Health and well-being responses to daylighting in northern buildings

Presenting by

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Northern Canada (50°N)

People
Light-related
health & wellbeing

Building
Daylighting
design & performance

Climate
Strong day/night cycles
(photoperiods)

Questions

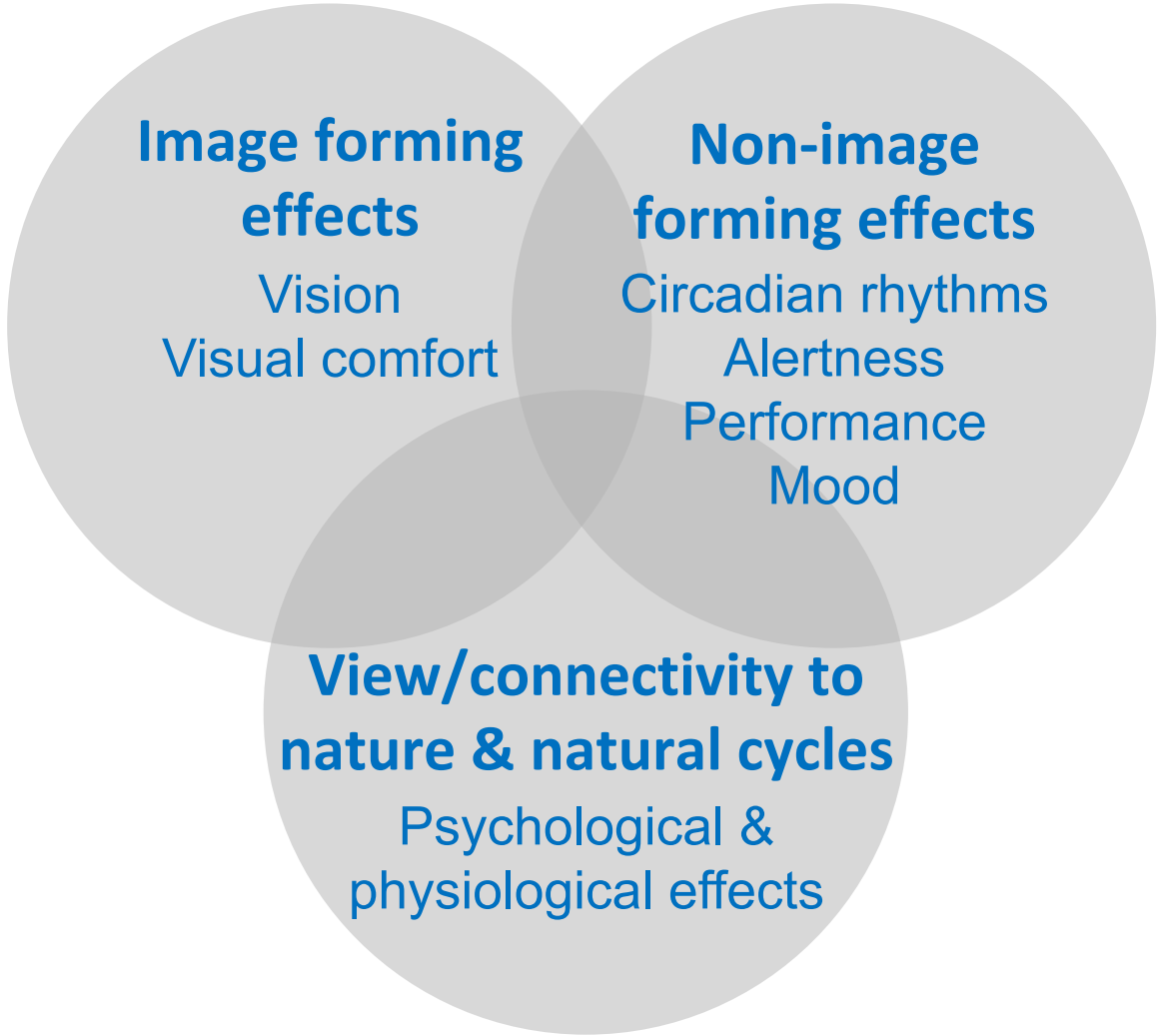
- How do Northern buildings respond to the climate and people's light-related needs?
- What are the potential health and wellbeing responses of occupants to daylighting inside Northern buildings?

Objective

Develop the daylighting design of northern buildings for occupants' health and wellbeing

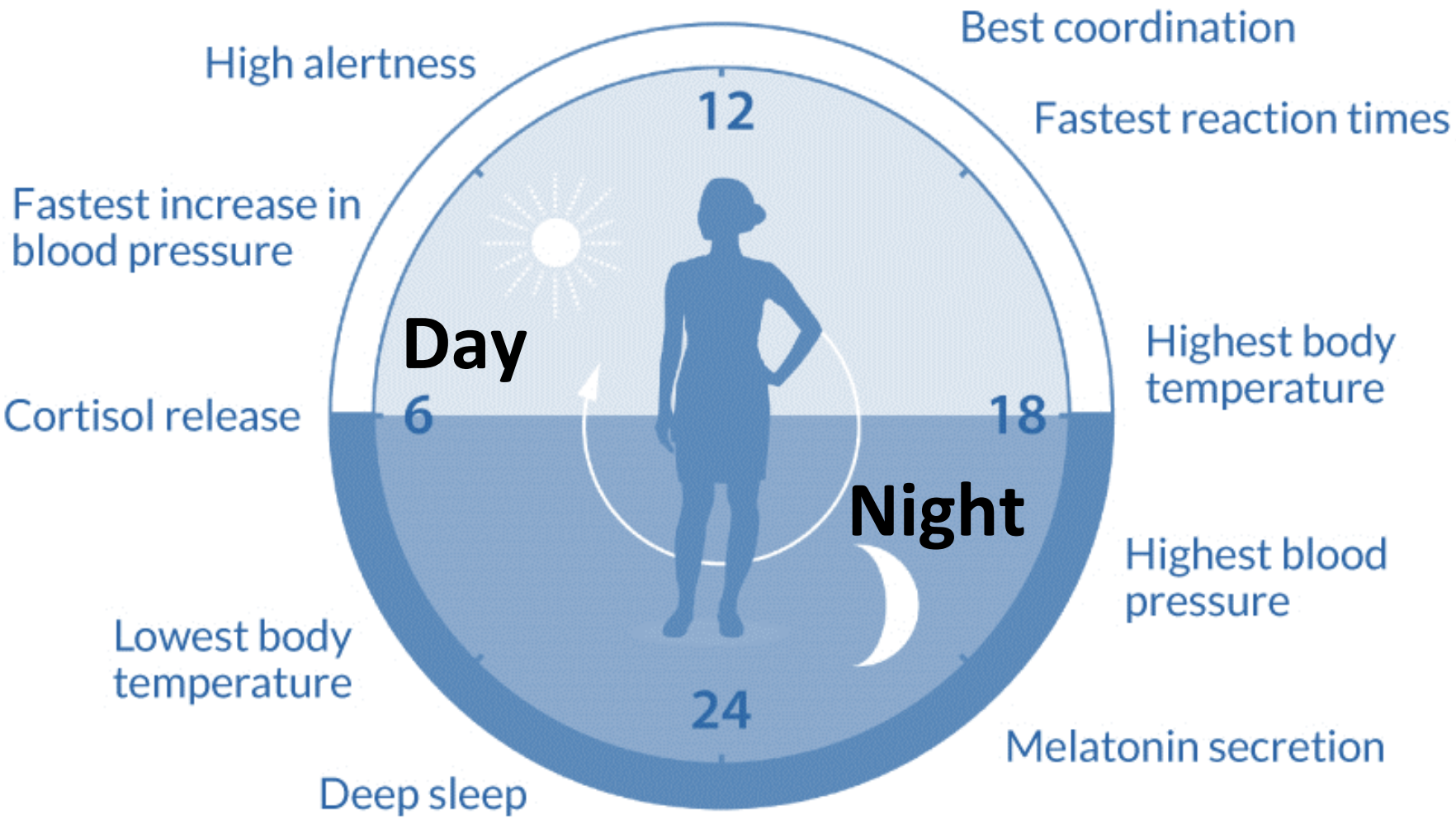
Light-related Health & wellbeing

- Photobiology
- Psychology
- Biophilic design



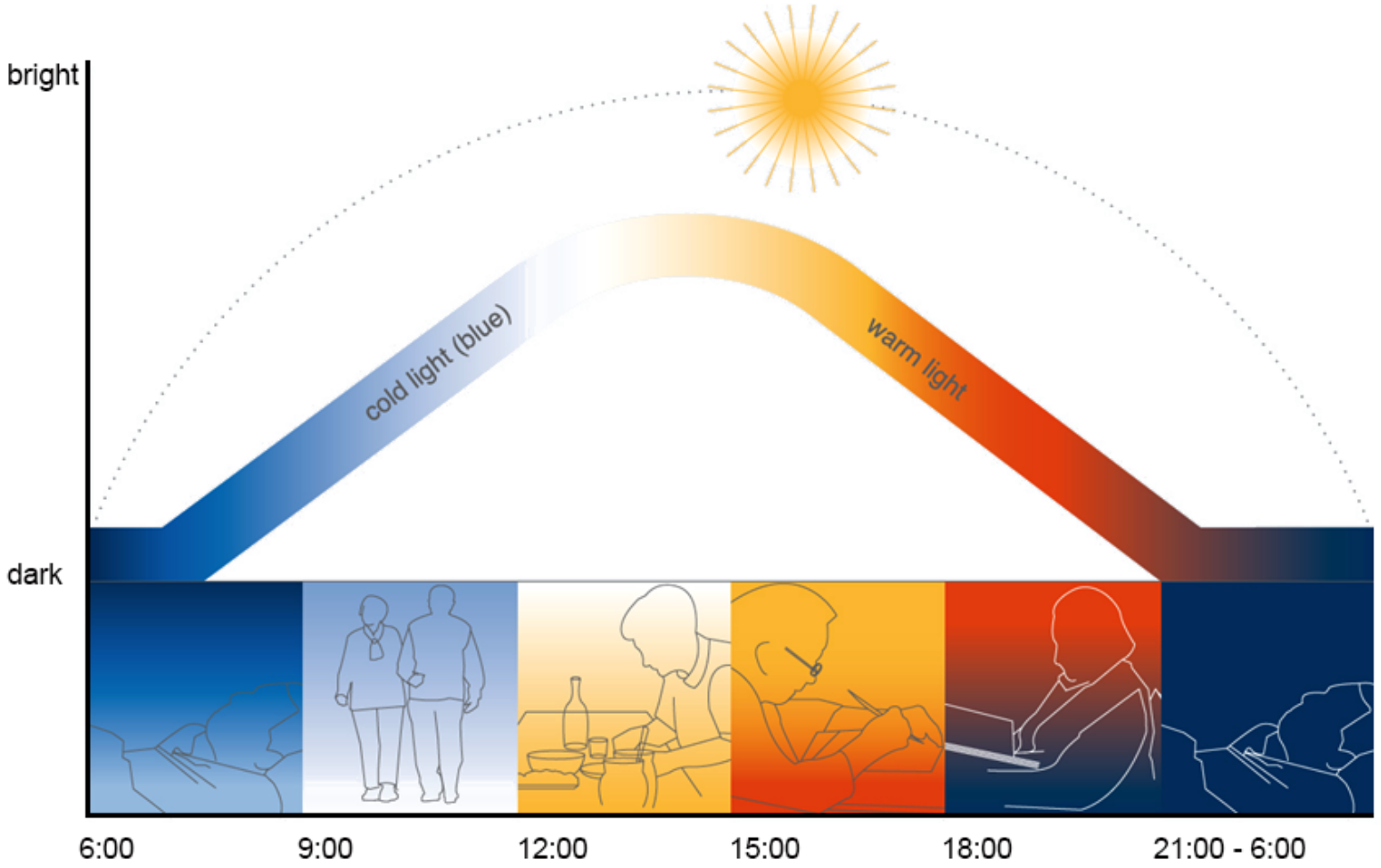
Refer to: (CIE, 2018, 2019; Dai, Huang, Hao, Lin, & Chen, 2018; DiLaura, Houser, Mistrick, & Steffy, 2011; International WELL Building Institute, 2018; Jung, 2017; Jung & Inanici, 2019; Konis, 2017; Lucas et al., 2014; Parsaee, Demers, Hébert, Lalonde, & Potvin, 2019; Rea & Figueiro, 2016)

Non-image forming effects



Proper Light at Proper Time

CIE (October 3, 2019), Position statement on non-visual effects of light



Light-related Health & wellbeing

- Lighting standards and practice often focus on image forming (visual) and energy efficiency aspects of light, with little or no consideration of non-image forming responses

Light-related Health & wellbeing

- An improper balance between these aspects can compromise human well-being, health and functioning related to lighting ambiance.

Light-related Health & wellbeing

- Many lighting products, especially LED systems, are available in the market that are aimed to affect non-image forming aspects.

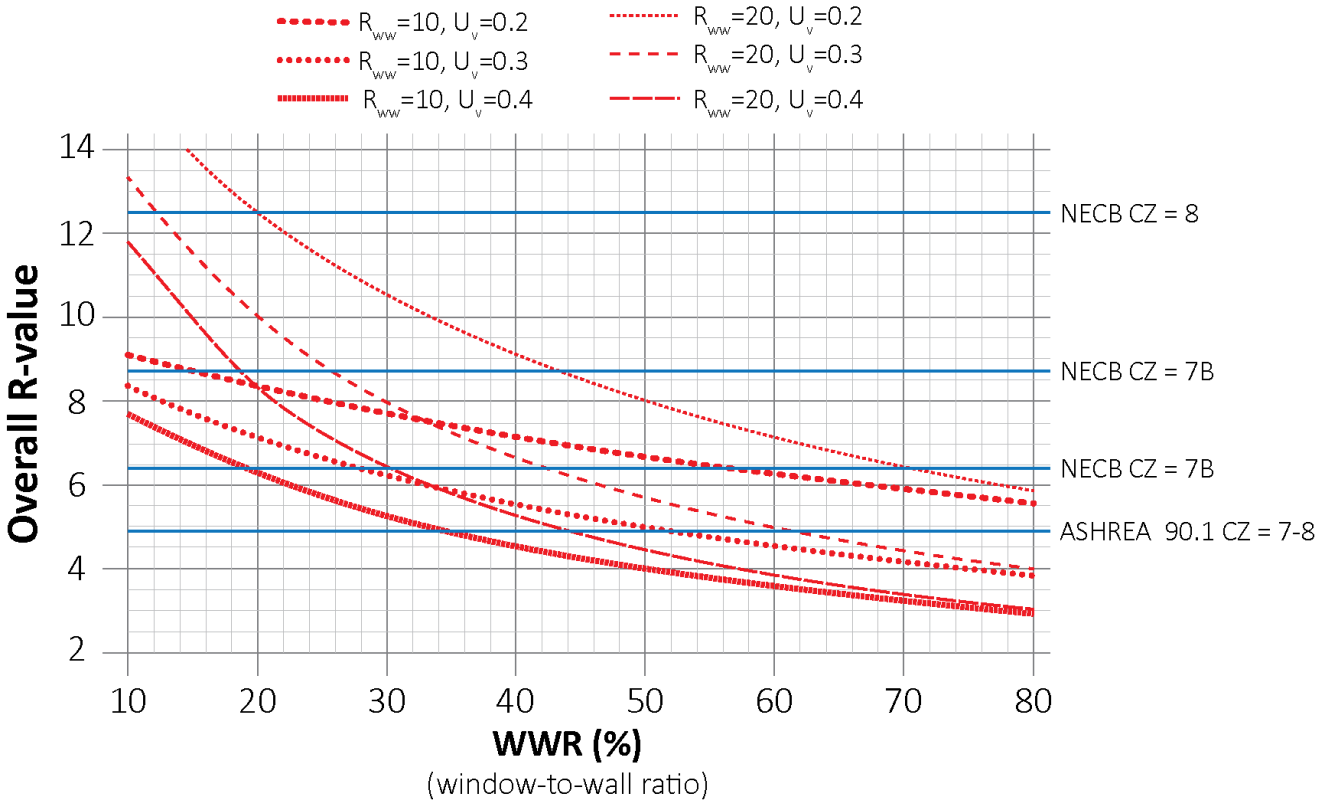
Don’t unnecessarily decrease or restrict availability and accessibility to daylight and outdoor nature inside buildings.

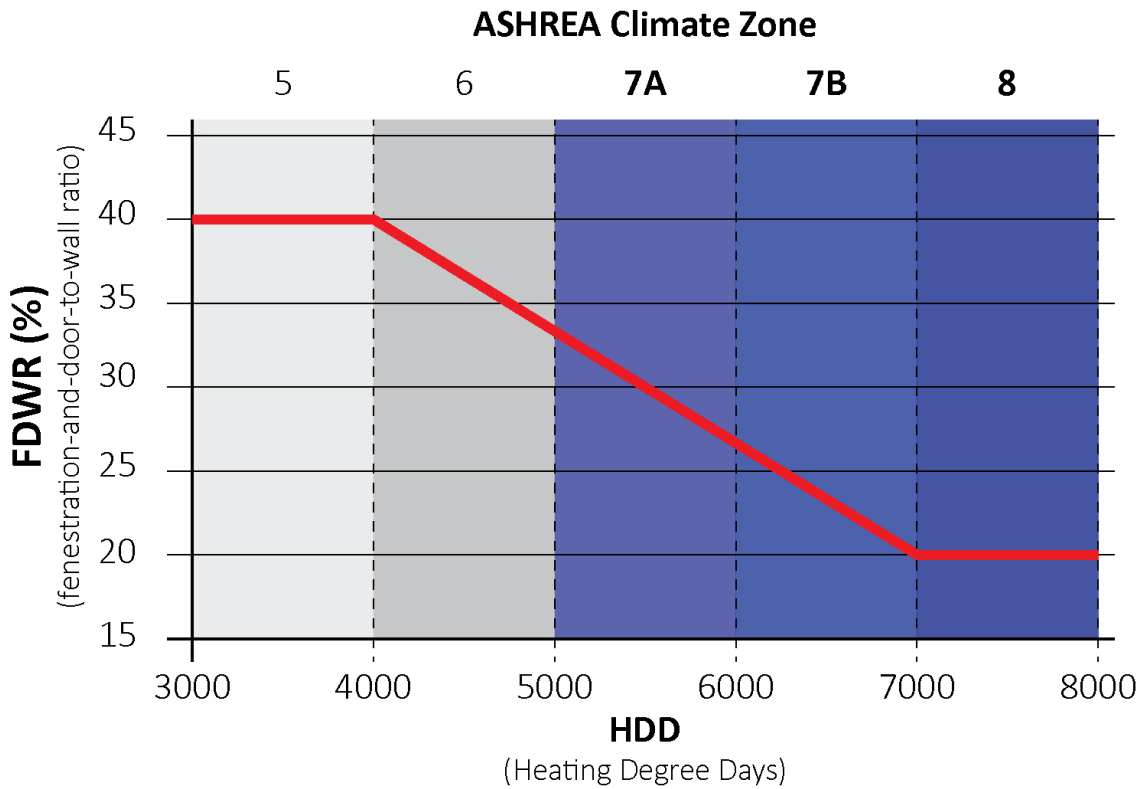
CIE (October 3, 2019), Position statement on non-visual effects of light

Challenging conditions in Northern Canada

Very low window-to-wall ratio (WWR)

recommended by National Energy Code of Canada for Buildings (NECB)





Combined impact of thermal performance of mass walls and windows and WWR (CZ=climate zone, R_{ww} is whole-wall R-value, and U_v is window U-value)

Refer to (NRC, 2015)

Northern Canada's Climate

Northern Canada's Climate

Cambridge Bay
[69° N]

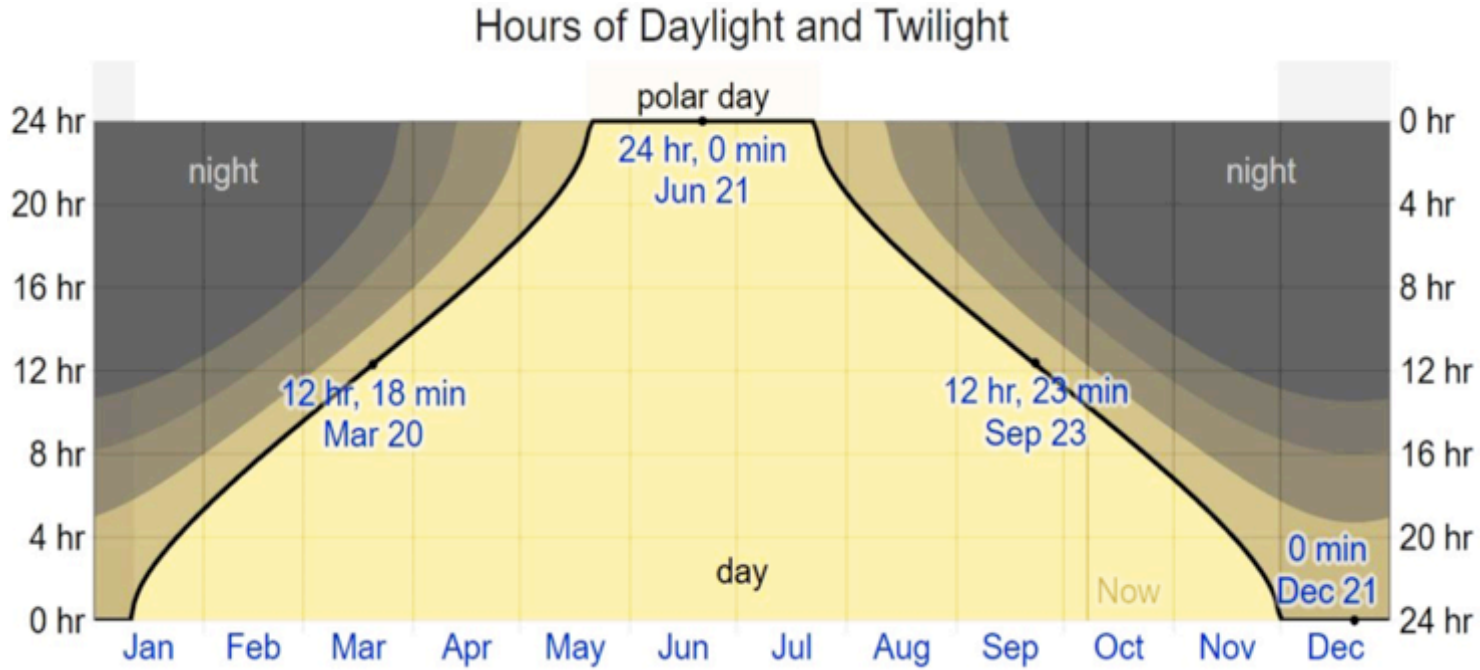
Northern Canada's Climate

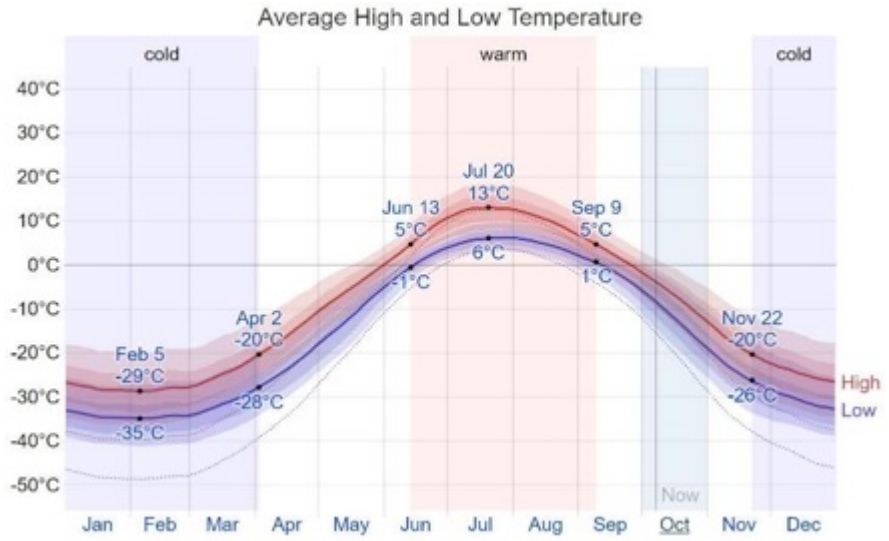
Cambridge Bay [69° N]

- **Strong photoperiods**

  (Day/night cycles)

- **Extreme cold weather**



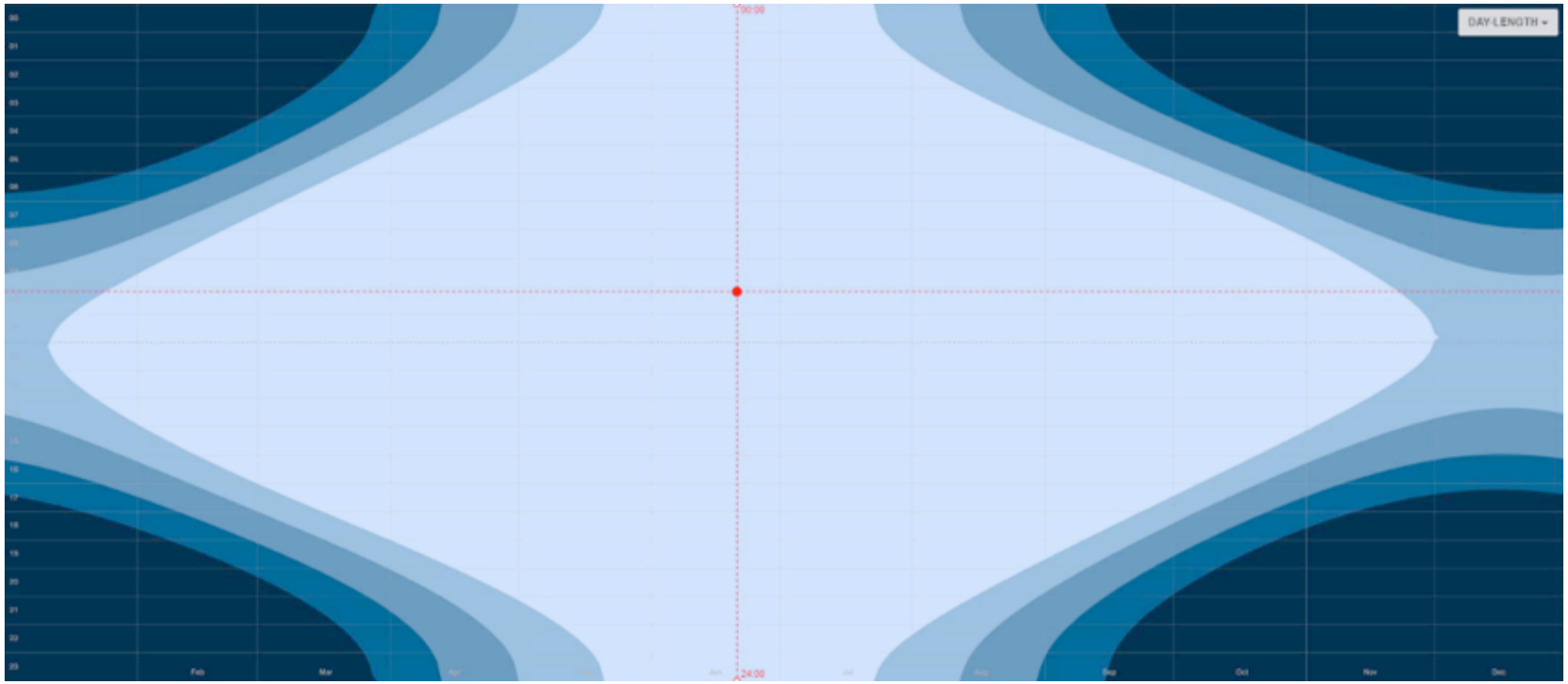


Published by (Wearher spark, 2018)

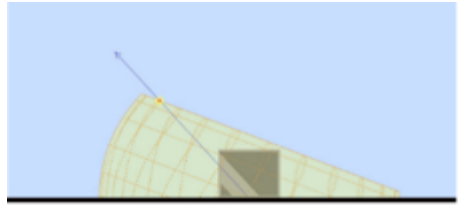
Northern Canada’s Climate lighting features

Cambridge Bay [69° N]

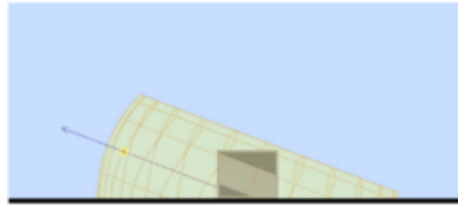
Photoperiod



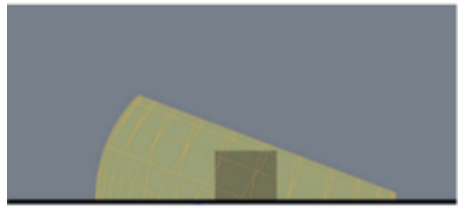
Solar elevation



Summer solstice



Fall/Spring equinox



Winter solstice

Northern Buildings

most often been designed with low WWR’s to respond to thermal issues

Northern Buildings

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Northern Buildings

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Northern Buildings

some few cases, such as airports, have very high WWR’s

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Observation

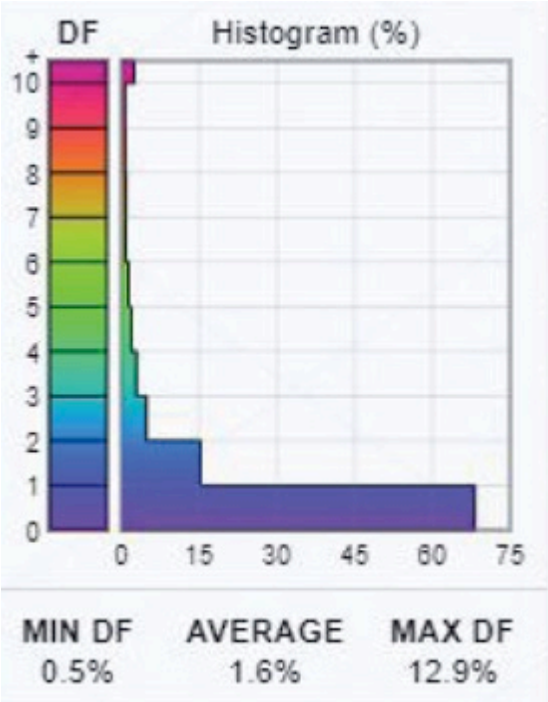
Openings are mostly covered by blinds in sunny and cloudy days

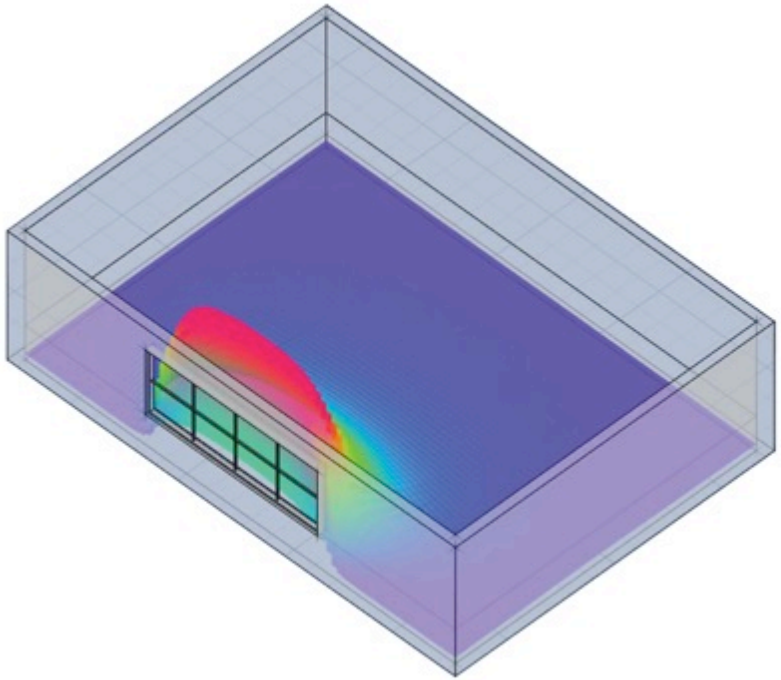


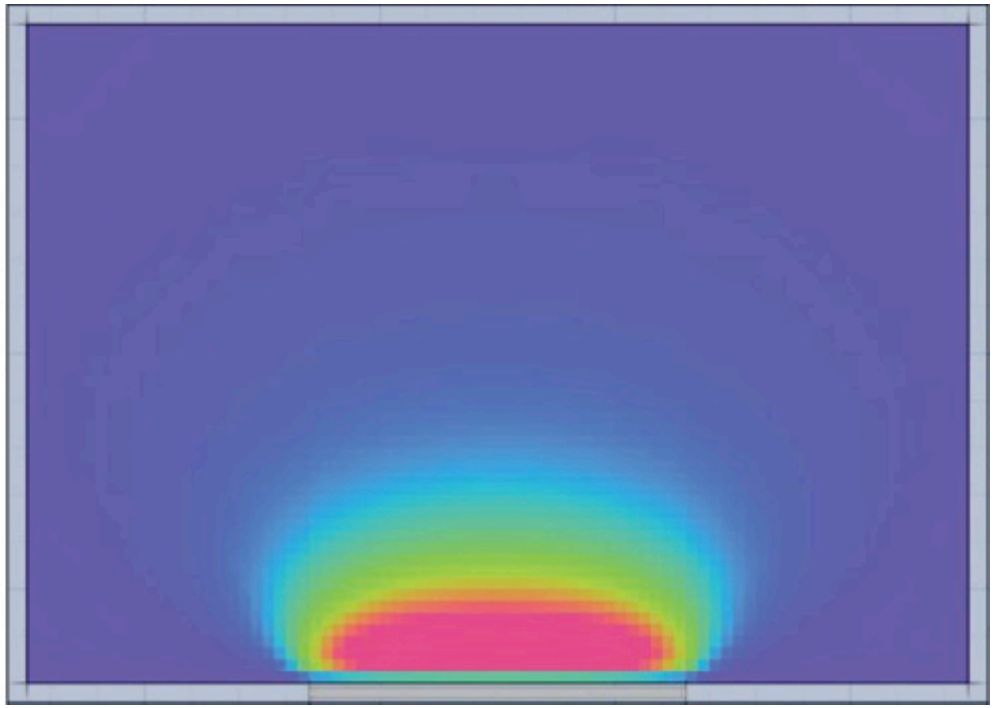



Daylight factor in a typical space recommended for Northern Canada

WWR = 20%







Experimental set-up

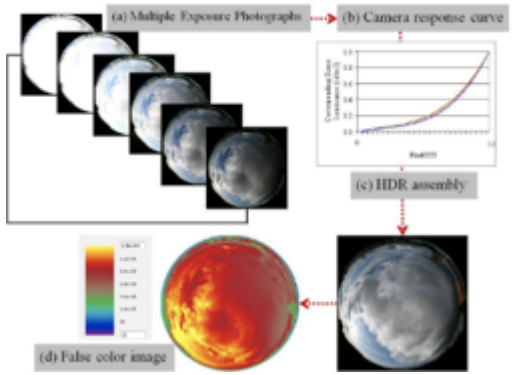
Models (n=18)

Scale 1:50

Measurement

Raspberry Pi fisheye camera

HDR imagery



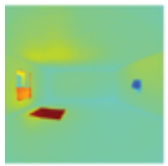
Parameter

Health & wellbeing

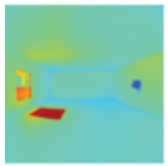
Side view
Back View

Distribution

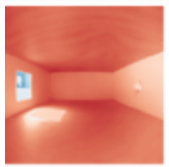
Color temperature



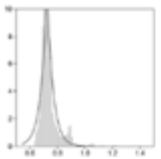
Photopic



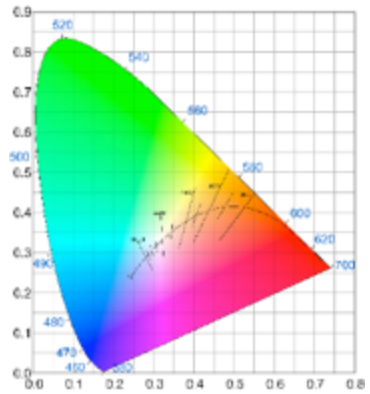
Melanopic



Ratio (M/P)



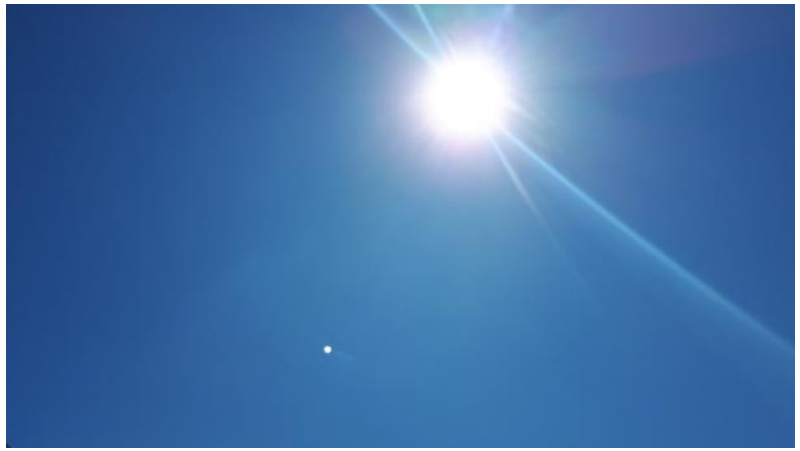
PDF*



Experimental set-up

Outdoor lighting

Quebec City
11:15am-12:45pm
September 18, 2019
South direction
Sunny
Cloud cover = 0



Measurement

Every 15 minutes

Konica CL-200A Chroma Meter

IL5000 Research Radiometer

Parameter

Health & wellbeing

Photopic lux

Equivalent Melanopic lux

Color temperature

CIE Chromaticity

Models

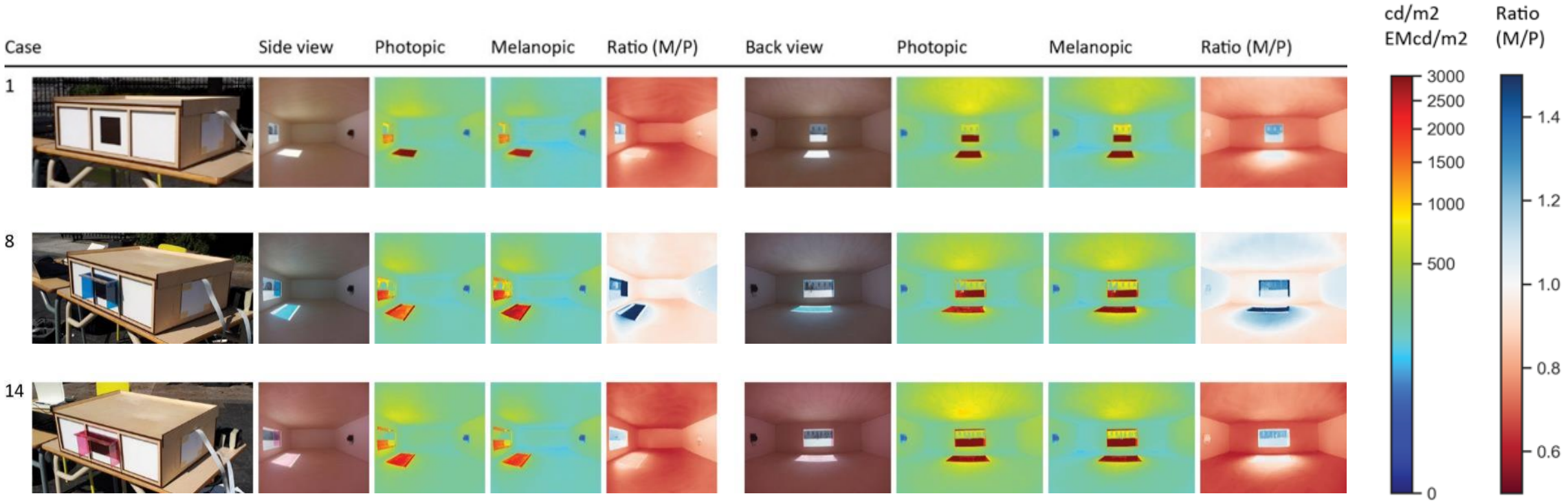
Scale 1:50

Variables:

- WWR (from 10% to 80%)
- Form of openings
- Simple shadings/reflectors with different
  - Color (blue for non-image forming effects, Red for image forming effects)
  - Opaque/Transparent (blue/red)
  - Orientation (vertical/horizontal)

Analysis

Health and wellbeing responses



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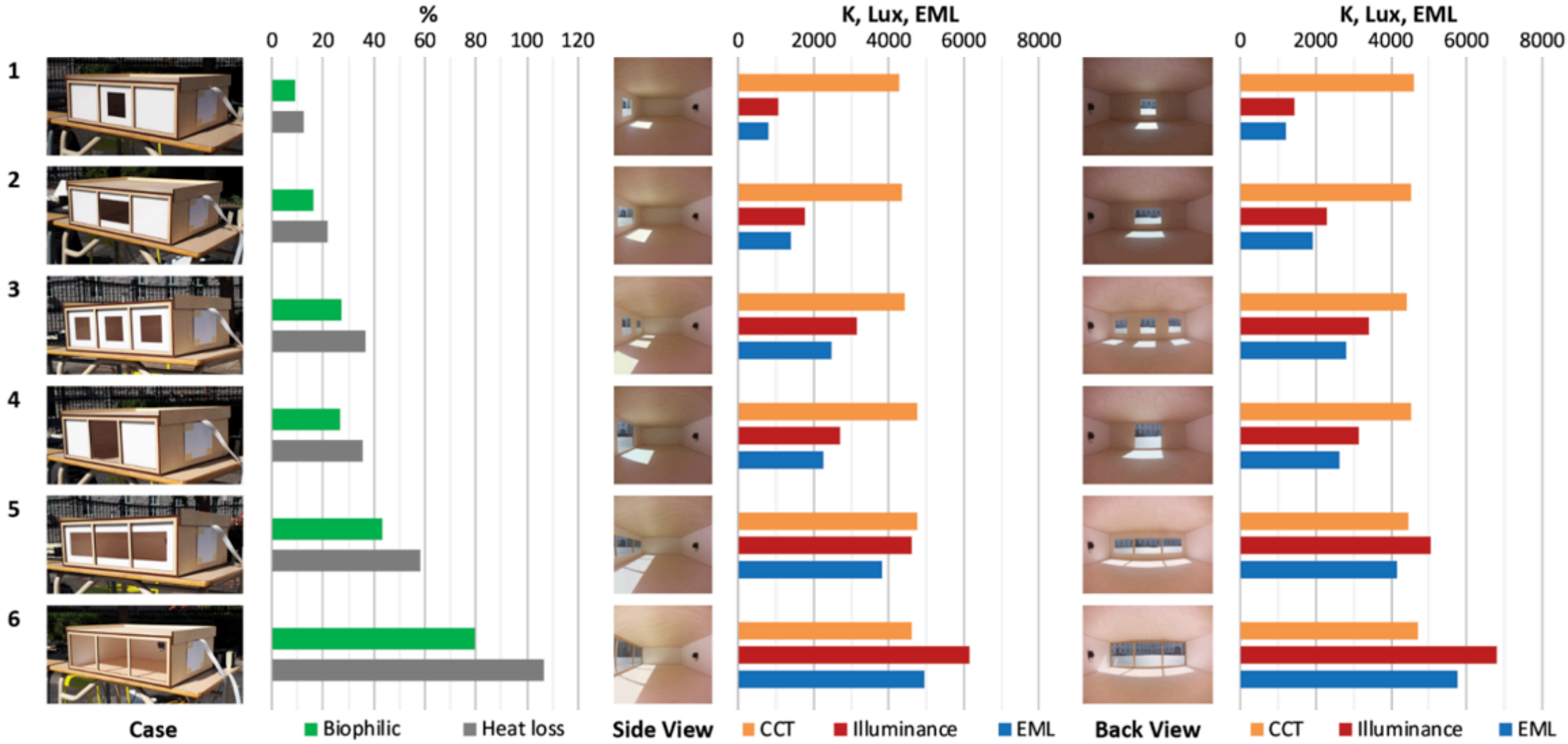
Health and wellbeing responses



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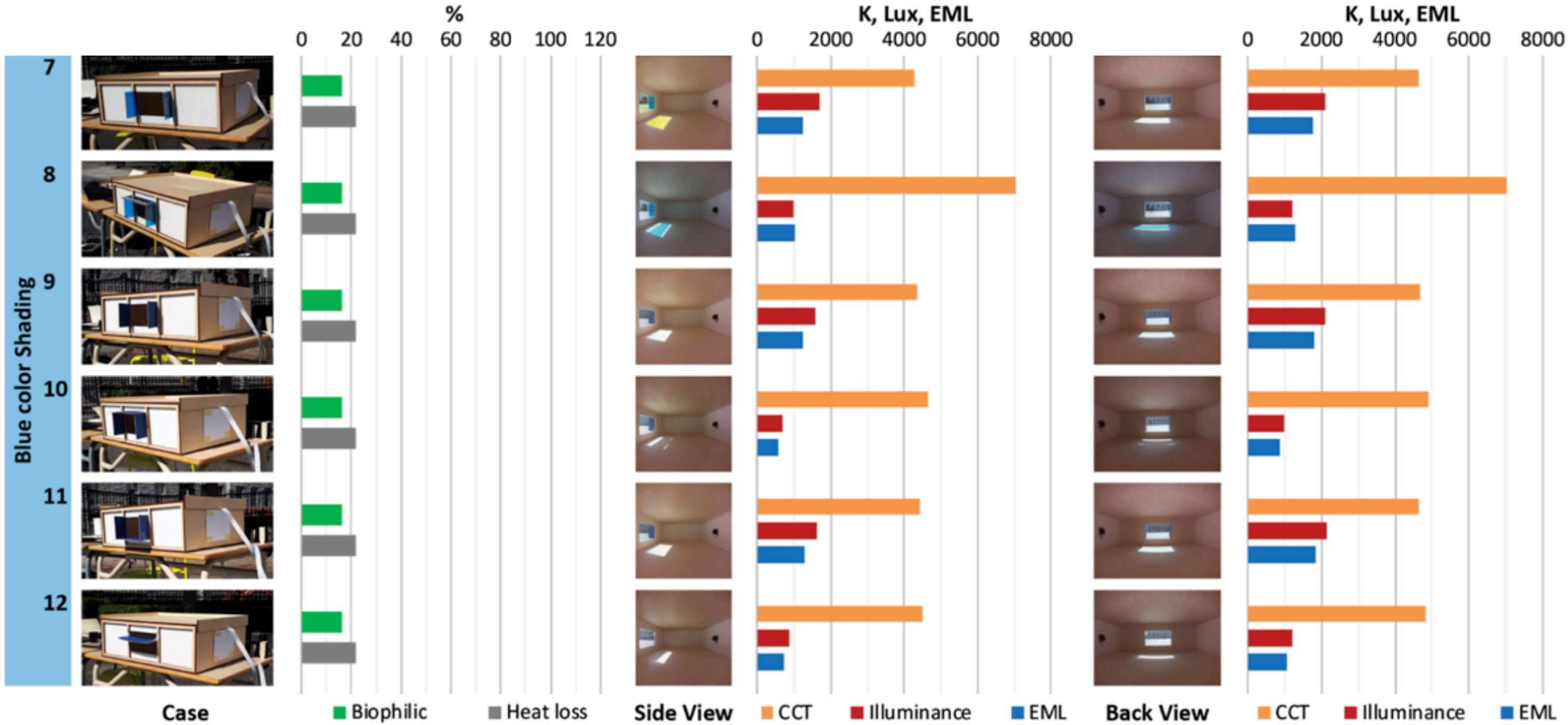

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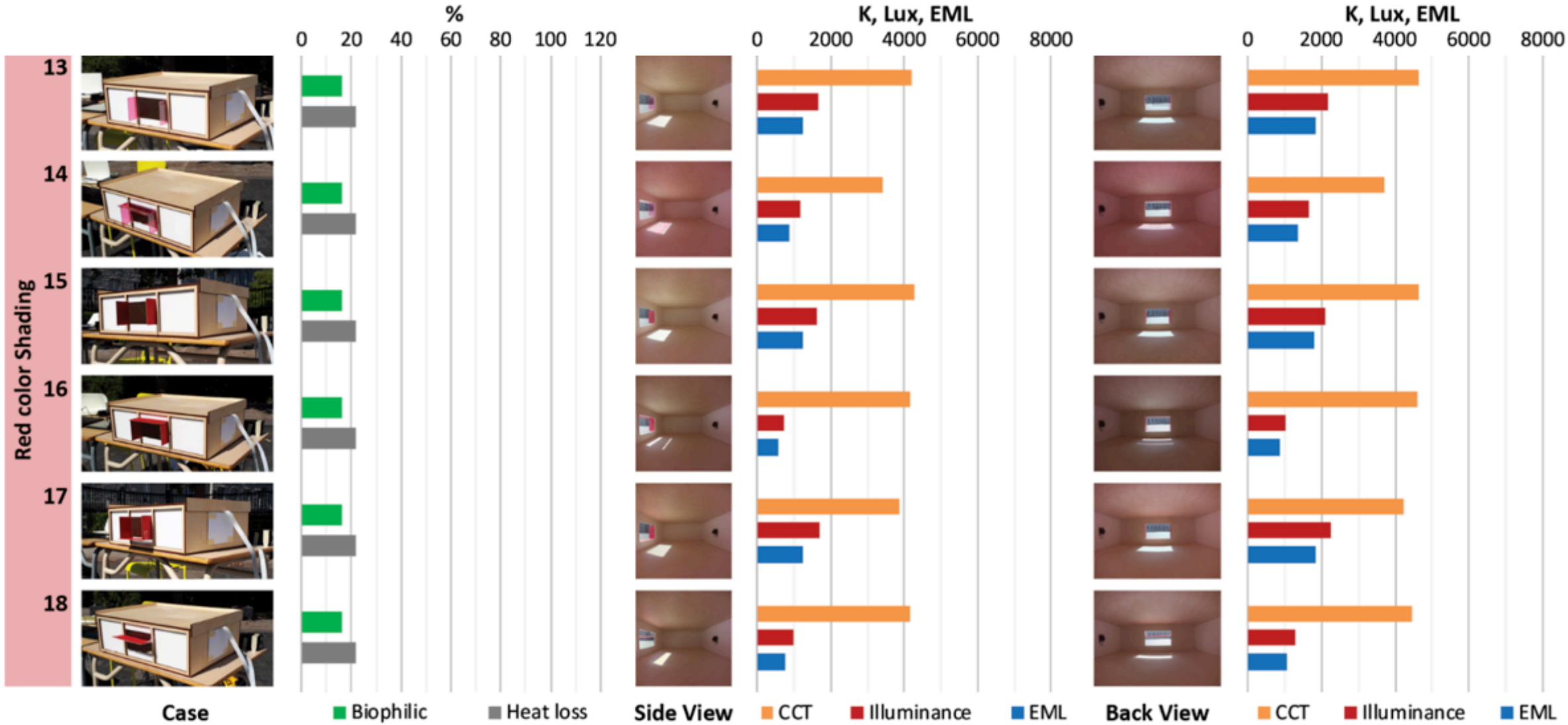

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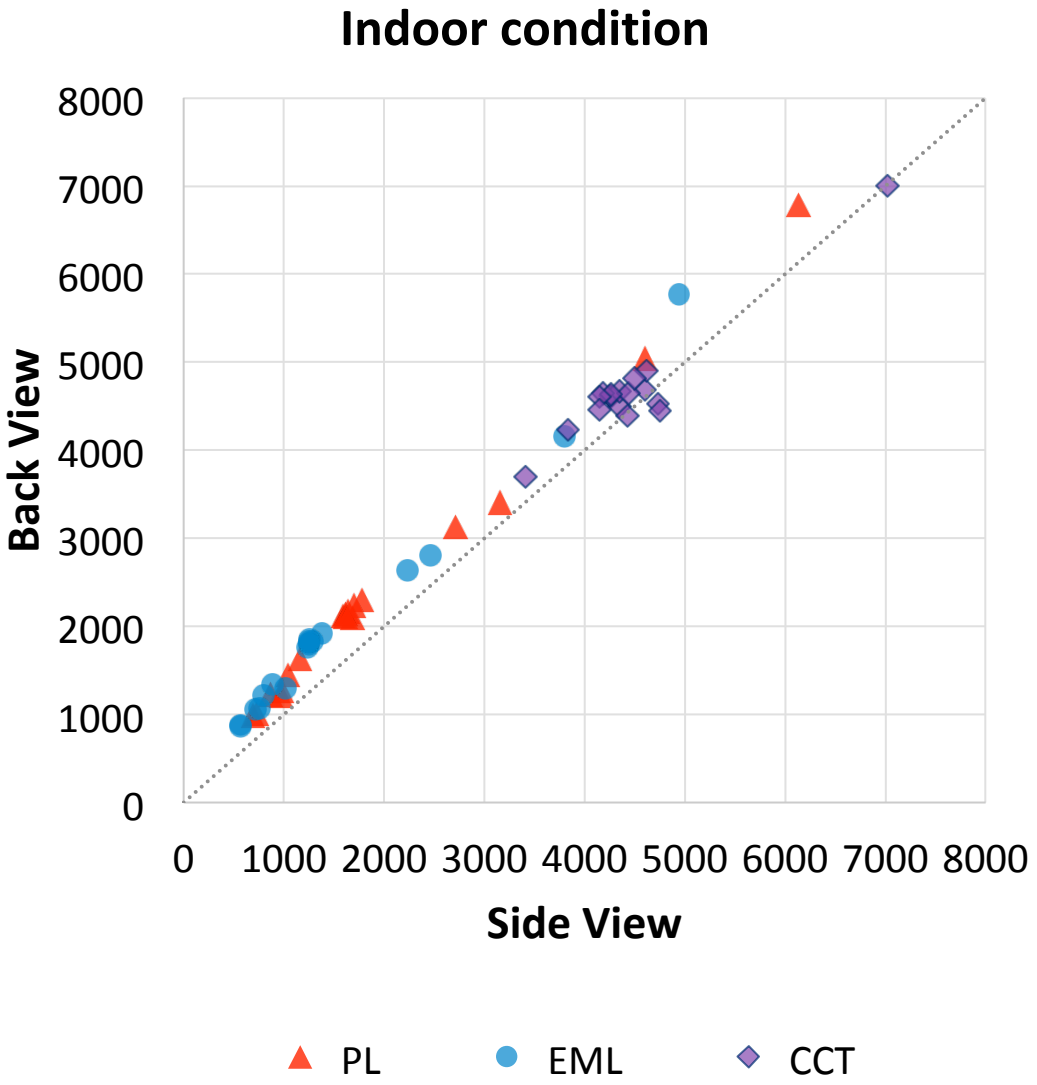

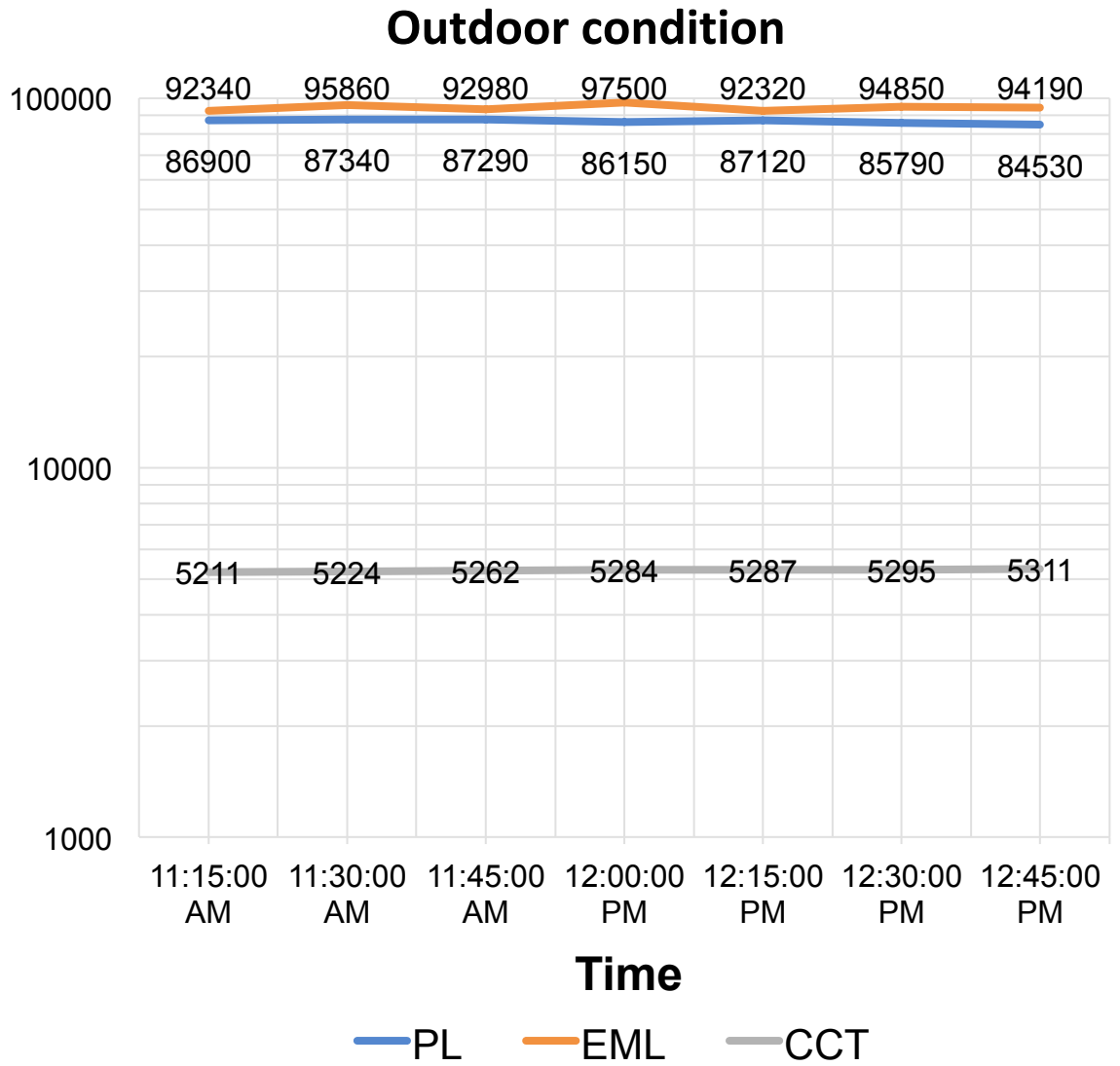

Conclusion & future studies

- Photobiological and biophilic lighting requirements must be considered in building design and recommendations for Northern Canada.
- A low WWR could not provide a healthy indoor lighting environment for Northern occupants.
- Availability of daylighting and accessibility to outdoor nature and natural cycles are compromised by a low WWR.
- A high WWR could improve photobiological and biophilic aspects of indoor lighting. However, it will cause serious thermal and energy issues.
- The use of opaque/transparent reflectors could improve indoor lighting which must be developed and optimized for Northern Canada.

Conclusion & future studies

- Photobiological and biophilic lighting requirements must be considered in building design and recommendations for Northern Canada.
- Adaptive and high-performance façade systems could be developed to deal with the issues and provide northern occupants a healthy environment.
- Lighting adaptation scenarios must be developed to respond to individual’s lighting needs and local photoperiods.
- An integrated approach must be developed to assess photobiological and biophilic aspects of light in the space.

Thank you for your attention!
Any question?

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