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# Integrated Design for Sustainable and Healthy Buildings

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***We make our buildings and  
afterwards they make us. They  
regulate the course of our lives.***

**- Winston Churchill**

English Architectural Association, 1924

# Progression of architecture



**Past**

Shelter/protective structure



**Present**

Energy efficiency



**Future**

Occupant health & wellbeing

1973 Oil shock

2020 COVID-19

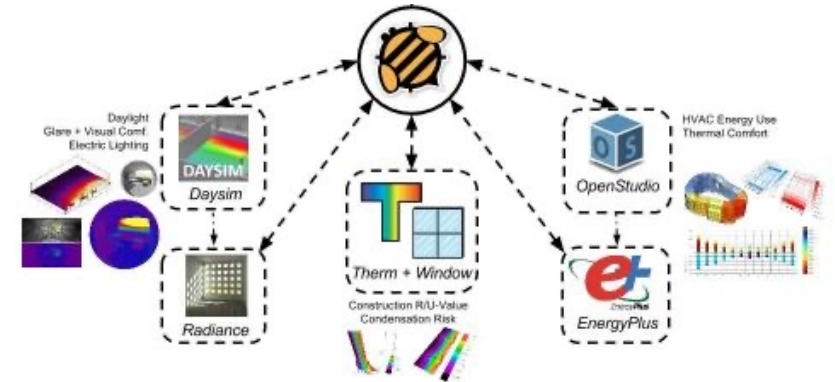
# Sustainability in practice and research



Building performance



Occupant



Advanced tools

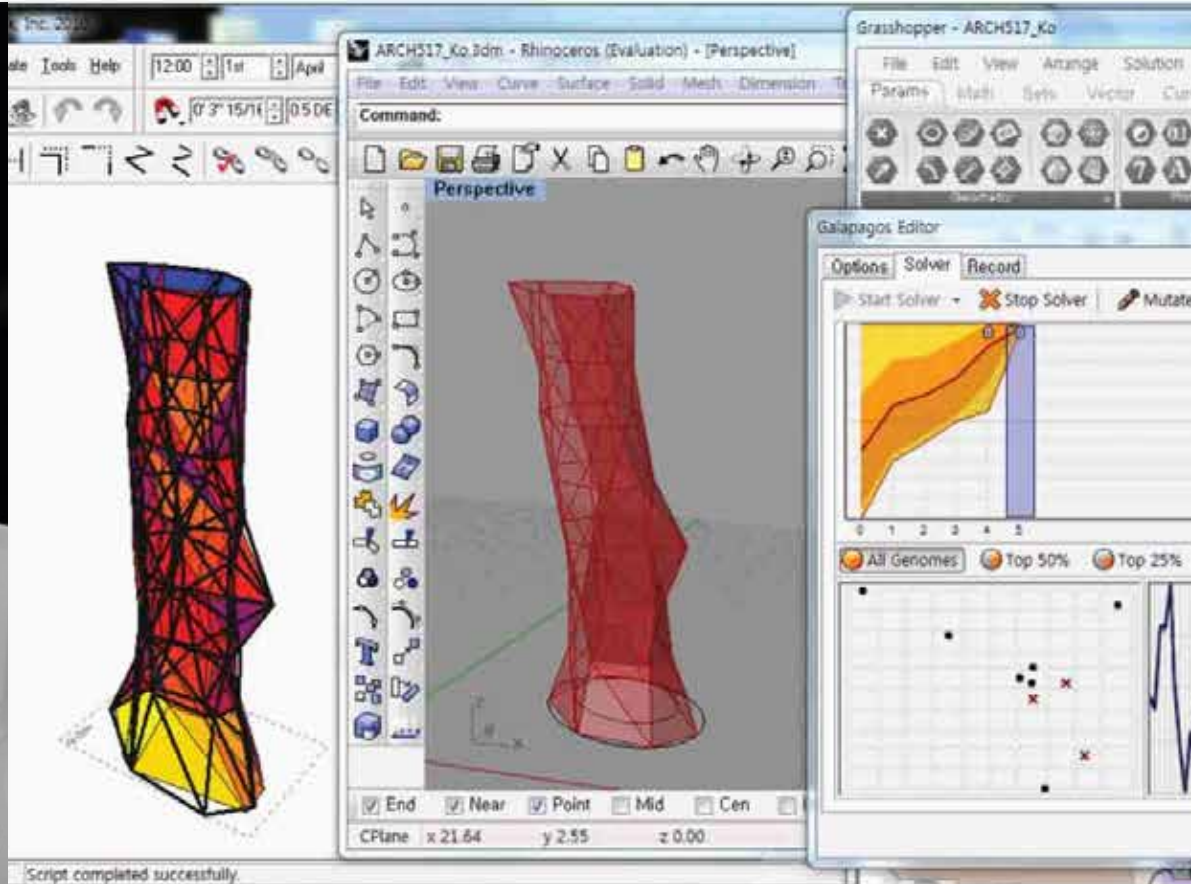
**Integrated design and  
application-driven research**



# My background



Architectural design



Building science and performance-based design



Professional experience

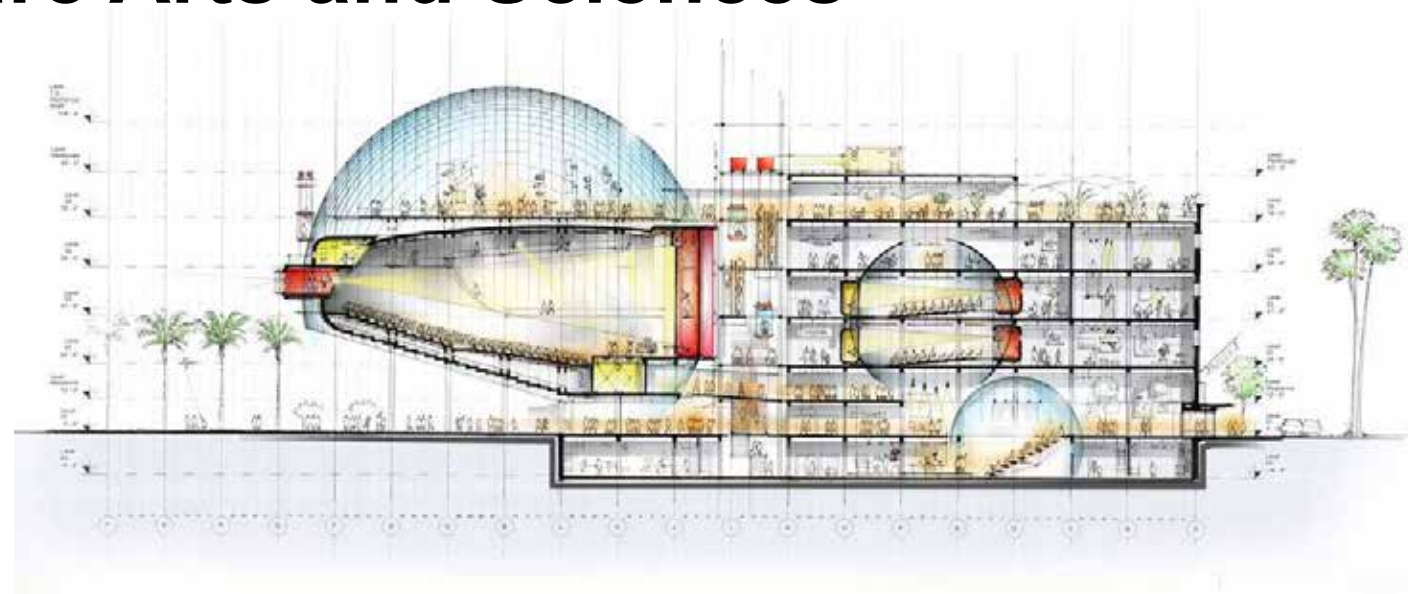
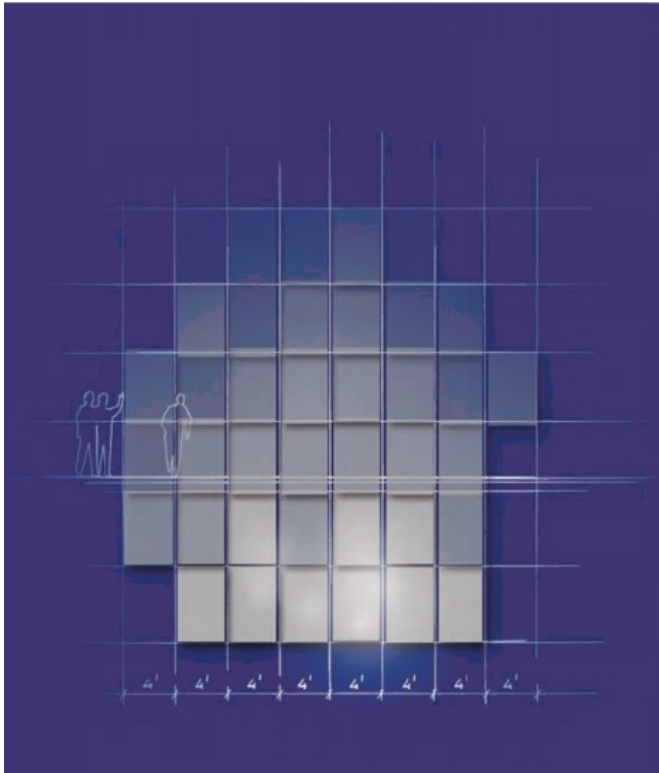
# Academy of Motion Picture Arts and Sciences

**Professional work:** Burohappold

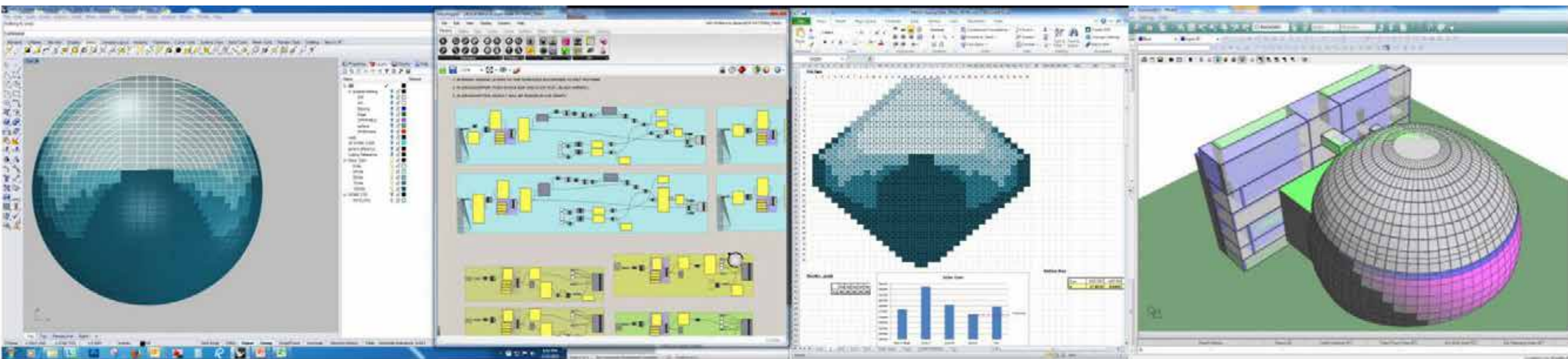
**Project location:** Los Angeles, CA

**Key responsibility:** Sustainable design

Worked mainly on SD / DD, 2013-2015







**Rhino model:**  
3D geometry, glazing, frit pattern input



**Grasshopper:**  
Connecting Rhino and Excel



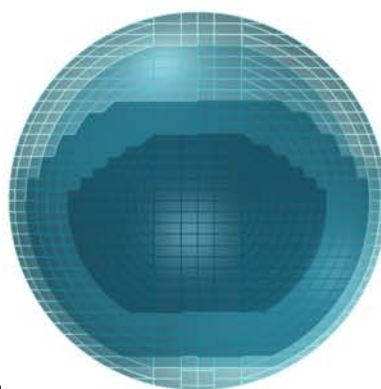
**Excel:**  
Solar gain analysis tool, mapping IES-VE results



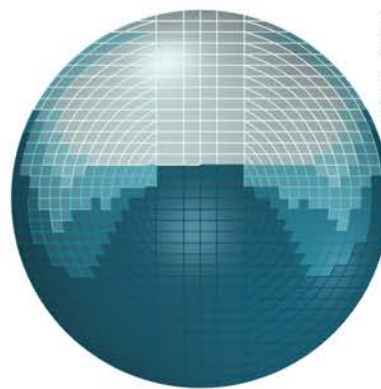
**IES-VE:**  
Solar gain analysis input

**Publication:**  
Won Hee Ko. (2014) "Complex Geometry Facades in Building Energy Simulations and Standards." ASHRAE/IBPSA-USA Building Simulation Conference. Atlanta, GA, USA.

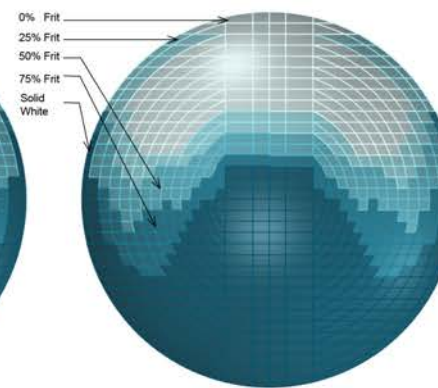
**Presentations:**  
Won Hee Ko. (2014) "Future of Building Skins and Complex Geometry." In the 9th Energy Forum, 513–26. Bressanone, Italy.  
Won Hee Ko. (2014) "Complex Façade and Performance-Driven Design." Façade Tectonics #14 Conference. Los Angeles, CA, USA.



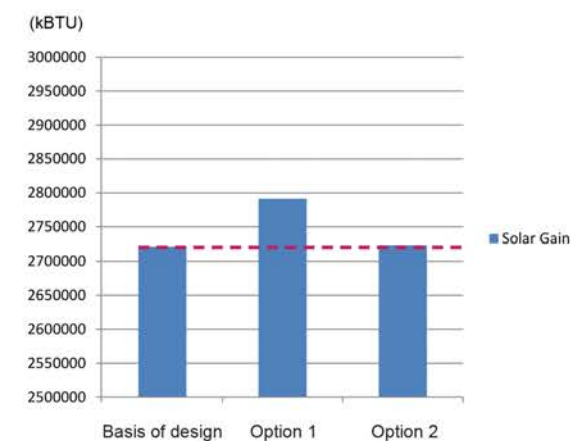
Basis of design:  
SD 100% pattern



Option 1:  
DD 50% pattern



Option 2:  
DD 100% pattern



***In practice, implementing high performance design is challenging***





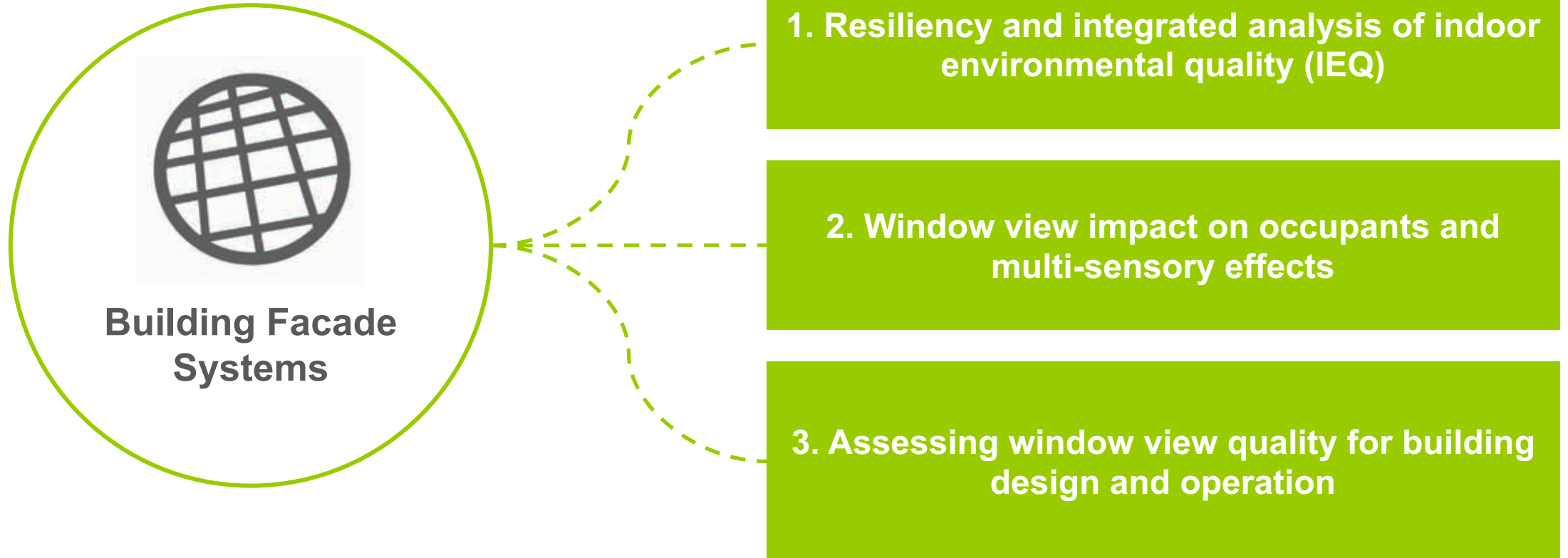
Berkeley  
UNIVERSITY OF CALIFORNIA



CBE  
CENTER FOR THE BUILT ENVIRONMENT

Application-driven research via  
CBE industry consortium

# Research projects



# 1. Resiliency and integrated analysis of indoor environmental quality (IEQ)





**Power outage**



**Climate change**



**Resource depletion**

# Research Question:

*How many hours can a building provide a comfortable environment without using energy?*



Lighting

+



Thermal

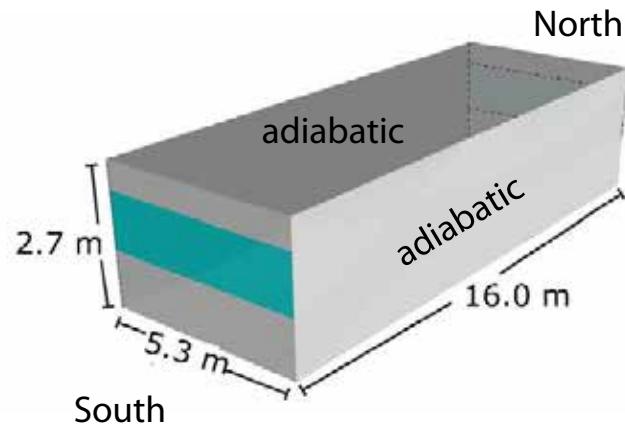
+



Ventilation

# Methods

## Simplified model



Commercial Reference Building  
by the Department of Energy

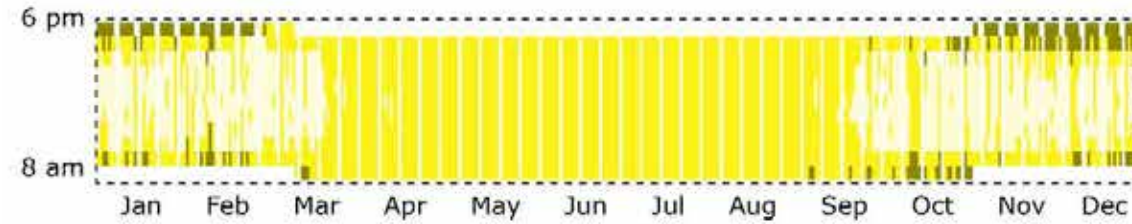
## Autonomy metrics - Color legend



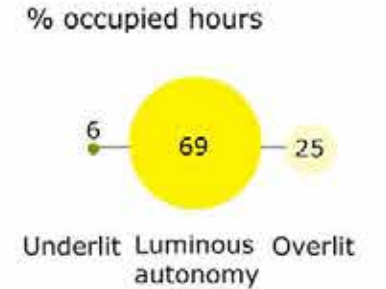
# Results

Luminous  
autonomy

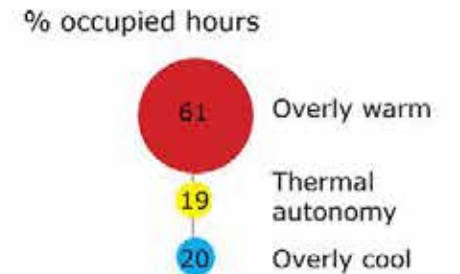
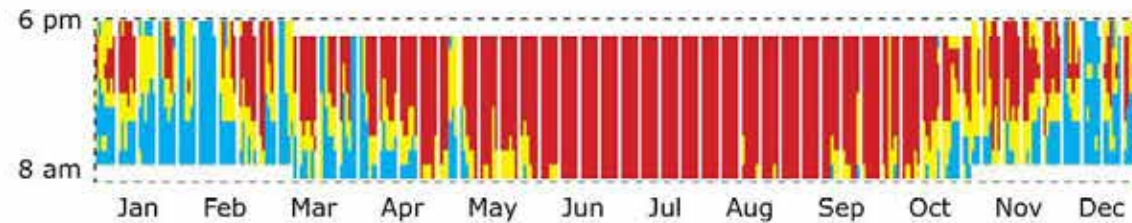
Hourly data



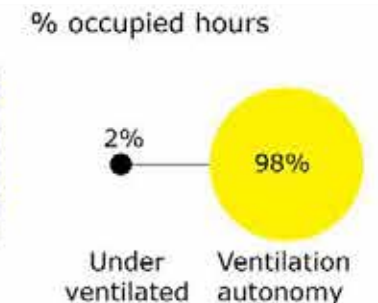
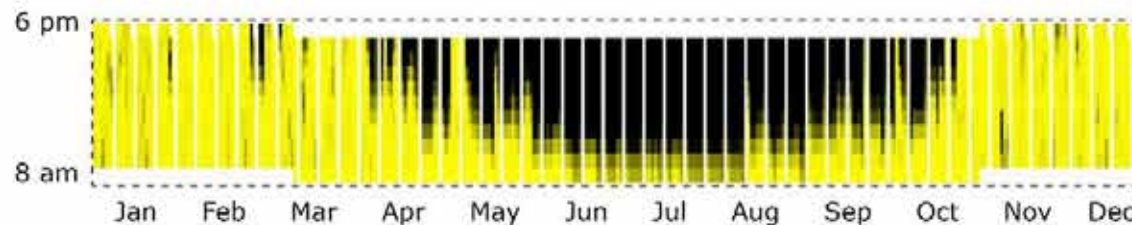
Annual data



Thermal  
autonomy



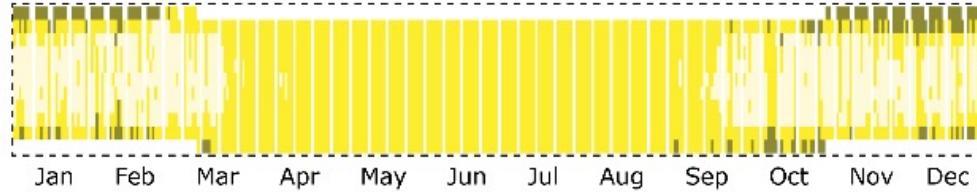
Ventilation  
autonomy



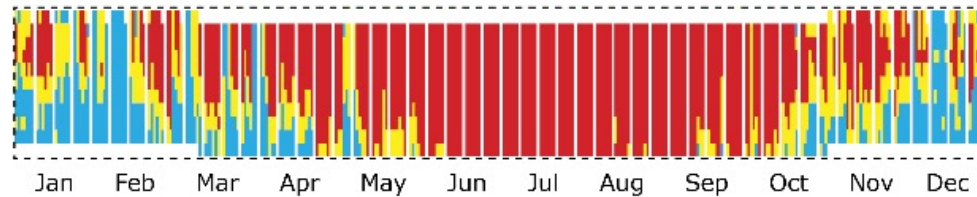
# Results

## Temporal analysis

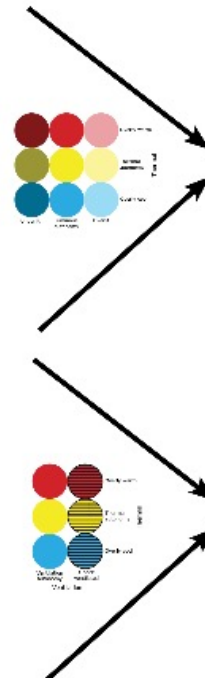
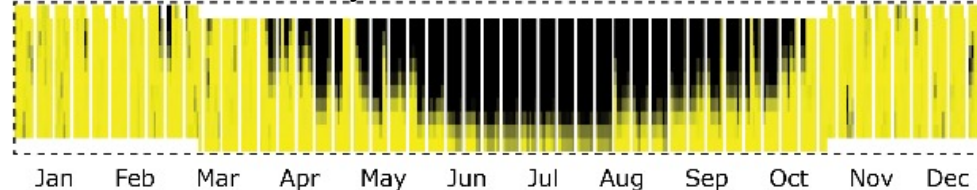
Luminous autonomy



Thermal autonomy

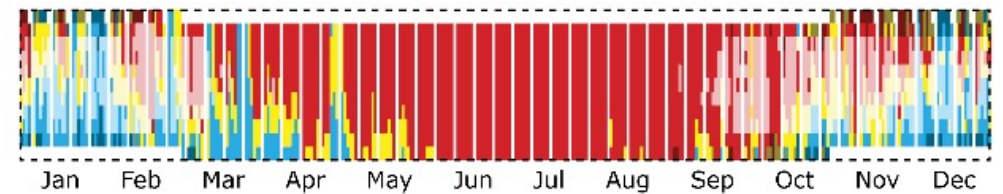


Ventilation autonomy

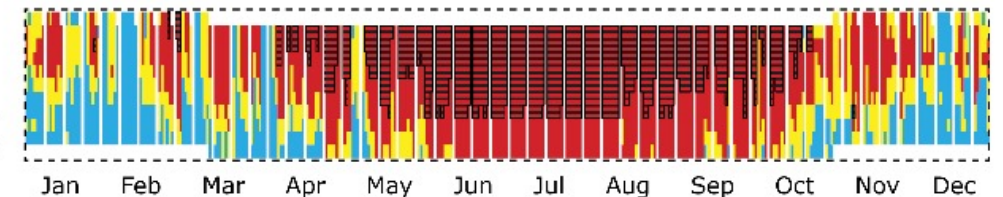


## Simultaneous analysis

Luminous and thermal autonomy



Thermal and ventilation autonomy



## 2. Window view impact on occupants and multi-sensory effects





Source: Multisensory Cog Lab, Trinity College Dublin



Source: Harry Cock, Designtrend



Source: Tori Powers, SJExpress

# Research Question:

*How do people perceive the thermal environment differently when they have a window view?*

# Methods

Thermally identical spaces with and without windows (82.4° F, slightly warm condition)



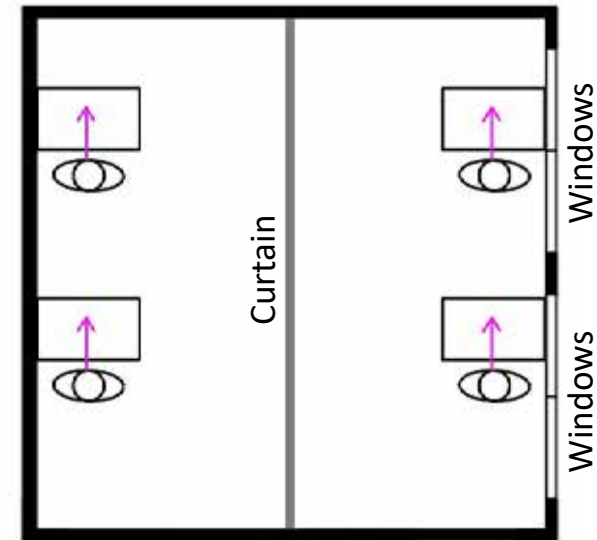
Without windows.



With windows.



View through the windows.



Floor plan of the CBE chamber.

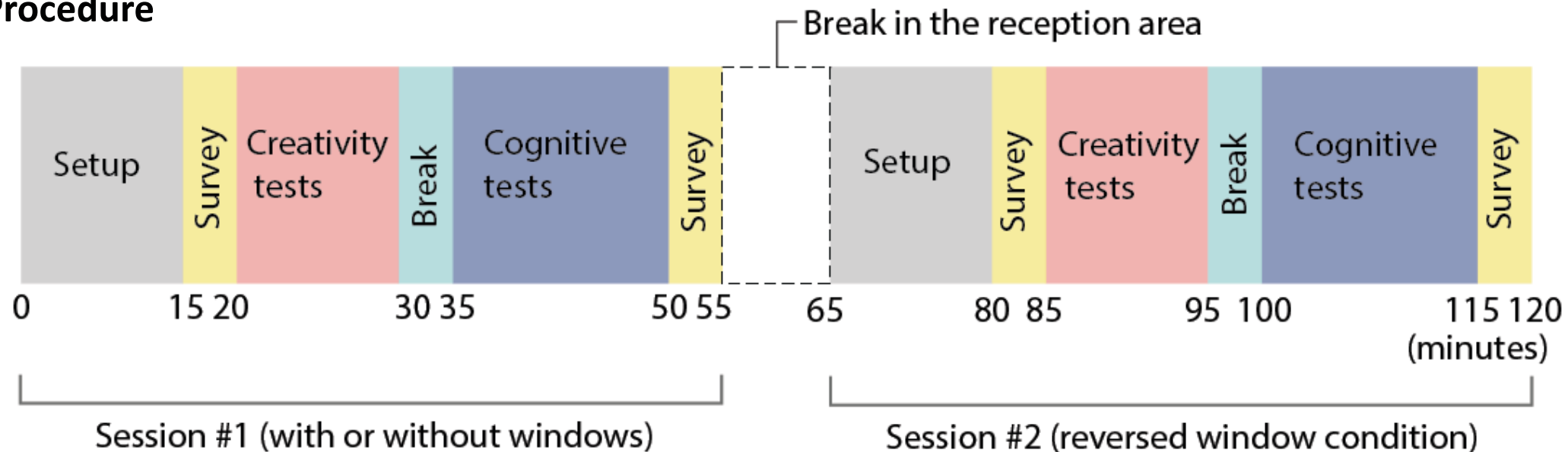


# Experimental design

## Study details

- 86 subjects (43 M & 43 F)
- Each subject participated in two experimental sessions (one with windows and one without)

## Procedure



## Measurements

- Subjective thermal perceptions, emotions, and cognitive performance of participants

# Results

## Felt cooler



At slightly warm ambient condition,

- 1.33 °F lower thermal sensation
- 12 % more thermal comfort
- 8% in cooling energy and 6.5% of total HVAC energy reduction for a building in SF.

## Felt happier



- Increase in positive emotions
- Decrease in negative emotions

## More focused



- 6% better working memory
- 5% better concentration

# 3. Assessing window view quality for building design and operation



# Research Question:

*What determines the quality of a window view?*

# Method

## Literature Review

### Building Standards

- CIBSE
- EN
- ASHRAE
- IES...

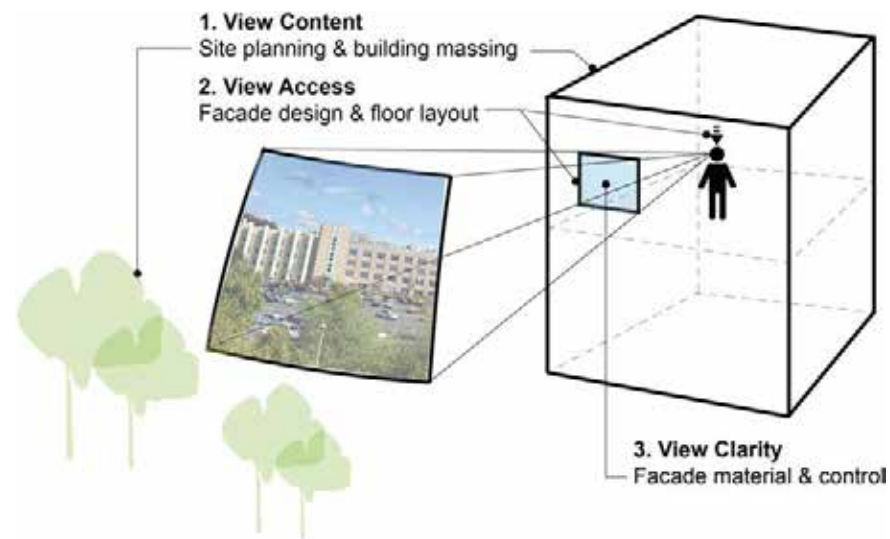
### Green certification systems

- LEED
- WELL
- BREEAM
- Green Globes
- Green Star...

### Scientific research papers

- Architecture
- Urban planning
- Landscape
- Environmental psychology
- Vision science

## View Quality Framework



- Virtual symposium
- In-person workshop
- Collaboration: global dataset






Ko, W.H., Kent, M.G., Schiavon, S., Levitt, B., Betti, G., 2021. A window view quality assessment framework. LEUKOS - Journal of Illuminating Engineering Society of North America 40. <https://doi.org/10.1080/15502724.2021.1965889>

Symposium on Research and Design Practice Related to Window Views, October 2021.

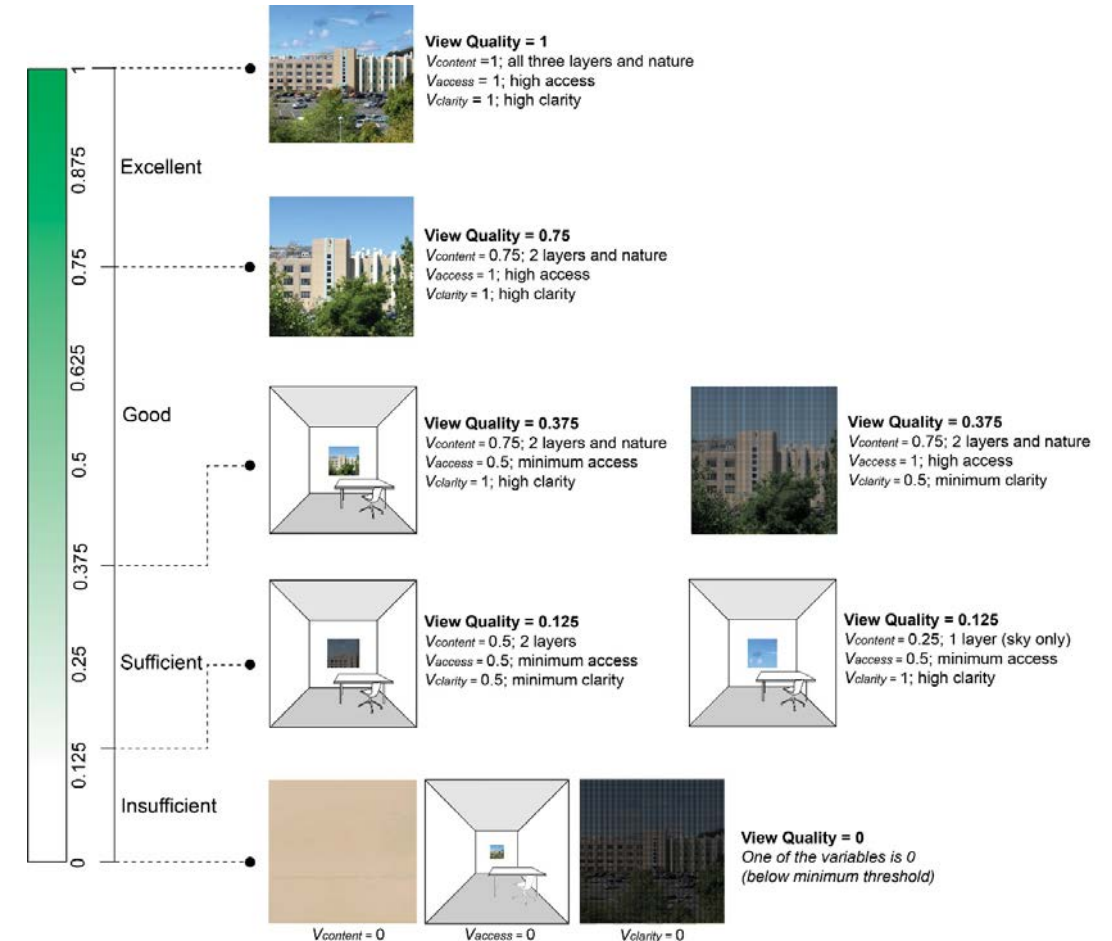
<https://pge.docebosaas.com/learn/course/external/view/elearning/1184/symposium-on-research-and-design-practice-related-to-window-views-previously-recorded>

# View Quality Index (VQI)

Variable	Criteria	Design considerations
<b>View content (<math>V_{content}</math>)</b> 	Nature and urban features	• Position windows to face greenery and/or natural water features when possible
	Horizontal stratification	• Ensure at least landscape and/or sky layer
	Content distance	• Avoid nearby content (< 6 m from window) in view particularly in urban content
	Dynamic features (movement)	• Provide views showing dynamic features ( $\geq 6$ m from window) (e.g., traffic flow and people)
<b>View access (<math>V_{access}</math>)</b> 	View angle	• Achieve the minimum view angle* • Achieve View Factor of at least 3
	Alternative access	• Design atrium and courtyard (at least 8m in width) with pleasant visual elements (e.g., nature)
	Spatial assessment	• At least 75 % of the floor area has direct access to window view ( $\geq$ minimum view angle*)
<b>View clarity (<math>V_{clarity}</math>)</b> 	Window design	• Avoid placing the horizontal/vertical mullions at the boundaries of the ground, landscape and sky layers
	Glazing and shading materials	• Select shading material considering the VCI* when available
	Temporal attributes	• Control the glazing and shading systems to provide the desired clarity of window view(s) ( $\geq$ minimum number of occupied hours* that exceed minimum view clarity* for the space)

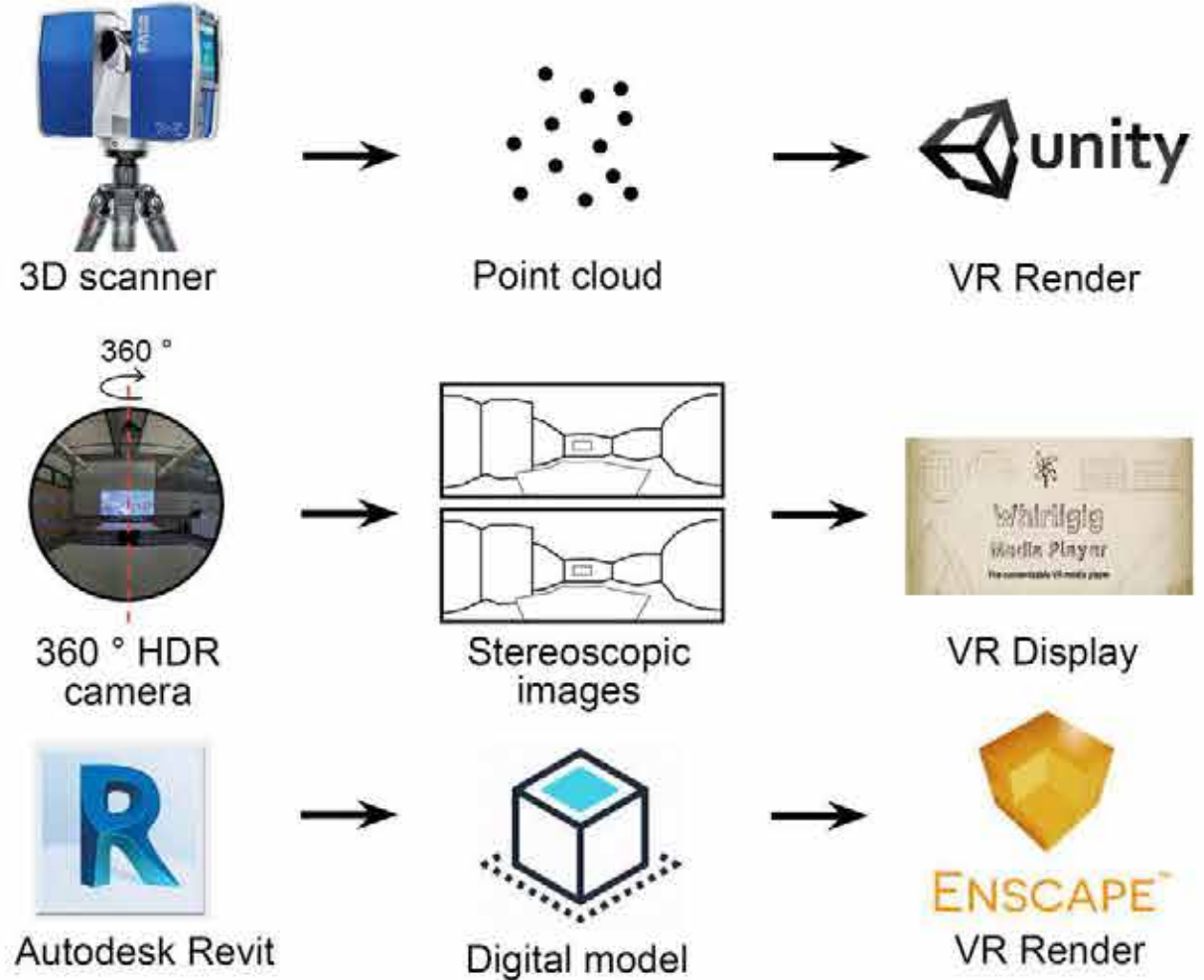
\* Design parameters that we could not find consensus in the reviewed standards, green certificate systems, and scientific literature. Section 7 discusses the future research.

$$VQI = V_{content} \cdot V_{access} \cdot V_{clarity}$$



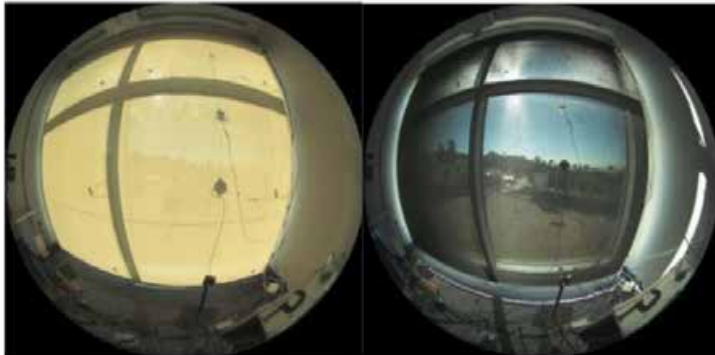


# Current work: Virtual reality in environmental research



# Future research ideas

# View clarity: dynamic facades to improve occupant well-being and building energy performance



Source: <https://www.100cia.site>

- Advanced façade design, materials
- Understanding of human perception and behavior
- Optimized façade control



# Healthier and more sustainable built environment using emerging technologies

Advanced sensing technology

+

In-depth understanding  
of human perception  
and behavior



Sustainable and healthy  
building design and operation



**Thank you! Questions?**

Won Hee Ko

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