Assessing Visual Comfort

Luis Santos, Luisa Caldas
UC Berkeley, Department of Architecture

Center for the Built Environment
An Industry/University Research Collaboration
University of California, Berkeley

Background

Visual comfort and glare

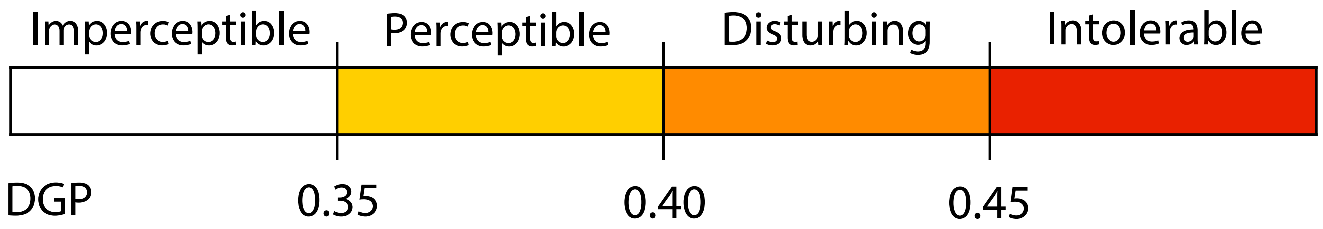
- Glare measures the physical discomfort caused by either excessive light or contrast
- Does it matter?
  - 80% of designers consider that glare is important (Mogri, 2011)
  - Impact on work productivity
  - As glazing area increases, so does the likelihood of glare
  - Standards are starting to address visual comfort

Glare might lead to visual discomfort, thus, reducing work productivity.

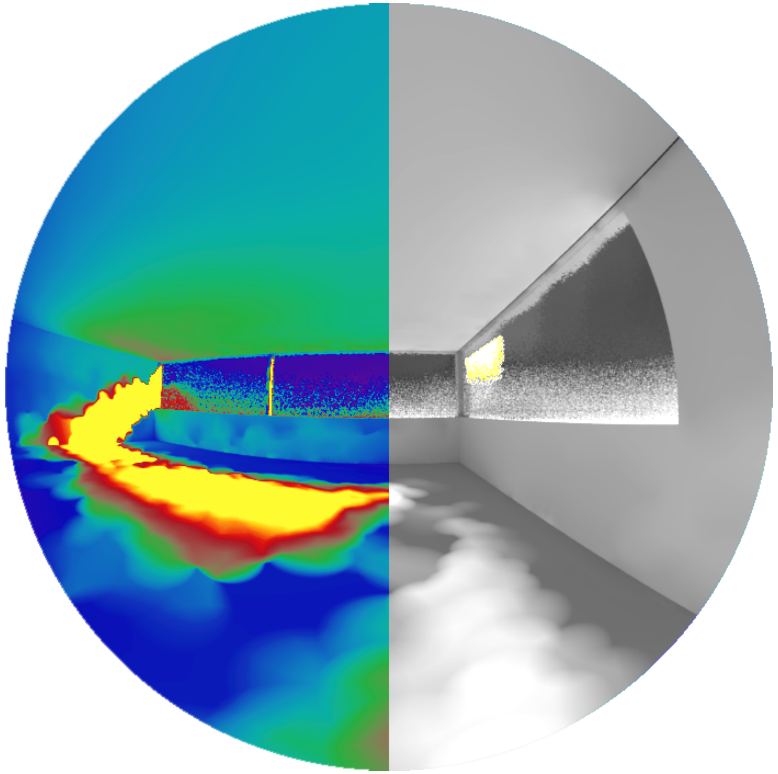
Background

Metrics

- Workplane illuminance may not correlate well with glare – no consensus
- Daylight Glare Probability (DGP)
  - Vertical Eye Illuminance (Ev)
  - Source size
  - Scene Luminance
  - Position



- DGP ⟶ Annual DGP (aDGP)



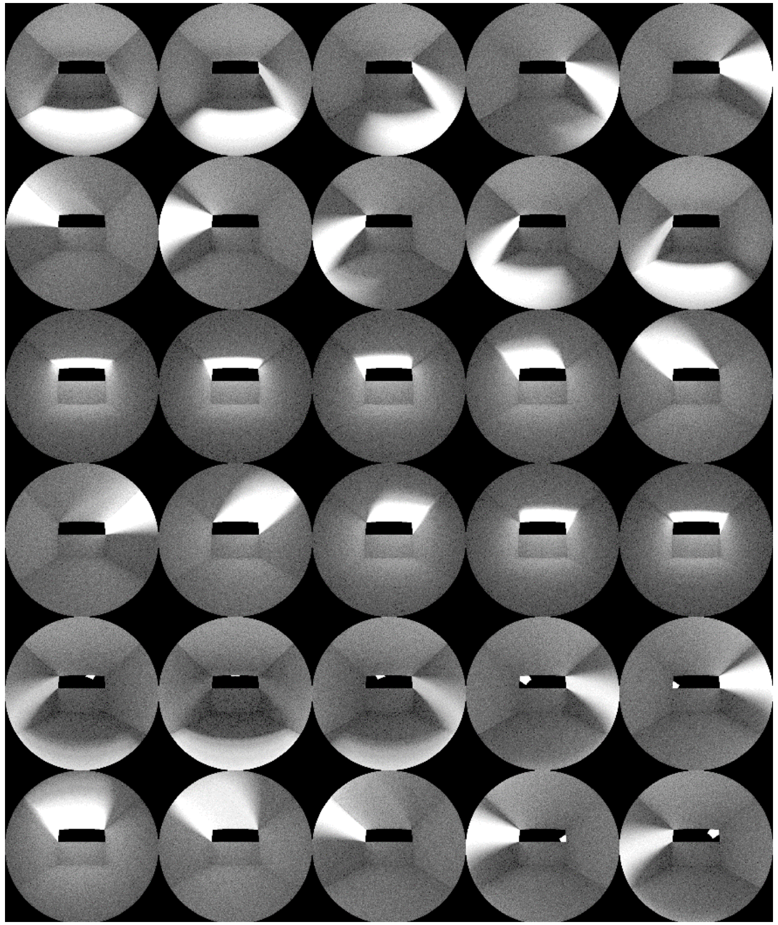
A synthetic High Dynamic Range (HDR) image produced by Radiance and post-processed as a luminance false color image (left) and as an evalglare HDR (right).

Background

Daylight Glare Probability (DGP) challenges

- Local – a point and direction at a time
- No modeling guidelines – requires expertise
- Hard to use in conceptual to intermediary design phases
- Slow to simulate

- **Where, when, and where to look?**

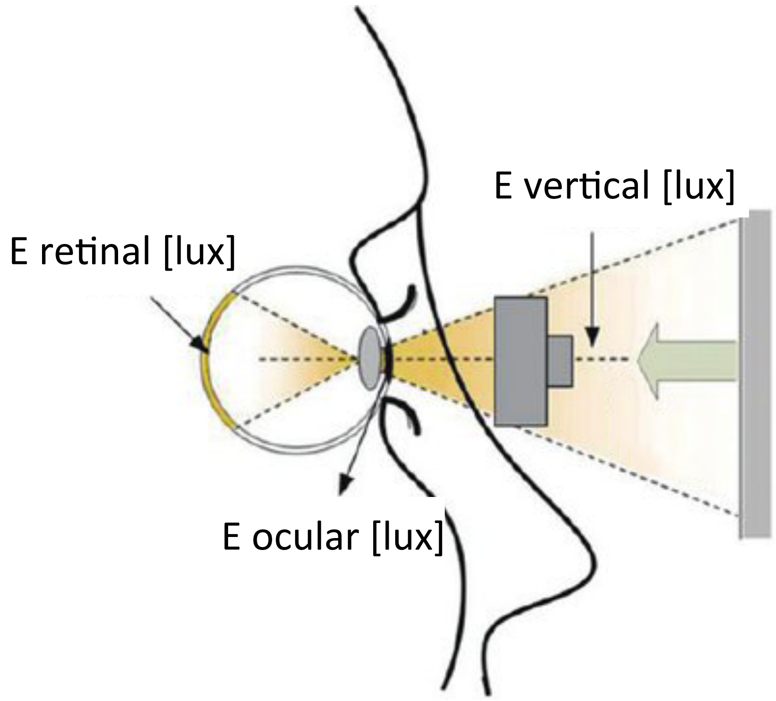


Contribution of different sky patches in a view matrix for climate-based daylight simulations.

Objectives

Propose a new workflow for glare assessment

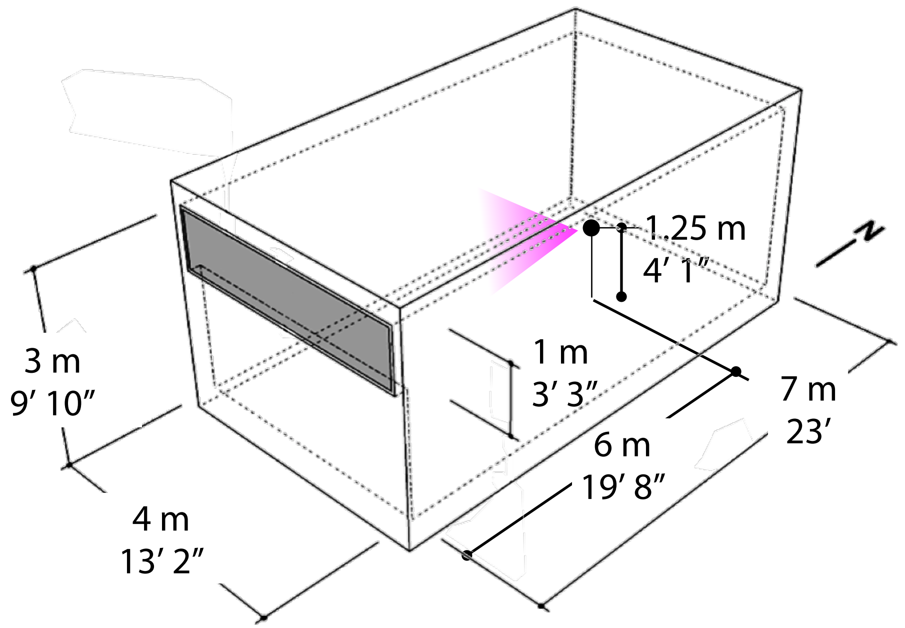
- Annual and climate-based
- Visually maps the spatial distribution of glare potential
- Based on a simpler metric – vertical eye illuminance (Ev)
- Detects critical:
    - Locations
    - Points-of-view (POV)
    - Time events



Vertical Illuminance (Hoof et al. 2012).

Approach

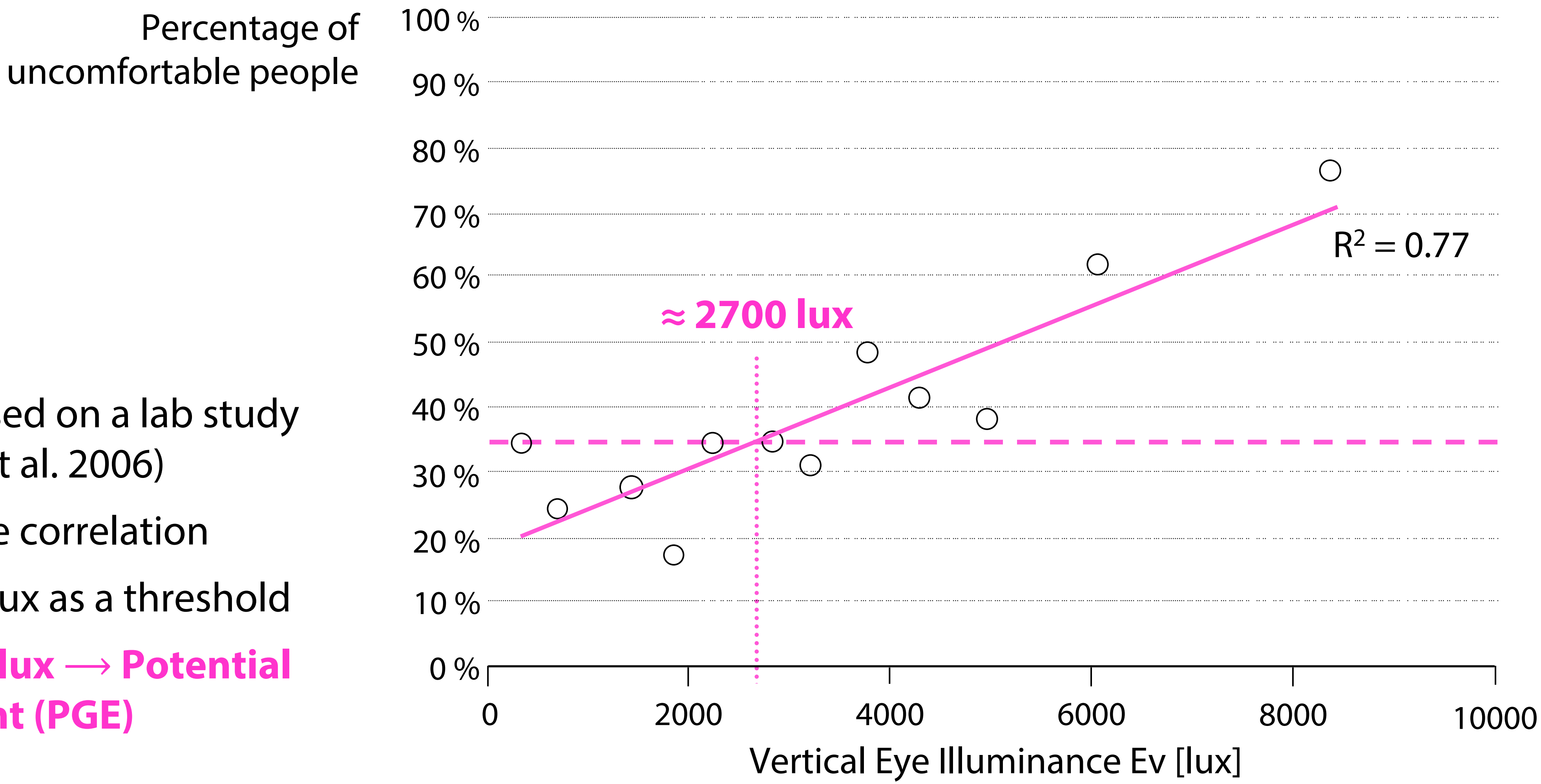
- Verification of annual Ev as a glare event marker
  - Based on previous research results
  - Annual Ev and annual DGP comparison
    - Typical overcast annual sky (London, UK)
    - Typical clear annual sky (Phoenix, AZ)
- Workflow development and implementation
  - Based on Radiance's 3-phase method
  - Implementation for Rhino/Grasshopper
  - Visualization and query functionalities
- Example
  - Typical open space office room



Shoe box model of the experiments conducted in Santos, L. et al. (2018) used in the verification of annual Ev as a glare event marker.

Visual comfort and vertical eye illuminance (Ev)

- Results based on a lab study (Wienold et al. 2006)
- Reasonable correlation
- Ev ≥ 2700 lux as a threshold
- **Ev ≥ 2700 lux ⟶ Potential Glare Event (PGE)**



Vertical eye illuminance (Ev) versus percentage of uncomfortable people. Adapted from: Wienold, J. et al. (2006).

Can vertical eye illuminance (Ev) detect glare events?

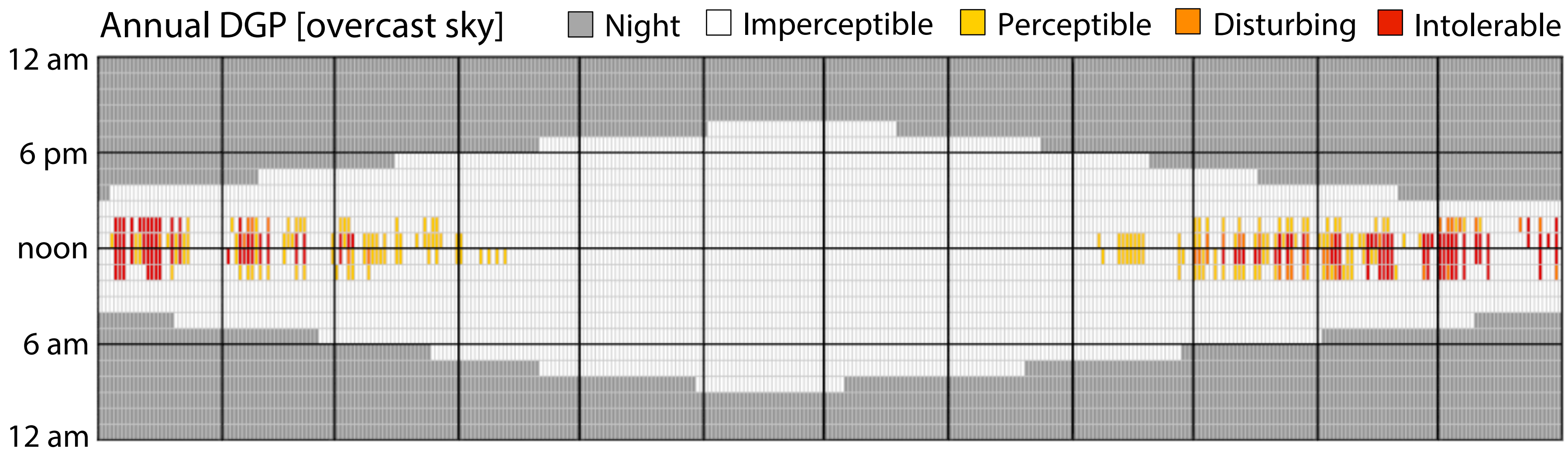
Overcast sky

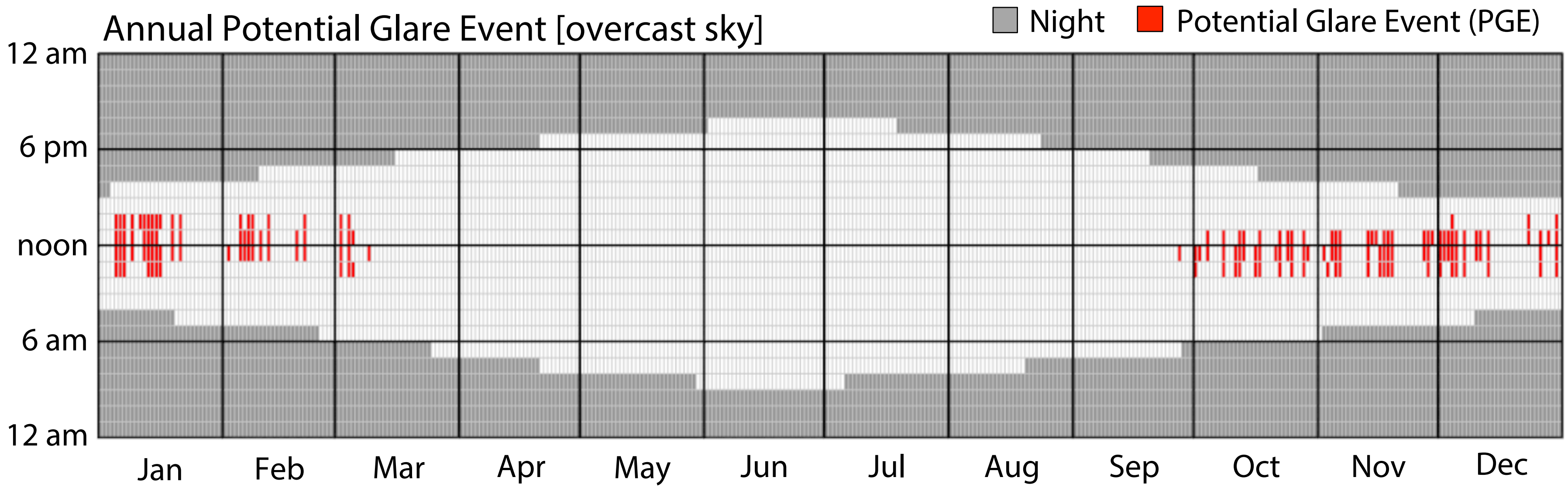
If DGP ≥ Perceptible:
Potential Glare Event captures 50.4%

If DGP ≥ Disturbing:
Potential Glare Event captures 89%

Clear sky has a similar trend

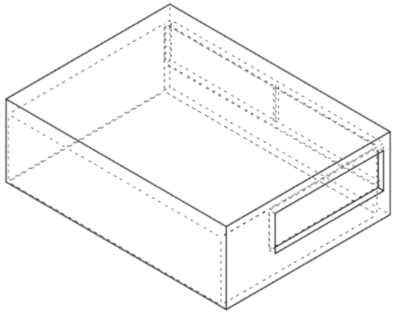
If DGP ≥ Disturbing:
Potential Glare Event captures 92%





Workflow

Inputs → Simulation → Post-process → Output



Geometry

+

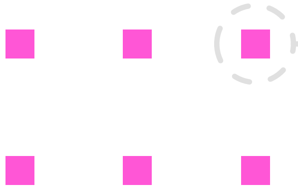
EnergyPlus Weather File

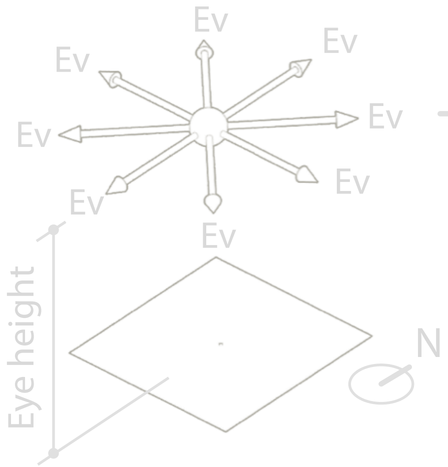
+

Radiance Materials

+

Sensor Grid

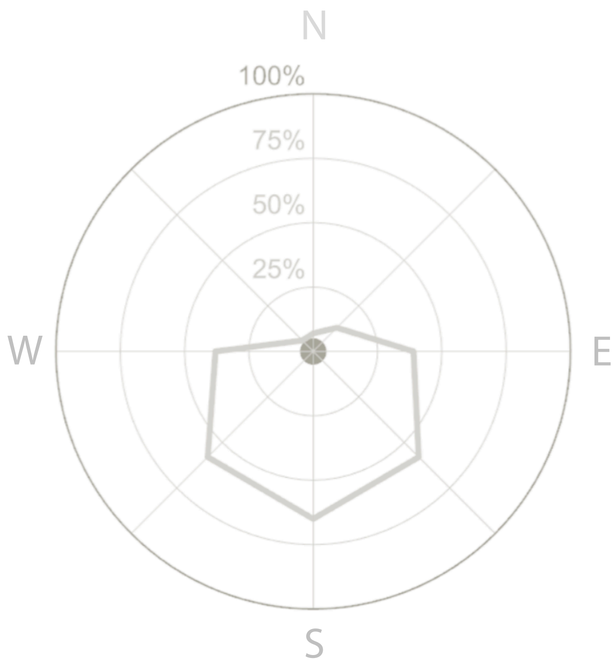




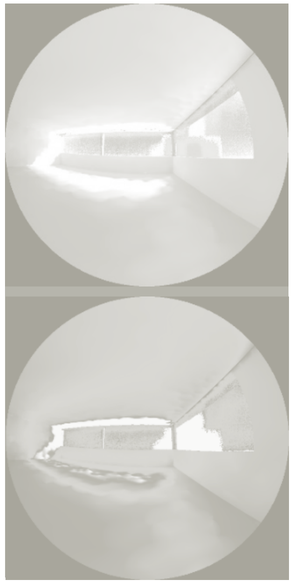
For each sensor:
Generate 8 Point-of-views (POV)
For each POV:
Calculate Ev

Count Potential Glare Events (PGE)

For each sensor:
For each POV:
Report:
Normalized PGE
Max Ev
Time event



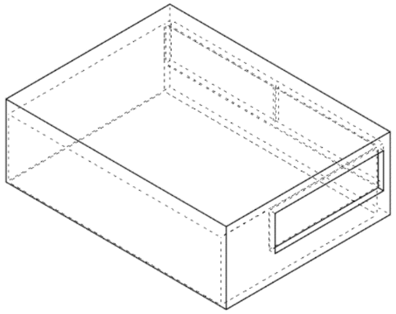
Build Radar Graph
Query



Further explore

Workflow

Inputs → Simulation → Post-process → Output



Geometry

\+

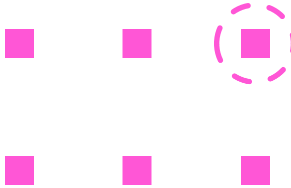
EnergyPlus Weather File

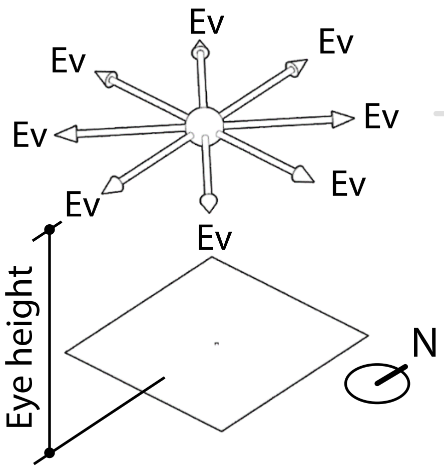
\+

Radiance Materials

\+

Sensor Grid

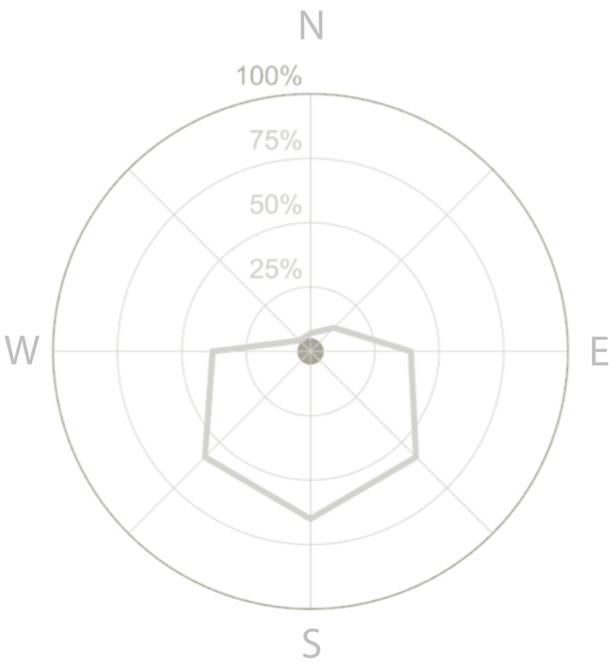




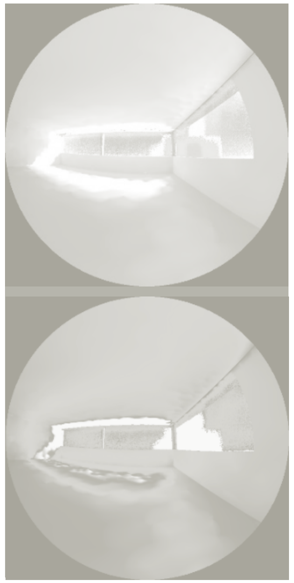
For each sensor:
  Generate 8 Point-of-views (POV)
  For each POV:
    Calculate Ev

Count Potential Glare Events (PGE)

For each sensor:
  For each POV:
    Report:
      Normalized PGE
      Max Ev
      Time event



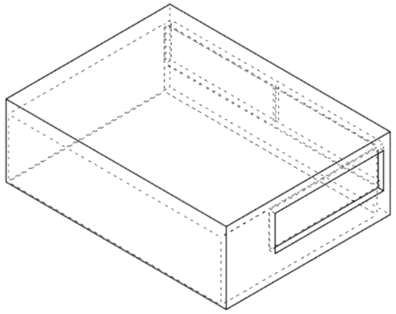
Build Radar Graph
Query Graph



Further explore

Workflow

Inputs → Simulation → Post-process → Output



Geometry

\+

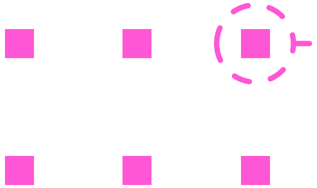
EnergyPlus Weather File

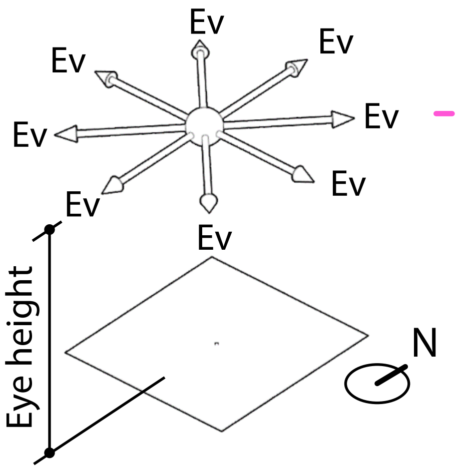
\+

Radiance Materials

\+

Sensor Grid

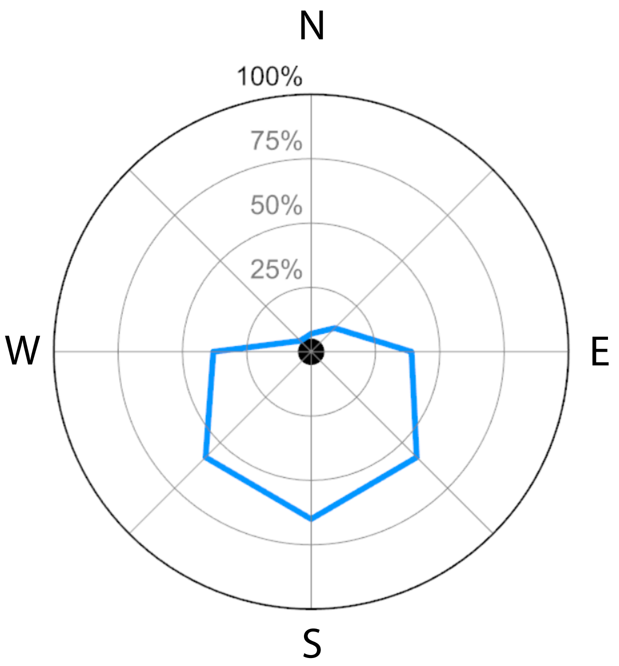




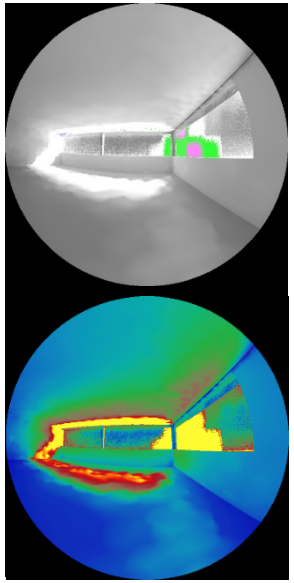
For each sensor:
  Generate 8 Point-of-views (POV)
  For each POV:
    Calculate Ev

Count Potential Glare Events (PGE)

For each sensor:
  For each POV:
    Report:
      Normalized PGE
      Max Ev
        Time event



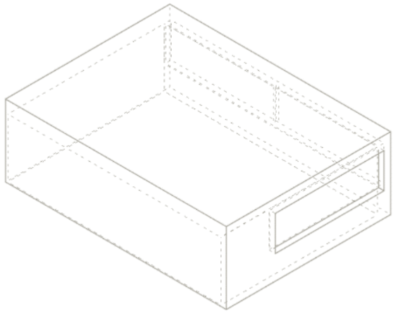
Build Radar Graph
Query Graph



Further explore

Workflow

Inputs → Simulation → Post-process → Output



Geometry

+

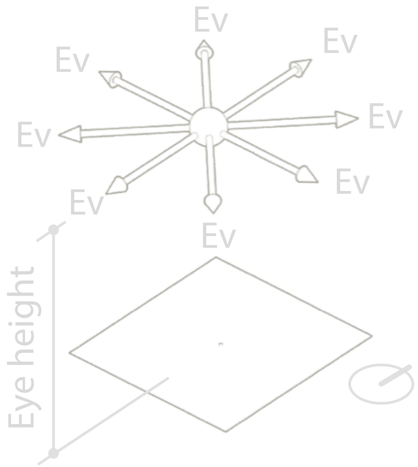
EnergyPlus Weather File

+

Radiance Materials

+

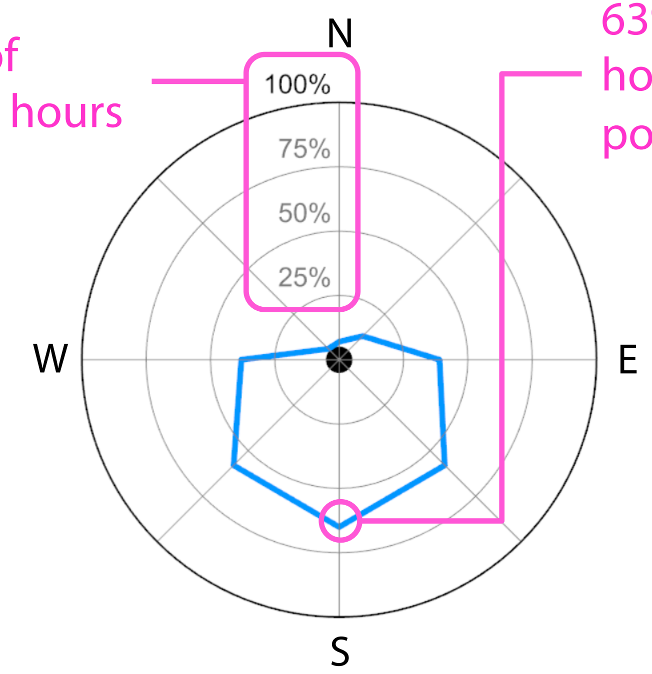
Sensor Grid



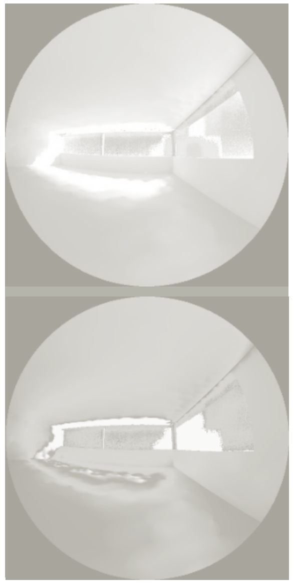
For each sensor:
Generate 8 Point-of-views (POV)
For each POV:
Calculate Ev

Count Potential Glare Events (PGE)

For each sensor:
For each POV:
Report:
Normalized PGE
Max Ev
Time event



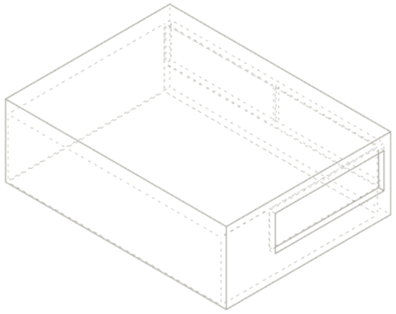
Build Radar Graph
Query Graph



Further explore

Workflow

Inputs → Simulation → Post-process → Output



Geometry

+

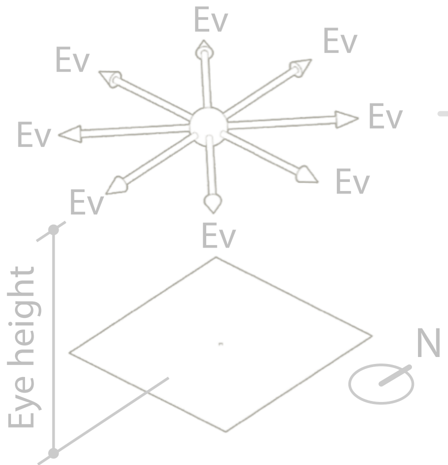
EnergyPlus Weather File

+

Radiance Materials

+

Sensor Grid

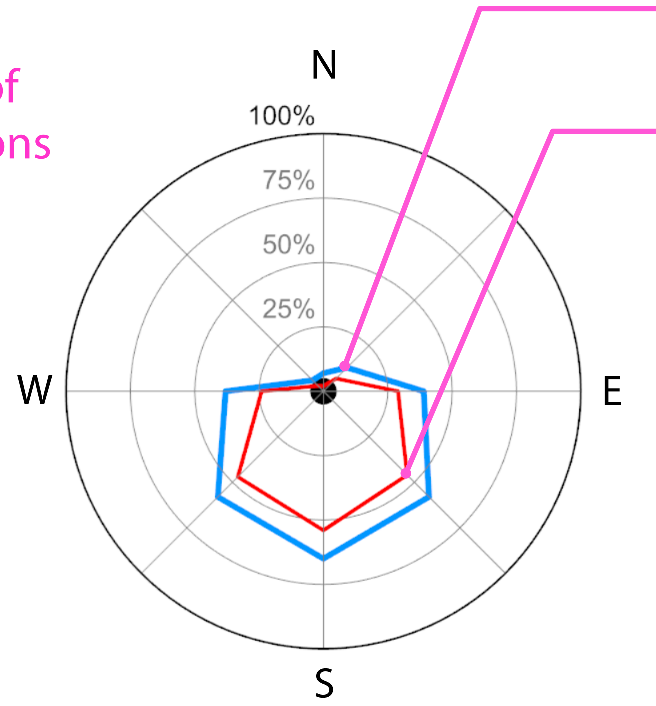


For each sensor:
Generate 8 Point-of-views (POV)
For each POV:
Calculate Ev

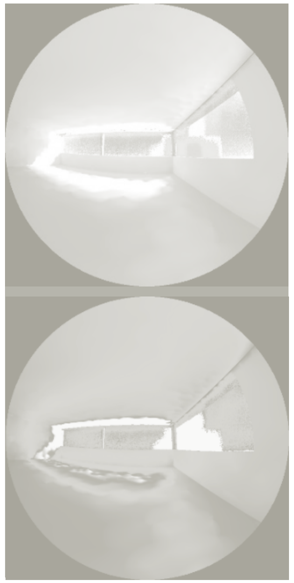
Comparison of design solutions

Count Potential Glare Events (PGE)

For each sensor:
For each POV:
Report:
Normalized PGE
Max Ev
Time event

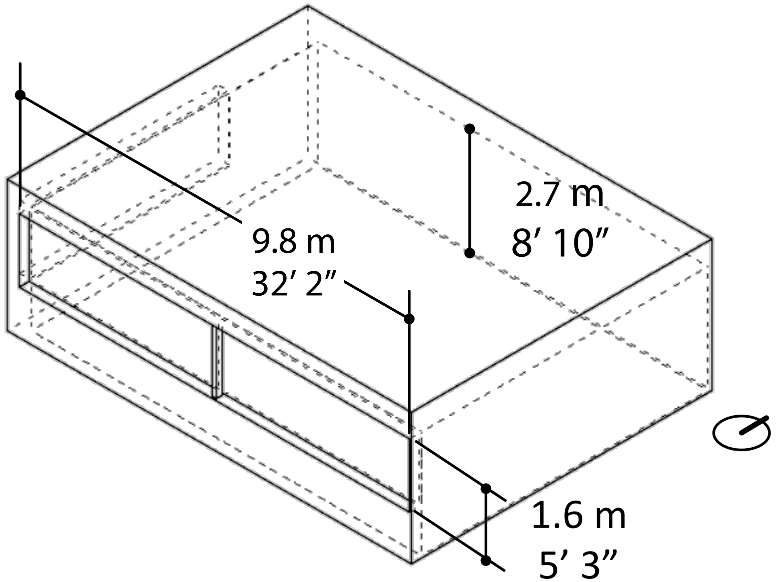


Build Radar Graph
Query Graph

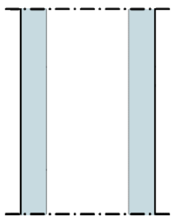


Further explore

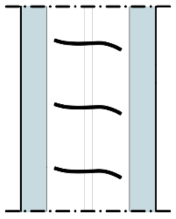
Example: Modeling assumptions



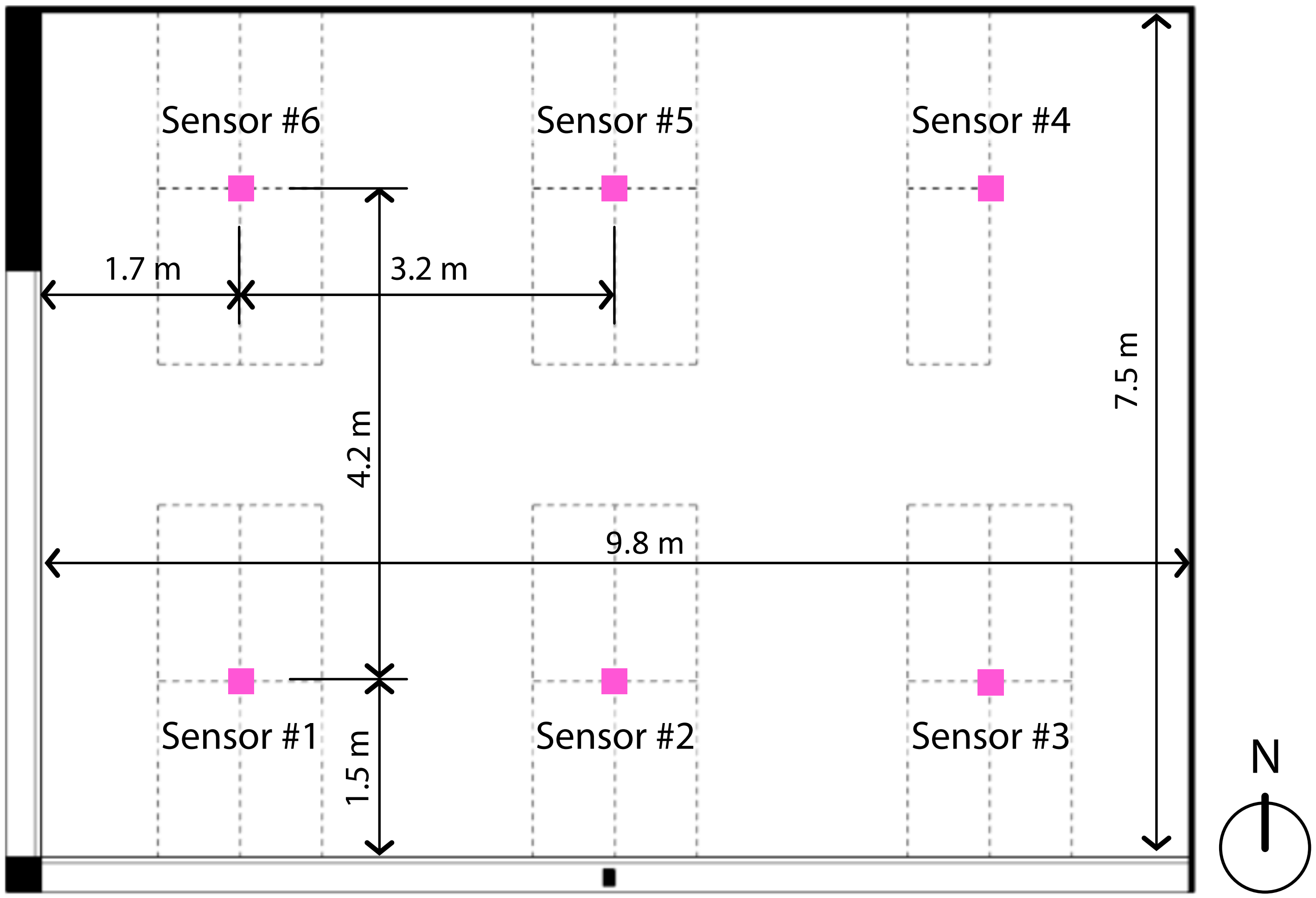
Glazing solutions



Double Clear Glazing

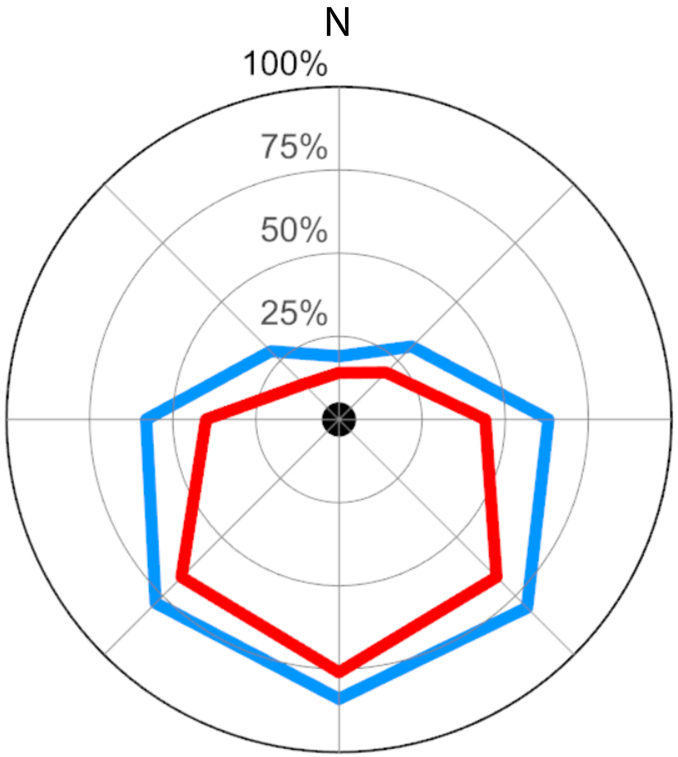


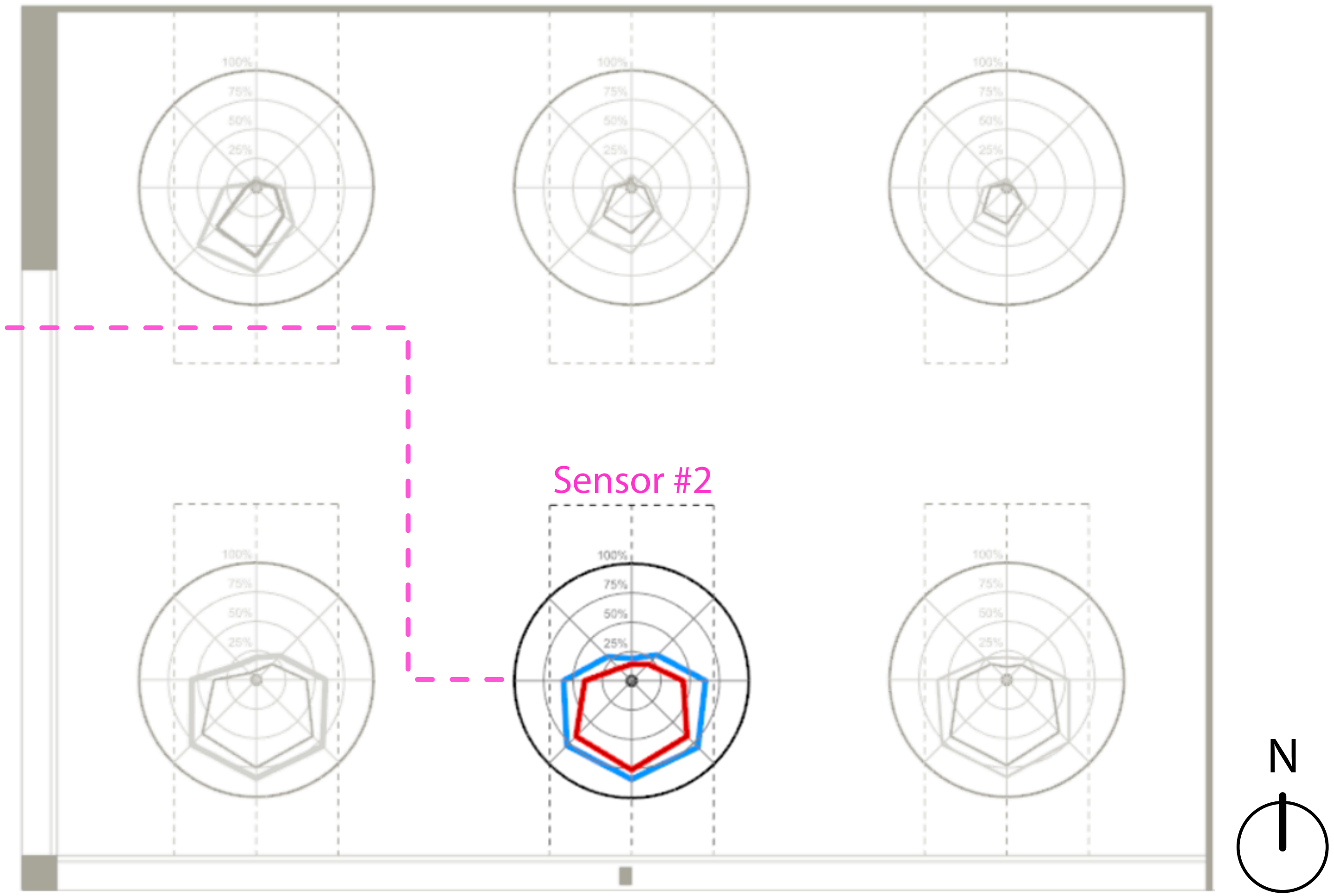
Light Redirecting System



Plan

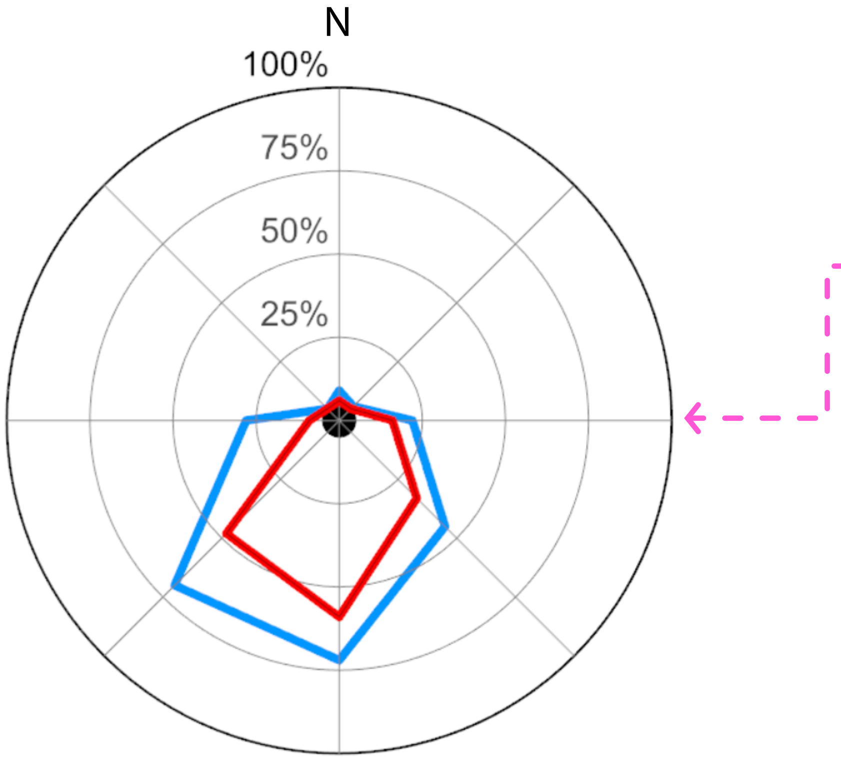
Example: Output and query

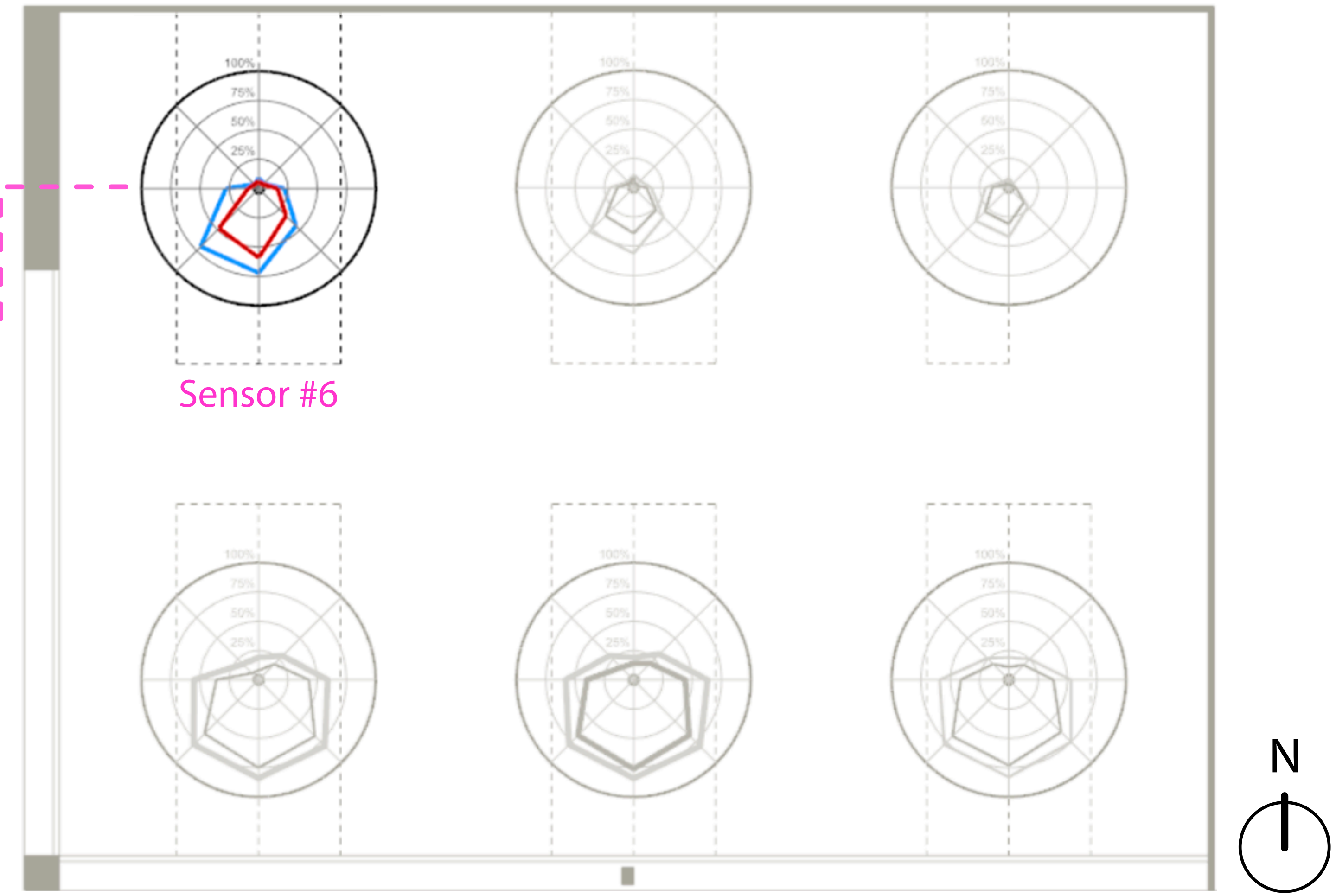




Double Clear Glazing	**Light Redirecting System**
Critical event	Critical event
POV direction: South	POV direction: South
Annual PGE: 84%	Annual PGE: 76%
5 JAN 3 pm: 4057 lux	30 DEC 2 pm: 3725 lux

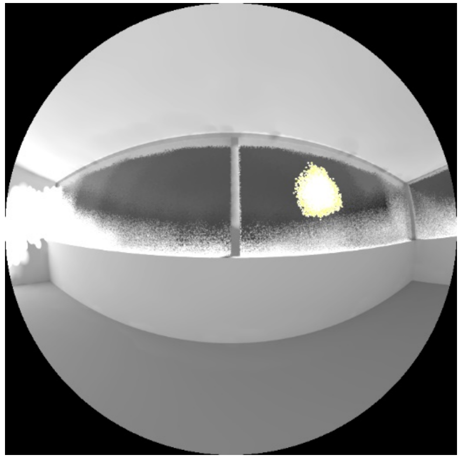
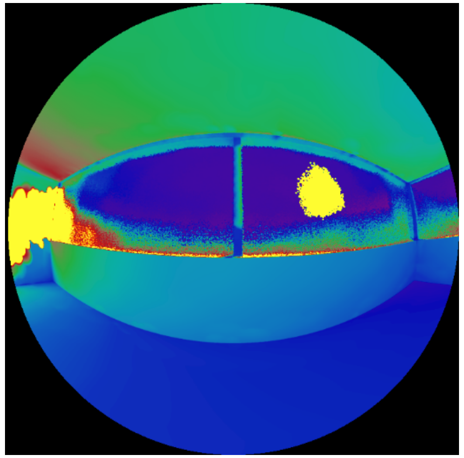
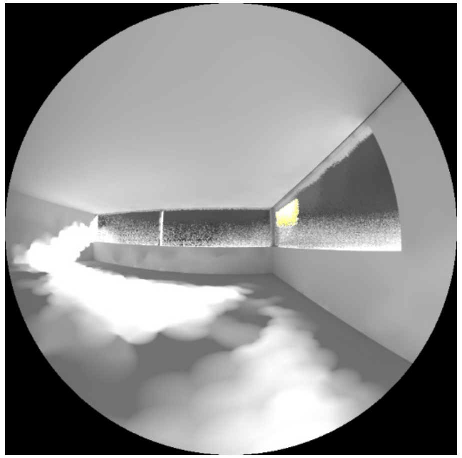
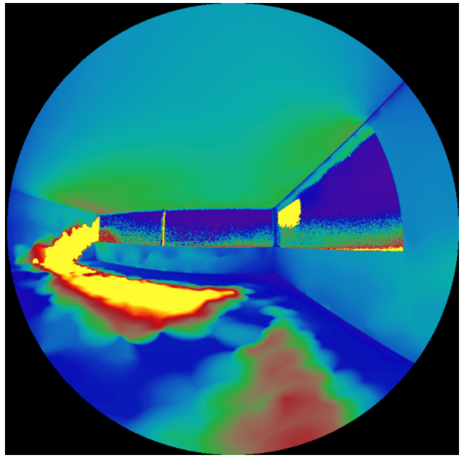
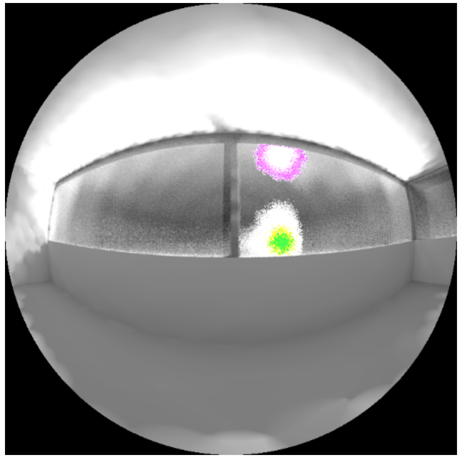
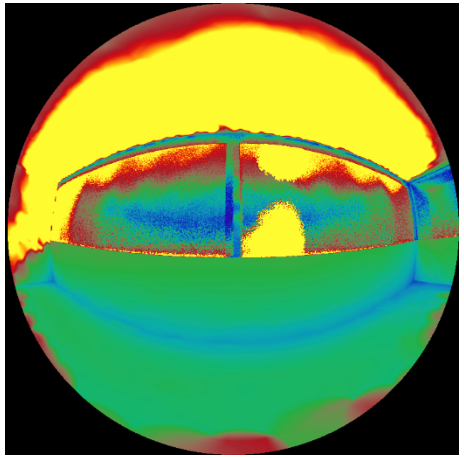
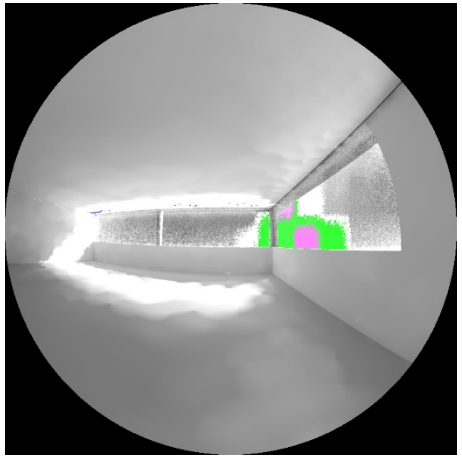
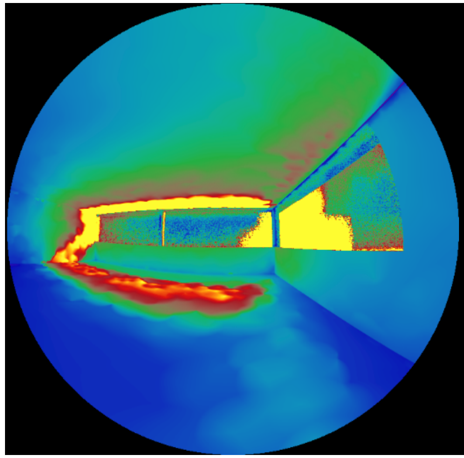
Example: Output and query





Double Clear Glazing	**Light Redirecting System**
Critical event	Critical event
POV direction: South	POV direction: South
Annual PGE: 72%	Annual PGE: 59%
27 NOV 2 pm: 8008 lux	30 DEC 2 pm: 7965 lux

Example: Subsequent detailed studies

	Sensor #2 :: Selected POV and time event		**Sensor #6 :: Selected POV and time event**	
	DGP	Luminance	DGP	Luminance
Double Clear Glazing	 Intolerable		 Intolerable	
Light Redirecting System	 Intolerable		 Intolerable	

Take-aways

Conclusions

- Ev can be used as a preliminary metric for glare assessments
- The workflow is able to:
  - Spatially map glare potential
  - Identify relevant POV and time events
  - Suitable for parametric or optimization studies
  - Be an alternative to expensive annual glare simulations

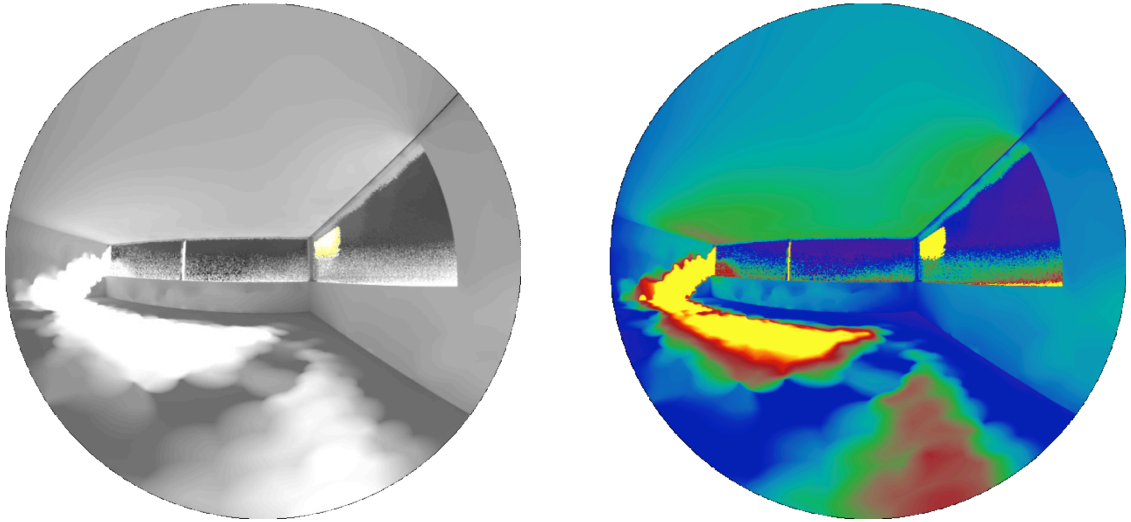
Future work

- Full work will be presented and published in PLEA conference proceedings
- Refine the query process
- Address more complicated examples
- Integrate with Building Optimization workflows

Q&A

Luis Santos
luis_sds82@berkeley.edu

Luisa Caldas
lcaldas@berkeley.edu



Please take a moment to fill out the feedback form.

Santos, L. and Luisa Caldas. 2018. Assessing the Glare Potential of Complex Fenestration Systems: a Heuristic Approach Based on Spatial and Time Sampling. Full paper accepted in the Proceedings of Passive Low Energy Architecture Building (PLEA) 2018. December.