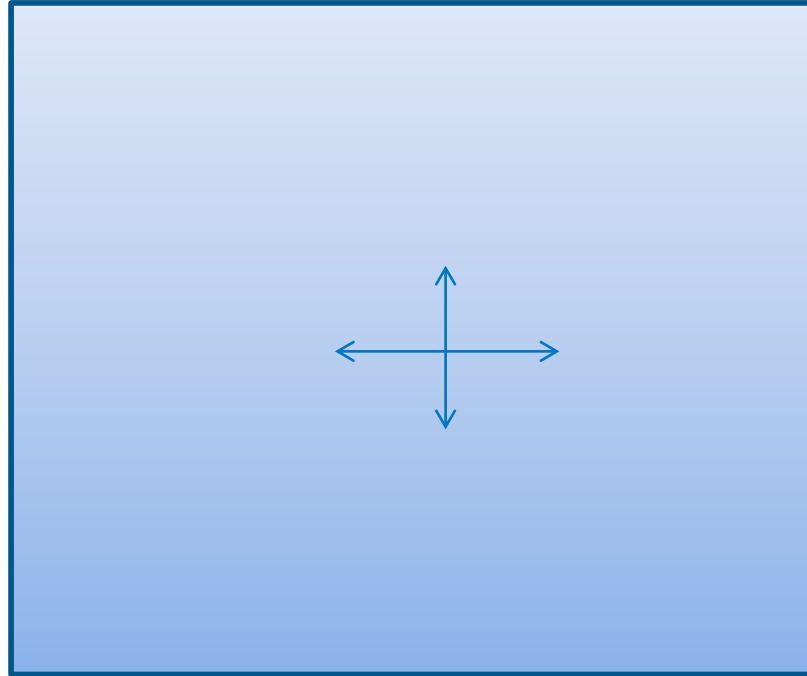
1. Make Radiance Object



MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object

2. Make Sky

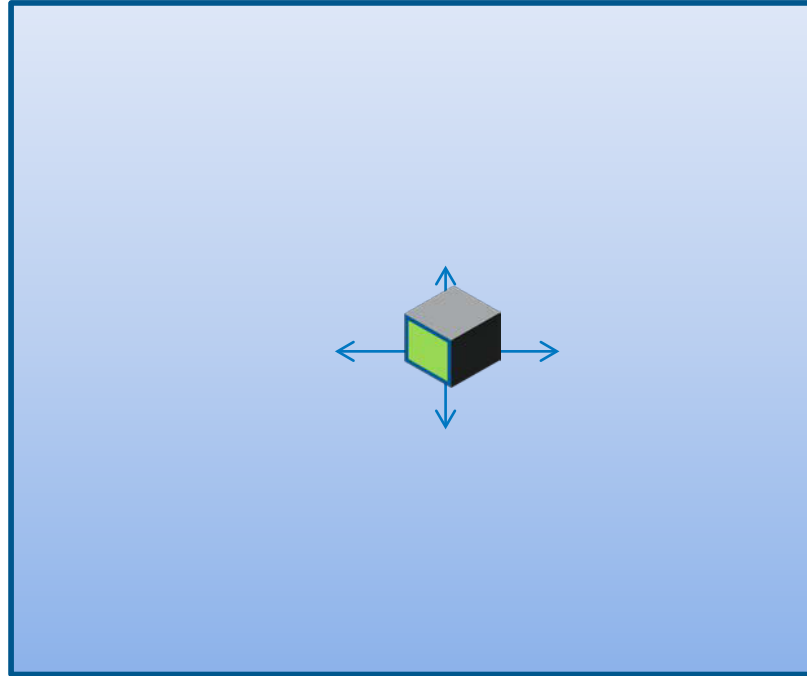


MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object

2. Make Sky

3. Make Module



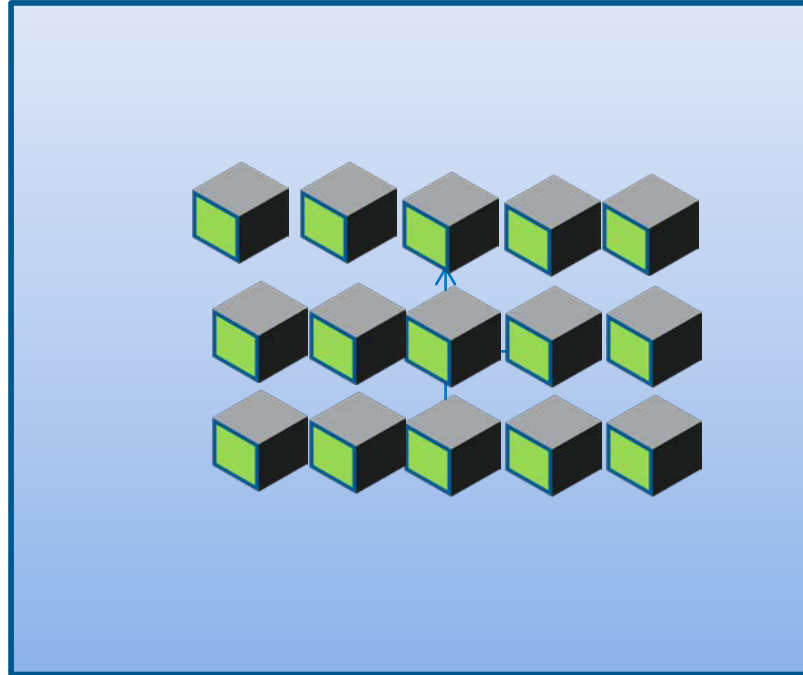
MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object

2. Make Sky

3. Make Module

4. Make Scene



MAIN STEPS / INSTRUCTIONS

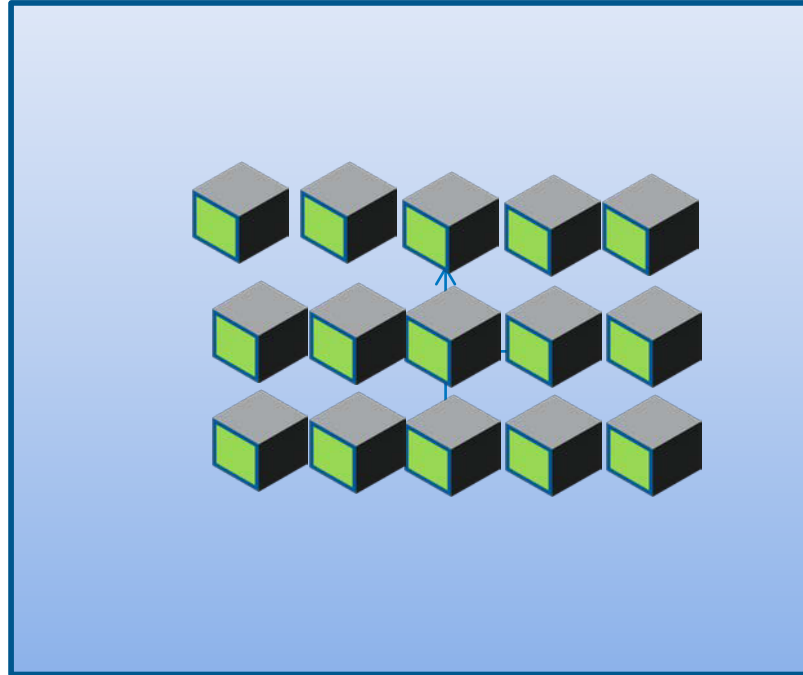
1. Make Radiance Object

2. Make Sky

3. Make Module

4. Make Scene

5. Make Oct



MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object

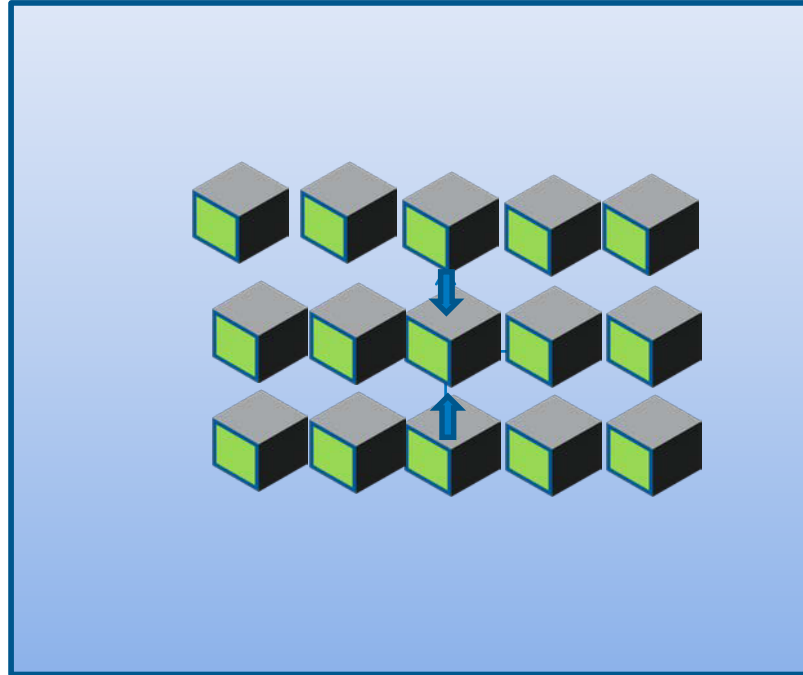
2. Make Sky

3. Make Module

4. Make Scene

5. Make Oct

6. Analysis Obj



MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object

2. Make Sky

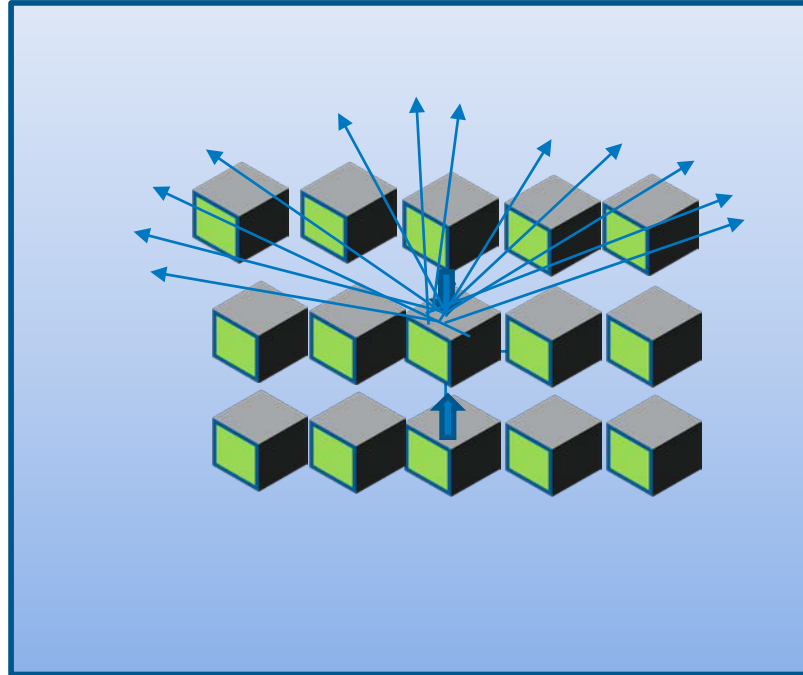
3. Make Module

4. Make Scene

5. Make Oct

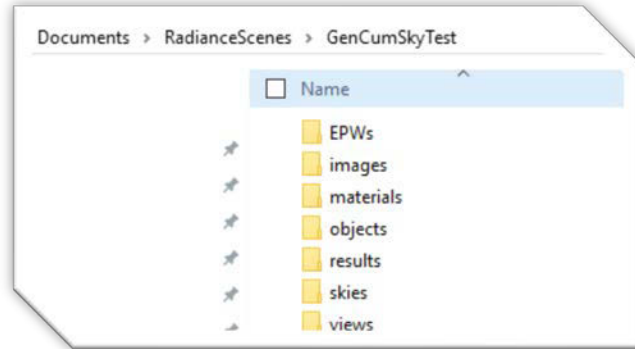
6. Analysis Obj

7. Analysis



MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object



MAIN STEPS / IN

1. Make Radiance Object

2. Make Sky

The image shows a workflow for creating a sky object in a simulation. It consists of three main components:

- Left Notepad (cumulative.rad):** Contains the Radiance object definition:

```
File Edit Format View Help
#Cumulative Sky Definition
void brightfunc skyfunc
2 skybright cumulative.cal
0
0

skyfunc glow sky_glow
0
0
0
4 1 1 1 0

sky_glow source sky
0
0
4 0 0 1 180

skyfunc glow ground_glow
0
0
4 0.996611520829 0.996611520829 0.996611520829 0
```
- Right Notepad (cumulative.cal):** Contains the sky generation script:

```
File Edit Format View Help
[ This .cal file was generated automatically by GenCumulativeSky ]
{ gencumulativesky +s1 -h 0 -a 37.5 -o -77.33 -m -75.0 -E -time 0 24 -date 1 1 1 31 EPWs\USA_VA_Richmond.Intl.

skybright=row0+row1+row2+row3+row4+row5+row6+row7;

row0=if(and(alt-0, 12-alt),select(floor(0.5+az/12.00)+1,
8958.339326,
9046.086505,
9096.713150,
9121.150082,
9152.248589,
9249.219459,
9505.784432,
10066.865817,
11157.326038,
13114.066034,
16200.616329,
16164.598678,
```
- File Browser:** Shows a directory structure with folders: EPWs, images, materials, objects, results, skies, and views. A blue arrow points from the 'results' folder to the 'cumulative.cal' Notepad window.

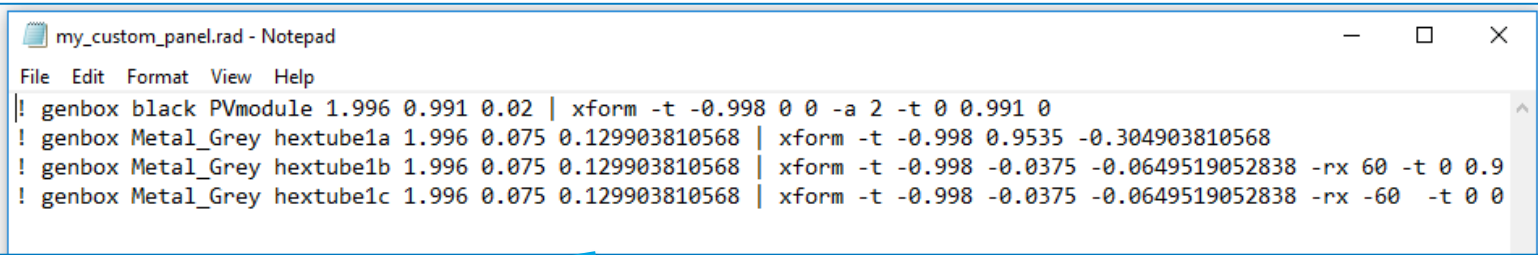
Blue arrows indicate the workflow: from the 'cumulative.cal' Notepad to the 'results' folder, and from the 'cumulative.rad' Notepad to the 'cumulative.cal' Notepad.

MAIN STEPS / INSTRUCTIONS

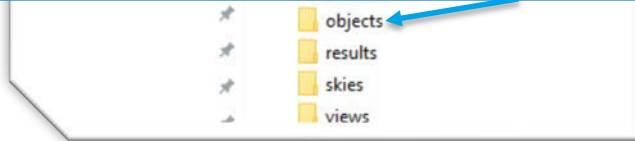
1. Make Radiance Object

2. Make Sky

3. Make Module



```
my_custom_panel.rad - Notepad
File Edit Format View Help
! genbox black PVmodule 1.996 0.991 0.02 | xform -t -0.998 0 0 -a 2 -t 0 0.991 0
! genbox Metal_Grey hextube1a 1.996 0.075 0.129903810568 | xform -t -0.998 0.9535 -0.304903810568
! genbox Metal_Grey hextube1b 1.996 0.075 0.129903810568 | xform -t -0.998 -0.0375 -0.0649519052838 -rx 60 -t 0 0.9
! genbox Metal_Grey hextube1c 1.996 0.075 0.129903810568 | xform -t -0.998 -0.0375 -0.0649519052838 -rx -60 -t 0 0
```



MAIN STEPS / INSTRUCTIONS

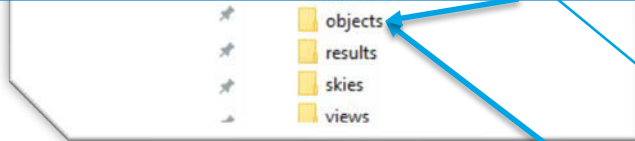
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my_custom_panel.rad - Notepad
File Edit Format View Help
! genbox black PVmodule 1.996 0.991 0.02 | xform -t -0.998 0 0 -a 2 -t 0 0.991 0
! genbox Metal_Grey hextube1a 1.996 0.075 0.129903810568 | xform -t -0.998 0.9535 -0.304903810568
! genbox Metal_Grey hextube1b 1.996 0.075 0.129903810568 | xform -t -0.998 -0.0375 -0.0649519052838 -rx 60 -t 0 0.9
! genbox Metal_Grey hextube1c 1.996 0.075 0.129903810568 | xform -t -0.998 -0.0375 -0.0649519052838 -rx -60 -t 0 0
```



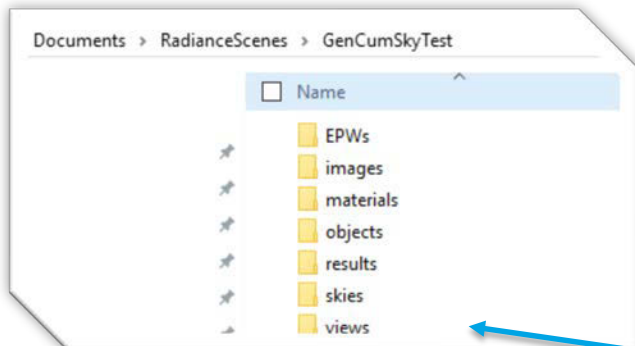
```
my_custom_panel_2.35_12.09_20x7.rad - Notepad
File Edit Format View Help
!xform -rx 10 -t 0 0 2.35 -a 20 -t 2.006 0 0 -a 7 -t 0 12.097 0 -i 1
|-t -19.96 -36.291 0 -rz 0 objects\my_custom_panel.rad
```

MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object

- 2. Make Sky
- 3. Make Module
- 4. Make Scene

5. Make Oct



```
Torque_tube_hex_test.oct - Notepad
File Edit Format View Help
#?RADIANCEoconv materials\ground.rad skies\cumulative.rad
objects\my_custom_panel_2.35_12.09_20x7.radFORMAT=Radiance_octree[-100.00001 -100.00001 -98.6480765784 200.00002
materials\ground.rad skies\cumulative.rad objects\my_custom_panel_2.35_12.09_20x7.rad 0 0 0 0 0 0
0 ' ( ) - / 0 0 ! # ' ) - 0 0 ' ) - 10 0 # ( ) / 10 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 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 & /0 0 & /0 0 + ,0 0 + ,0 ) ,0
<
```

MAIN STEPS / IN

1. Make Radiance Object

```
cumulative.rad - Notepad
File Edit Format View Help
#Cumulative Sky Definition
void brightfunc skyfunc
2 skybright cumulative.cal
0
0
skyfunc glow sky_glow
0
0
4 1 1 1 0
sky_glow source sky
0
```

2. Make Sky

3. Make Module

4. Make Scene

5. Make Oct

```
my_custom_panel.rad - Notepad
File Edit Format View Help
! genbox black PVmodule 1.996 0.991 0.001 | xform -t -0.998 0 0 -a 2 -t 0 0.991 0
! genbox Metal_Grey hextube1a 1.996 0.075 0.129903810568 | xform -t -0.998 0.9535 -0.304903810568
! genbox Metal_Grey hextube1a 1.996 0.075 0.129903810568 | xform -t -0.998 0.9535 -0.304903810568
! genbox Metal_Grey hextube1a 1.996 0.075 0.129903810568 | xform -t -0.998 0.9535 -0.304903810568
! genbox Metal_Grey hextube1a 1.996 0.075 0.129903810568 | xform -t -0.998 0.9535 -0.304903810568

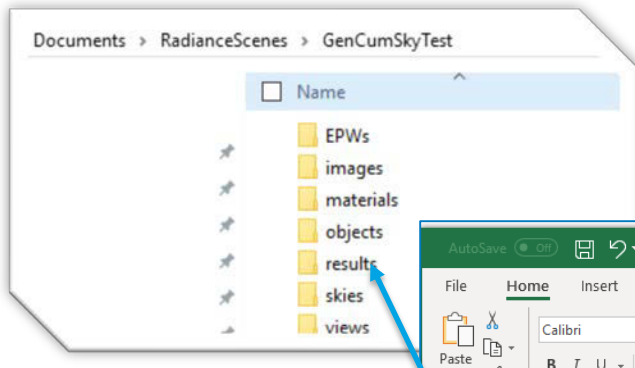
my_custom_panel_2.35_12.09_20x7.rad - Notepad
File Edit Format View Help
!xform -rx 10 -t 0 0 2.35 -a 20 -t 2.006 0 0 -a 7 -t 0 12.097 0 -i 1
|-t -19.96 -36.291 0 -rz 0 objects\my_custom_panel.rad
```

```
Torque_tube_hex_test.oct - Notepad
File Edit Format View Help
#?RADIANCEoconv materials\ground.rad skies\cumulative.rad
objects\my_custom_panel_2.35_12.09_20x7.rad FORMAT=Radiance_oconv 100.00001 -100.00001 -98.6480765784 200.00002
materials\ground.rad skies\cumulative.rad objects\my_custom_panel_2.35_12.09_20x7.rad 0 0 0 0 0 0
0 ' ( ) - / 0 0 ! # ' ) - 0 0 ' ) - 10 0 # ( ) / 10 0 ' ( ) -
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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 0 & / 0 0 & / 0 0 + , 0 0 + , 0 0 ) ,
+ , .0 0 & + , .0 0 & / 0 0 & / 0 0 + , 0 0 + , 0 0 ) ,
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```

MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object

- 2. Make Sky
- 3. Make Module
- 4. Make Scene



irr_Torque_tube_hex_test.csv - Excel

POSSIBLE DATA LOSS: Some features might be lost if you save this workbook in the comma-delimited (.csv) format. To preserve these features, save it in an Excel file format.

	A	B	C	D	E	F	G	H	I	J
1	x	y	z	rearZ	mattype	rearMat	Wm2Front	Wm2Back	Back/FrontRatio	
2	0	0.009711	3.694171	2.321712	a10.3.a0.PVmodule.6457	a10.3.a0.PVmodule.2310	76758.41333	33357.68	0.43458	
3	0	0.019422	3.694171	2.321712	a10.3.a0.PVmodule.6457	a10.3.a0.PVmodule.2310	76760.16	33345.74	0.434415	
4	0	0.029133	3.694171	2.321712	a10.3.a0.PVmodule.6457	a10.3.a0.PVmodule.2310	76759.81333	33333.91667	0.434263	
5	0	0.038844	3.694171	2.321712	a10.3.a0.PVmodule.6457	a10.3.a0.PVmodule.2310	76759.48	33322.09667	0.43411	
6	0	0.048554	3.694171	2.321712	a10.3.a0.PVmodule.6457	a10.3.a0.PVmodule.2310	76759.13667	33310.27	0.433958	
7	0	0.058265	3.694171	2.321712	a10.3.a0.PVmodule.6457	a10.3.a0.PVmodule.2310	76758.79667	33298.45	0.433806	
8	0	0.067976	3.694171	2.321712	a10.3.a0.PVmodule.6457	a10.3.a0.PVmodule.2310	76758.45	33286.62667	0.433654	
9	0	0.077687	3.694171	2.321712	a10.3.a0.PVmodule.6457	a10.3.a0.PVmodule.2310	76758.10667	33274.80333	0.433502	

5. Make Oct

6. Analysis Obj

7. Analysis

MAIN STEPS / INSTRUCTIONS

1. Make Radiance Object

- 2. Make Sky
- 3. Make Module
- 4. Make Scene

```
cmd gencumsky
```

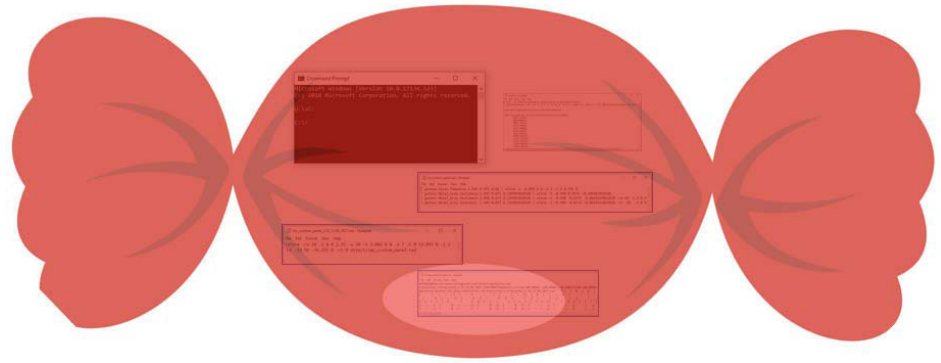
5. Make Oct

```
cmd oconv
```

6. Analysis Obj

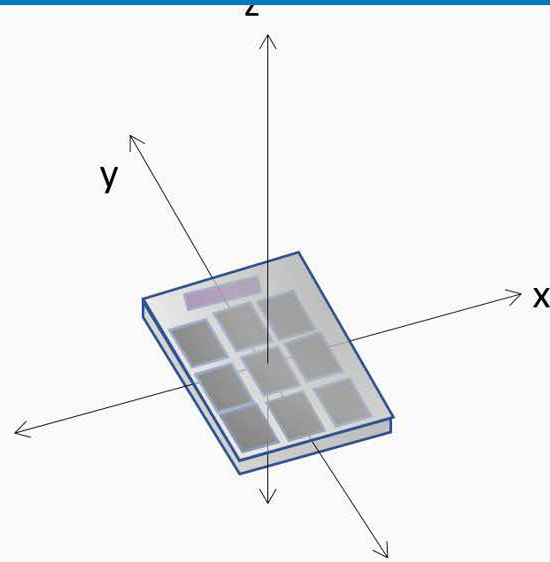
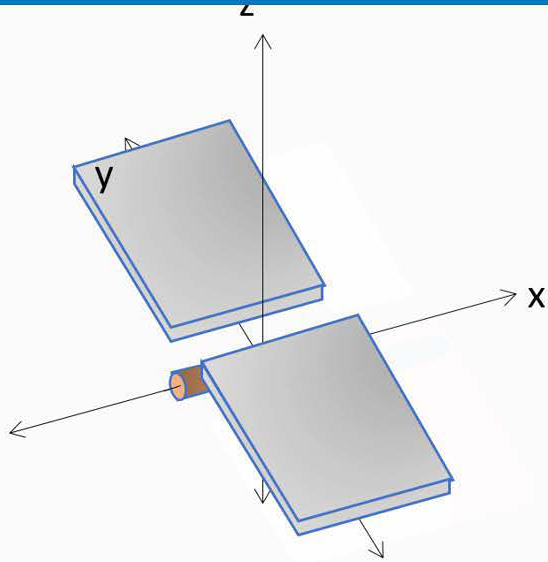
7. Analysis

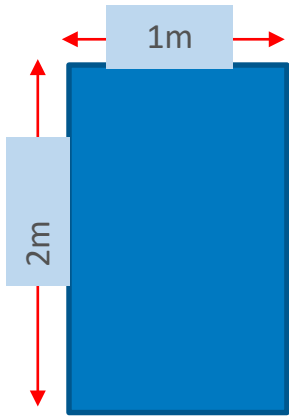
```
cmd rtrace
```



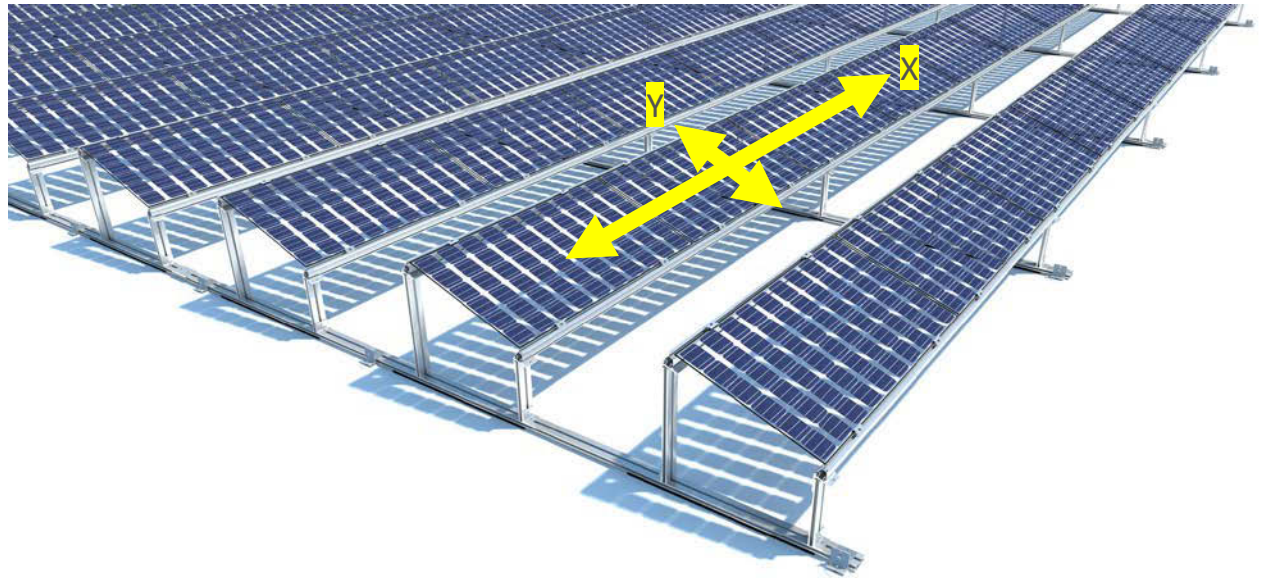
Geometry

makeModule: “module unit” (module, cells, torque tube, etc) to replicate





Assign x and y depending on which value should go along the axis / slope



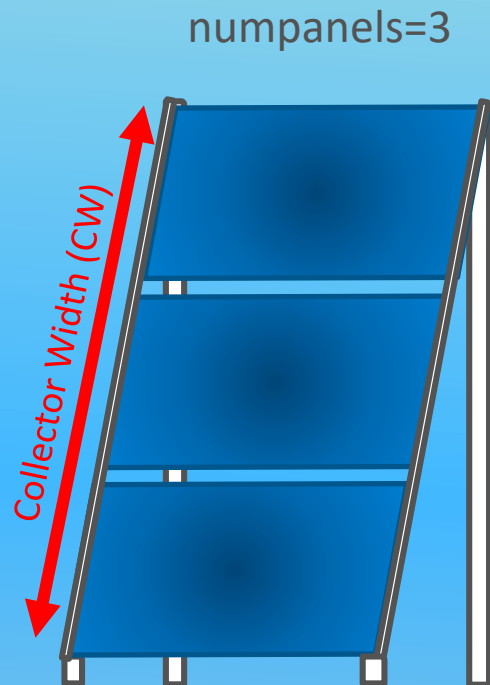
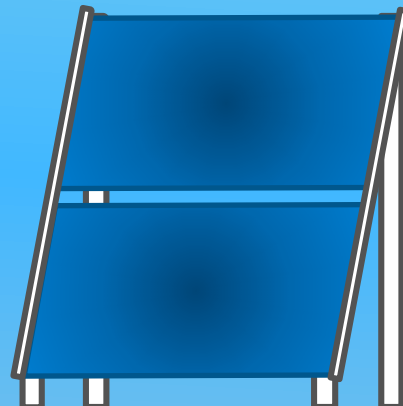
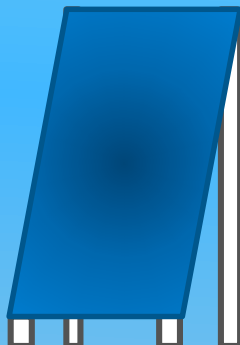
For example:

'PORTRAIT'

$y = 2, x = 1$

LANDSCAPE

$y = 1, x = 2$



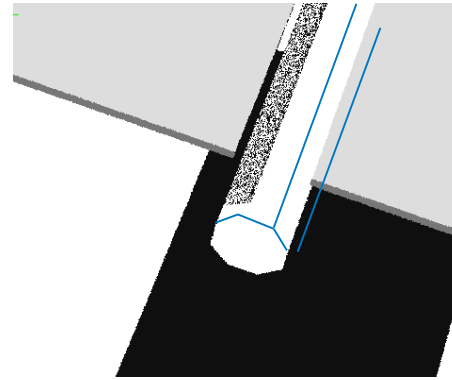
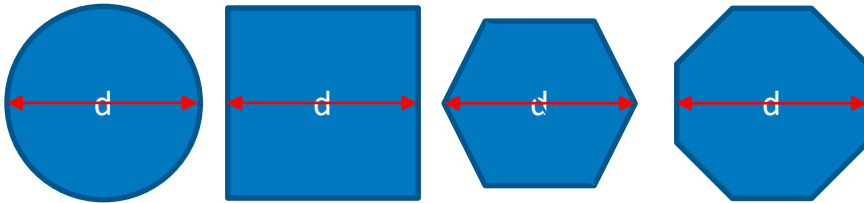
numpanels=2

numpanels=3

Collector Width (CW)

Torque Tube

All based on “diameter”

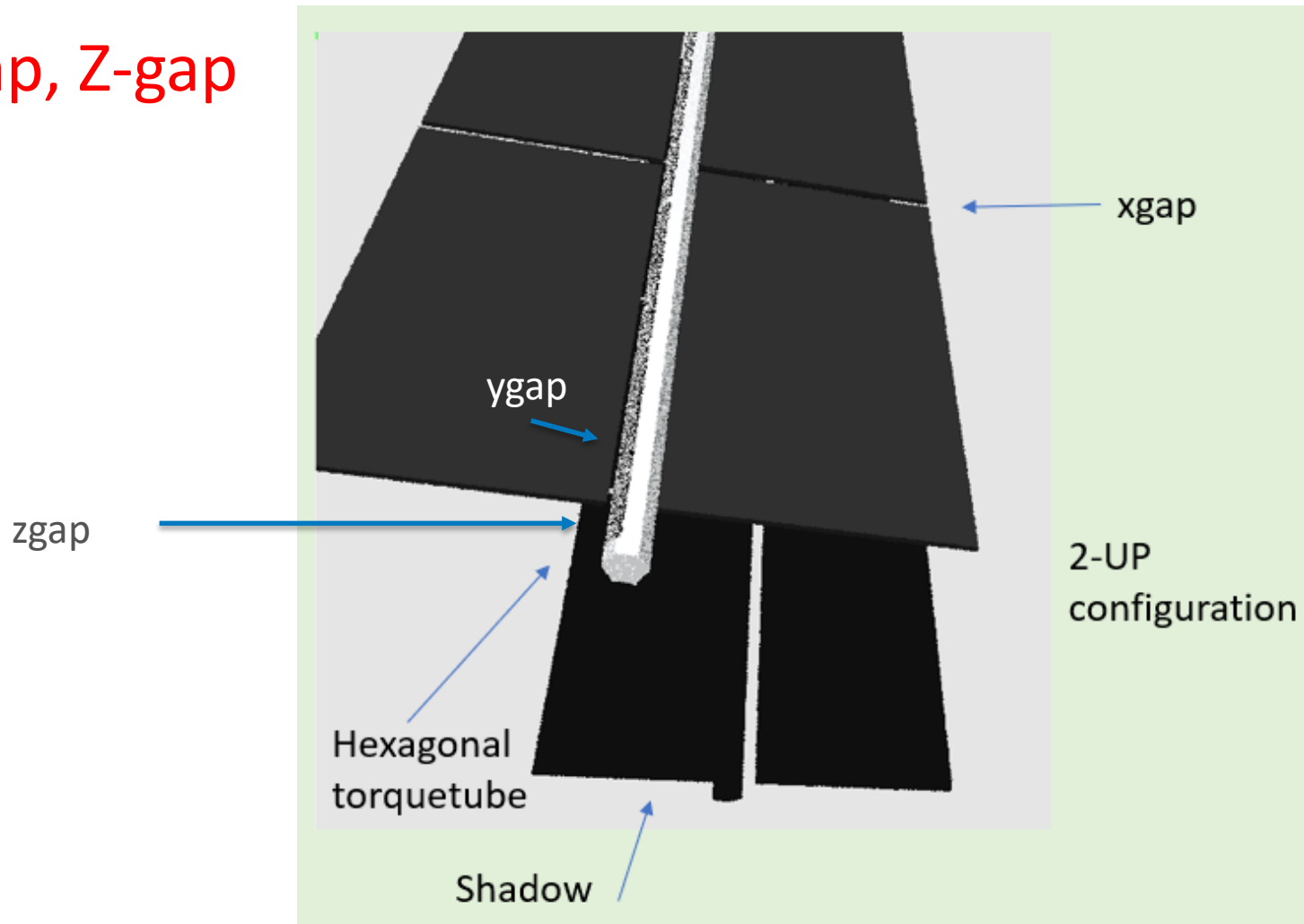


Modifiable material

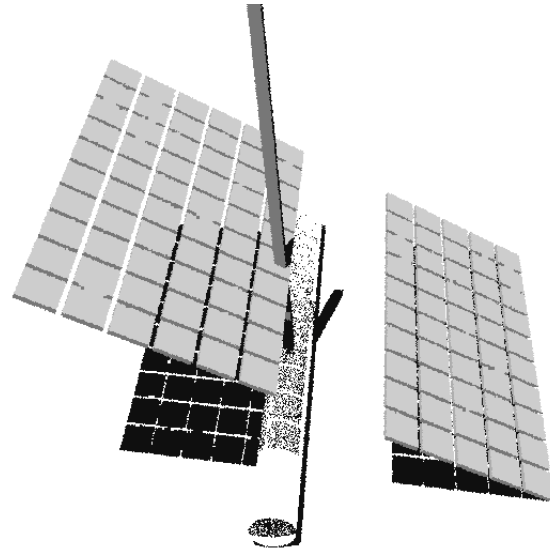
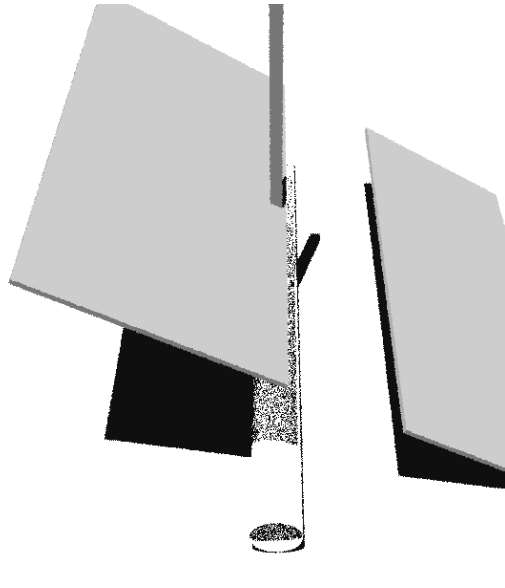
Metal_Grey (GREY NOT GRAY) → 44% reflectivity.

Black → Absorptive.

X-gap, Y-gap, Z-gap

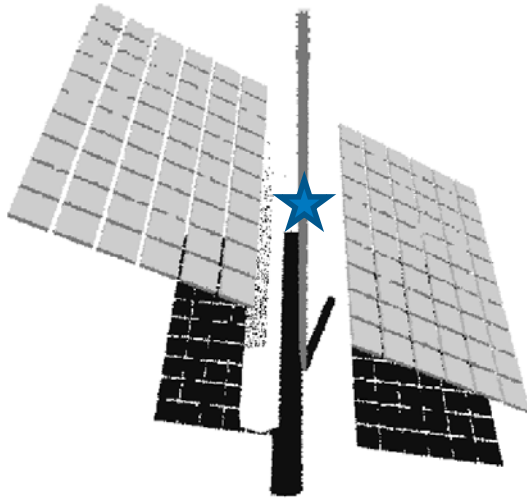


Cell Level Module

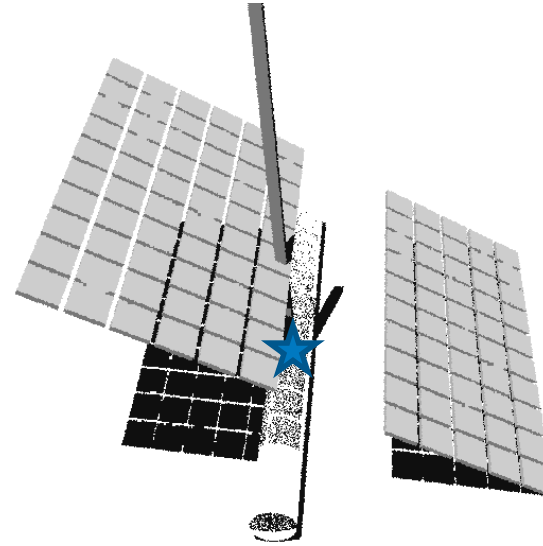


Axis of rotation Torquetube

- FALSE

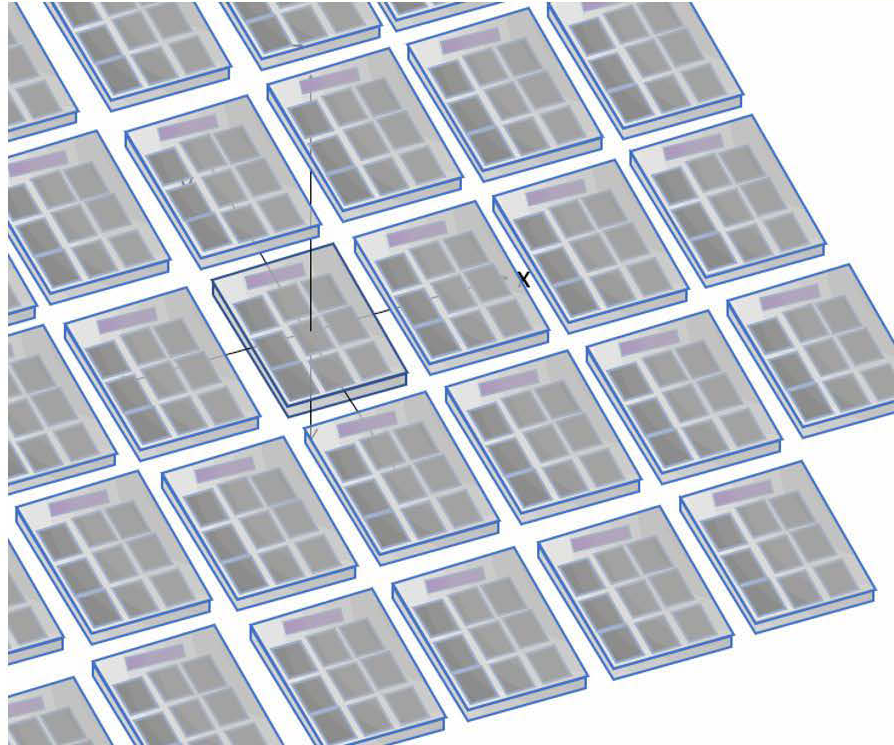


- TRUE



Offset from axis of rotation = $z_{gap} + \text{diam}/2$

makeScene: replicates whatever was defined as the module unit to make the Scene



`!xform -rx 10 -t 0 0 2.35 -a 4 -t 2.046 0 0 -a 1 -t 0 12.552 0 -i 1 -t -4.092 -0.0 0 -rz 90 objects\Panel1.rad`

tilt
↓

clearance
height
↓

nRows
↓

Rtr
↓

place center module in 0
(self.scenex * nMods/2)
↓

Azimuth rotation
↓

nMods
↑

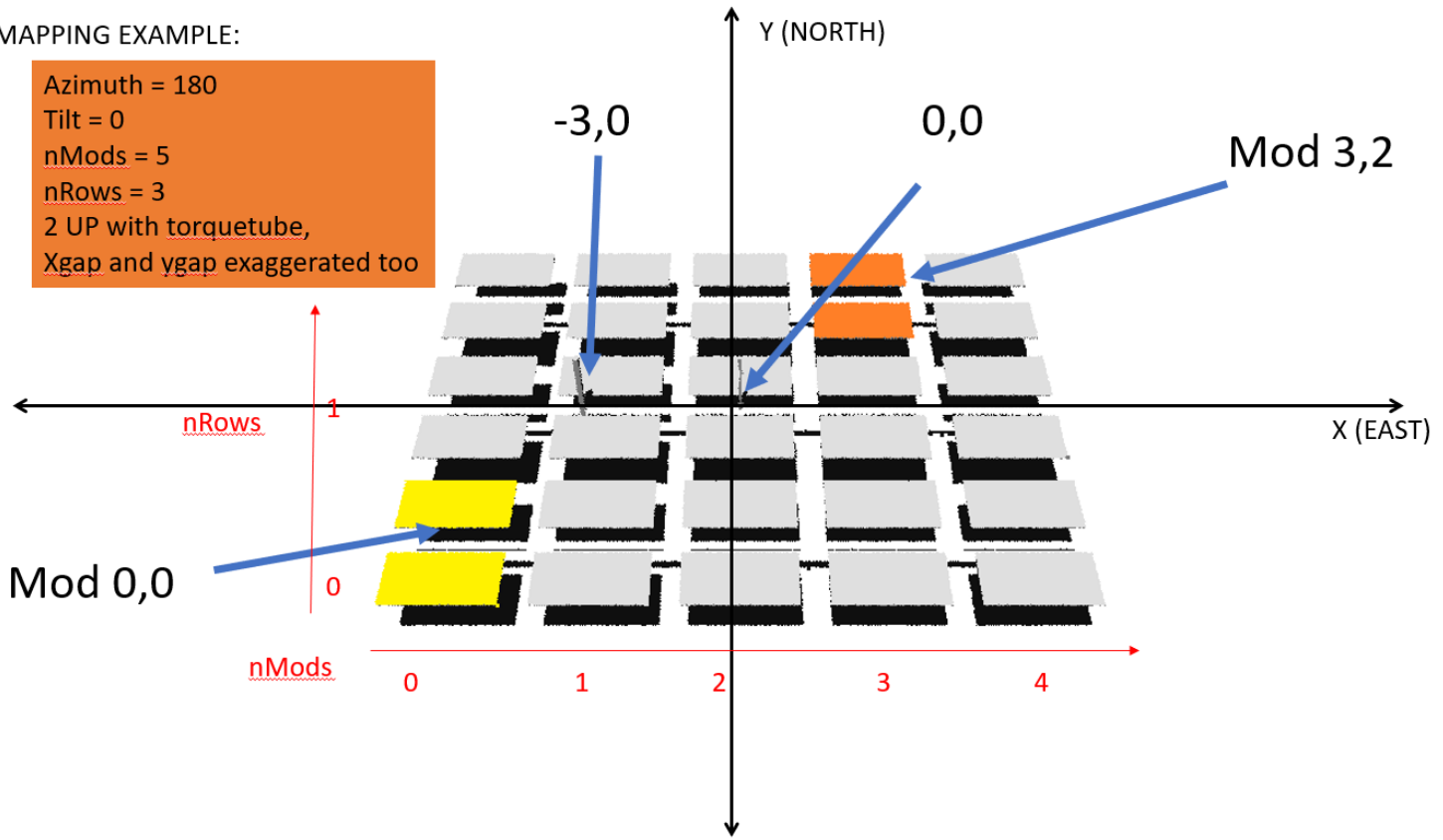
self.scenex
↑

Place center row
on 0
↑

Object to Replicate
↑

MAPPING EXAMPLE:

Azimuth = 180
Tilt = 0
nMods = 5
nRows = 3
2 UP with torquetube,
Xgap and ygap exaggerated too



Sky

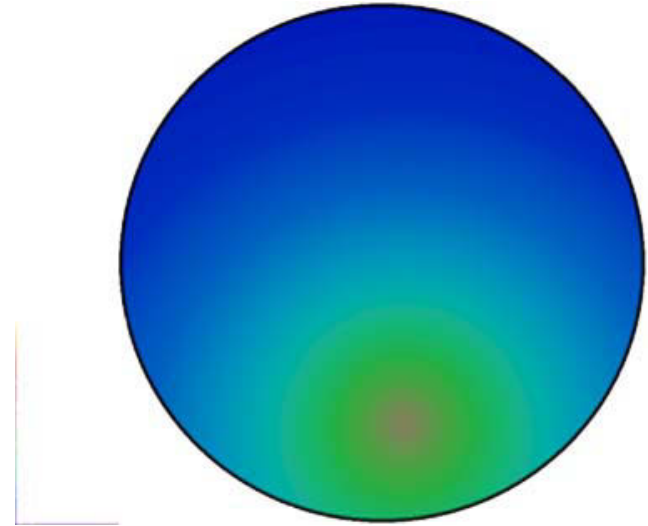
Hourly Sky

“Gendaylit”

Hourly distribution

Perez Model

Must know: sun position, DNI, DHI



Pvlib.sun azimuth-180

```
!gendaylit -ang 29.44 -3.3976 -W 476 149 - g 0.62 -O 1
```

Pvlib.sun altitude

DNI DHI

ground
albedo

W/m²-sr
solar radiation

Richmond, Virginia EPW, timestamp[11] ---- January 1st at Noon

Cumulative sky

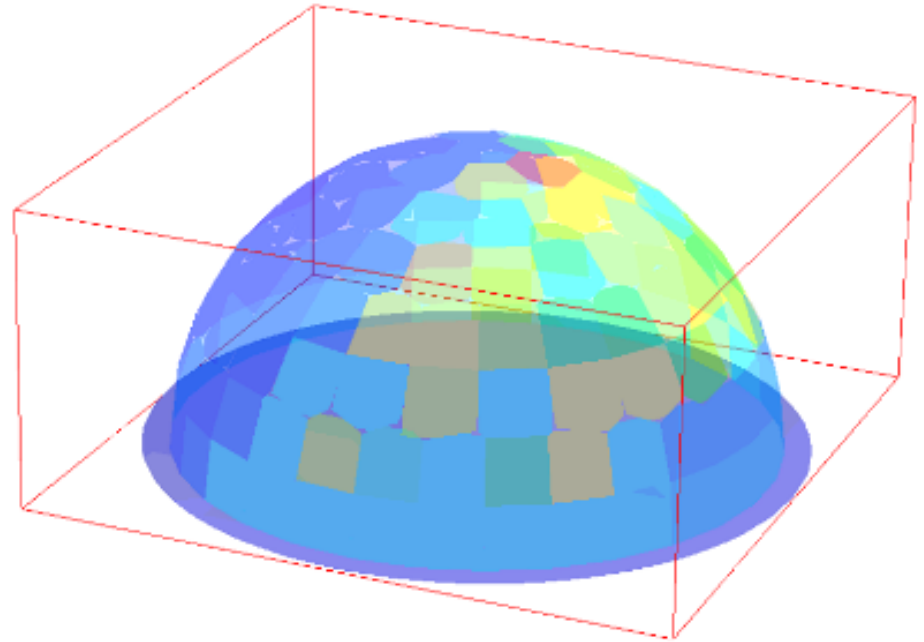
“Gencumsky”

Bins sky into 145 patches of same angular extent

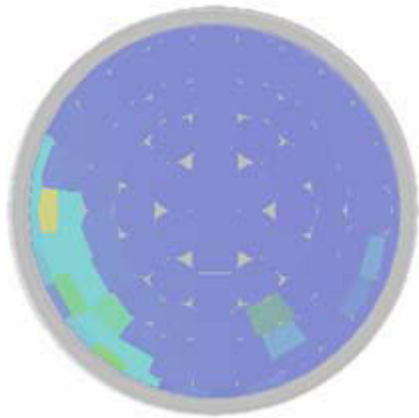
Irradiances for each patch can be cumulative for any period of time.

→ Increase in speed

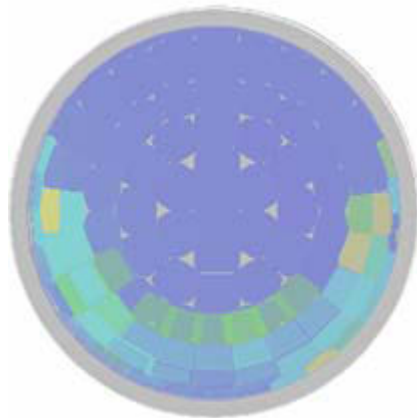
Robinson, Stone “Irradiation modelling made simple: the cumulative sky approach” 2004



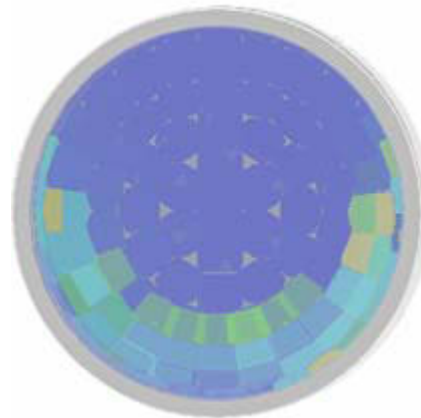
Gencumulative Sky



Simulate Hourly
~4380 simulations



Simulate Daily
~365 simulations



Simulate Monthly
~12 simulations

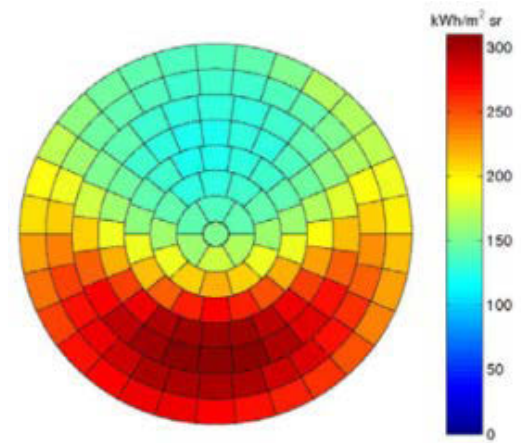
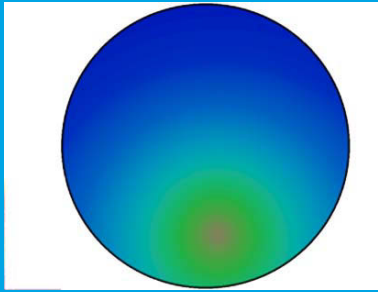


Figure 1 Cumulative diffuse sky radiance distribution for Oslo (based on 10yr mean solar data).

Simulate Yearly
~1 simulations

Gendaylit

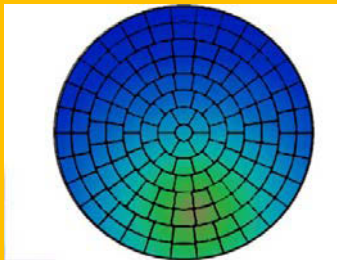


Perez Model

```
sky2_1axisTrack_3.rad - Notepad
File Edit Format View Help
# start of sky definition for daylighting studies
# location name: Richmond LAT: 37.5 LON: -77.33 Elev: 54.0
# Sun position calculated w. PVLib
!gendaylit -ang -45.5637656782 -94.442474712 -W 0 0 -g 0.62 -0 1
skyfunc glow sky_mat
0
0
4 1 1 1 0
|
sky_mat source sky
0
0
4 0 0 1 180

skyfunc glow ground_glow
0
0
4 0.996611520829 0.996611520829 0.996611520829 0
```

GencumSky



Robinson and Stone

```
cumulative.rad - Notepad
File Edit Format View Help
#Cumulative Sky Definition
void brightfunc skyfunc
2 skybright cumulative.cal
0
0

skyfunc glow sky_glow
0
0
4 1 1 1 0

sky_glow source sky
0
0
4 0 0 1 180

skyfunc glow ground_glow
0
```

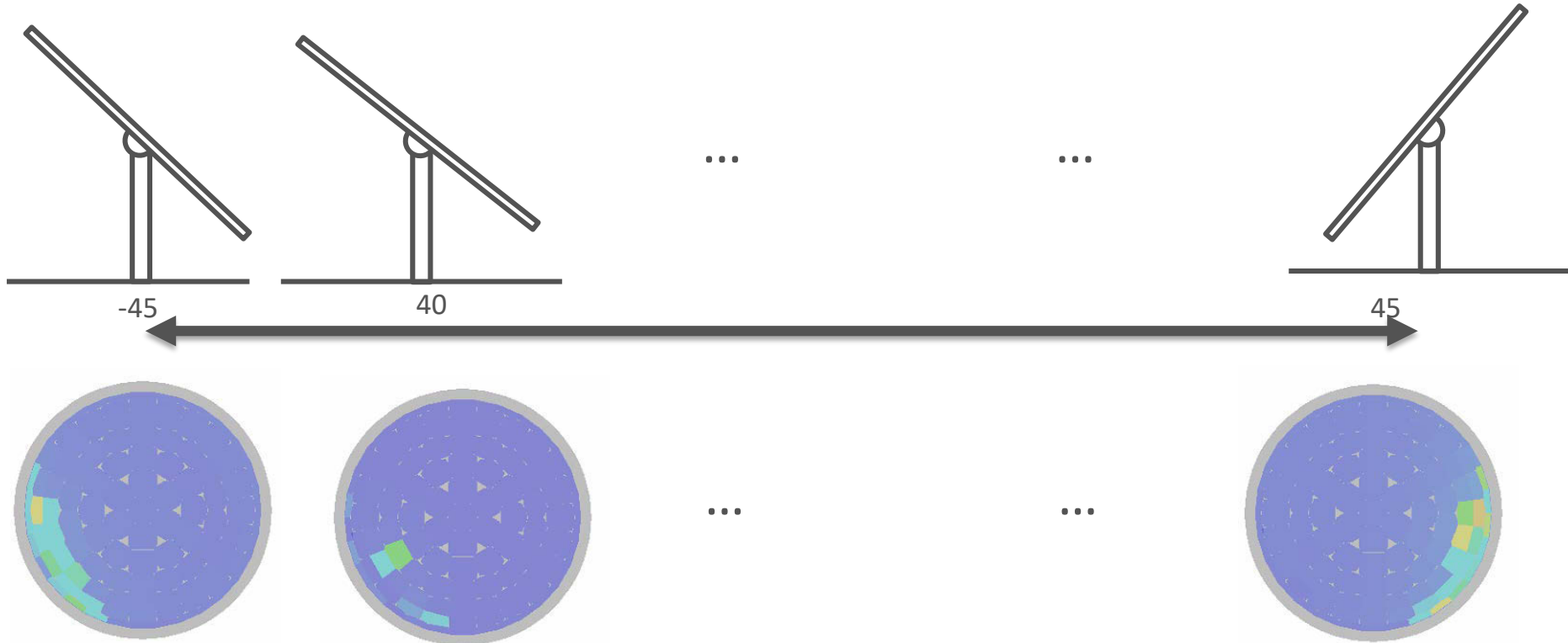
```
cumulative.cal - Notepad
File Edit Format View Help
{ This .cal file was generated automatically by GenCumulativeSky }
{ gencumulativesky +s1 -h 0 -a 37.5 -o -77.33 -m -75.0 -E -time 0 24 -date 1 1 1 31 EPWs\USA_VA_Ri

skybright=row0+row1+row2+row3+row4+row5+row6+row7;

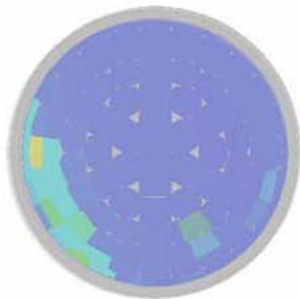
row0=if(and(alt-0, 12-alt),select(floor((0.5+az/12.00))+1,
8958.339326,
9046.086505,
9096.713150,
9121.150082,
9152.248589,
9249.219459,
9505.784432,
10066.865817,
11157.326638,
13114.966034,
16200.616329,
```

Cummulative Sky by Tracker Angle

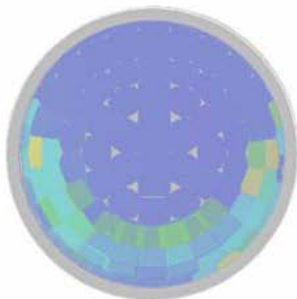
S. Ayala Pelaez, C. Deline, P. Greenberg, J. S. Stein, and R. K. Kostuk, "Model and Validation of Single-Axis Tracking with Bifacial PV - Preprint," IEEE Journal of Photovoltaics, 2019, vol 9 no. 3, pp. 715-721.



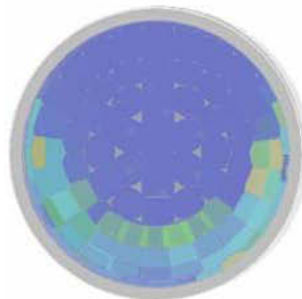
Cummulative Skies



Hourly
~4380 simulations



Accumulate Daily
~365 simulations



Accumulate Monthly
~12 simulations

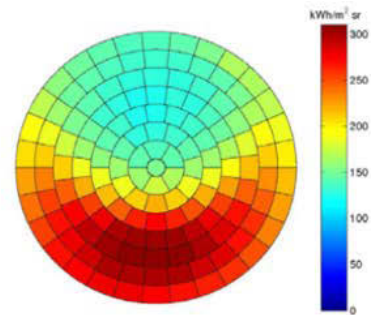
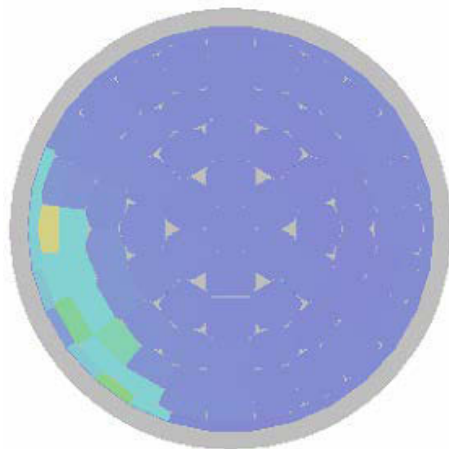


Figure 1 Cumulative diffuse sky radiance distribution for Oslo (based on 10yr mean solar data).

Accumulate Yearly
~1 simulations



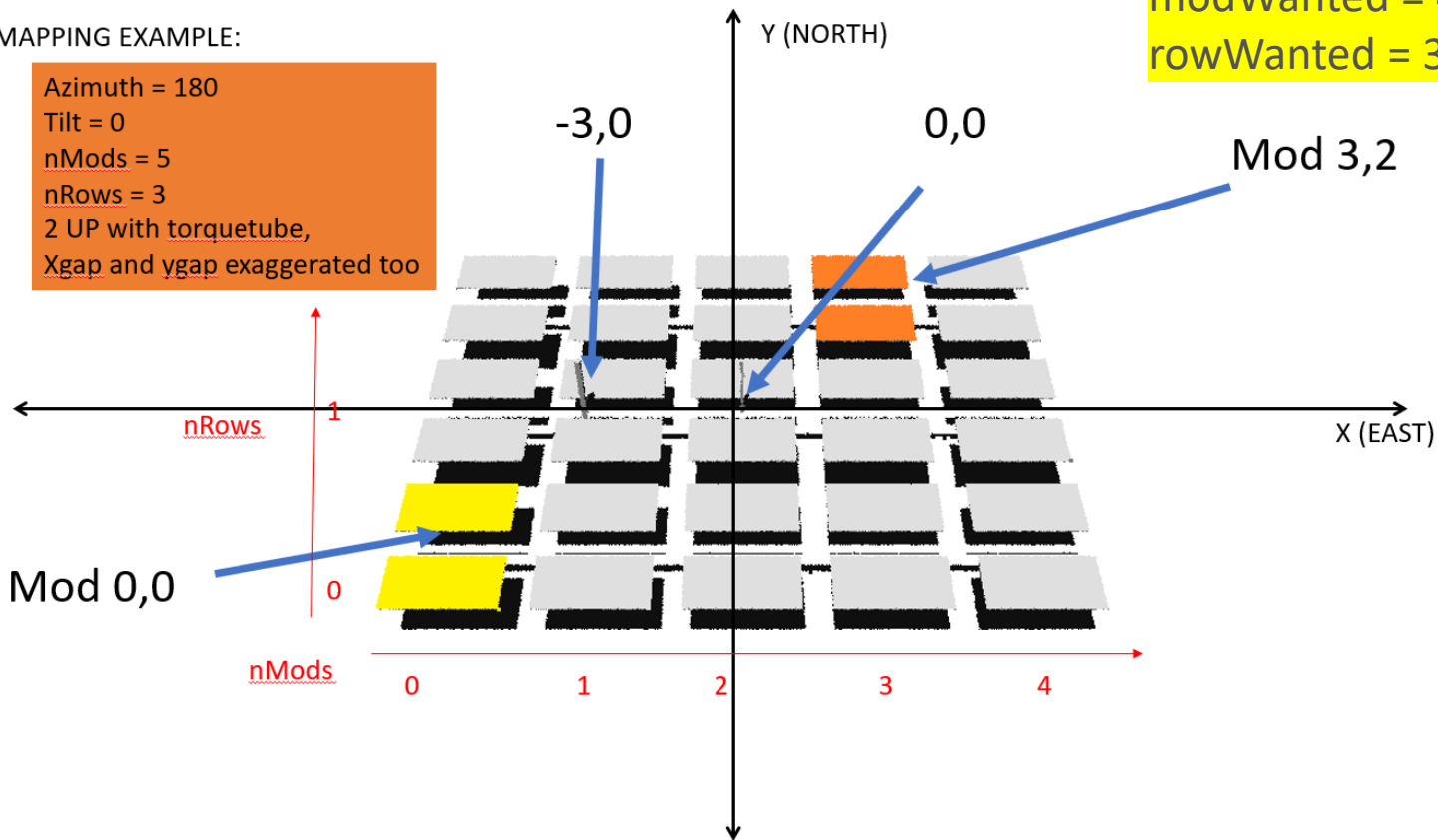
Tracking
Accumulate by tracker angle
-45 to 45: ~19 simulations

Analysis Objects

MAPPING EXAMPLE:

Azimuth = 180
Tilt = 0
nMods = 5
nRows = 3
2 UP with torquetube,
Xgap and ygap exaggerated too

modWanted = 4
rowWanted = 3

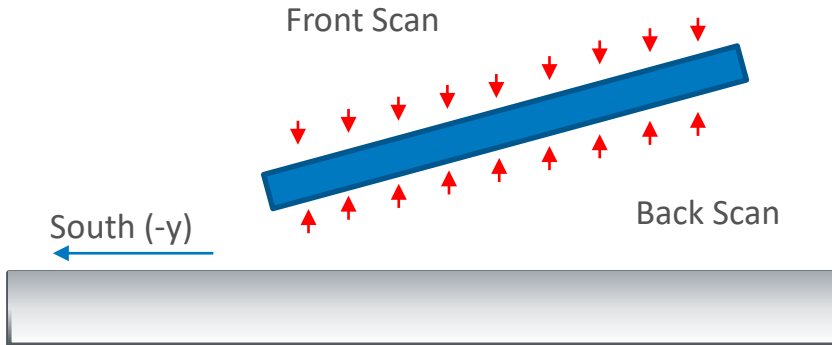


sensory

Sensors are spaced equidistant to each other
No 'safety distance' from edges.

The detectors measure irradiance at the
first surface they 'see'.

Sensors are placed close to the surfaces to avoid hitting
torque tubes.



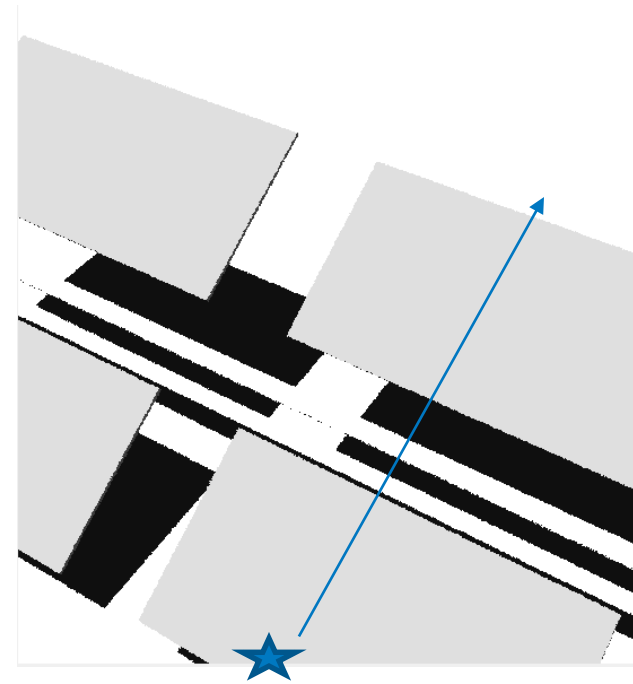
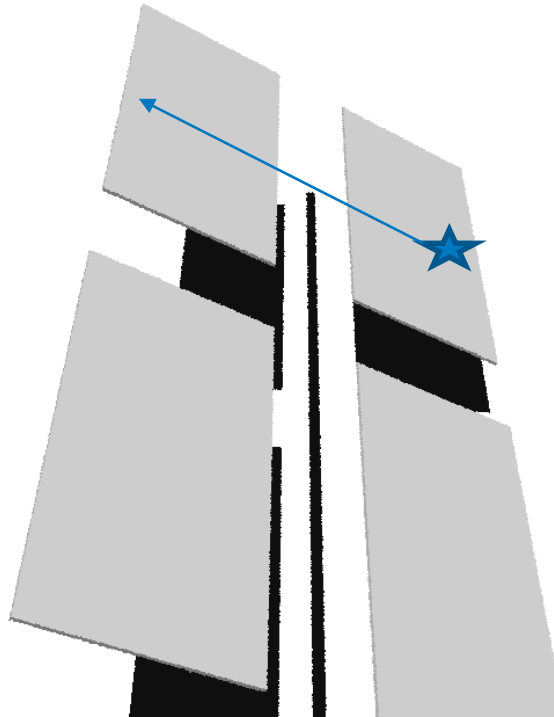
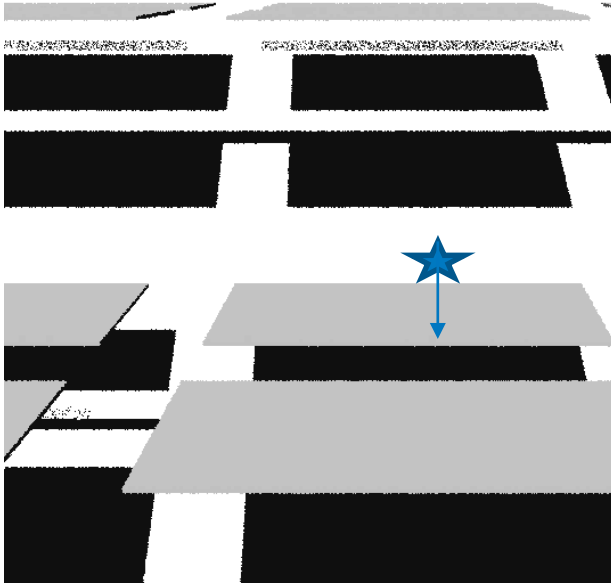
Complex geometries might
require "Cleaning Up"
the results

Azimuth

0

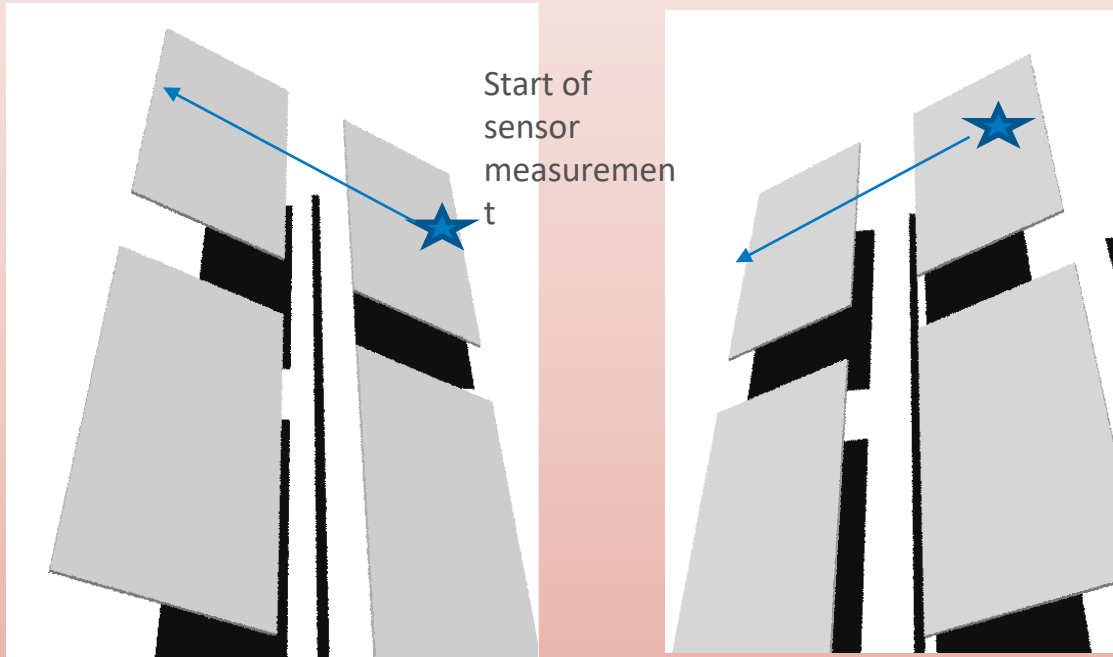
90

210



Tracking Sensor Position

Tracking: same azimuth_axis, tilts are negative for the afternoon.
Sensor locations fall on the same place in the module!



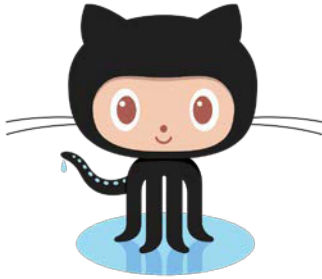
Bifacial_radiance Training Part 1

- 1 Why/how we raytrace
- 2 Geometry
- 3 Skies
- 4 Github**
- 5 Demo 1: Tutorial 1 in Jupyter Journal
- 6 Other Tutorials
- 7 Demo 2: GUI

Github

Tutorials

Jupyter Notebooks



Website to store and manage code, track and control changes and new versions.










https://github.com/NREL/bifacial_radiance/



Open-source web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text.

Example starting-guide: <https://realpython.com/jupyter-notebook-introduction/>

Journals

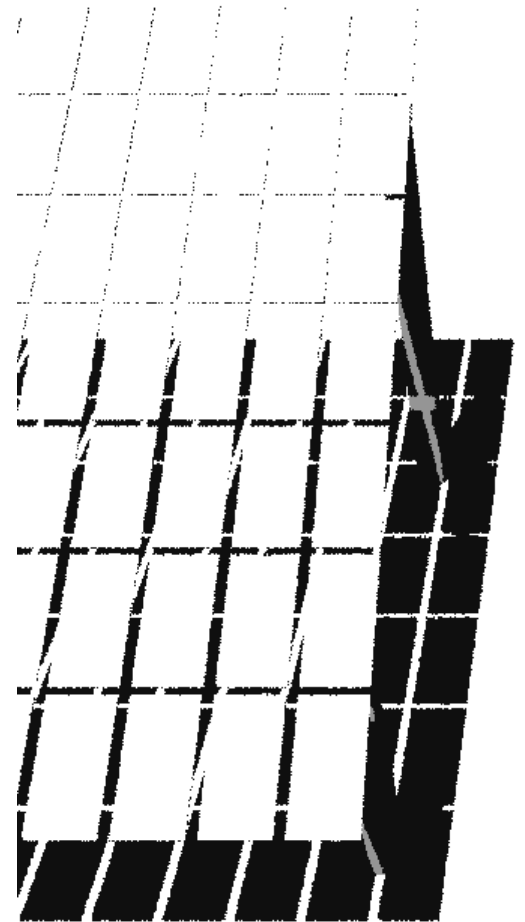
-  1 - Introductory Example - Fixed Tilt simple setup.ipynb
-  2 - Introductory Example - Single Axis Tracking with cumulative Sky.ipynb
-  3 - Medium Level Example - Single Axis Tracking - hourly.ipynb
-  4 - Medium Level Example - Debugging your Scene with Custom Objects (Fixed Tilt 2-up with Torque Tube + CLEAN Routine + CustomObject).ipynb
-  5 - Medium Level Example - Bifacial Carports and Canopies + sampling across a module!.ipynb
-  6 - Advanced topics - Understanding trackerdict structure.ipynb
-  7 - Advanced topics - Multiple SceneObjects Example.ipynb
-  8 - Advanced topics - Calculating Power Output and Electrical Mismatch.ipynb
-  9 - Advanced topics - 1 axis torque tube Shading for 1 day (Research documentation).ipynb

https://github.com/NREL/bifacial_radiance/tree/master/docs/tutorials

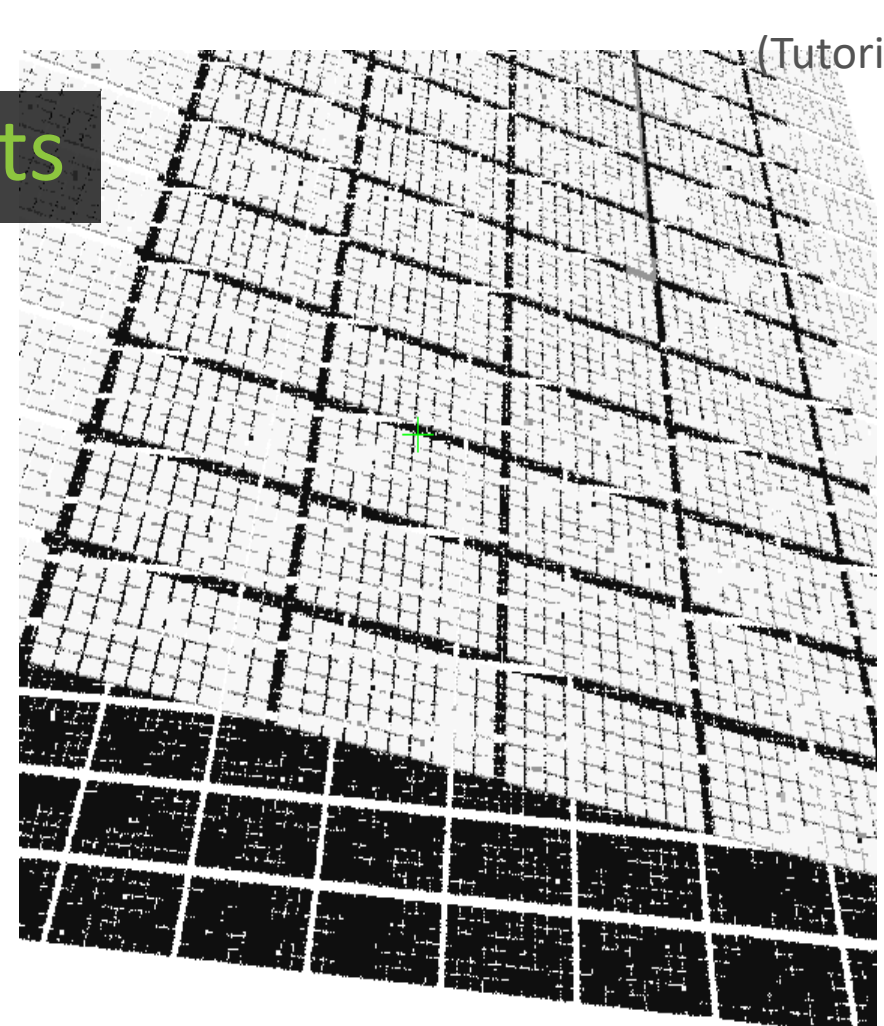
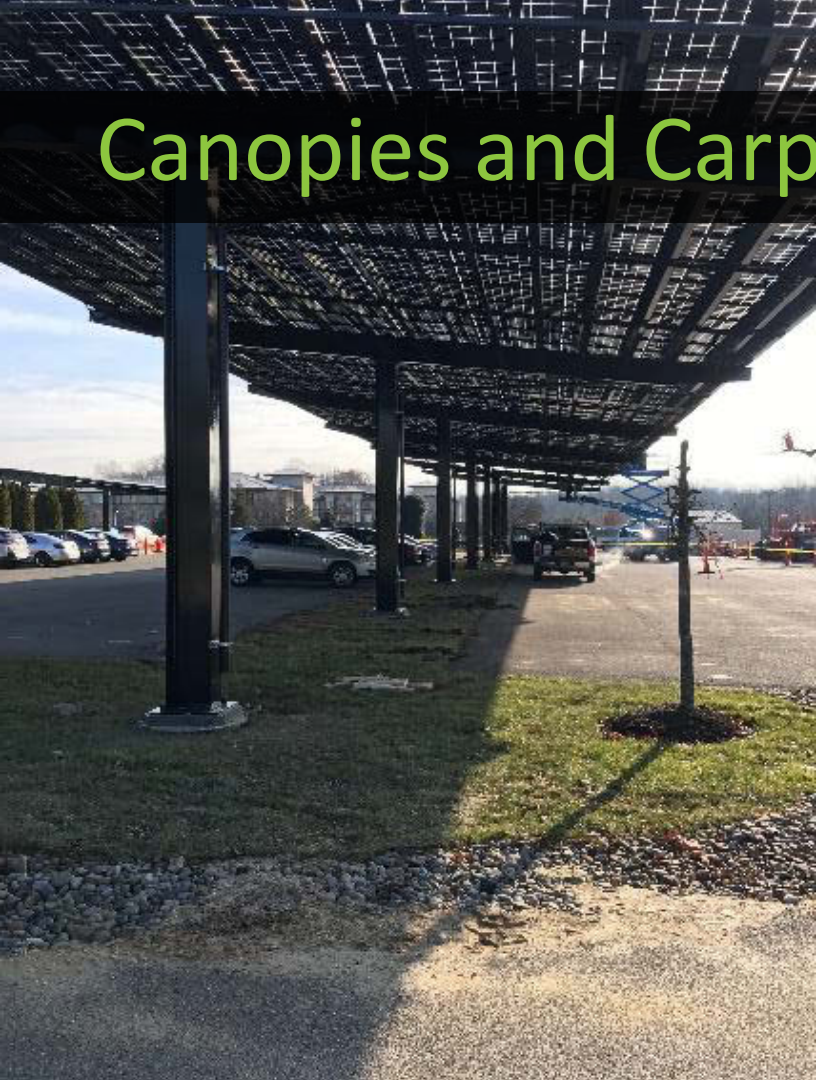
Canopies and Carports



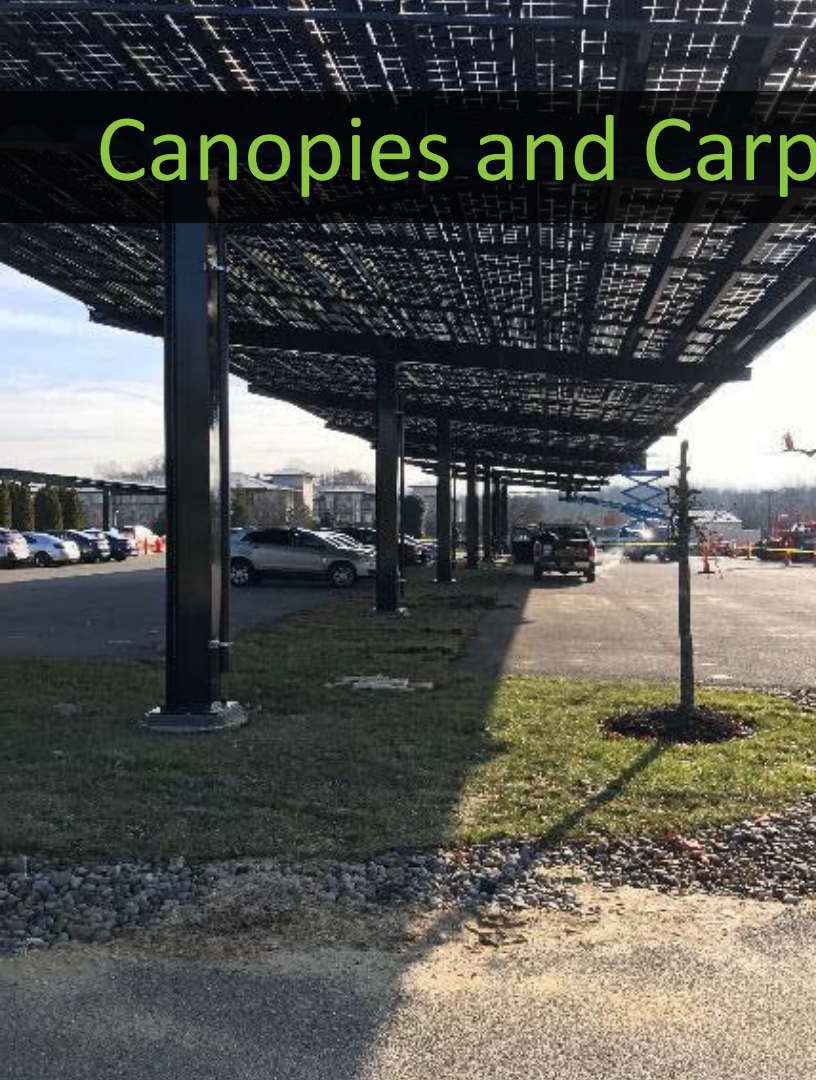
(Tutorial 5)



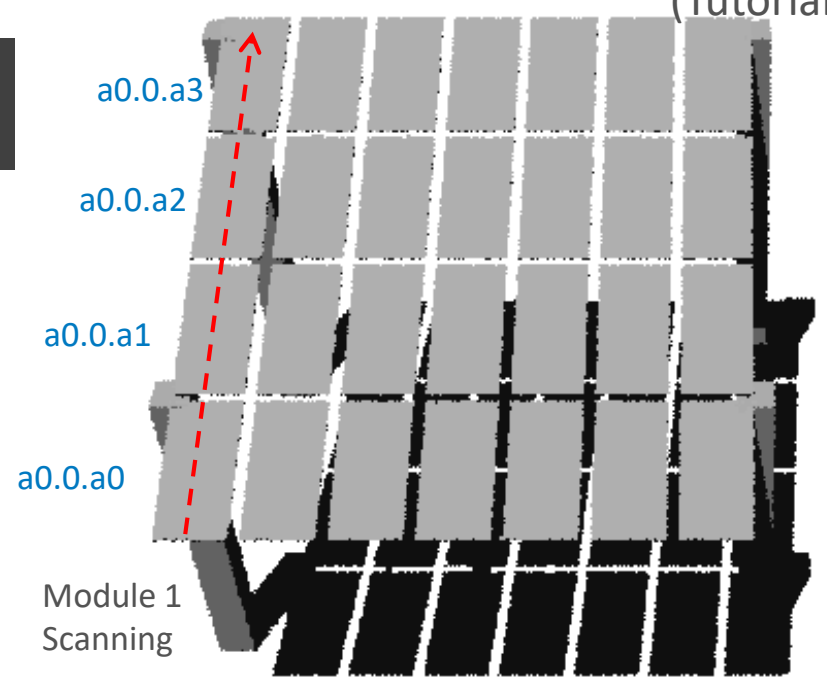
Canopies and Carports



Canopies and Carports

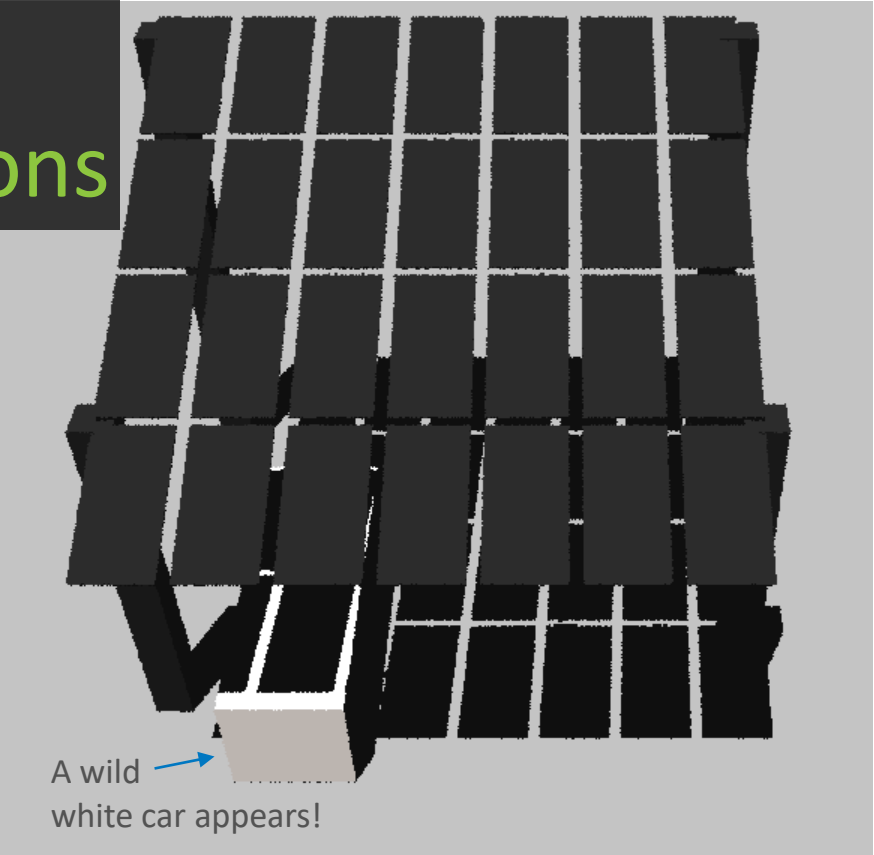


(Tutorial 5)



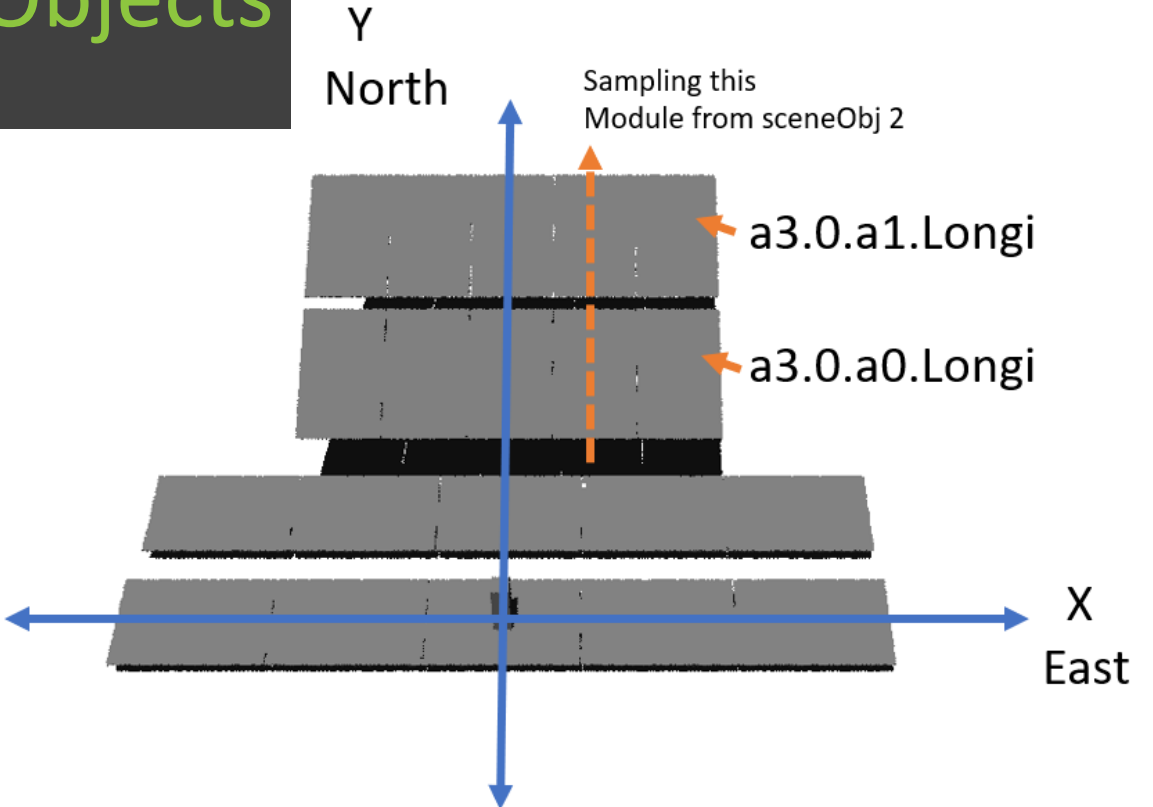
irr_HotelCaprortMod1.csv								
2	x	y	z	rearZ	matttype	rearMat	Wm2Fron	Wm2Back
3	-3.3	-3.62011	4.42757	4.33757	a0.0.a0.PrismSolar.6457	a0.0.a0.PrismSolar.2310	787.6552	161.1096
4	-3.3	-3.43446	4.49514	4.40514	a0.0.a0.PrismSolar.6457	a0.0.a0.PrismSolar.2310	787.6781	158.4337
39	...	...	...	...	...	...	...	...
40	...	...	...	...	...	...	...	...
41	-3.3	3.063169	6.860084	6.770084	a0.0.a3.PrismSolar.6457	a0.0.a3.PrismSolar.2310	787.4609	139.0144
42	-3.3	3.248815	6.927654	6.837654	a0.0.a3.PrismSolar.6457	a0.0.a3.PrismSolar.2310	787.4696	135.2156
43	-3.3	3.434462	6.995223	6.905223	a0.0.a3.PrismSolar.6457	a0.0.a3.PrismSolar.2310	787.4783	132.7424
44	-3.3	3.620109	7.062793	6.972793	a0.0.a3.PrismSolar.6457	a0.0.a3.PrismSolar.2310	787.4871	129.142

Roofs, Cars, and Different albedo sections

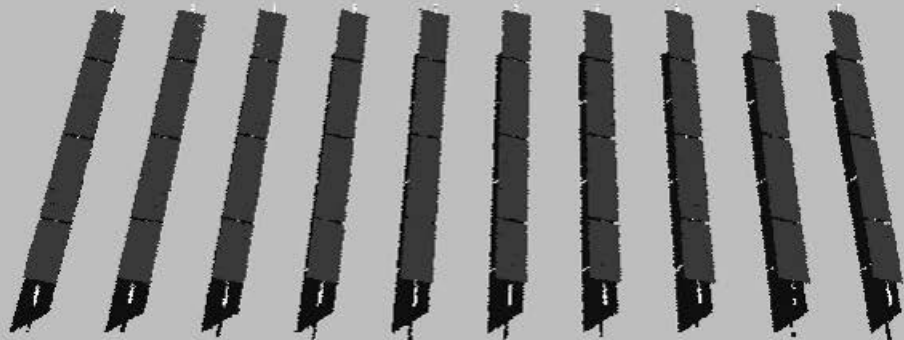
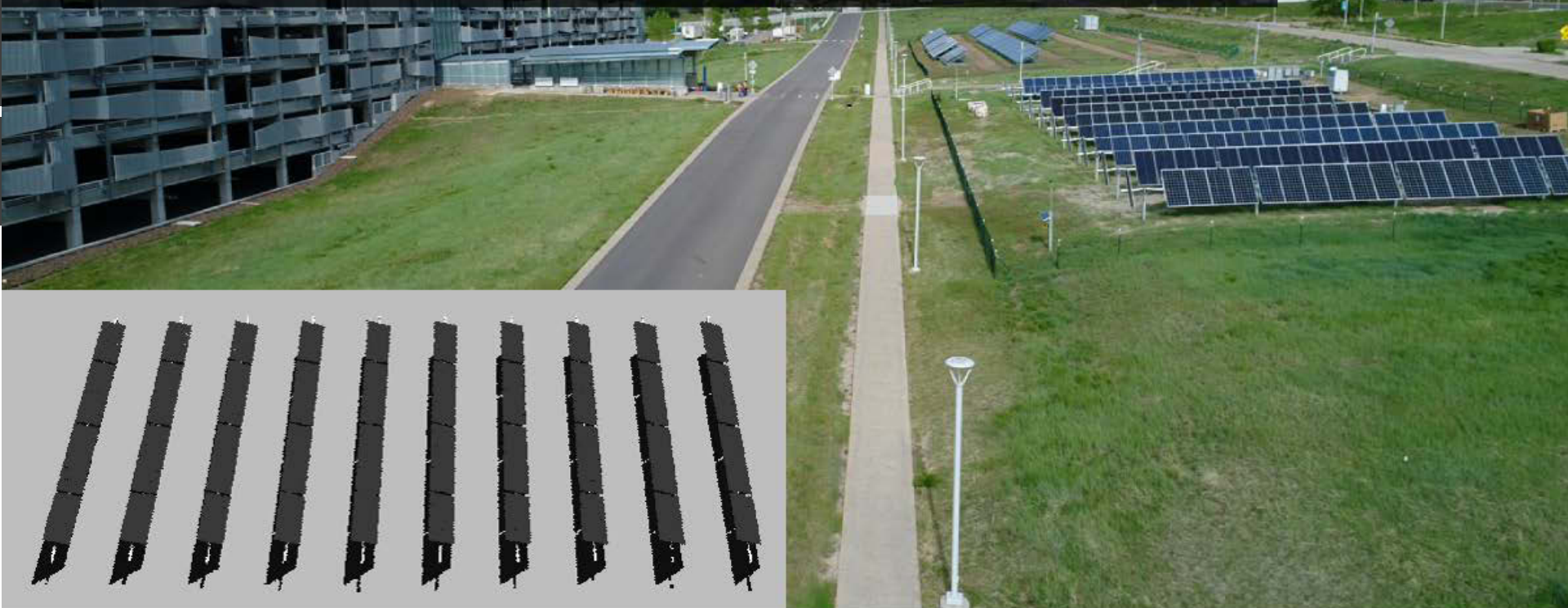


A wild white car appears!

Multiple Scene Objects



75 kW HSAT | 5 bifacial technologies



Shading Factors

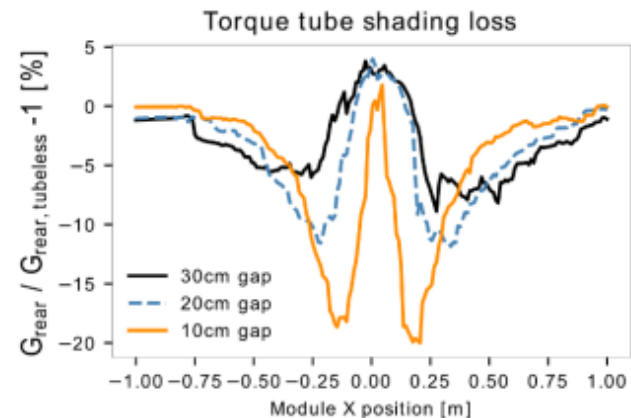
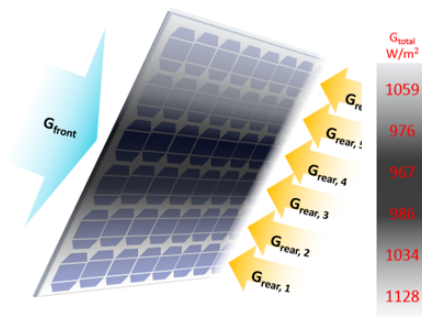


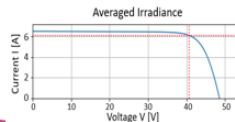
Fig. 13. a) RADIANCE image showing torque tube behind a modules row and b) G_{rear} across the module averaged over a sunny day.

S. Ayala Pelaez, C. Deline, S. M. MacAlpine, B. Marion, J. S. Stein and R. K. Kostuk, "Comparison of Bifacial Solar Irradiance Model Predictions With Field Validation," in *IEEE Journal of Photovoltaics*, vol. 9, no. 1, pp. 82-88, Jan. 2019. doi: 10.1109/JPHOTOV.2018.2877000
 URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8534404&number=8585410>

Electrical Mismatch Losses

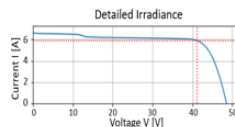


Averaging Irradiance for the module $\sim 1031 W/m^2$



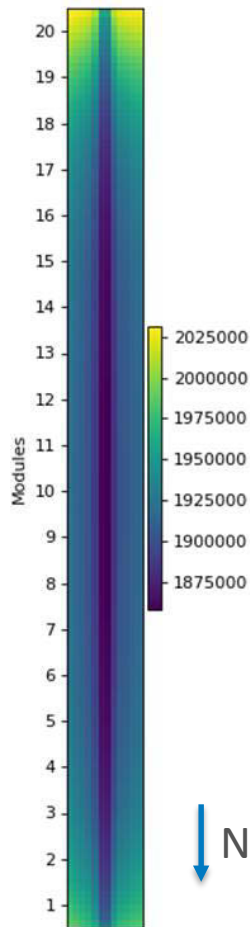
P_0

Detailed Irradiance value



P_1

$$L_{DC} = M = 1 - \frac{P_1}{P_0}$$

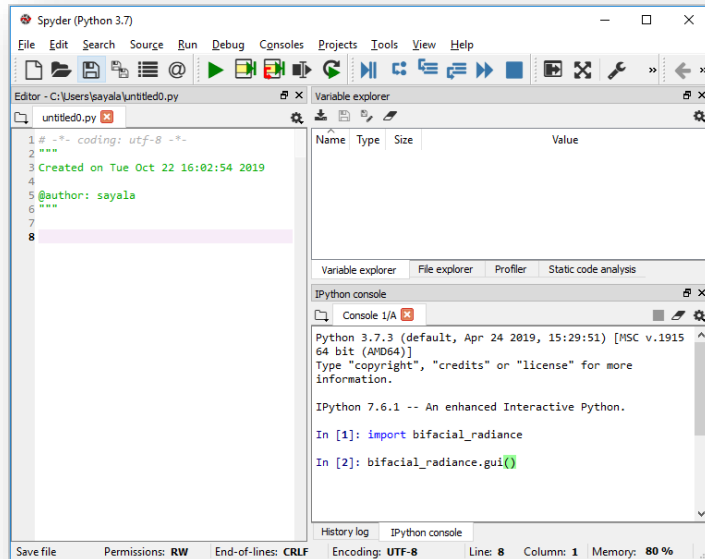


N

GUI (Visual Interface)

In Spyder Console:

```
import bifacial_radiance
bifacial_radiance.gui()
```



The screenshot displays the bifacial_radiance GUI interface, which includes several control panels and a 3D diagram of a bifacial solar panel.

Main Control

Input Variables File: **BB** [Search]
READ SAVE
TestFolder: **C:\Users\sayala\Docum** [Search]
WeatherFile Input: GetEPW ReadEPW / TMY
Get EPW (Lat/Lon): **33** **-110**
EPW / TMY File: **EPWs\USA_VA_Richm** [Search]
Simulation Name: **Demo1**

Simulation Control

Fixed, Cumulative Sky Yearly
Fixed, Cumulative Sky with Start/End times
Fixed, Hourly by Timestamps
Fixed, Hourly for the Whole Year
Tracking, Cumulative Sky Yearly
Tracking, Hourly for a Day
Tracking, Hourly with Start/End times
Tracking, Hourly for the Whole Year

StartDate (MM | DD | HH): **6** **21** **5**
Enddate (MM | DD | HH): **6** **30** **20**
Timestamp Start: **4020**
Timestamp End: **4024**

Tracking Parameters

Backtrack: True False
Limit Angle (deg): **60**
Angle delta (deg): **5**
Axis of Rotation: Torque Tube Panels

TorqueTube Parameters

TorqueTube: True False
Diameter: **0.1**
Tube type: Round Square Hex Oct
TorqueTube Material: Metal_Grey Black

Module Parameters

Prism Solar Bi60
Number of Panels: **2**
Cell Level Module: False True
numcells x: **12** numcells y: **6**
Size Xcell: **0.15** Size Ycell: **0.15**
Xcell gap: **0.01** Ycell gap: **0.01**
Module size x: **0.98** y: **1.98**
Xgap | Ygap | Zgap: **0.05** **0.15** **0.10**
Bifacial Factor (i.e. 0.9): **0.9** [VIEW]
Module Name: **Prism Solar Bi60**
Rewrite Module: True False

Scene Parameters

Row spacing by: GCR Pitch
GCR: **0.35** Pitch: **10**
Albedo: **0.62**
Mods: **20** # Rows: **7**
Azimuth Angle (i.e. 180 for South): **180**
Clearance height: **0.8** Tilt: **10**
Axis Azimuth (i.e. 180 for EW HSATracker): **180**
Hub height: **0.9** [VIEW]

Analysis Parameters

Sensors: **9**
Mod Wanted: **10** Row Wanted: **3**
[CLEAR] [DEFAULT] [RUN]

3D Diagram

The diagram illustrates a bifacial solar panel with various dimensions labeled: collector width CW, module size, gap, clearance height, and Tube-z gap.

Q&A

https://github.com/NREL/bifacial_radiance/issues

silvana.ayala@nrel.gov

www.nrel.gov

NREL/PR-5K00-75218

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