SOLAR HEATING & COOLING PROGRAMME
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Visual and Non-Visual Lighting Requirements for Decarbonisation
Collected Scientific Evidence and Emerging Insights

TASK 70

Low Carbon, High Comfort Integrated Lighting

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Trondheim, Norway

Visual & Non-Visual User Requirements

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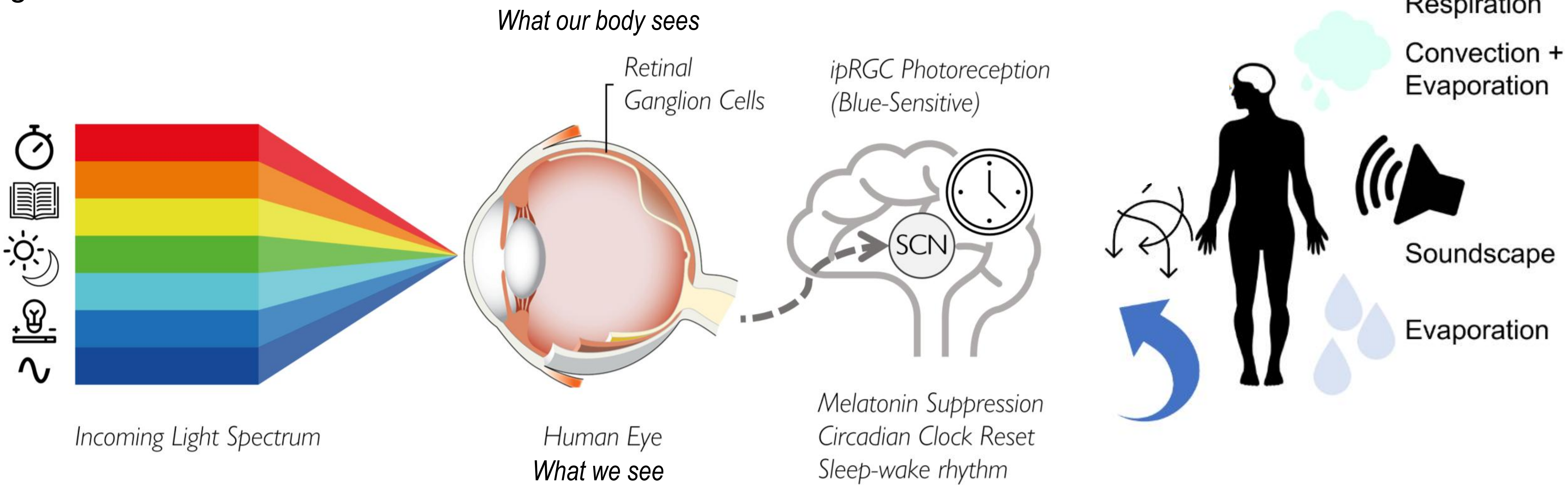
Objective

To identify and address visual and non-visual requirements based on the latest knowledge related to decarbonisation goals.



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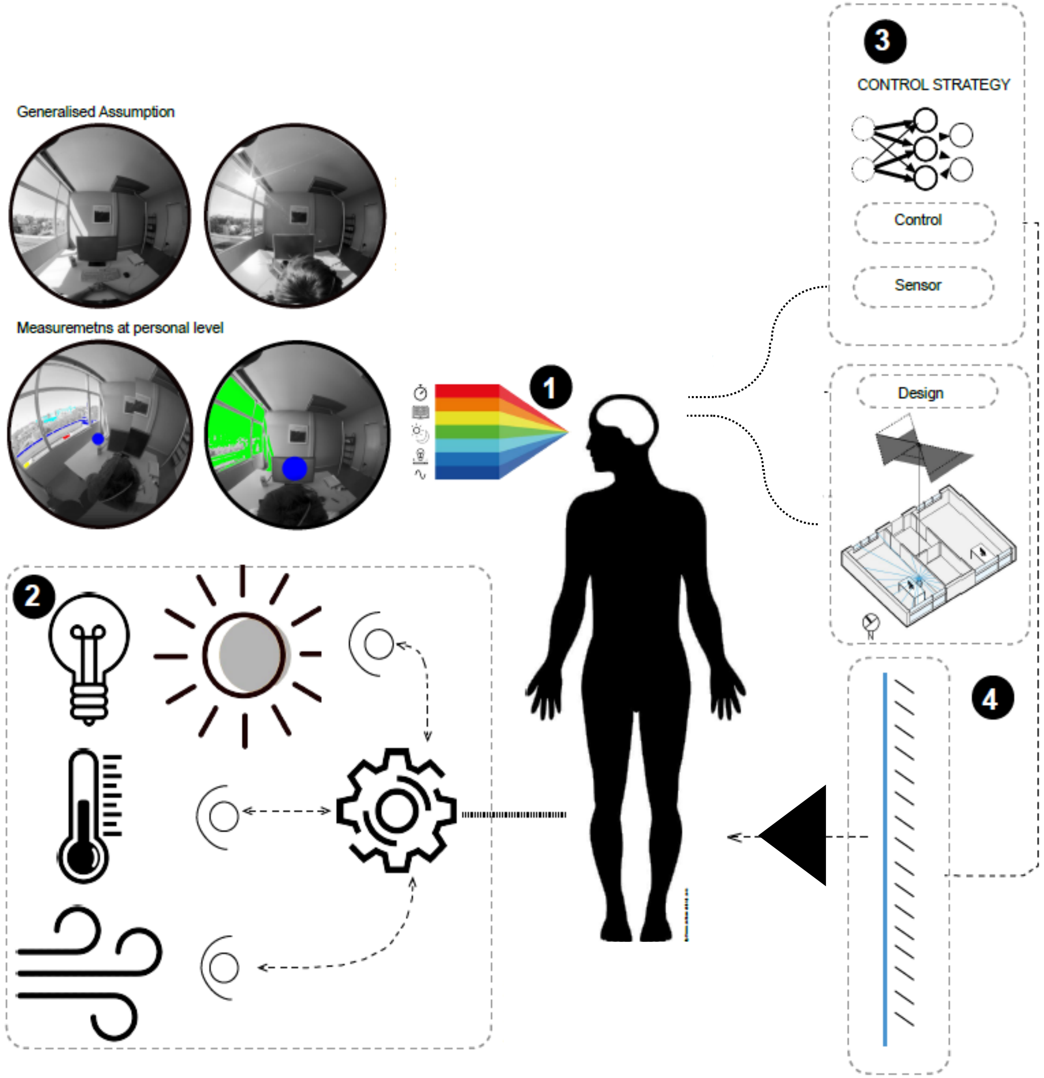
Are such requirements aligned with decarbonisation goals?

- **Various research directions are needed** to better understand visual and non-visual user requirements and thresholds to be considered for the design and operation of buildings.

- **Emerging Insights: 5 Balancing Relationships**



1 Personal Exposure
2 Indoor Conditions
3 Control Strategies
4 System, e.g., Façade Technology

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Balancing Relationship 1 OF 5

Visual Non-Visual Requirement	How does the strategy influence building Operations? (Visual/non-Visual/thermal/behavioural/ energy	How this translates to Operational Carbon?	Operational Carbon Outcome

1 Daylight & view access vs. overheating

More daylight and view improve wellbeing and performance, but can increase solar gains, overheating risk and glare.

Includes view quality:
- ✓ Psychological restoration
- ✓ Cognitive benefits
- ✓ Occupant tolerance of higher luminance when view is present

VISUAL PATHWAYS
- ↑ Daylight → ↓ electric lighting energy ↓
- ↑ View quality → psychological restoration, cognitive performance, wellbeing ↑
- May increase glare risk → visual discomfort ↓
- Occupants may tolerate higher luminance or discomfort when view is present ↑

NON-VISUAL (CIRCADIAN) PATHWAYS
- ↑ Daylight (especially morning) → higher melanopic exposure → circadian entrainment, alertness, sleep quality, wellbeing ↑
- View access supports mood, satisfaction and reduces eyestrain ↑

THERMAL PATHWAYS
- ↑ Solar gains through windows → ↑ cooling energy ↑
- May increase peak cooling demand ↑
- Shading improves thermal performance and reduces overheating risk ↑
  but → ↓ daylight → ↑ lighting energy ↓↓

BEHAVIOURAL PATHWAYS
- Occupants adjust blinds/shades, windows and lighting based on comfort and preferences ↓
- Behavioural adaptation can reduce or increase energy use
- View presence influences acceptance of higher brightness or discomfort ↑

GRID-RELATED PATHWAYS
- Electric lighting and cooling draw from the grid ↑
- Carbon intensity varies by time of day
- Timing of increased cooling or lighting demand affects operational carbon ↓

Net operational carbon impact depends on:
- Climate & orientation
- Glazing & shading design
- Daylight availability (site, time, sky)
- Building form & façade performance
- Internal loads & schedules
- Occupancy & behaviour
- Grid carbon intensity (time-varying)

Outcome can be:
- **Decrease** (savings from daylight > extra cooling/lighting)
- **Increase** (cooling/glare outweigh lighting savings)

LEGEND (applies to all five balancing relationships)
- ⟶ Primary (direct) effect
- - - → Context-dependent / indirect effect
- ········ Interdependence / feedback across pathways
- ⟷ Influence / interaction between pathways
- ↑ ↓ Increase / decrease

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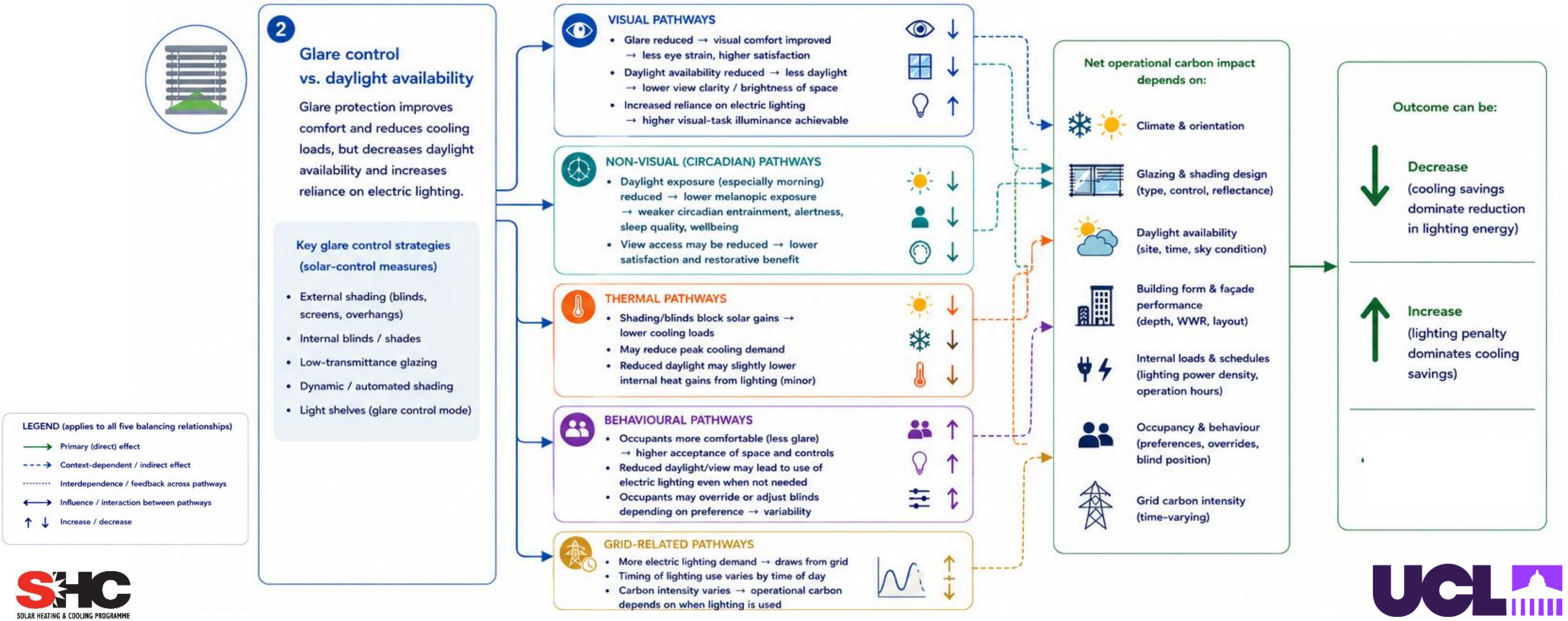
Balancing Relationship 2 OF 5

Visual Non-Visual Requirement	How does the strategy influence building Operations? (Visual/non-Visual/thermal/behavioural/ energy	How this translates to Operational Carbon?	Operational Carbon Outcome



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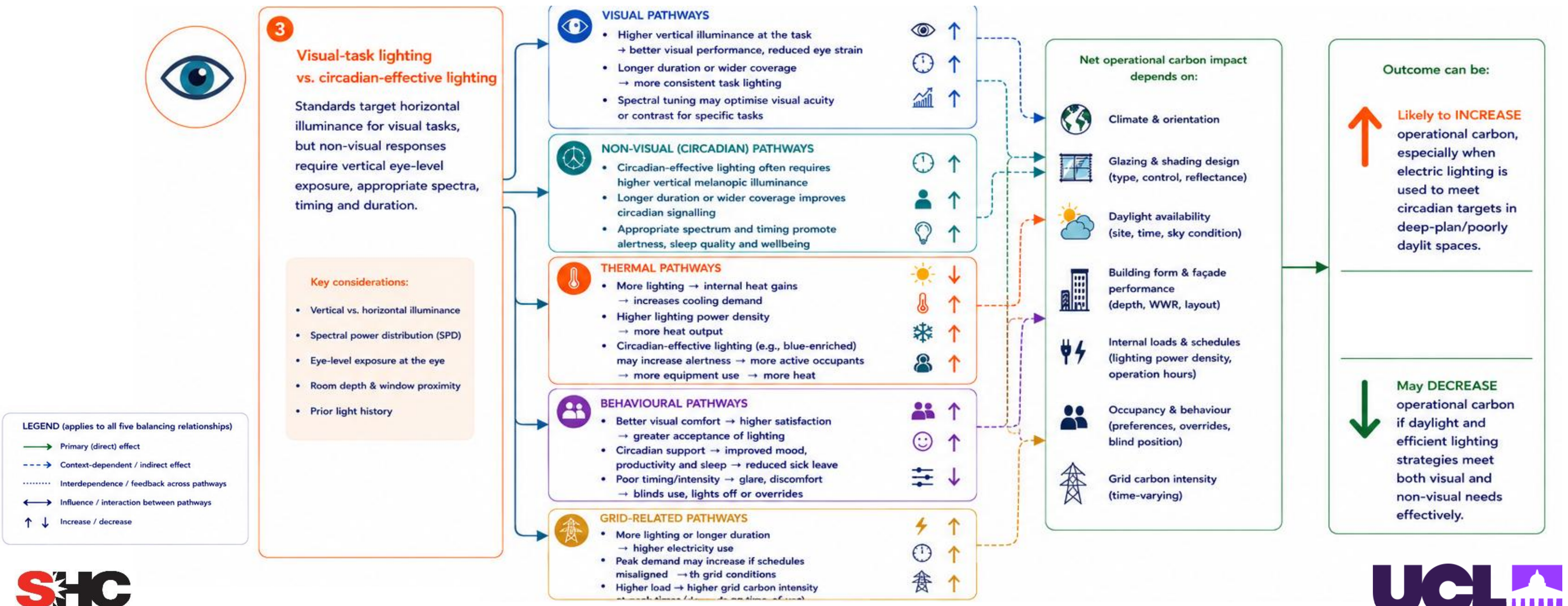
Balancing Relationship 3 OF 5

Glare(Visual Stress) vs Daylight Availability

Visual Non-Visual Requirement	How does the strategy influence building Operations? (Visual/non-Visual/thermal/behavioural/ energy	How this translates to Operational Carbon?	Operational Carbon Outcome



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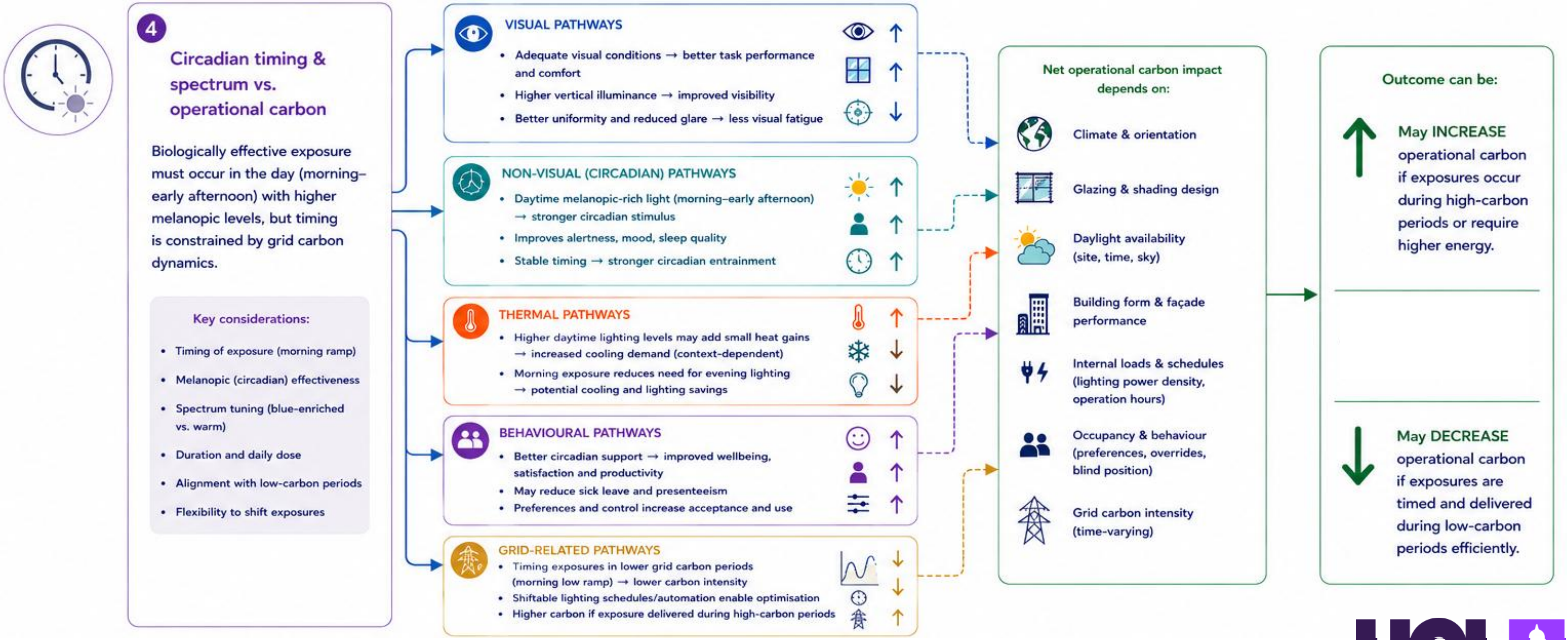
Balancing Relationship 4 OF 5

Visual Non-Visual Requirement	How does the strategy influence building Operations? (Visual/non-Visual/thermal/behavioural/ energy	How this translates to Operational Carbon?	Operational Carbon Outcome



Visual & Non-Visual User Requirements

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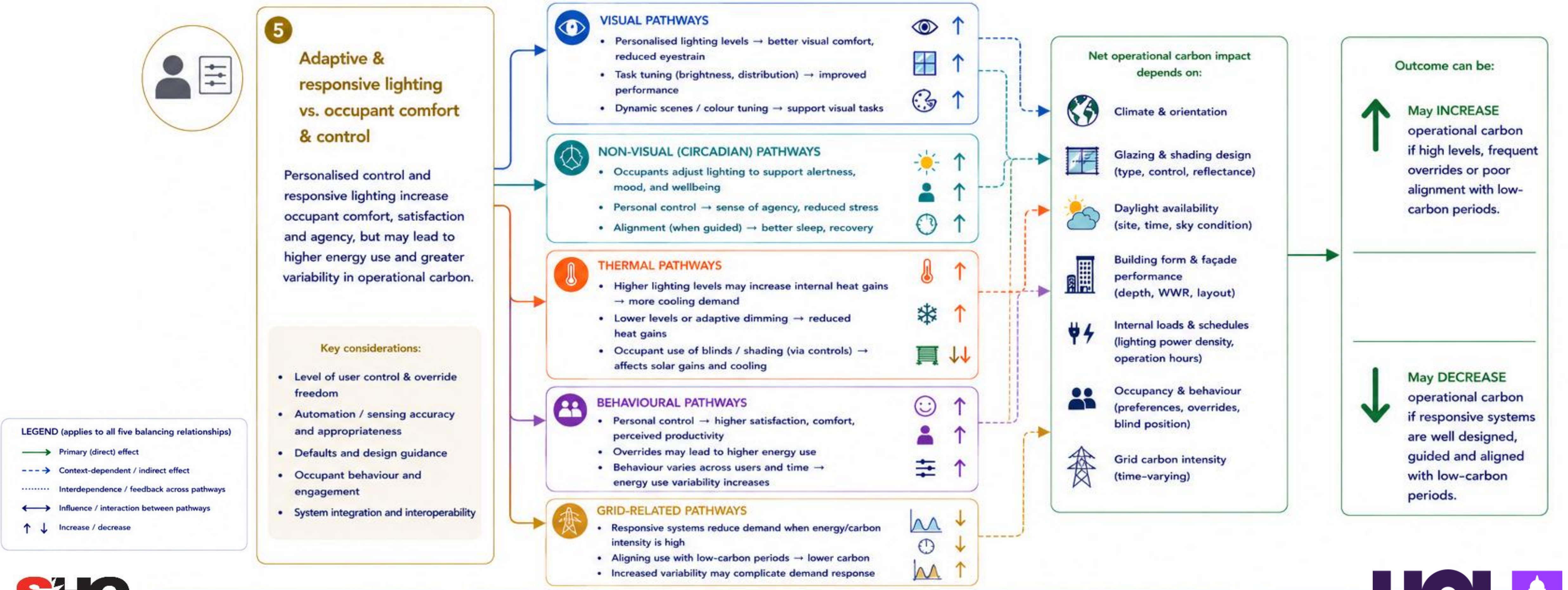
Balancing Relationship 5 OF 5

Visual Non-Visual Requirement	How does the strategy influence building Operations? (Visual/non-Visual/thermal/behavioural/ energy	How this translates to Operational Carbon?	Operational Carbon Outcome



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Overall conclusion

- Lighting and daylight strategies can both **reduce and increase operational carbon** depending on how visual and non-visual requirements are delivered. The operational carbon impact of occupant-centred lighting is therefore not determined solely by lighting energy demand, but by the interaction between daylight availability, façade design, glare control, circadian timing, occupant behaviour, personalisation, and the temporal dynamics of the energy system.
- Circadian-effective lighting introduces additional **spatial, spectral, and temporal** constraints because biologically meaningful exposure must occur at specific times and often requires higher vertical melanopic illuminance. Consequently, strategies intended to support health and wellbeing may conflict with decarbonisation or demand-flexibility goals in some contexts.
- At the same time, **integrated daylighting, façade, lighting-control, and personalisation strategies** may provide opportunities to simultaneously support wellbeing and operational carbon reduction if designed holistically. Future progress depends on interdisciplinary approaches that integrate human health, behavioural adaptation, building performance, and time-varying operational carbon within unified frameworks.

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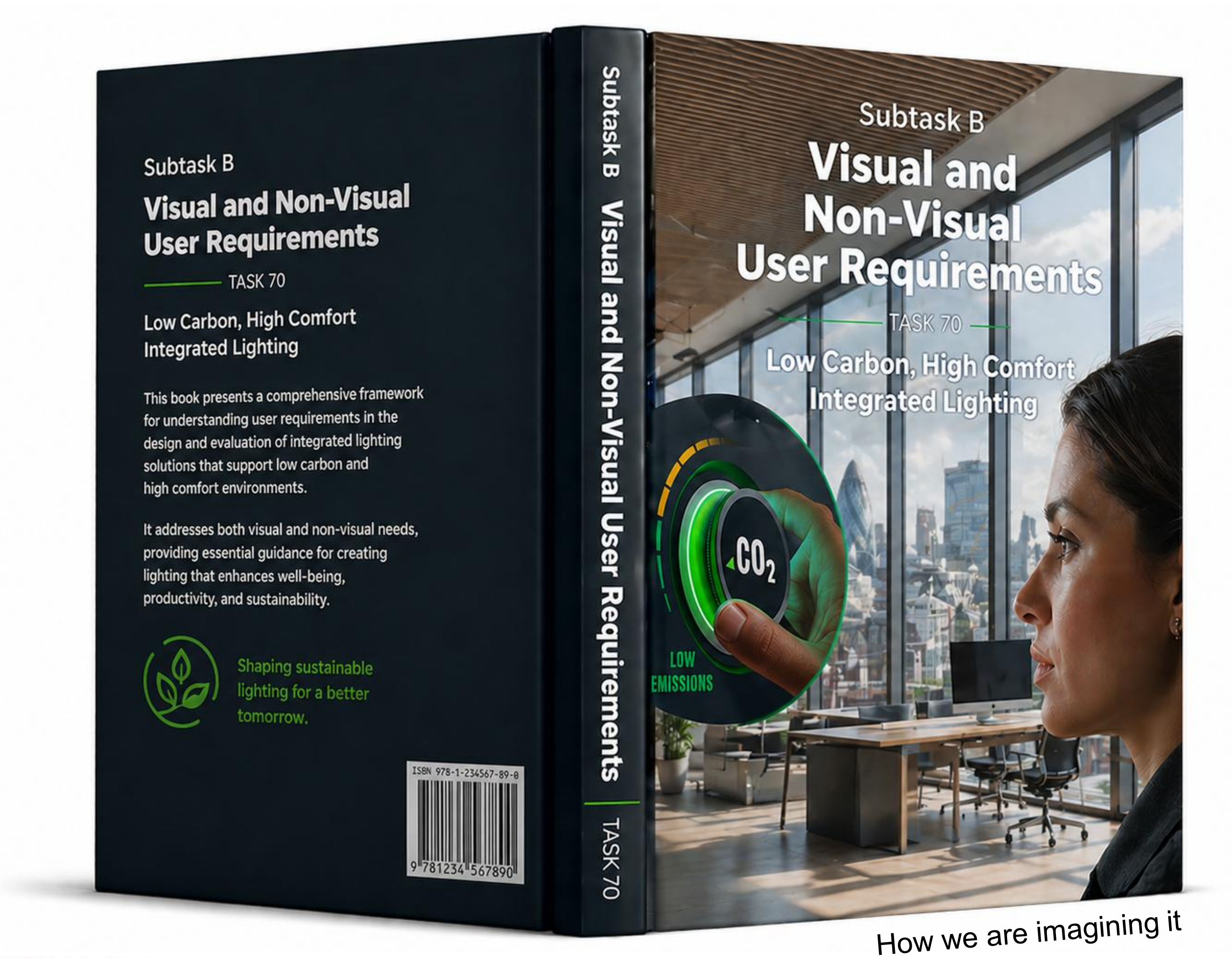

How we are imagining it

Contents

Part 1. Visual Stress & Mitigation

Improved understanding of the visual environment for humans

Part 2. Window View

Window view
Relationship between window view and urban morphology

Part 3. Non-Visual Effects

New developments in non-visual aspects
Measurement and assessment methods of non-visual aspects

Part 4. Digital Tools

Digital tools and emerging technologies

Part 5. Case Study

Applied case studies and practical implementation

Part 6. Carbon Footprint

Carbon footprint and sustainability considerations

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1. Improved understanding of the visual environment for humans

S. Altomonte M. Maskarenj UCLouvain

Discomfort glare: the effect of light spectrum and time of day

0° ANGLE 35° ANGLE

Characterization of View through Solar Control Systems

Khanie, Mandana Sarey, and Rune Korsholm Andersen, UCL, DTU

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2 View preferences/descriptors for rooms with different visual stimuli and activities

B Matusiak, A Diakite-Kortlever, N Sokol, M Khanie,et. al.

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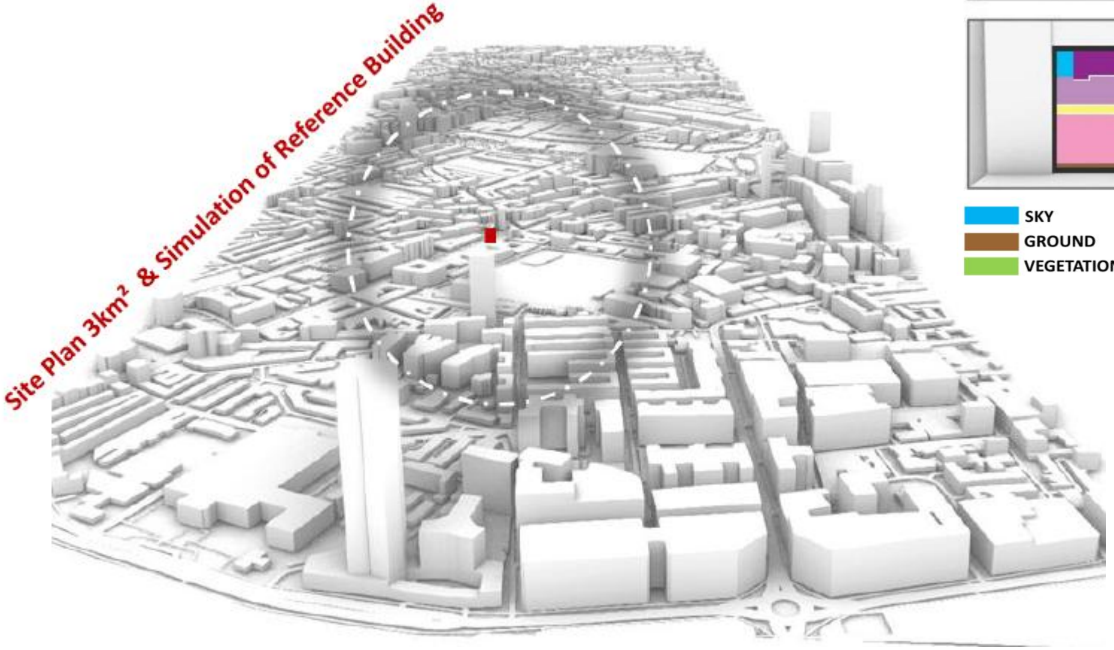
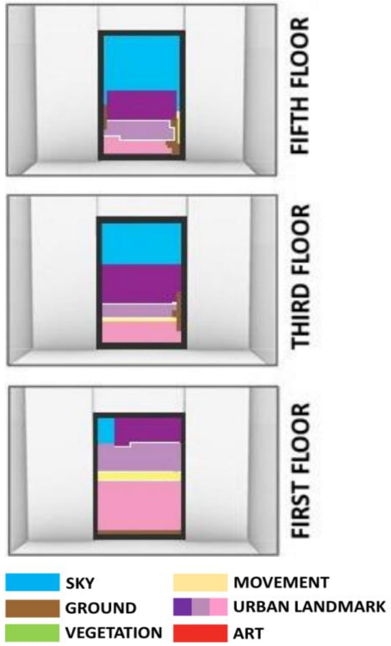
B.3 Relation between the window view and urban morphology

Koga Y., KYUSHU Uni
Designing Building envelop from a moving eye





Sabet P., Jamil M., Giovanni C., Scorpio M., Sibilio S.
The University of Campania Luigi Vanvitelli (V:)
Multi-element evaluation of view content

Università degli Studi della Campania Luigi Vanvitelli

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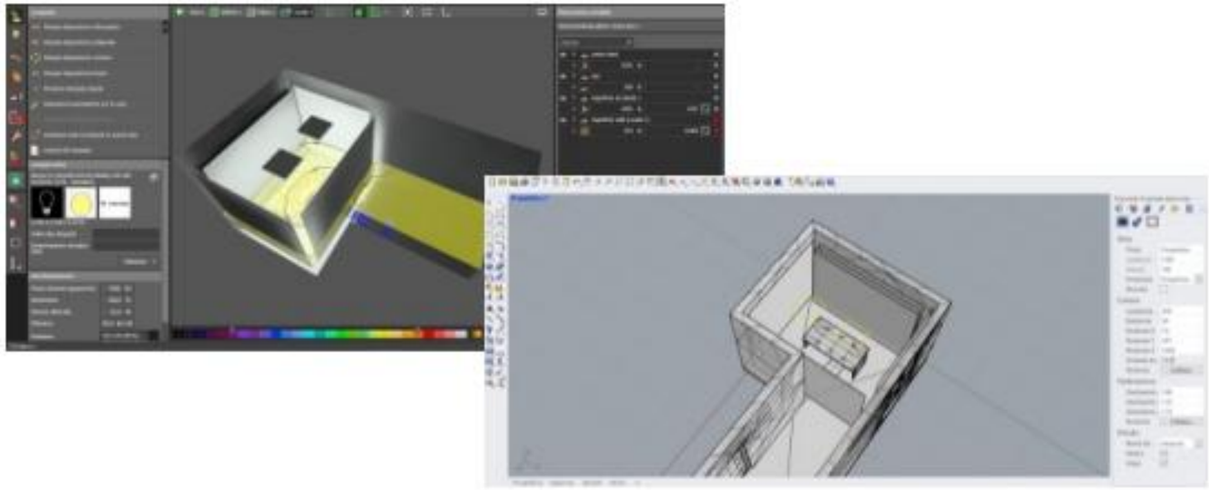
SUBTASK B

Visual & Non-Visual User Requirement

B.4 New developments for non-visual aspects

Politecnico di Torino
1859



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SUBTASK B

Visual & Non-Visual User Requirement

B.5 Measurements and assessment methods of non-visual aspects

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ITC

Salamone F. et al.

Nanolambda

LYS Technologies LTD

Light-dosimeter

Daysimeter


B

SUBTASK B

Visual & Non-Visual User Requirement

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QUT Queensland University of Technology

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