Spectral assessment of shading systems, a step towards balancing human health, comfort and energy requirements

ES-SO Technical workshop

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Spectral assessment of shading systems

Content

- ❑ Introduction and context
- ❑ Spectral data
- ❑ Simulation tool OWL
- ❑ Alternative model
- ❑ Conclusions

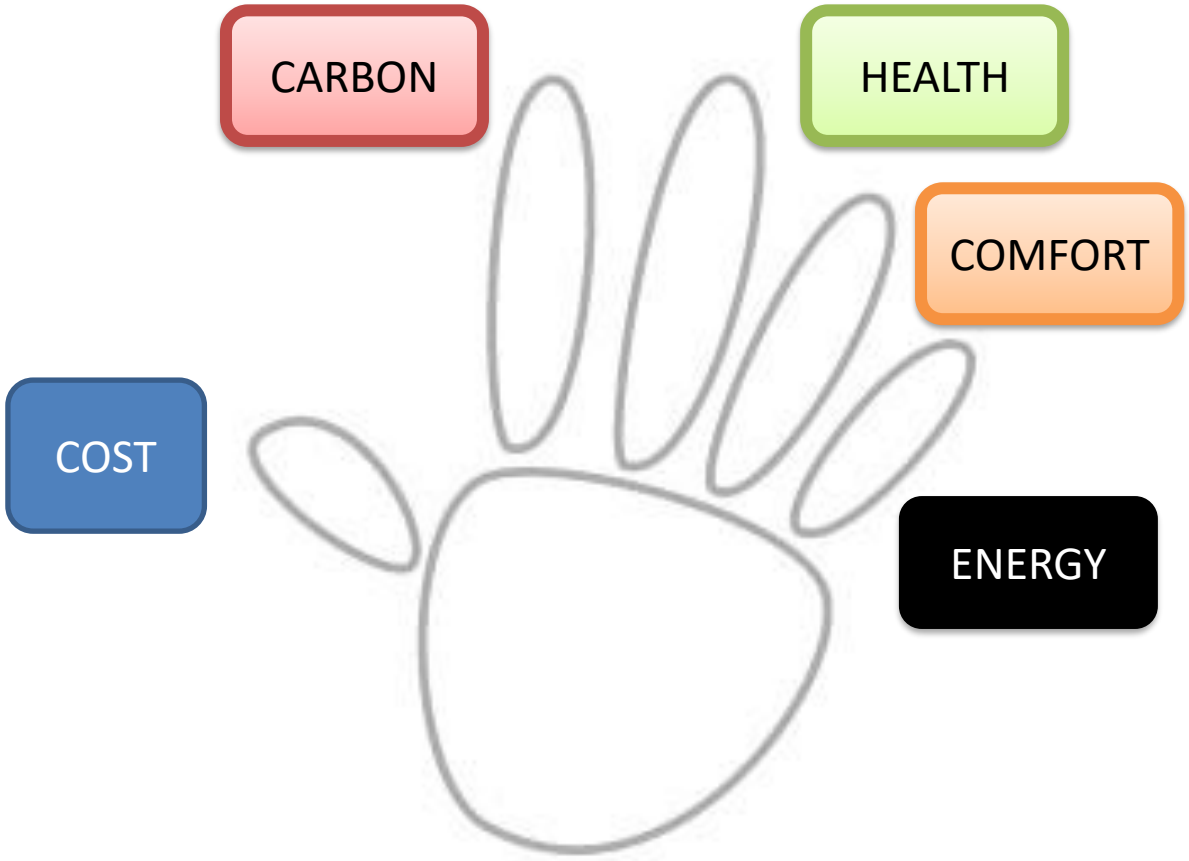
Spectral assessment of shading systems

Why solar shading?

1. **Indoor climate** (visual/thermal comfort, …)
   - ❑ Modulating solar gains (variable conditions/needs)
   - ❑ Buildings more sensitive for overheating
   - ❑ Frequency and intensity of heat waves increases
2. **Energy saving** (towards NZEB)
   - ❑ Passive design strategies (no active cooling)
   - ❑ Relax on internal conditions requirements
3. **Environmental impact** (Zero carbon!)
   - ❑ Minimize resources (Refuse/Reduce/Reuse/Recycle)
   - ❑ …

Spectral assessment of shading systems

Design criteria



Balancing multiple requirements for each situation and context

Spectral assessment of shading systems

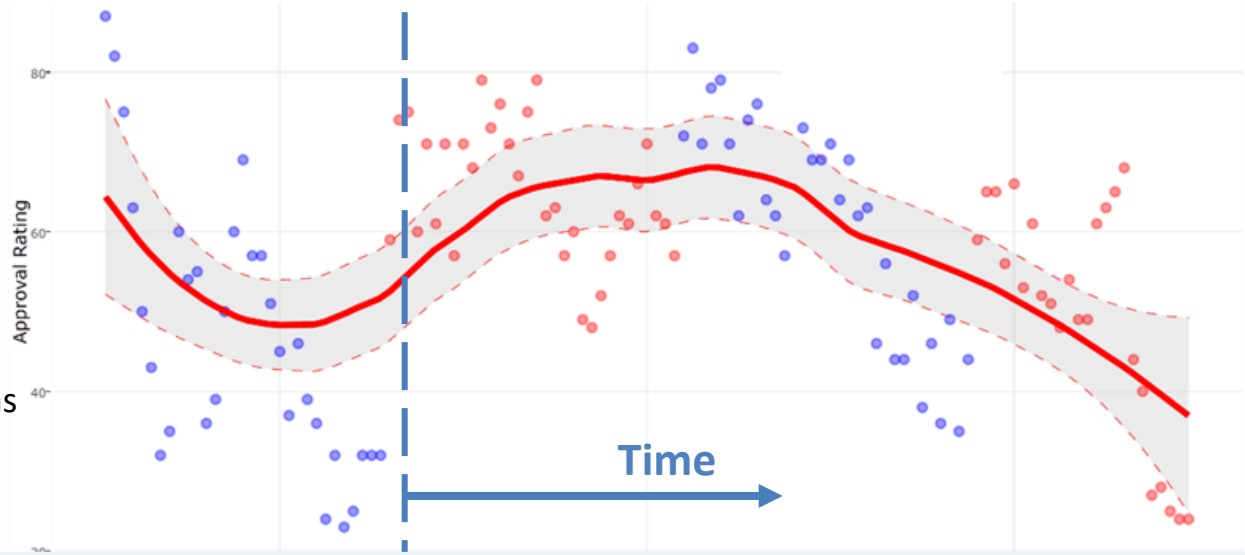
Design criteria - Health

HEALTH

HEALTH ≠ COMFORT

Comfort = subjective, perceptible sense of ease
(quasi)-instantaneous!

Health = Harmonious state of body and mind over long time
(quasi)-permanent!



Health effects are time-integrated!

'*Salutary*' = beneficial for health
Upper threshold

'*Healthy*' = Adequate range of conditions

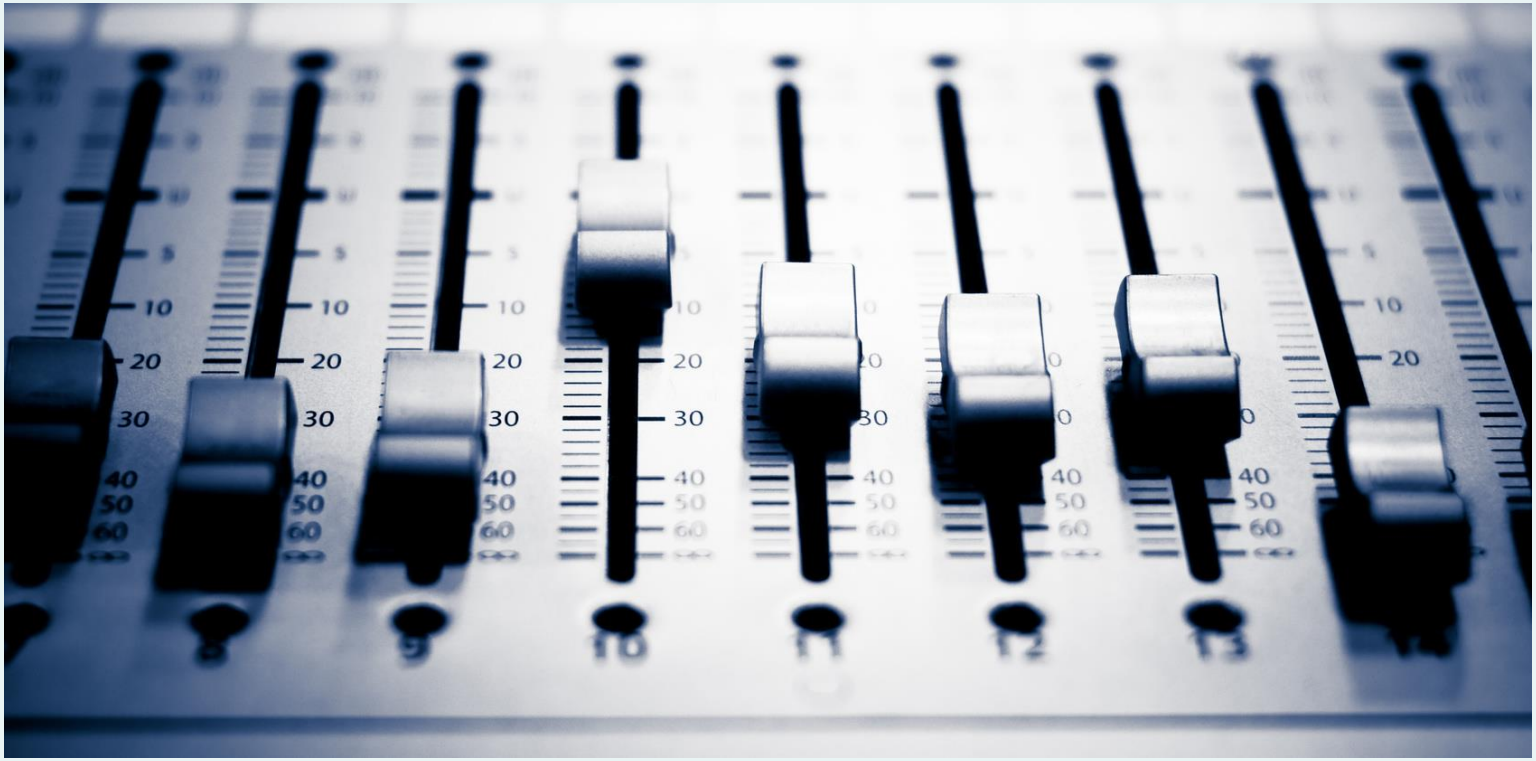
'*Hygienic*' = No negative impact
Lower threshold

Spectral assessment of shading systems

Design criteria for sustainable buildings

Missing HEALTH issues in evaluation

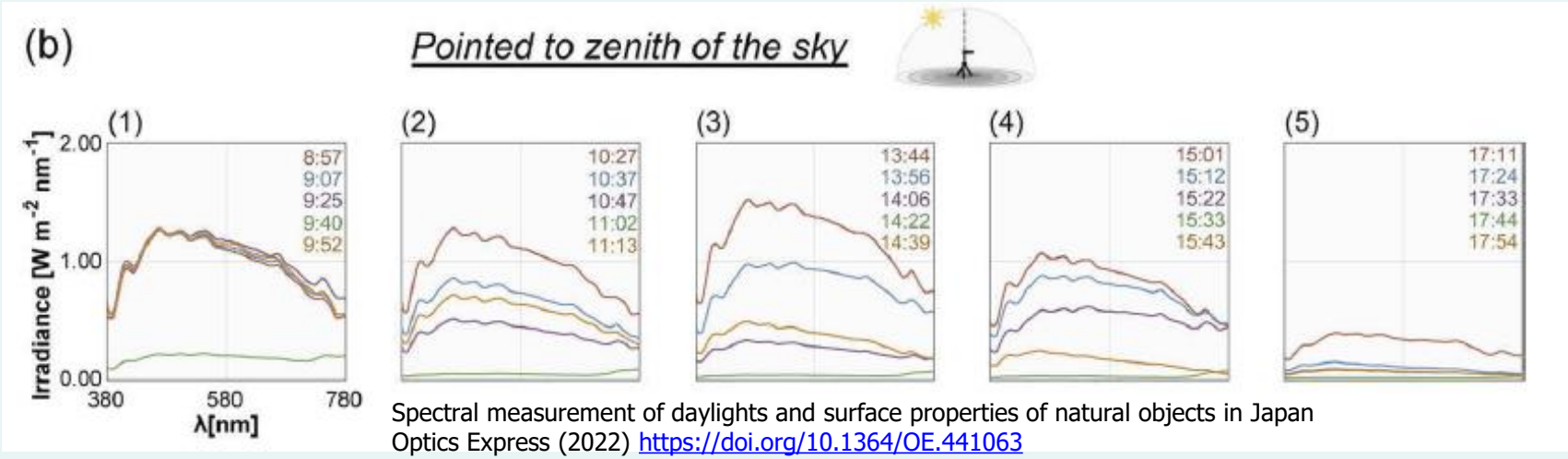
- Use NIF metrics as proxy for circadian stimulus



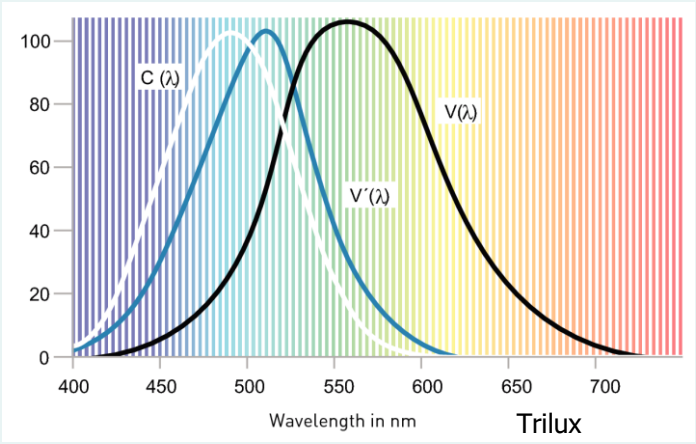
Spectral data

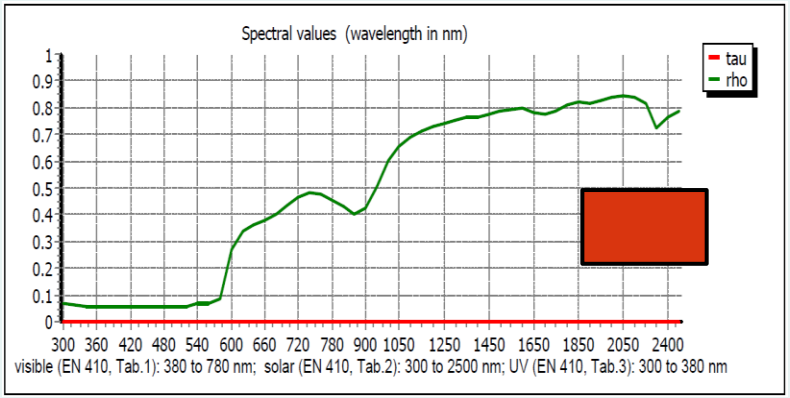
Components for spectral assessment

- Source / Scene / Receiver



Spectral measurement of daylights and surface properties of natural objects in Japan
Optics Express (2022) https://doi.org/10.1364/OE.441063





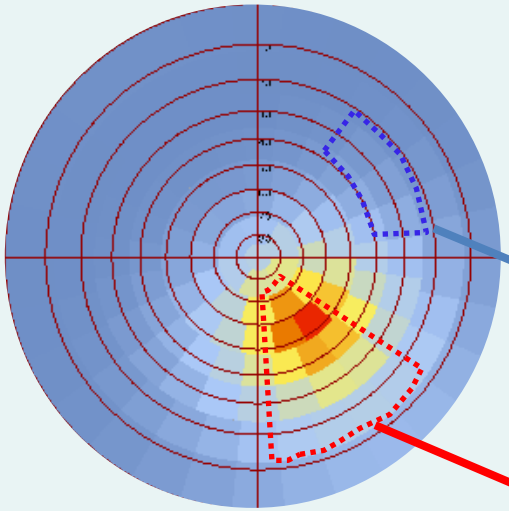
Spectral reflectance Terracotta lamella for solar shading

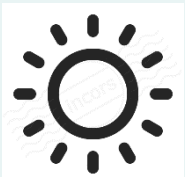
Spectral data

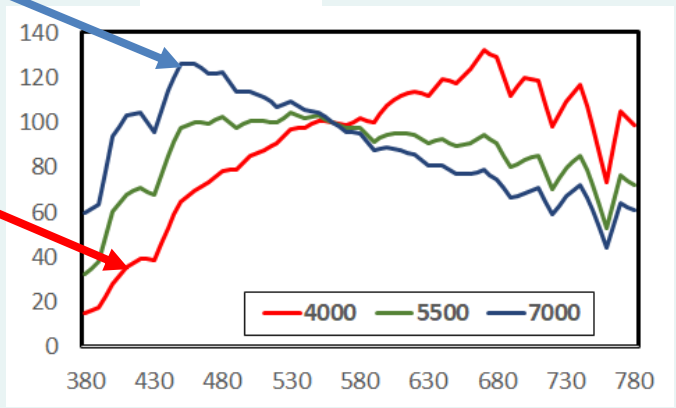
Dynamic daylight conditions variable

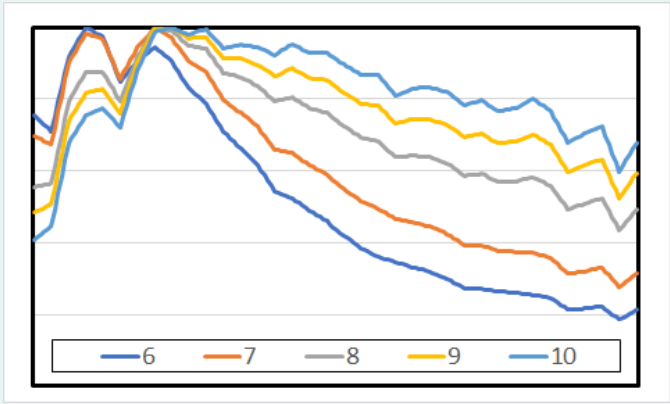
- Spectrum is variable with time/location,
- Spectrum varies for different sky patches.

➡ **Viewing directions matter**







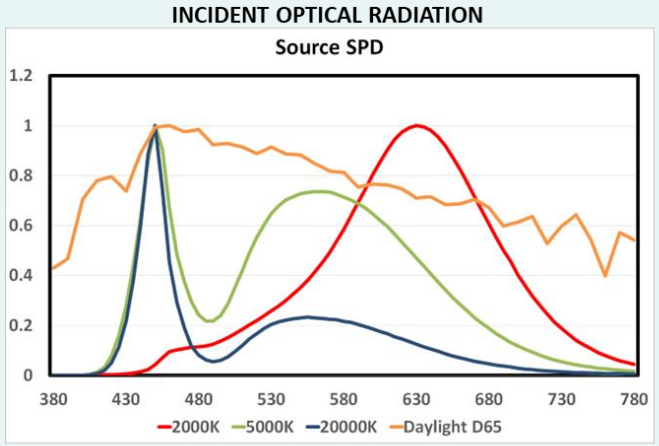


CIE TC 3.60 Spectral daylight characteristics to establish reliable daylight spectra

Spectral data

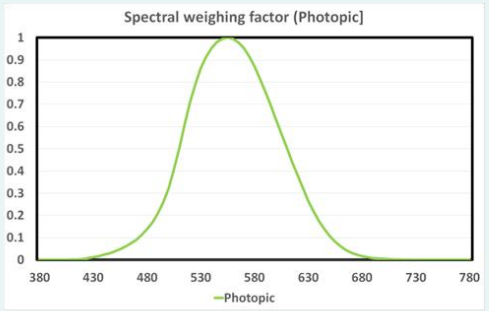
Combining spectral data

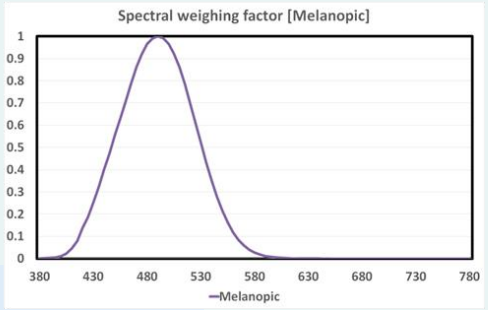
- Spectrum impacts

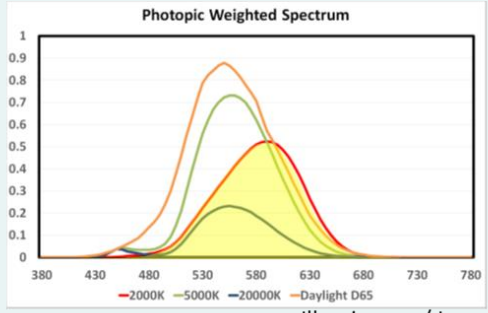


Normalized SPD curves for daylight & few LEDs

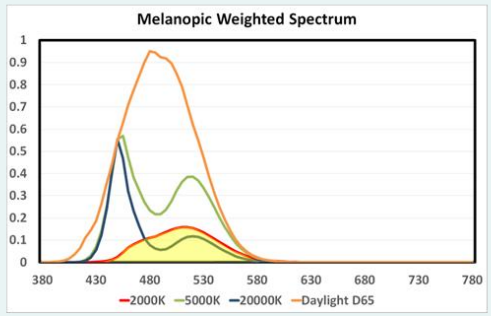
X



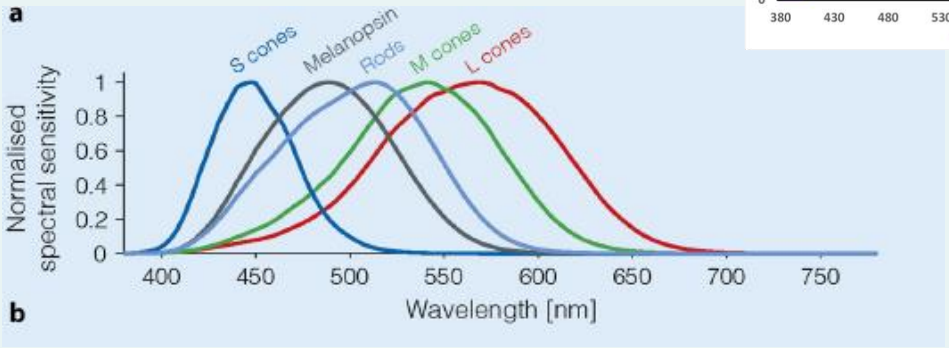




Illuminance / Lux



Melanopic-equivalent Daylight Illuminance (mEDI) / Equivalent Melanopic Lux (EML)



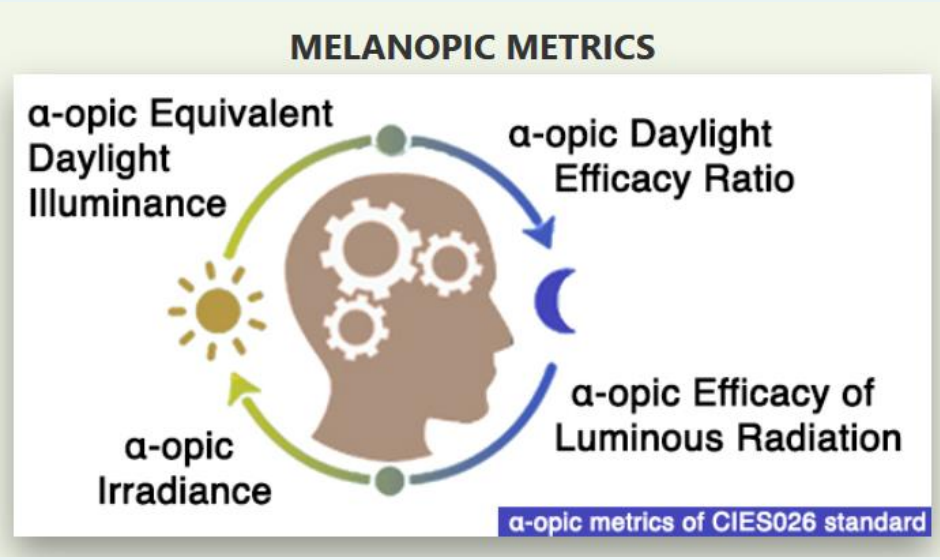
Effects of light on human circadian rhythms, sleep and mood
Somnologie 2019
https://doi.org/10.1007/s11818-019-00215-x

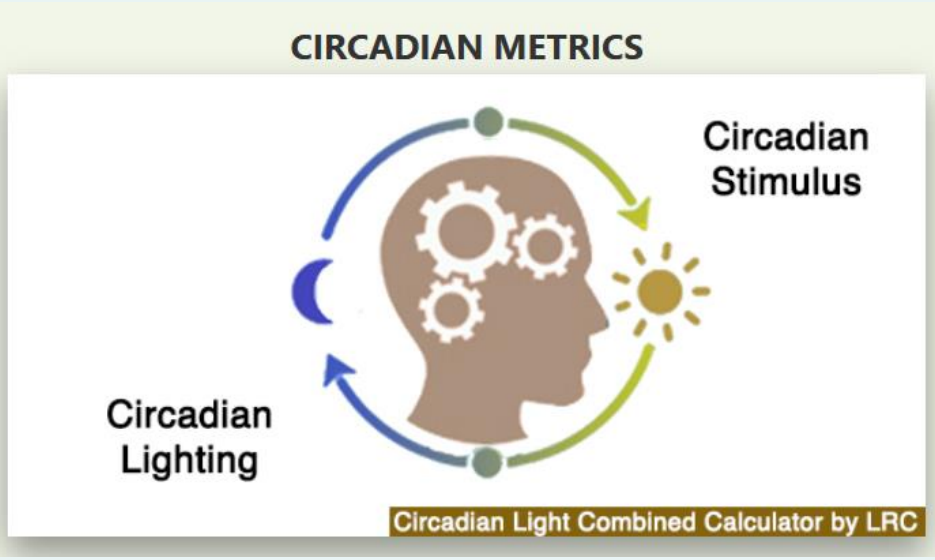
Simulation tool OWL

Occupants well-being through Lighting / OWL

Evaluation of luminous exposures at the eye

- ❑ Melanopic metrics (subset α-opic metrics) CIE S 026:2018
- ❑ Circadian metrics (Lighting Research Centre)





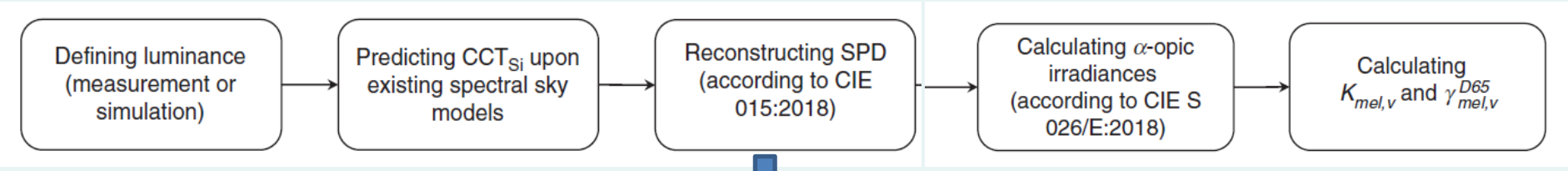
α-opic **Equivalent Daylight Illuminance** = illuminance produced by radiation conforming to standard daylight (D65) that provides an equal α-opic irradiance, as the test source"

$$E_{v,\alpha}^{D65} = E_{\alpha} / K_{\alpha,v}^{D65}$$

Simulation tool OWL

Occupants well-being through Lighting / OWL

Workflow



Using cumulative sky SPD as input for spectral simulations

Assessing hemispherical lum from view position (image-based sim)

Discretising luminance to patch-luminance

Patch-luminance >> CCT >> SPD >> NIF (CIE & LRC)

1. Sky luminance to CCT using luminance-to-CCT models.
2. Reconstructing daylight SPD from CCT using CIE015.
3. SPD and Illuminance data used in NIF toolboxes.
4. Evaluate α-opic metrics via CIES026 and CS via LRC.
5. For view, luminance generated via image-based simulation.

Simulation tool OWL

Occupants well-being through Lighting / OWL

Workflow / components

Defining luminance (measurement or simulation) → Predicting CCT_{Si} upon existing spectral sky models → Reconstructing SPD (according to CIE 015:2018) → Calculating α-opic irradiances (according to CIE S 026/E:2018) → Calculating $K_{mel,v}$ and $\gamma^{D65}_{mel,v}$

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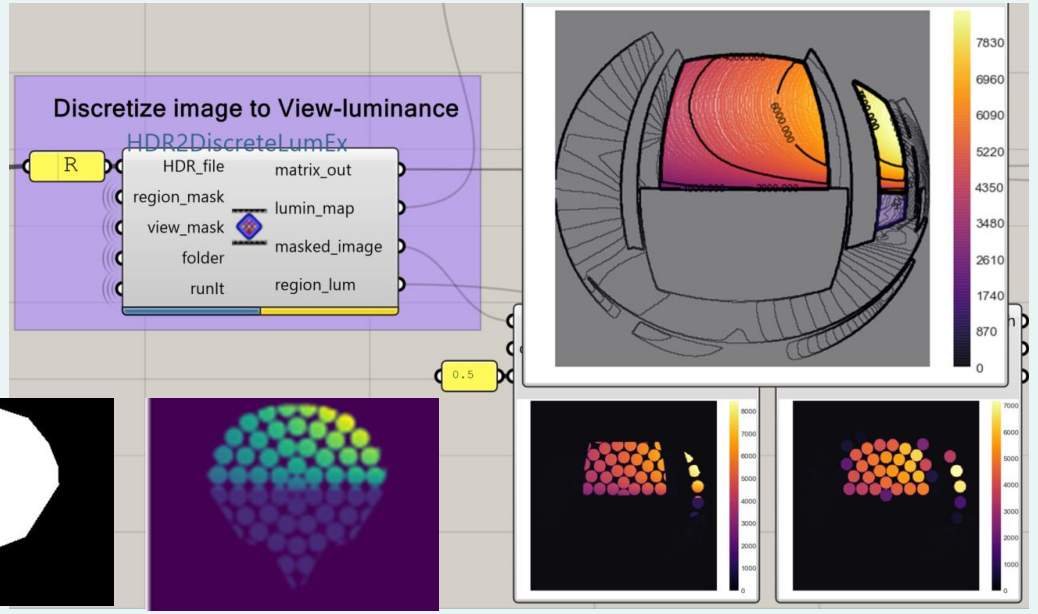

Human vision mask

Simulation tool OWL

Occupants well-being through Lighting / OWL

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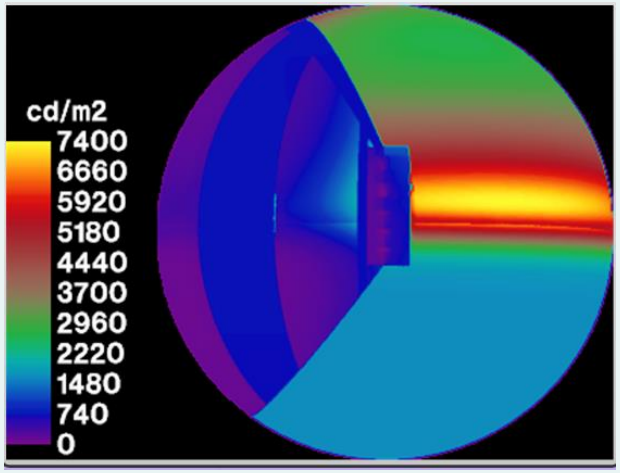
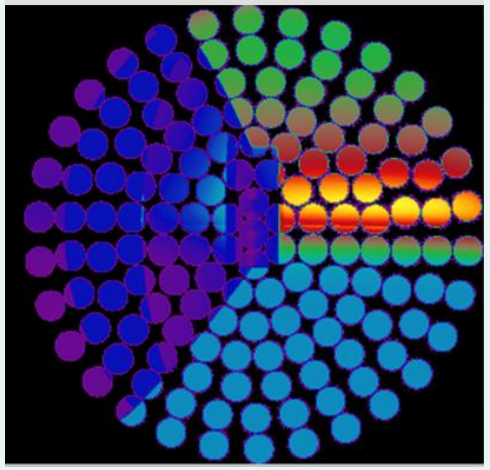
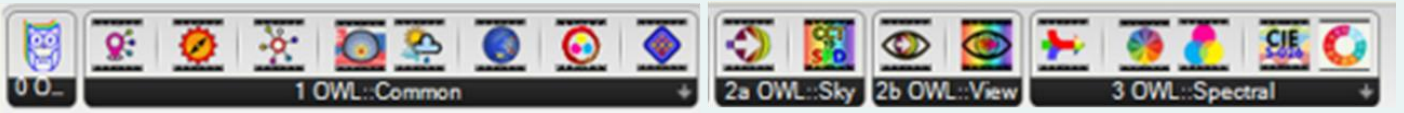


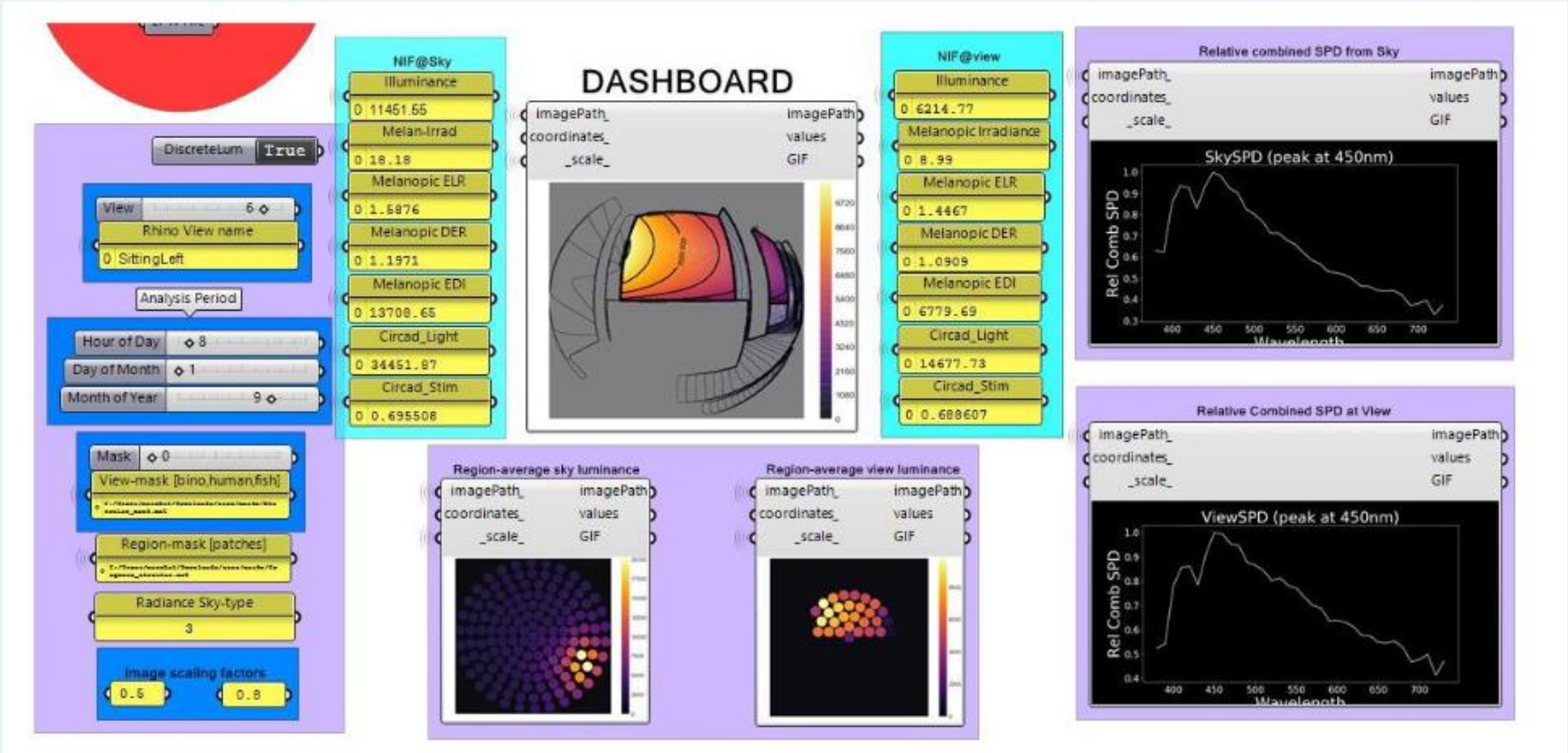


Spectral assessment of shading systems

Occupants well-being through Lighting / OWL

Dashboard





17 original Rhino GH components scripted in Python

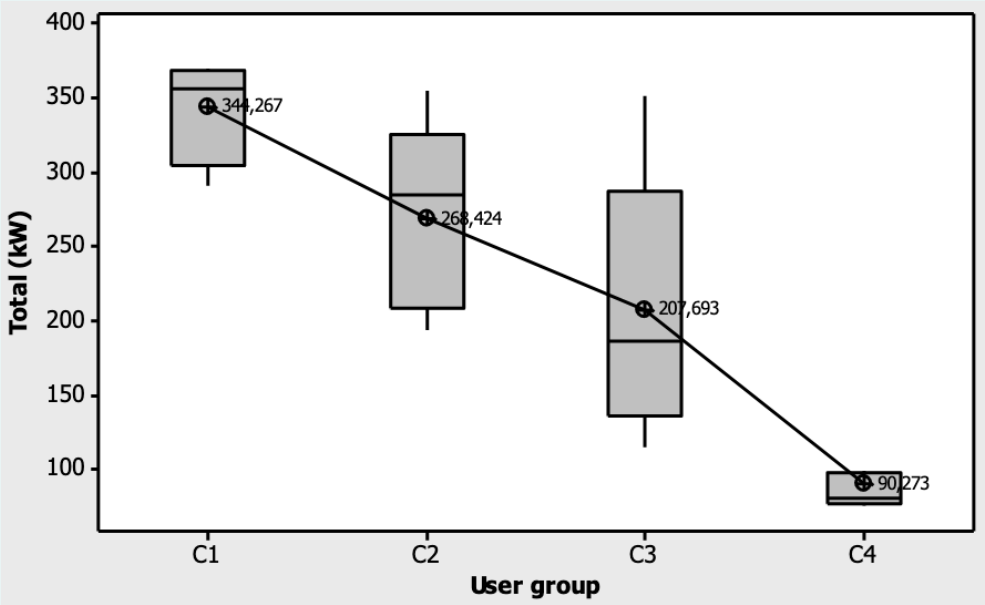
Spectral assessment of shading systems

Control of shading systems

Balancing needs

- Health (non-visual effects)
- Occupant's comfort
- Operational energy

C1 – users making few adjustments
C2 – users making average adjustments
C3 – users making many adjustments
C4 – system control



Meerbeek B., van Druenen T., Aarts M., van Loenen E., Aarts E. (2014). Impact of blinds usage on energy consumption: automatic versus manual control. European Conference on Ambient Intelligence.

Would conclusions be the same if considering health aspects?

Simulation tool OWL

OWL

Discussion:

- No time-integrated metrics yet for NIF (timing and duration!)
- Target levels still to be firmly established
- Relation with all IEQ-parameters
- …

Future work:

- Checking results of tool with in-situ measurements
- Verify main assumptions (direct component)
- Human subject evaluation for long-term health
- Extension with electric lighting
- Multichannel spectral simulations

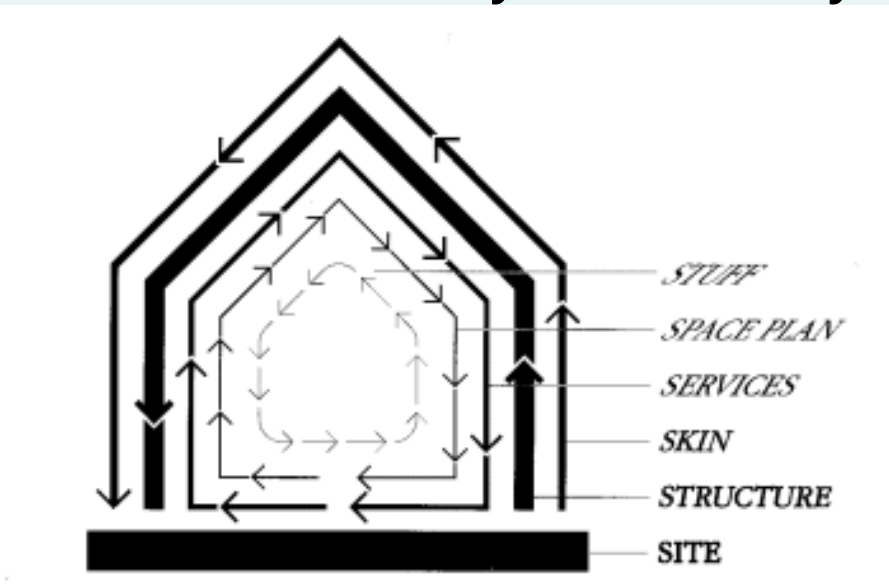
Alternative model

Occupants centric approach

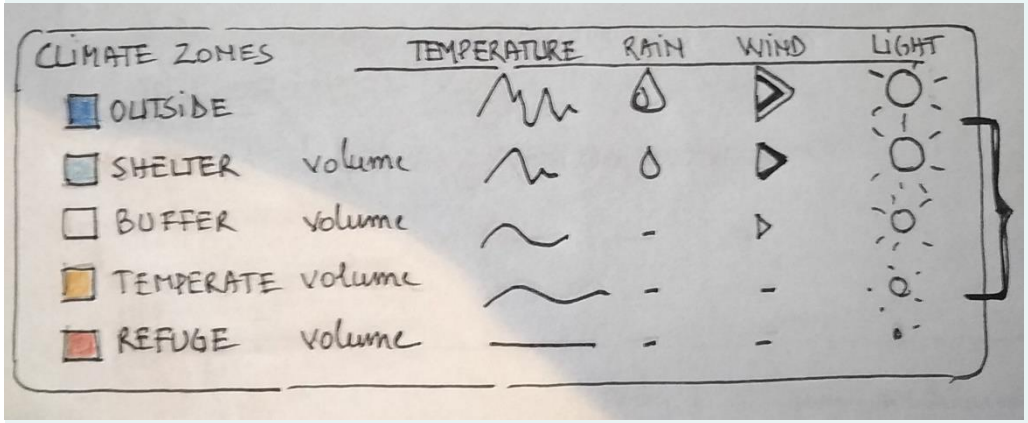
Design for people not for specifications

- Layering strategy (six ‘S’)
- Transitional climates zones

Move away from binary IN/OUT thinking



“Transitional climates zones”



Whole building skin as solar shading and rainscreen

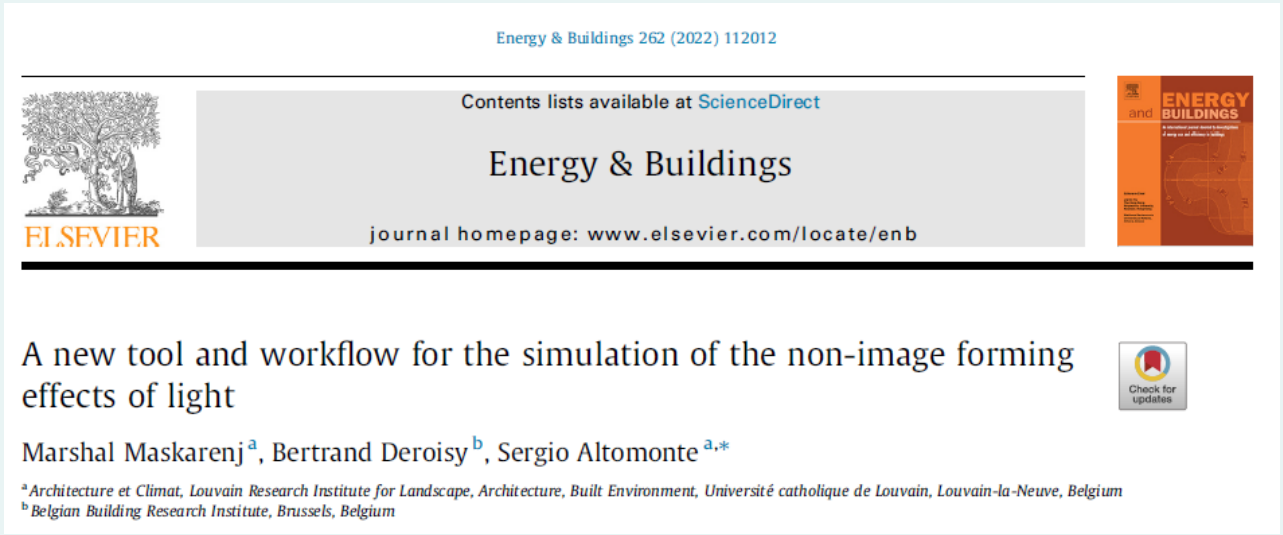
Spectral daylight simulations

Questions?

OWL-tool website (download and documentation)

https://marshalmaskarenj.github.io/OWL_Web

A new tool and workflow for the simulation of the non-image forming effects of light
Energy & Buildings 262 (2022) 112012



Energy & Buildings 262 (2022) 112012

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/enb

A new tool and workflow for the simulation of the non-image forming effects of light

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[b] Belgian Building Research Institute, Brussels, Belgium