ADAPTIVE FAÇADE DESIGN FOR THE REGULATION OF VISUAL COMFORT

Shirin Masoudi

SUSTAINABILITY & ENERGY PERFORMANCE

Overview

SUSTAINABILITY &
ENERGY PERFORMANCE

ARCHITECTS

DESIGN

Overview

SUSTAINABILITY &
ENERGY PERFORMANCE

CONSTRUCTION
COMPANY

ARCHITECTS

PRODUCT ····· Innovation ····· DESIGN

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44% energy
consumption for
LIGHTING

OFFICE
BUILDINGS

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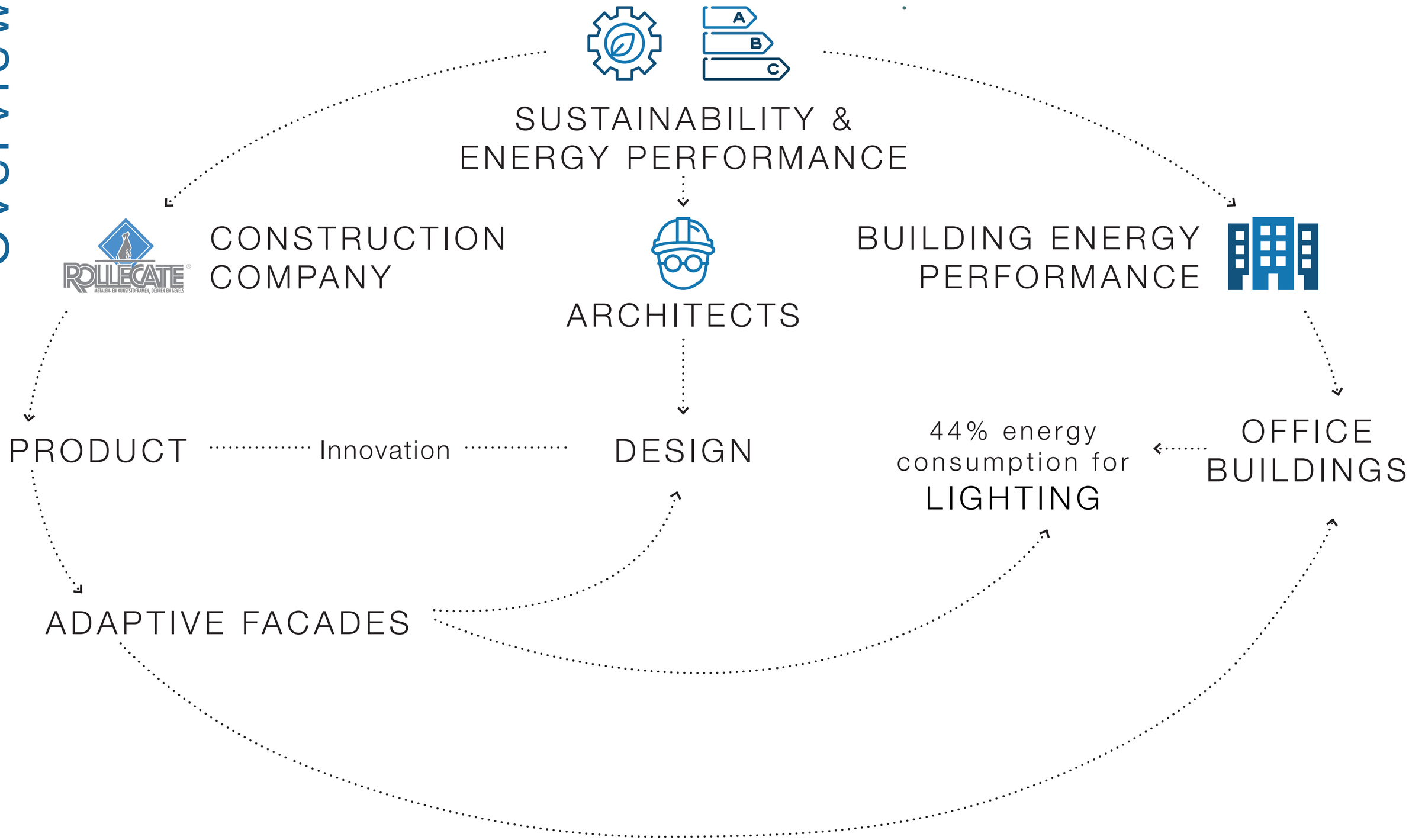
ADAPTIVE FACADES

Overview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ADAPTIVE FACADES

What is an adaptive facade?

Adaptive façades are envelopes that respond both to indoor and outdoor stimuli and change configuration – both physically or chemically - to take advantage of the outdoor climate and offer a systematic flexibility that responds situationally in relation to specific points in time with the aim to improve both the building performance and the user comfort.

Adaptive facades

Exterior

Solar radiation
Temperature
Humidity
Wind
Precipitation
Noise

Interior

Light
Temperature
Humidity
Sound level
Air exchange rate

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Response

Dynamic
Static

Control

Manual
Mechanical
Smart

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Humidity
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Air exchange rate

Response time

Seconds
Minutes
Hours
Days
Seasons

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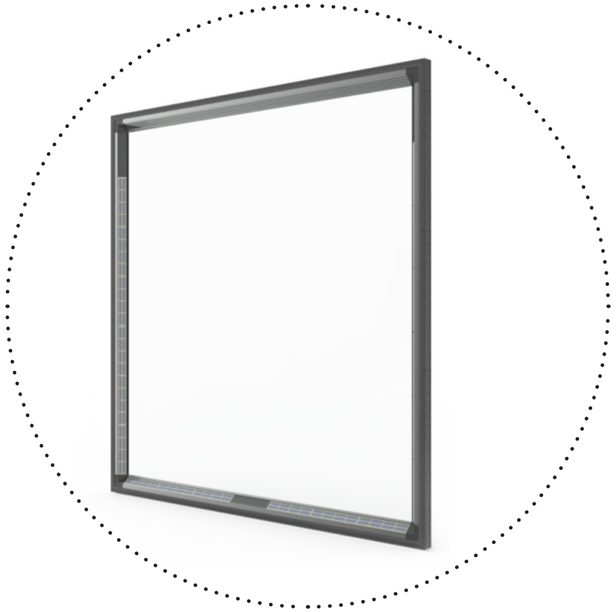
Purpose
Thermal comfort
Visual Comfort
IAQ
Acoustic comfort
Energy

Reference projects

Buildings

Al Bahr Towers
Aedas Architects
Abu Dhabi, United Arab Emirates
2012

Products



Smart Window and Power Window
PHYSEE
Delft, Netherlands
2014

Research projects

Adaptive Solar Facade
ETH Foundation
House of Natural Resources (HoNR),
Campus ETH Honggerberg, Zurich,
Switzerland
2015

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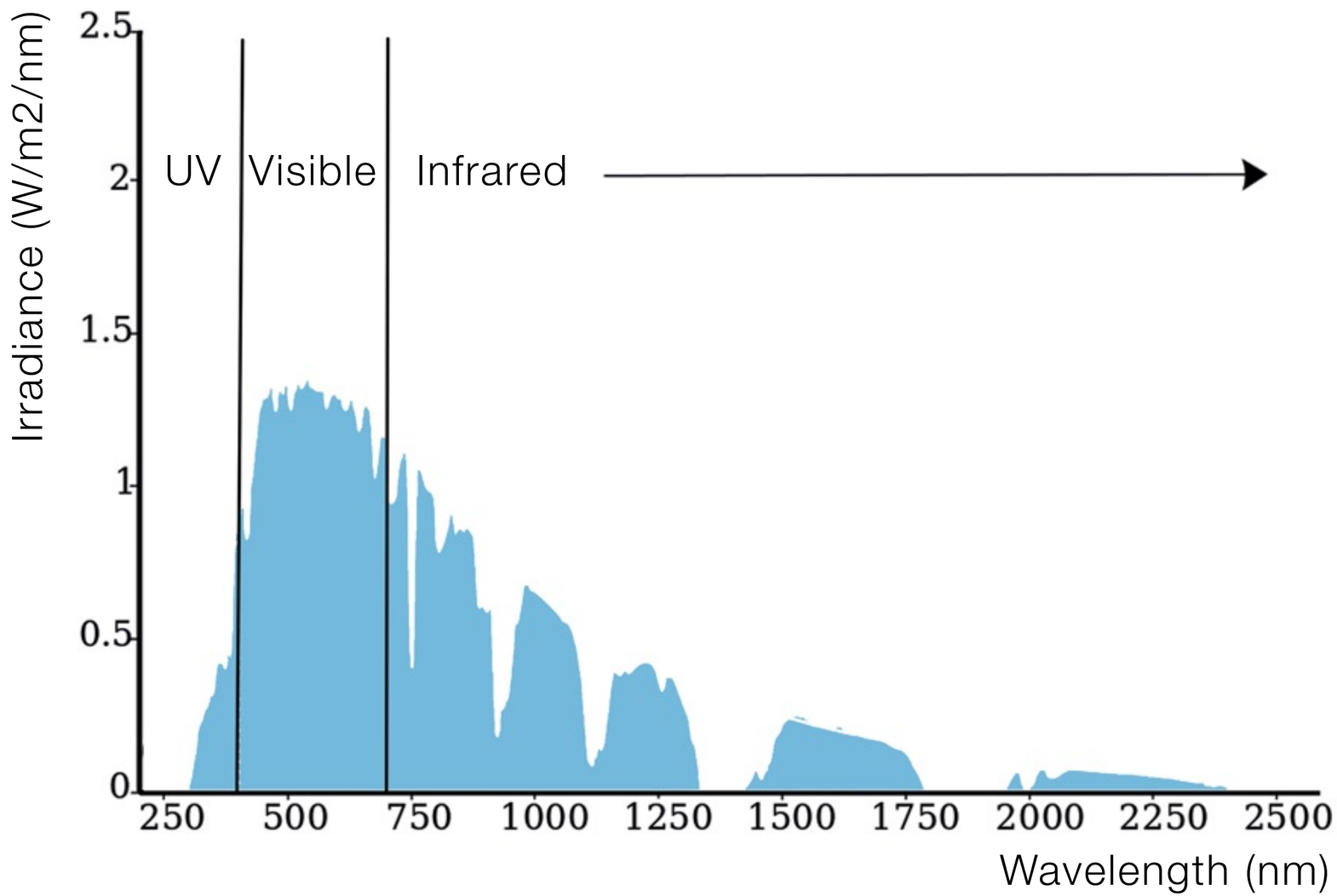
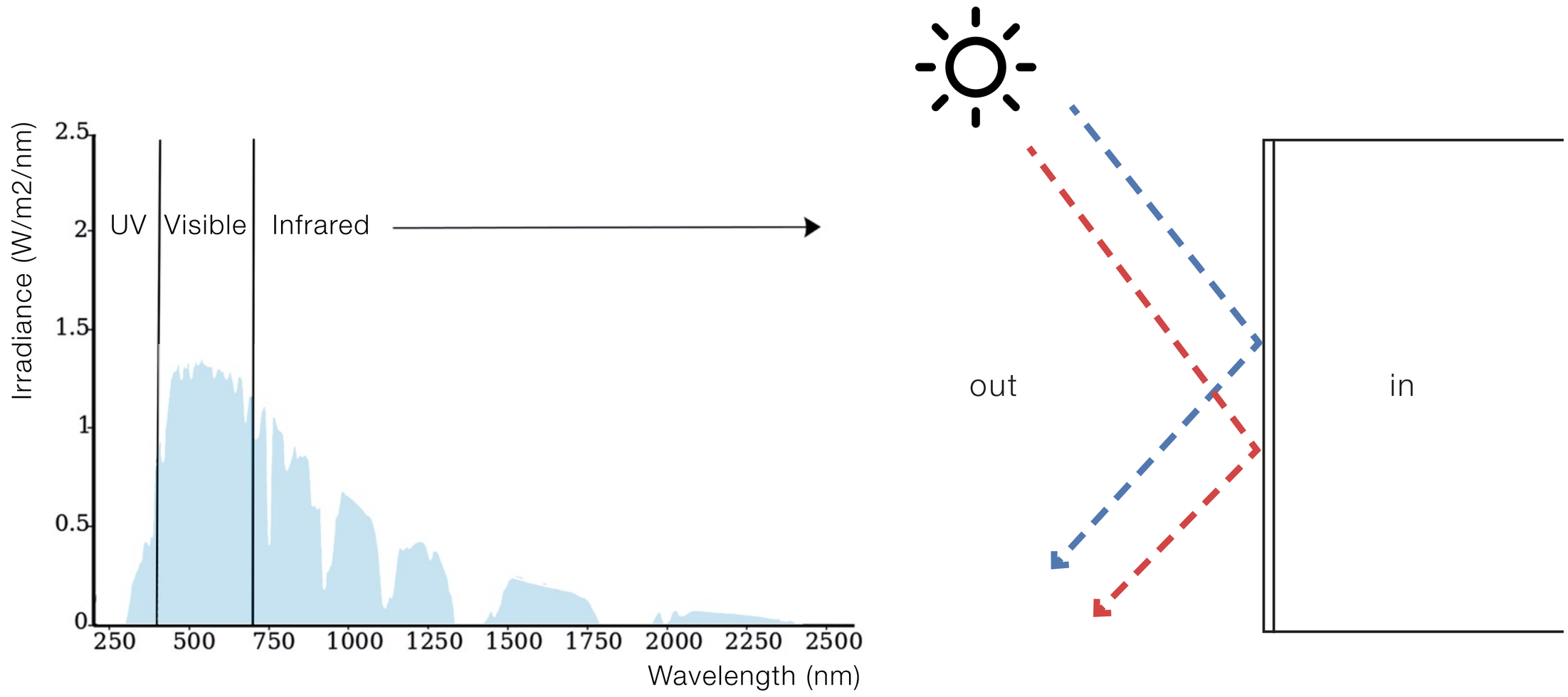
Solar radiation



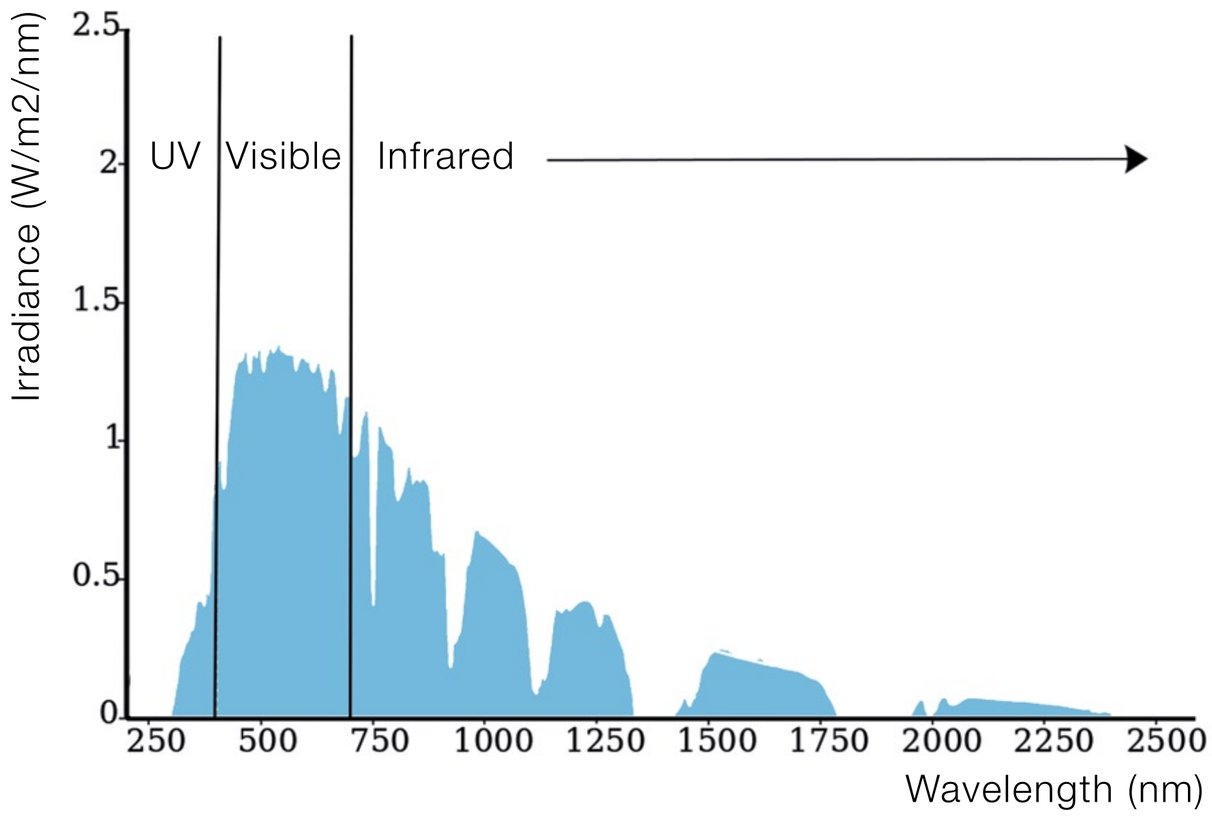
Solar radiation - Control

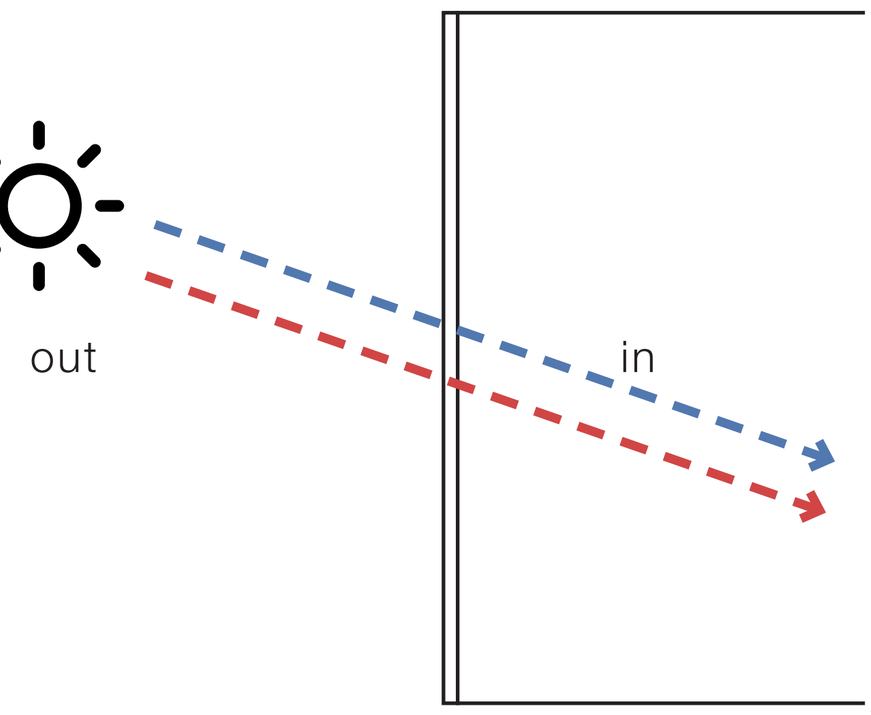
Summer - visual discomfort



Solar radiation - Control

Winter - visual comfort





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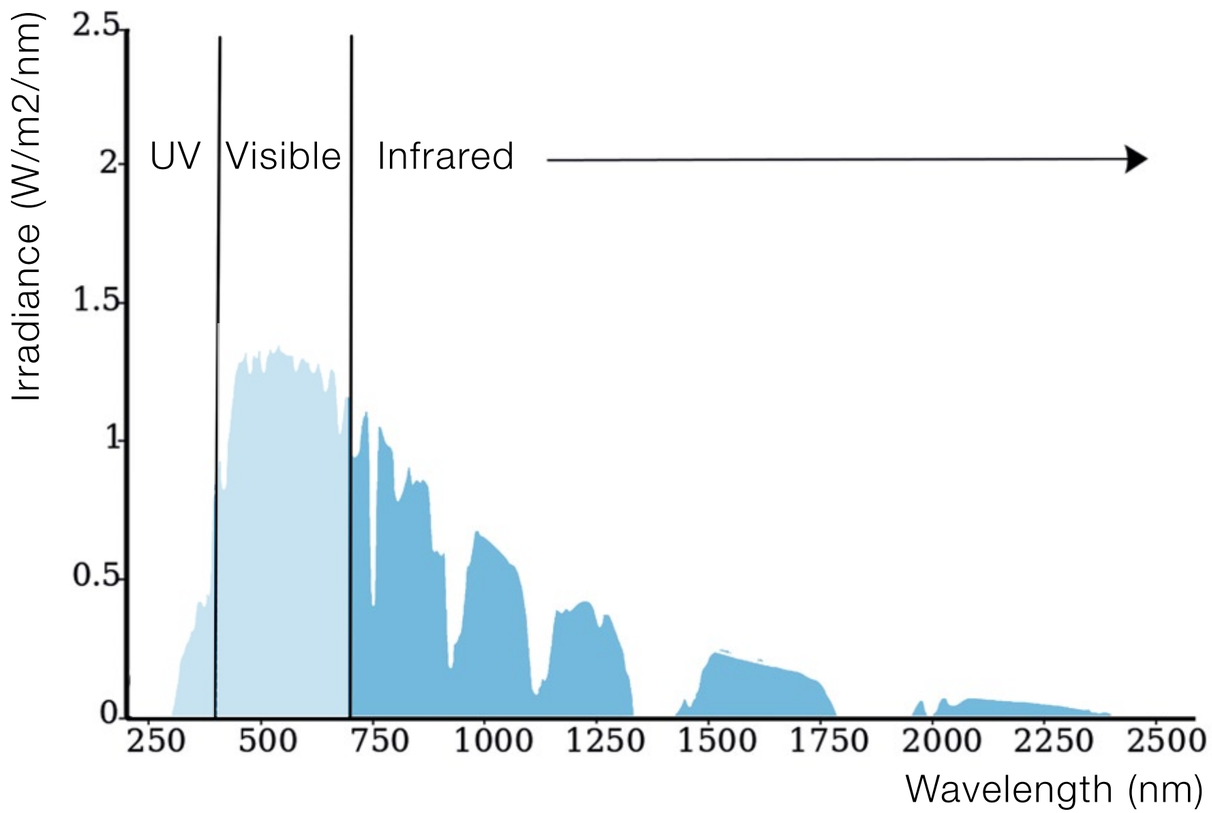

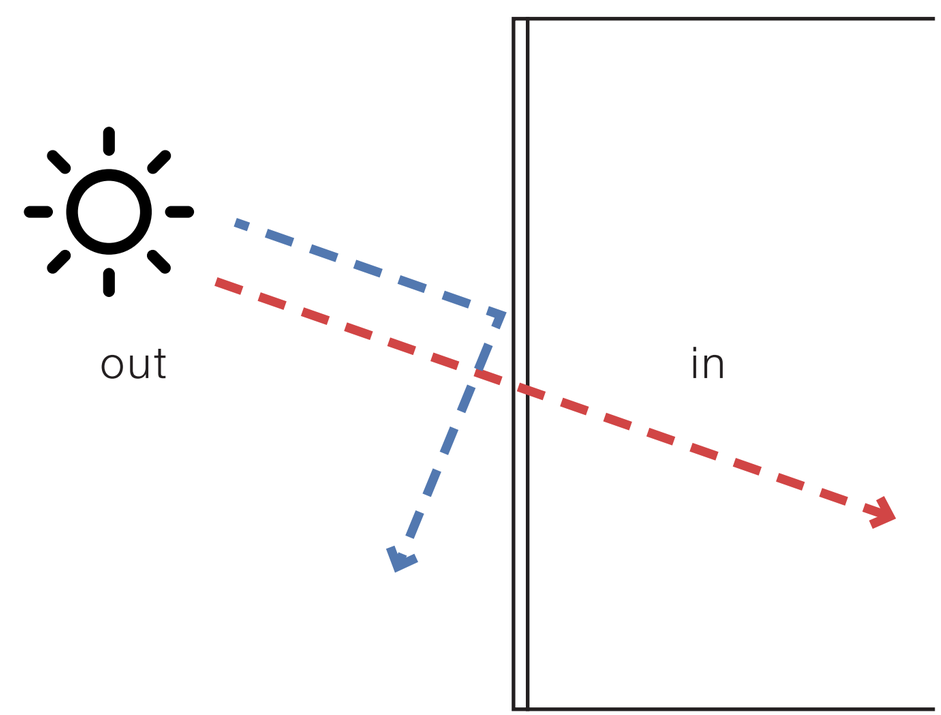

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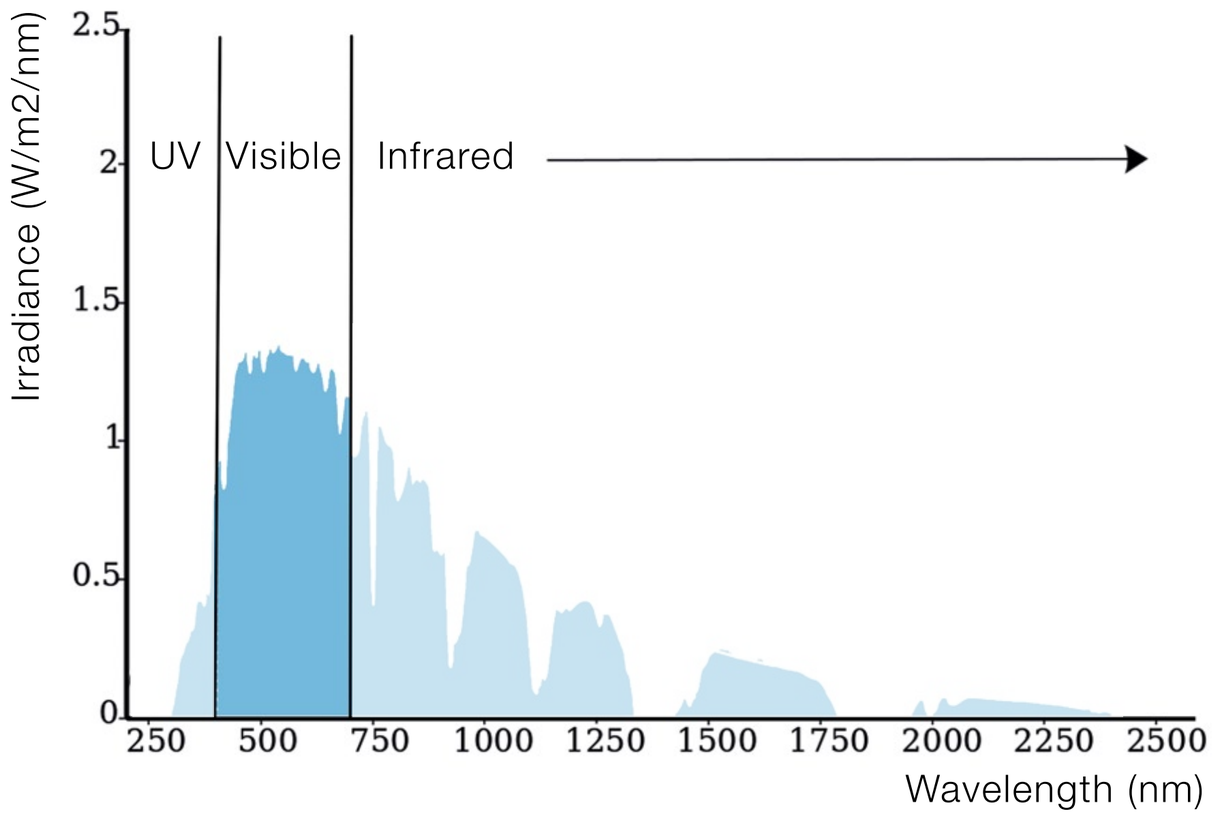
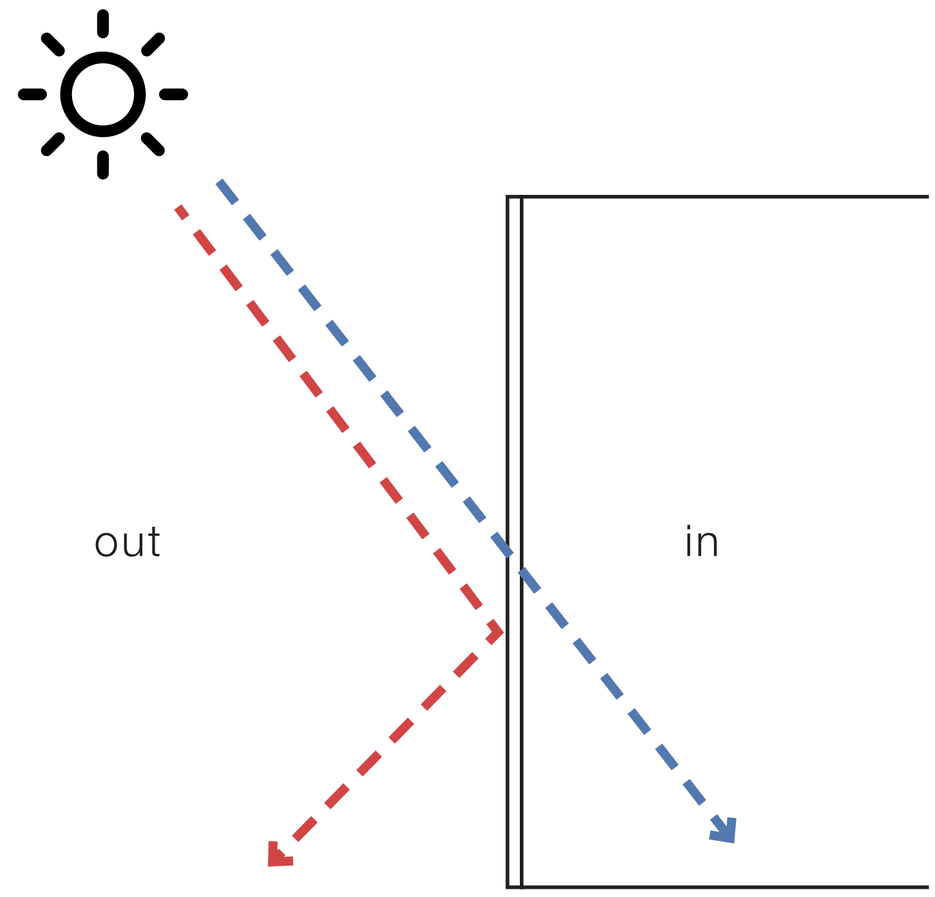




Visual Comfort

Illuminance: 300-500 lux

Daylight Glare Probability (DGP) < 0,35

High quality light (daylight)

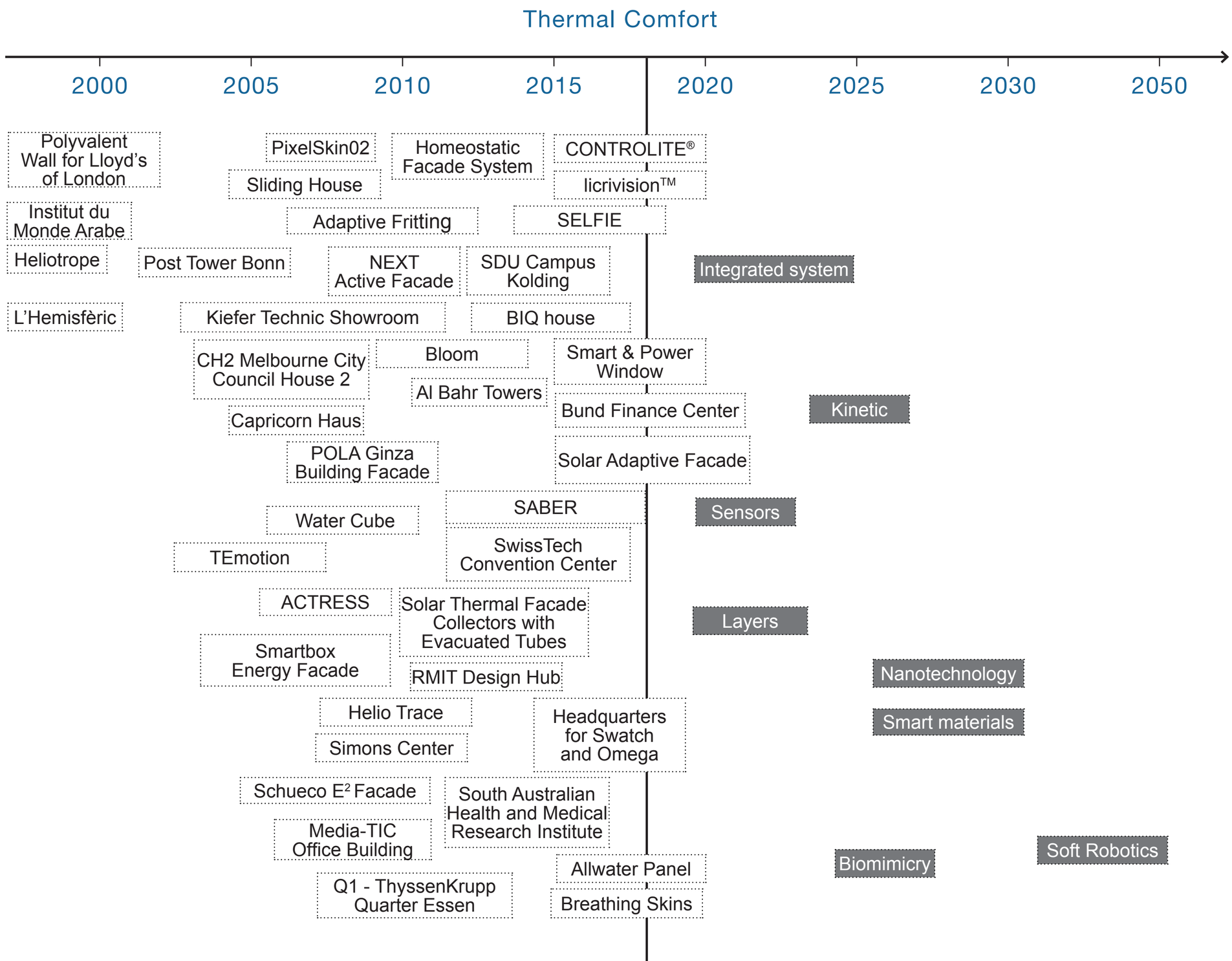
View to the outside environment

Thermal Comfort

Temperature winter: 20-23 °C

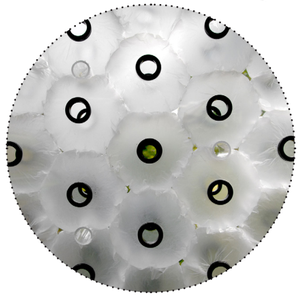
Temperature summer: 23-26°C

Trends of Adaptivity



Concept of Adaptivity

Biomimicry

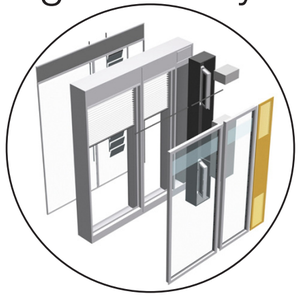


Smart materials

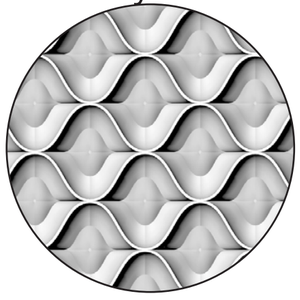
Nanotechnology

Sensors

Integrated system

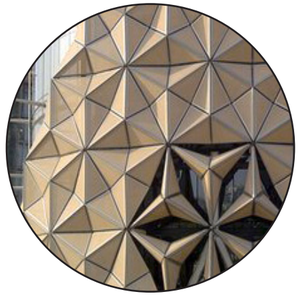


Layers



Low-tech

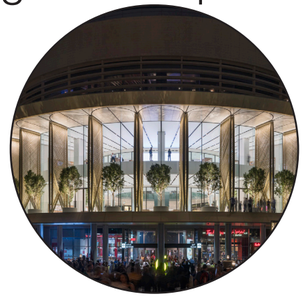
Aesthetics



Kinetics

Soft robotics

High transparency



Energy generator

Concept of Adaptivity

Biomimicry

Smart materials

Nanotechnology

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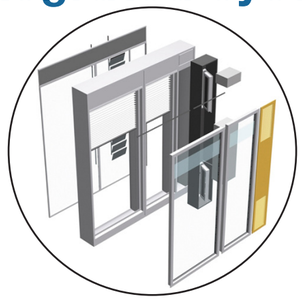

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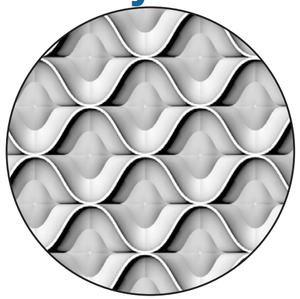


Low-tech

Aesthetics

Kinetics

Soft robotics

High transparency

Energy generator

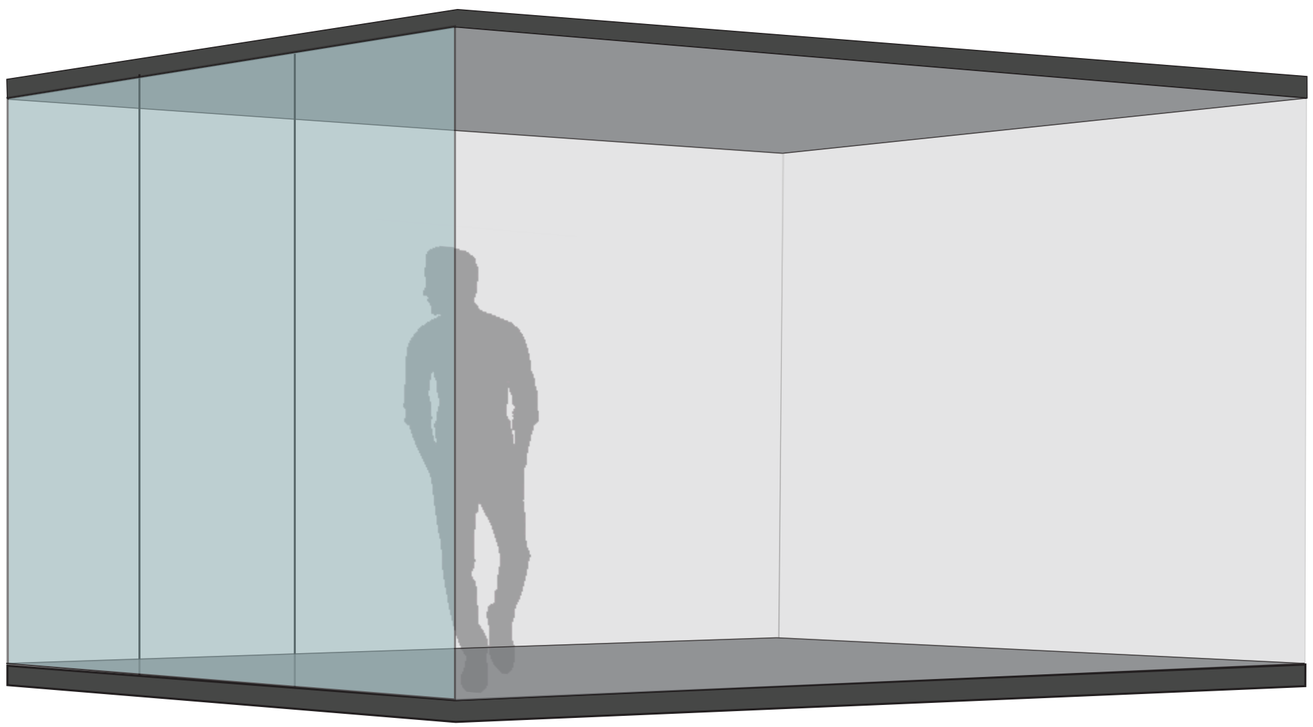
Design objectives

Improve Visual Comfort of an Office Space by:

Reducing Daylight Glare Probability

Increasing daylight and DA

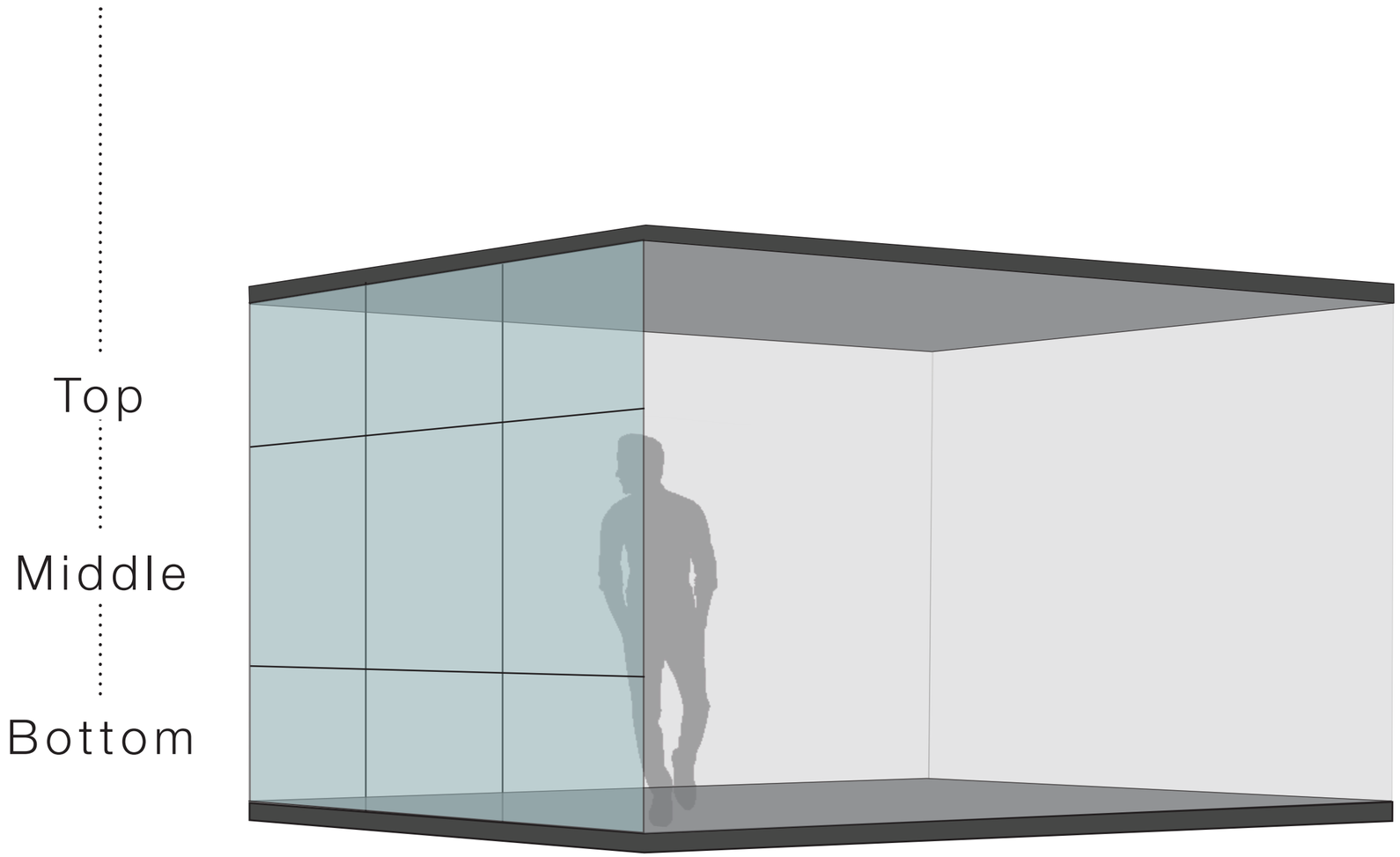
Assuring view



Design strategies

Facade subdivision

Independent control of each panel to improve daylight and view



Design strategies

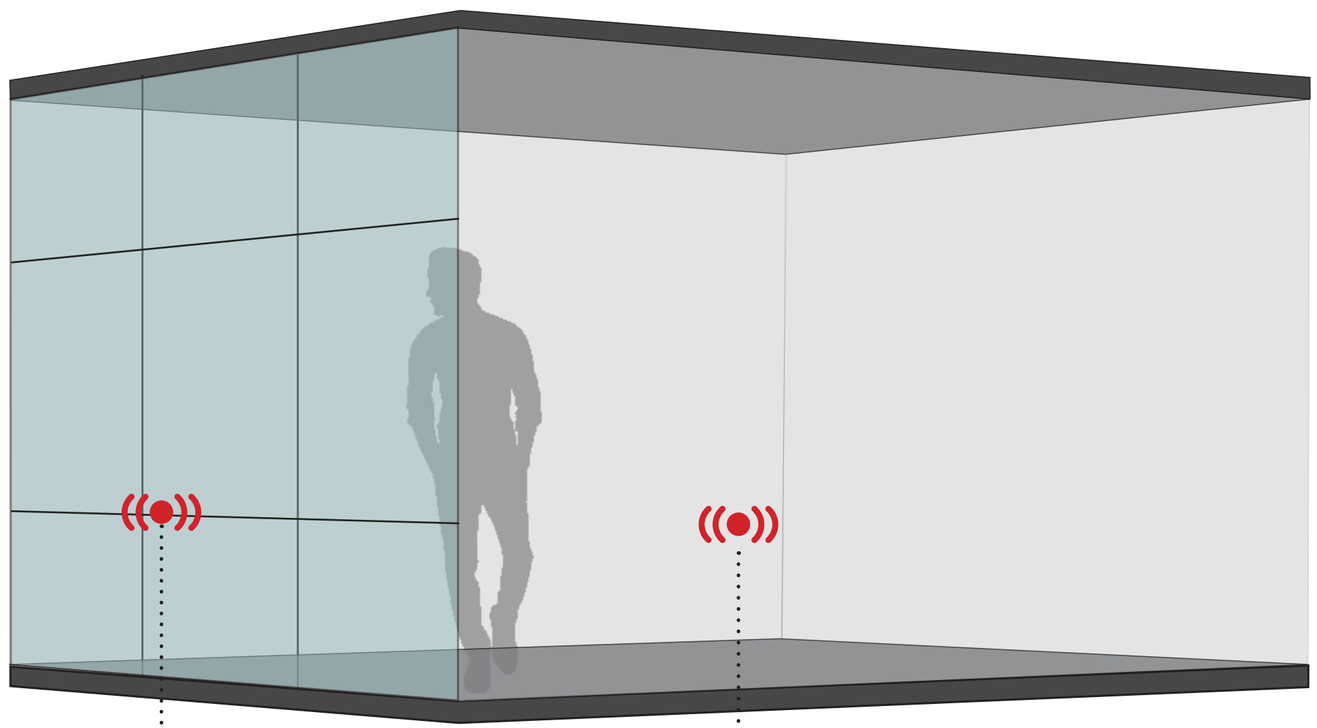
Facade subdivision

Independent control of each panel to improve daylight and view

Top

Middle

Bottom



Measurement of indoor and outdoor conditions to optimize the facade response

Sensors

Design strategies

Facade subdivision

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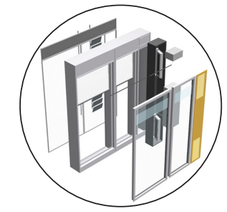
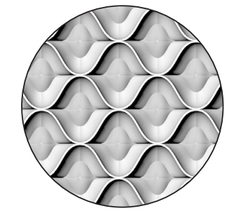


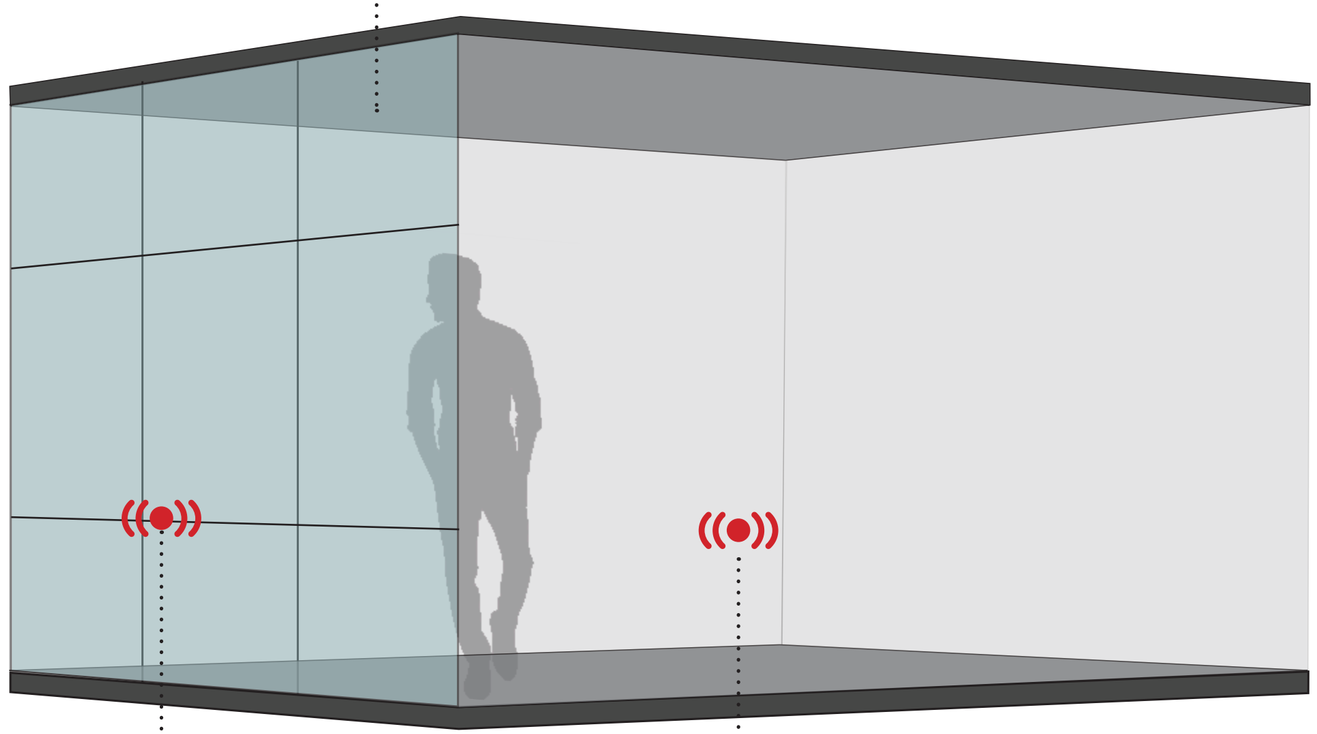


Adaptive solution that reacts independently from each panel according to the information received by the sensors

Top

Middle

Bottom



Measurement of indoor and outdoor conditions to optimize the facade response

Sensors

Requirements:

Daylight control
Thermal control
Fast adaptation
View preservation
Neutral colour
Low energy demand

→ **Adaptive solution**

Adaptive technologies

Adaptive solutions

- Roller shading
- Venetian blinds
- Smart glass

Roller shading, Venetian blinds → Traditional solutions

Smart glass → Passive solutions

Photochromic

Thermochromic

Active solutions

Liquid Crystals (LC)

Electrochromic Polymer Glazing

Suspended-particle Device (SPDs)

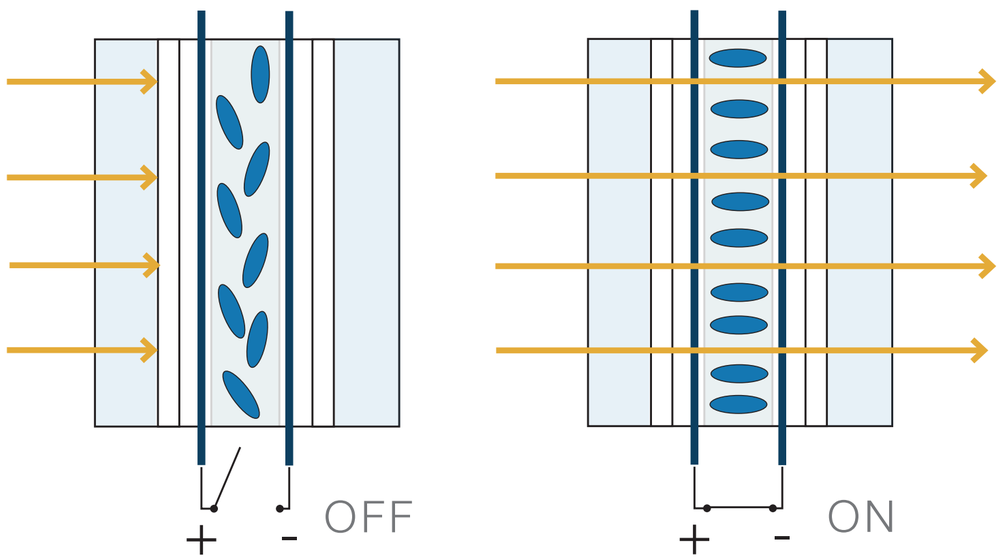
Cholesteric Liquid Crystals (Ch-LC)

Gasochromic Windows

Smart glass

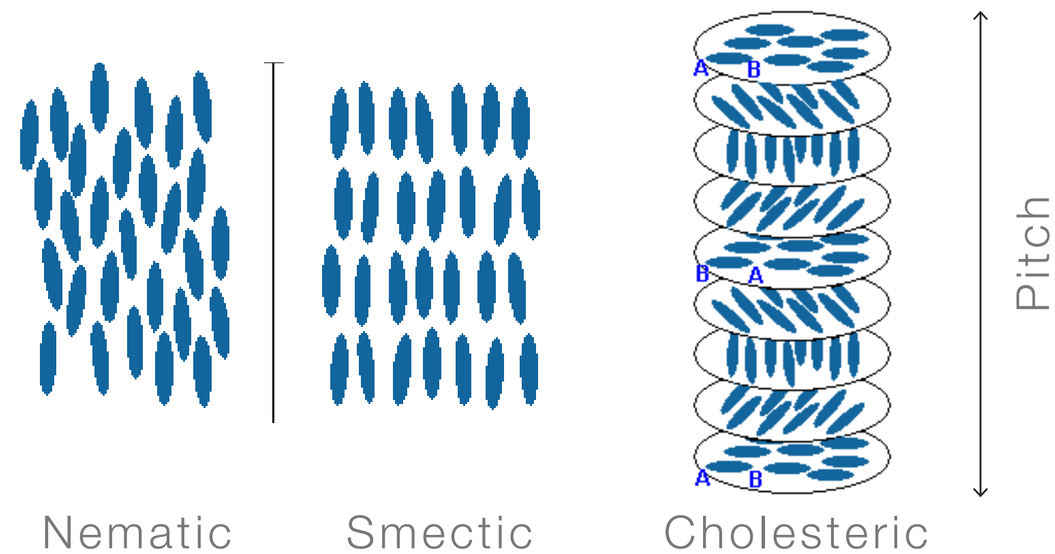
Different portions of the spectrum are regulated by different layers and materials

VIsible Light



Liquid Crystals (LC)

Infrared

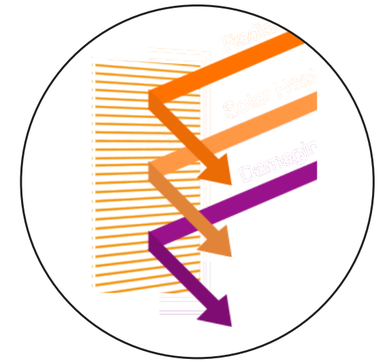


Cholesteric Liquid Crystals (Ch-LC)

Case studies

Iicrivision™, Merck

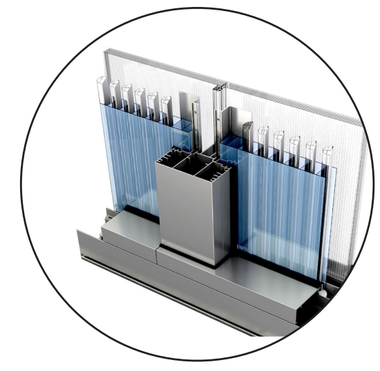
SageGlass, Saint-Gobain



iSolar Blinds, LCG

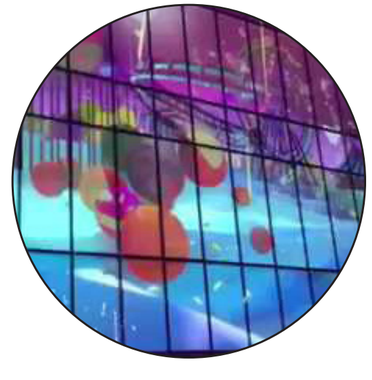
ECONTROL®, EControl-Glas

Polyarch, TU Delft and TU/e



CONTROLITE®, Danpal®

PowerWindow, Physee



LCG® Films, Gauzy

Kindow Binds, Kindow

Design concept

Reference project 1

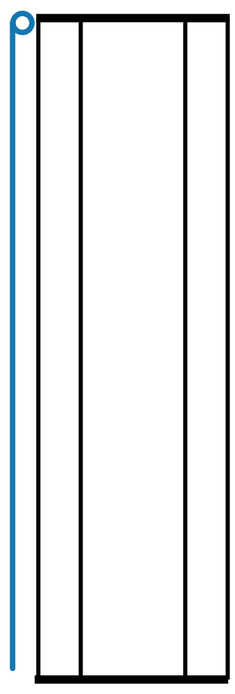
Roller shading

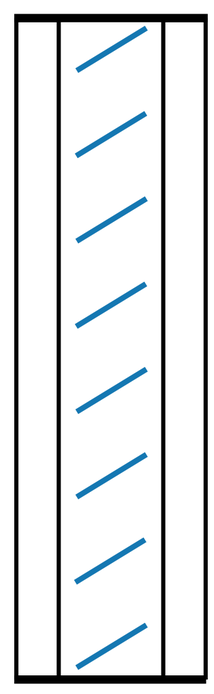
Reference project 2

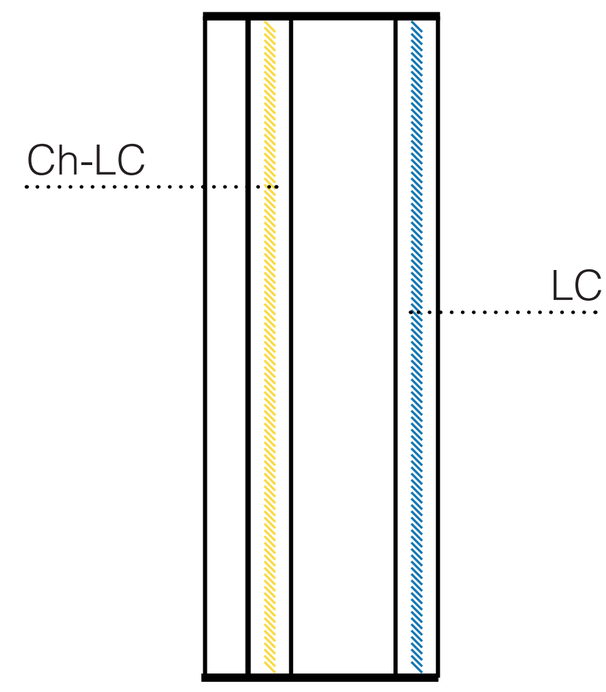
Venetian blinds

Design option

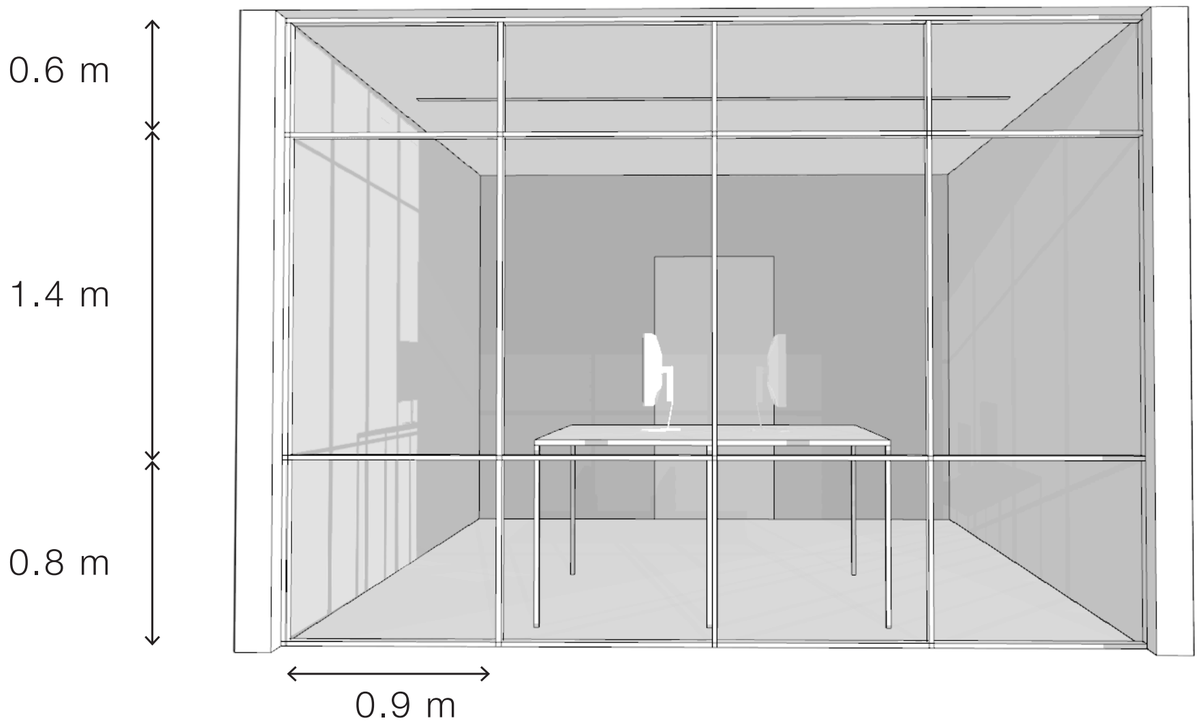
Ch-LC + LC



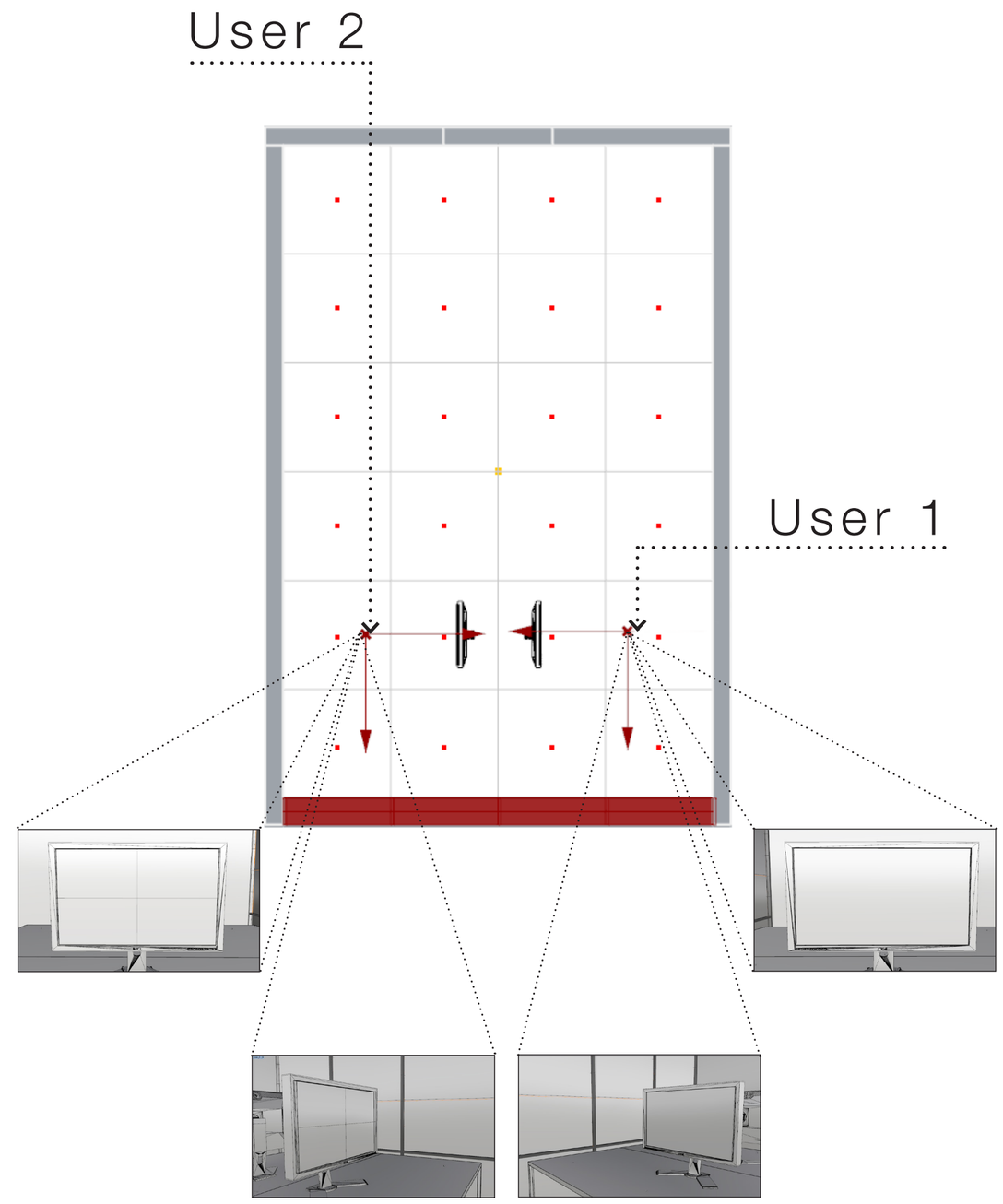




Simulation

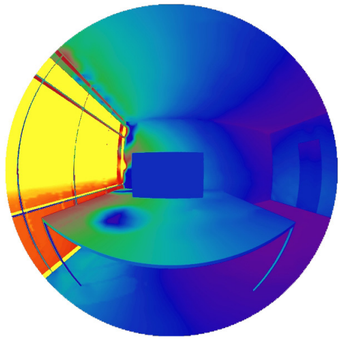


South facing facade



Simulation

Annual DGP
(User 1)



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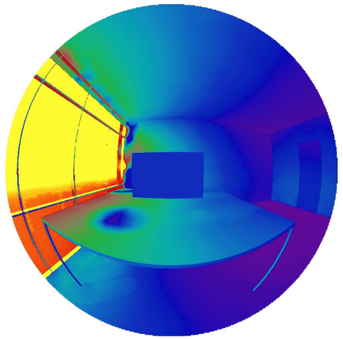
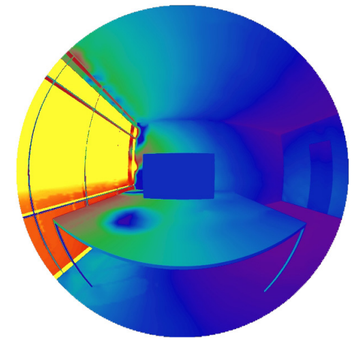


The facade responds changing light transmittance

Shading schedule

Simulation

Annual DGP
(User 1)

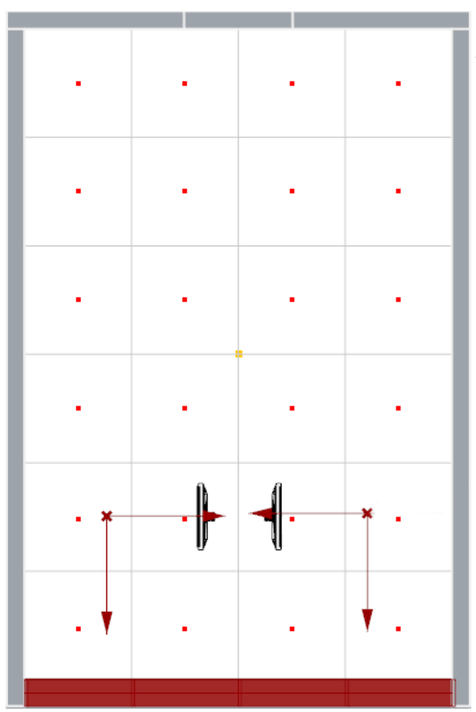


The facade responds changing light transmittance

Shading schedule

Influence on

Illuminance DA



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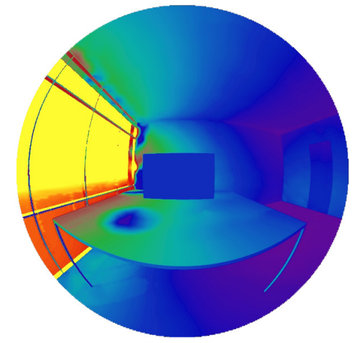

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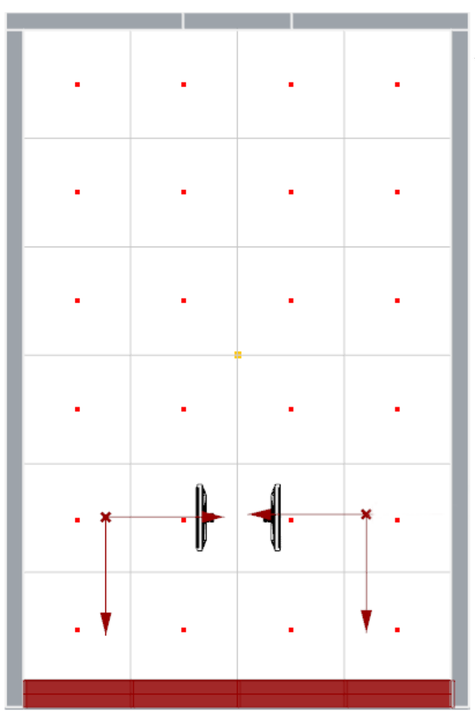


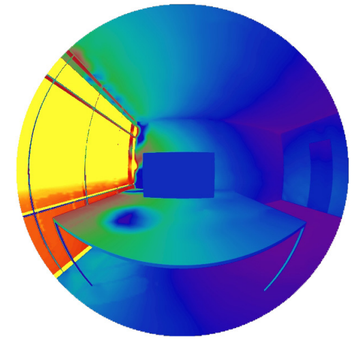
Electric lighting
on when illuminance < 500 lux on task

Energy balance

Simulation

DIVA
(Radiance)

Annual DGP
(User 1)



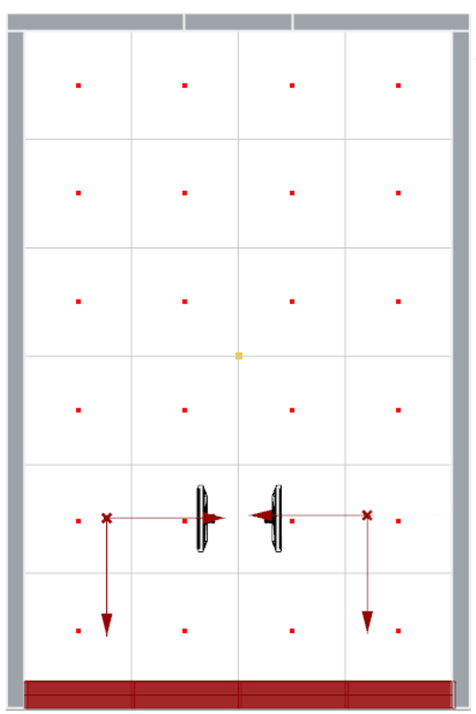
The facade responds changing light transmittance

Shading schedule

Influence on
Illuminance
DA

Energy balance

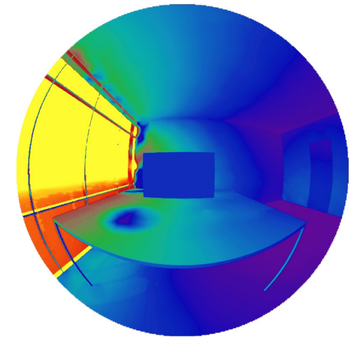
Electric lighting
on when illuminance < 500 lux on task



Simulation

DIVA (Radiance)

Annual DGP
(User 1)



The facade responds changing light transmittance

Shading schedule

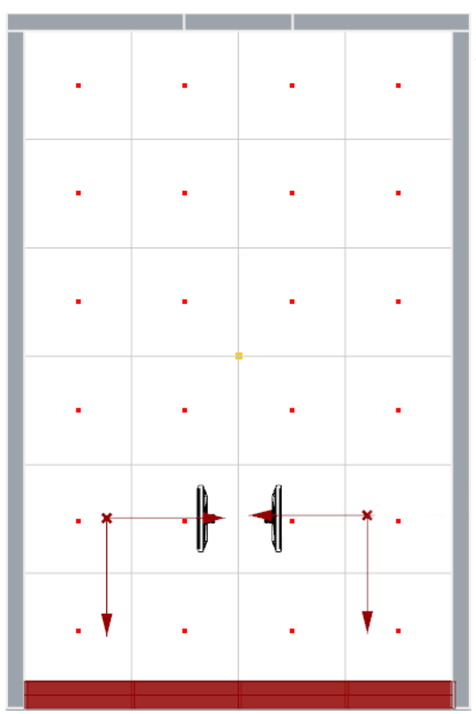
T → IR reflected
T → IR transmitted

Influence on the **Heating & Cooling**

on when
T < 20°C
T > 26°C

Energy balance

Influence on **Illuminance DA**

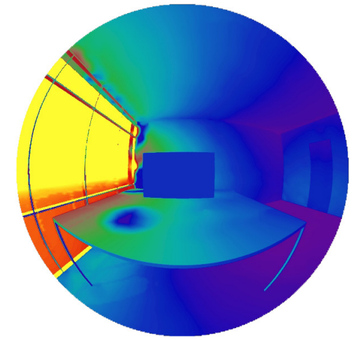


Electric lighting
on when illuminance < 500 lux on task

Simulation

DIVA (Radiance)

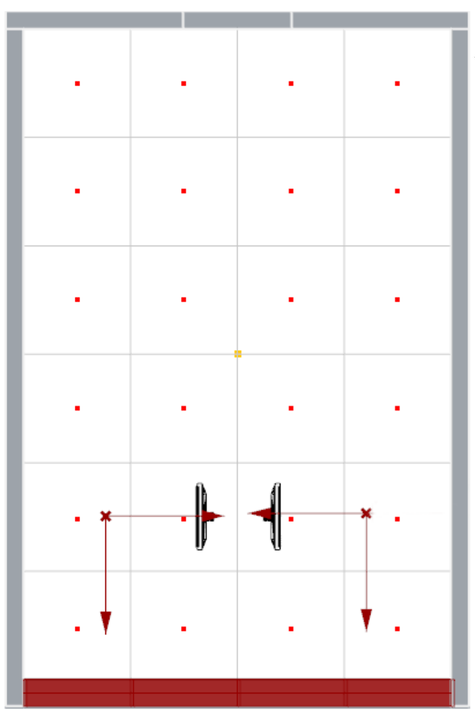
Annual DGP (User 1)



The facade responds changing light transmittance

Shading schedule

Influence on **Illuminance DA**



Electric lighting on when illuminance < 500 lux on task

Energy balance

DesignBuilder (Energy Plus)

T → IR reflected
T → IR transmitted

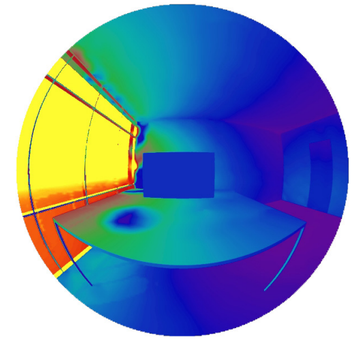
Influence on the **Heating & Cooling**

on when
T < 20°C
T > 26°C

Simulation

DIVA (Radiance)

Annual DGP (User 1)

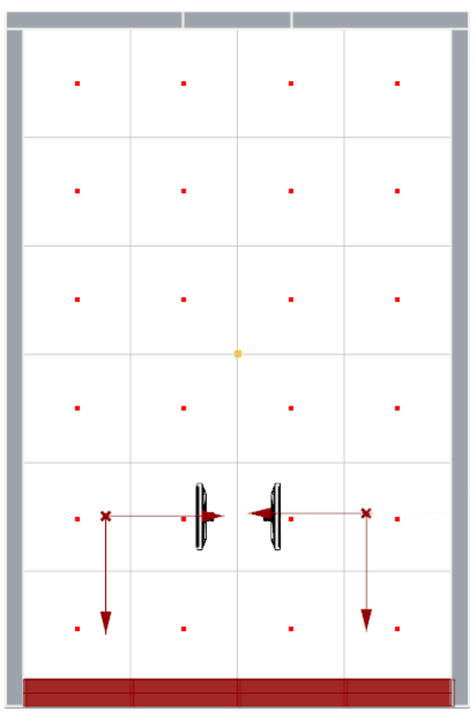


The facade responds changing light transmittance

Shading schedule

Influence on **Illuminance DA**

Electric lighting on when illuminance < 500 lux on task



Energy balance

DesignBuilder (Energy Plus)

T → IR reflected
T → IR transmitted

Influence on the **Heating & Cooling**

on when
T < 20°C
T > 26°C

Ventilation

Equipment &Users

Do not vary between the different cases

Roller shading

Glare control

Shading control:

base: clear facade

shading state 1: top

shading state 2: middle

shading state 3: top & middle

Venetian blinds

Glare control

2 independent shading groups: Top & middle

base: clear facade

shading state 1: 0°

shading state 2: 45°

shading state 3: 90°

Thermal control

The shading control is actvated by the glare perception. Therefore, the influence of the shading system on the thermal balance is due to this factor

New design option

Glare control

LC

base: clear facade

shading state 1: 30% VT

shading state 2: 2% VT

Thermal control

Ch-LC

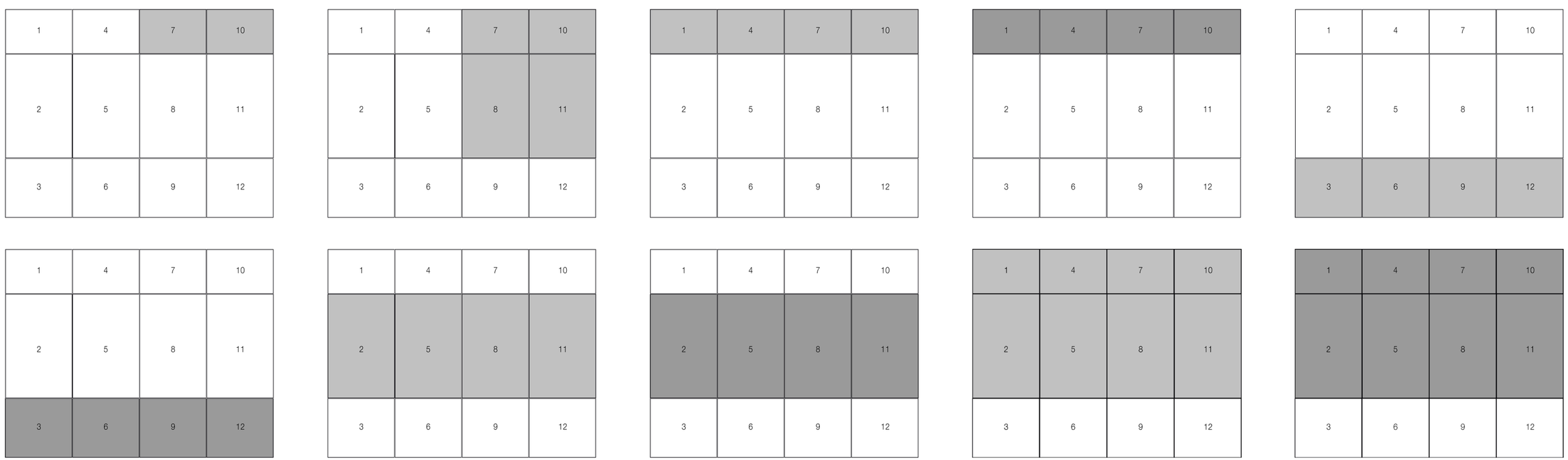
transparent insulation

base: 95% ST = 100% Ch-LC

state 1: 60% ST = 50% Ch-LC

state 2: 22% ST = 0% Ch-LC

Shading combinations



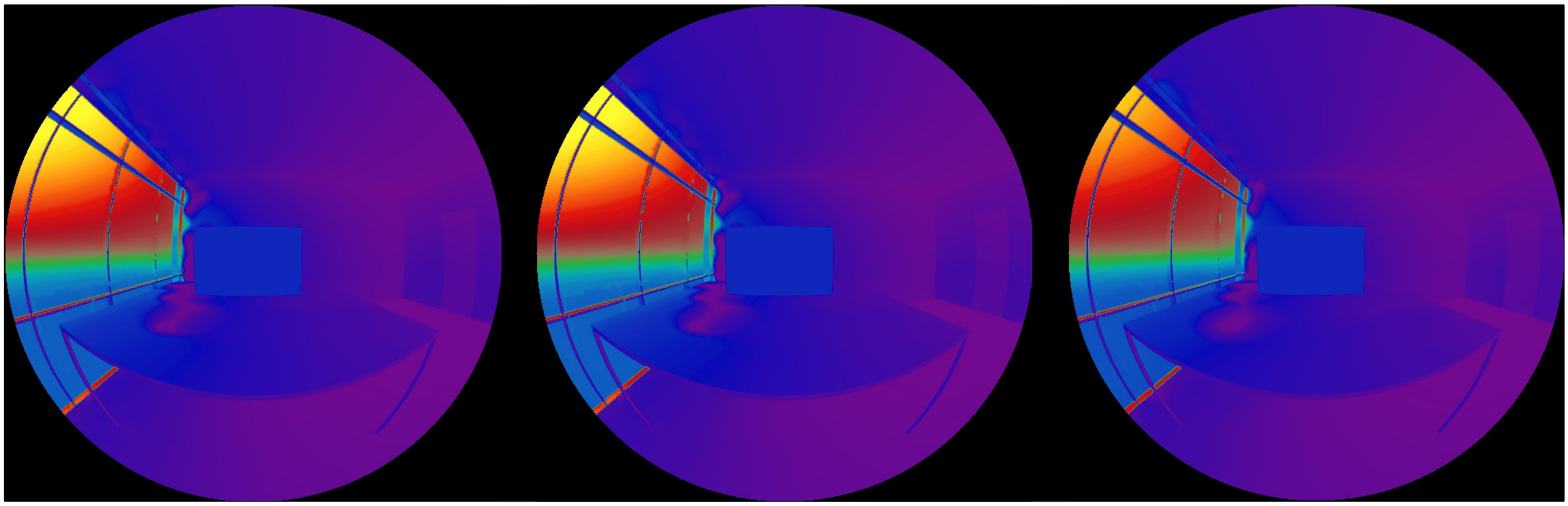
Results

21st March 9:00

Roller shading

Venetian blinds

Smart window



Roller shading	Venetian blinds	Smart window
200 lux	200 lux	200 lux
		Infrared control: 100%
24.5 °C	24.5 °C	21,5 °C
0.33 kW	0.32 kW	0.14 kW

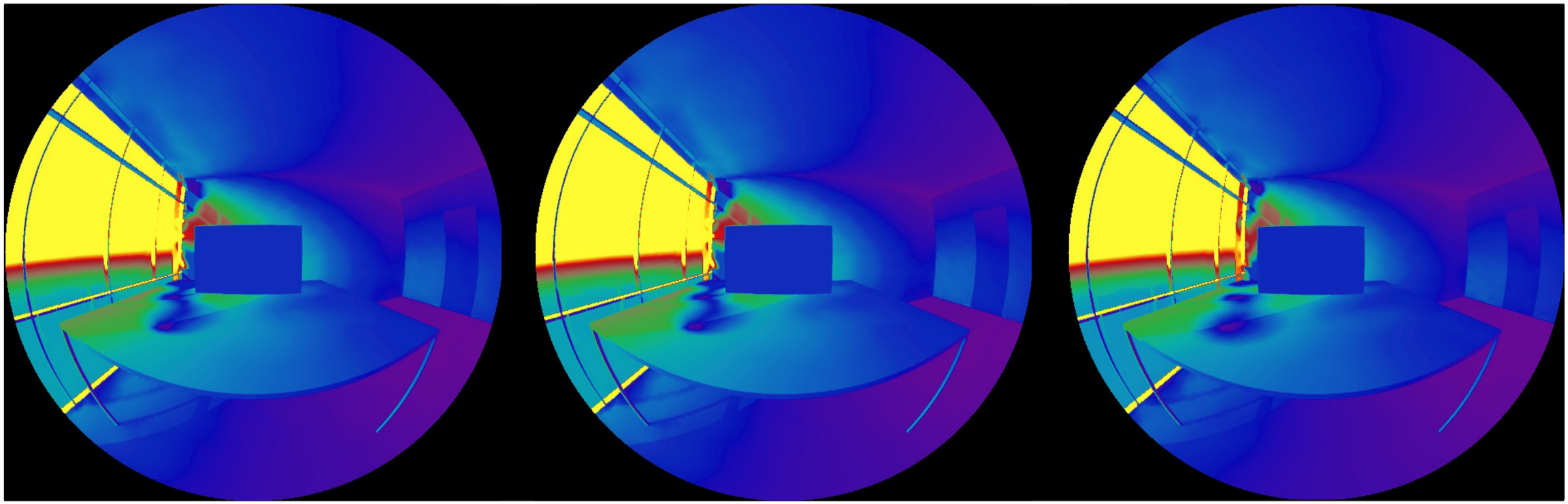
Results

21st March 10:00

Roller shading

Venetian blinds

Smart window



Roller shading	Venetian blinds	Smart window
400-500 lux	400-500 lux	400-500 lux
		Infrared control: 100%
24.5 °C	24.5 °C	21.5 °C
0.32 kWh	0.32 kWh	0.21 kWh

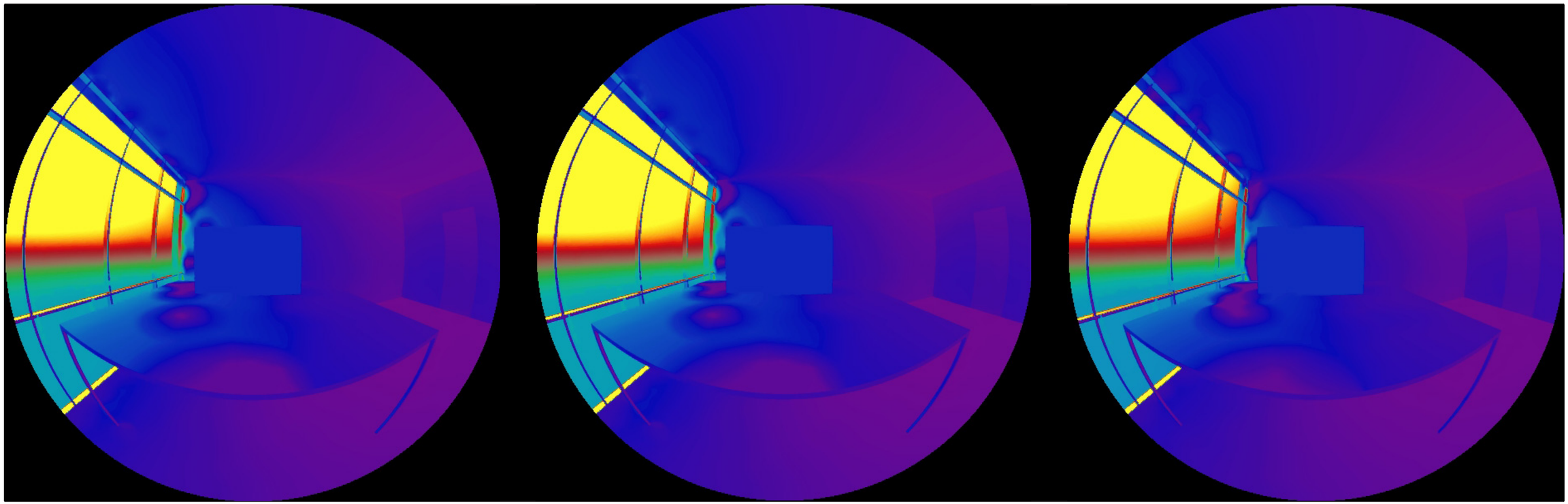
Results

21st March 11:00

Roller shading

Venetian blinds

Smart window



Roller shading	Venetian blinds	Smart window
100-200 lux	100-200 lux	100-200 lux
		Infrared control: 100%
24.5 °C	24.5 °C	21.5 °C
0.32 kWh	0.31 kWh	0.22 kWh

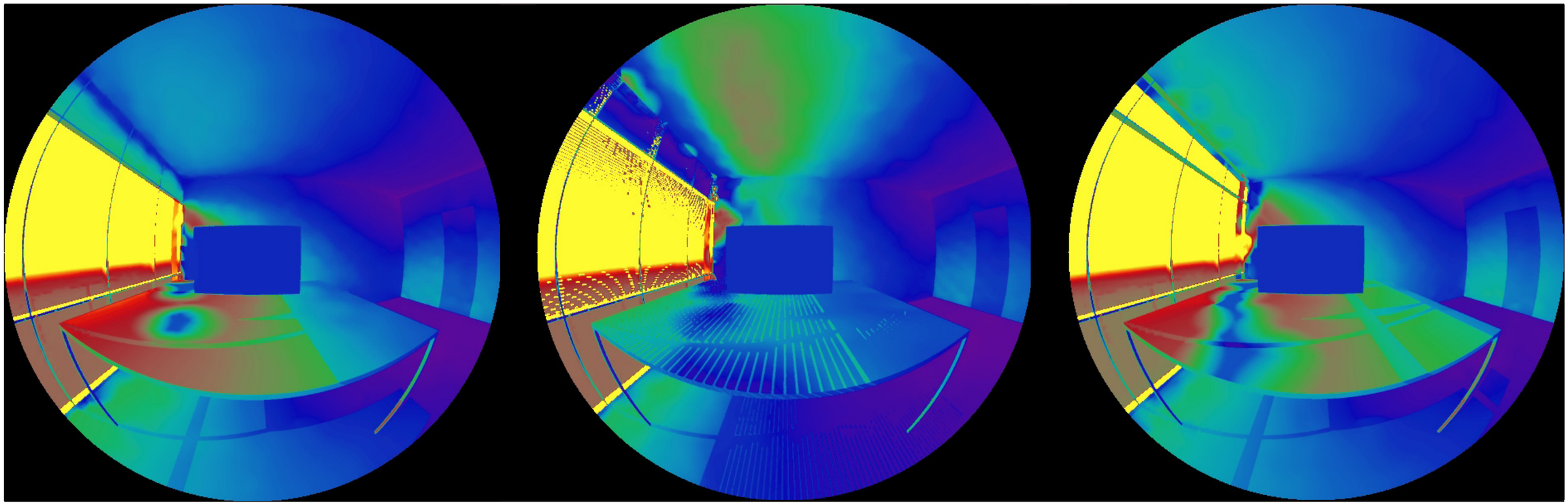
Results

21st March 12:00

Roller shading

Venetian blinds

Smart window



900-1000 lux	200-700 lux	700-900 lux
		Infrared control:
25.5 °C	25 °C	22 °C
0.34 kWh	0.35 kWh	0.27 kWh

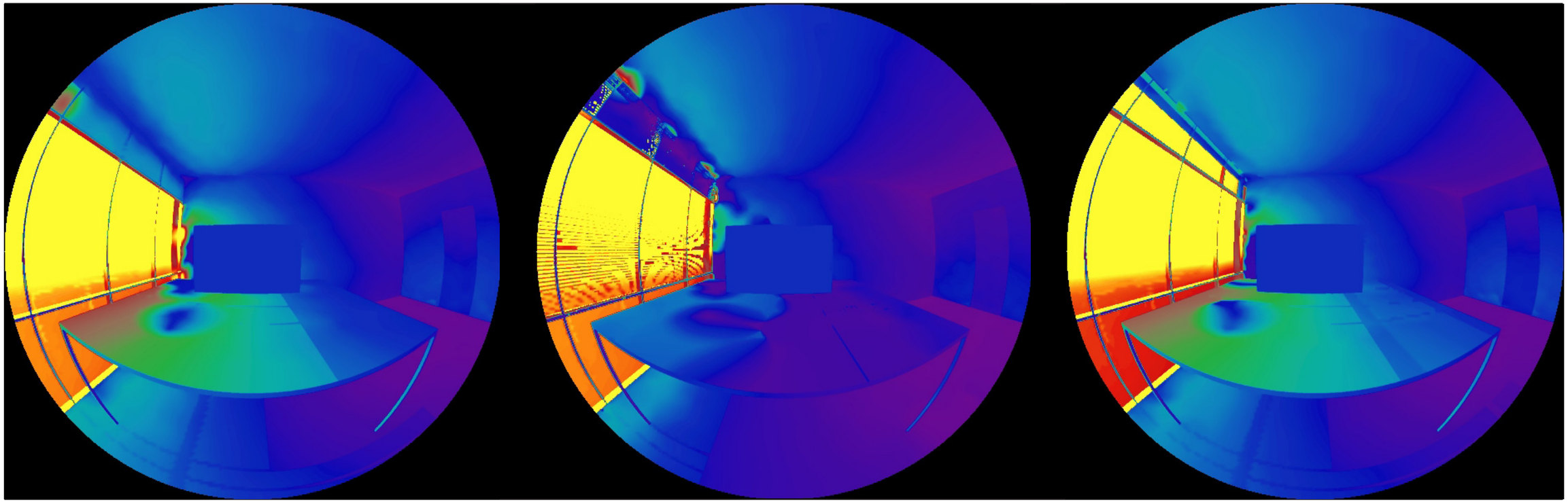
Results

21st March 13:00

Roller shading

Venetian blinds

Smart window



Roller shading	Venetian blinds	Smart window
500-700 lux	100-300 lux	500-700 lux
		Infrared control: 100%
25.5 °C	25.5 °C	22.5 °C
0.40 kWh	0.40 kWh	0.27 kWh

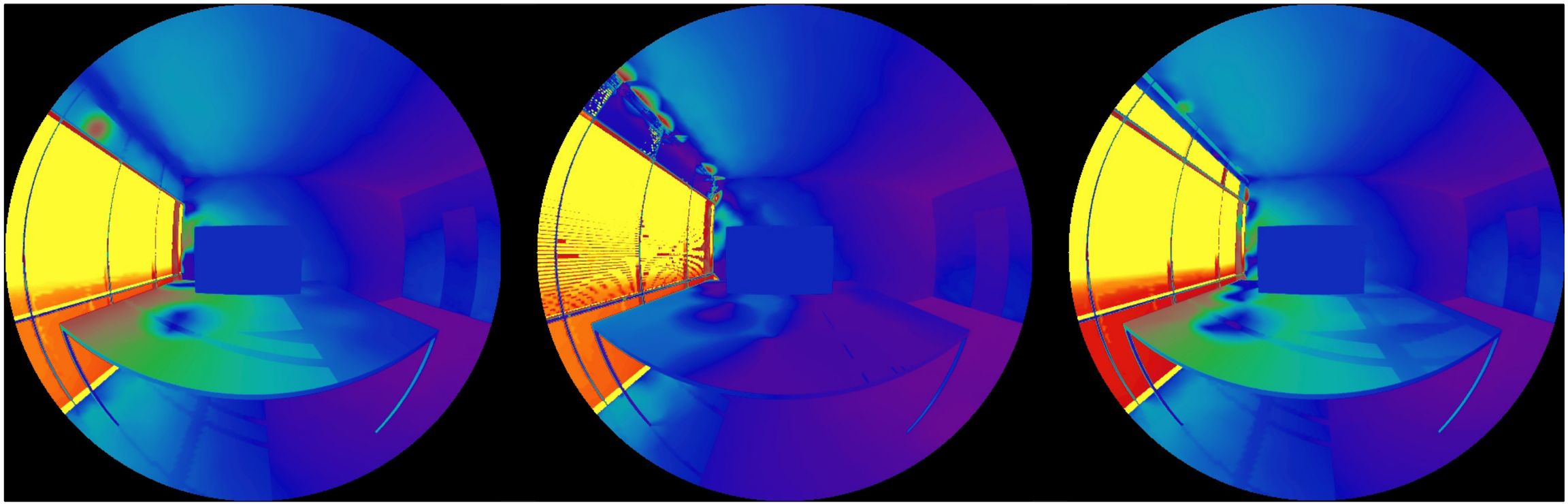
Results

21st March 14:00

Roller shading

Venetian blinds

Smart window



Roller shading	Venetian blinds	Smart window
500-700 lux	100-300 lux	500-700 lux
		Infrared control: 100%
25.5 °C	25.5 °C	23 °C
0.42 kWh	0.41 kWh	0.27 kWh

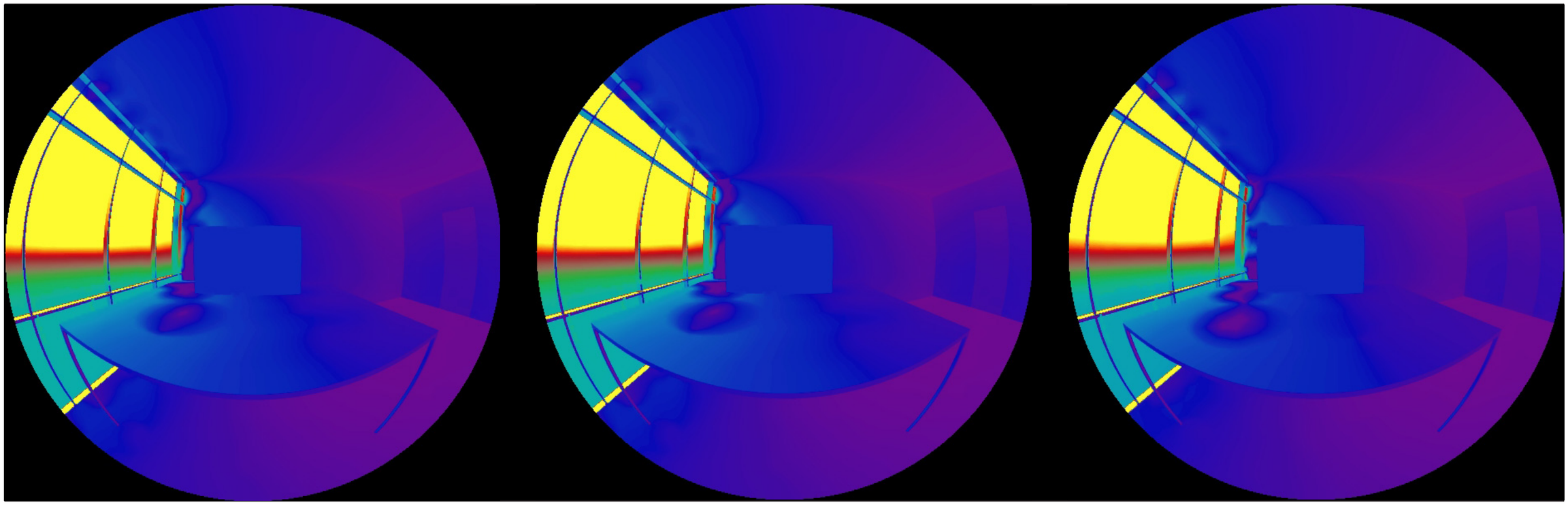
Results

21st March 15:00

Roller shading

Venetian blinds

Smart window



200-300 lux	200-300 lux	200-300 lux
		Infrared control: 100%
25.5 °C	25.5 °C	22.5 °C
0.38 kWh	0.31 kWh	0.26 kWh

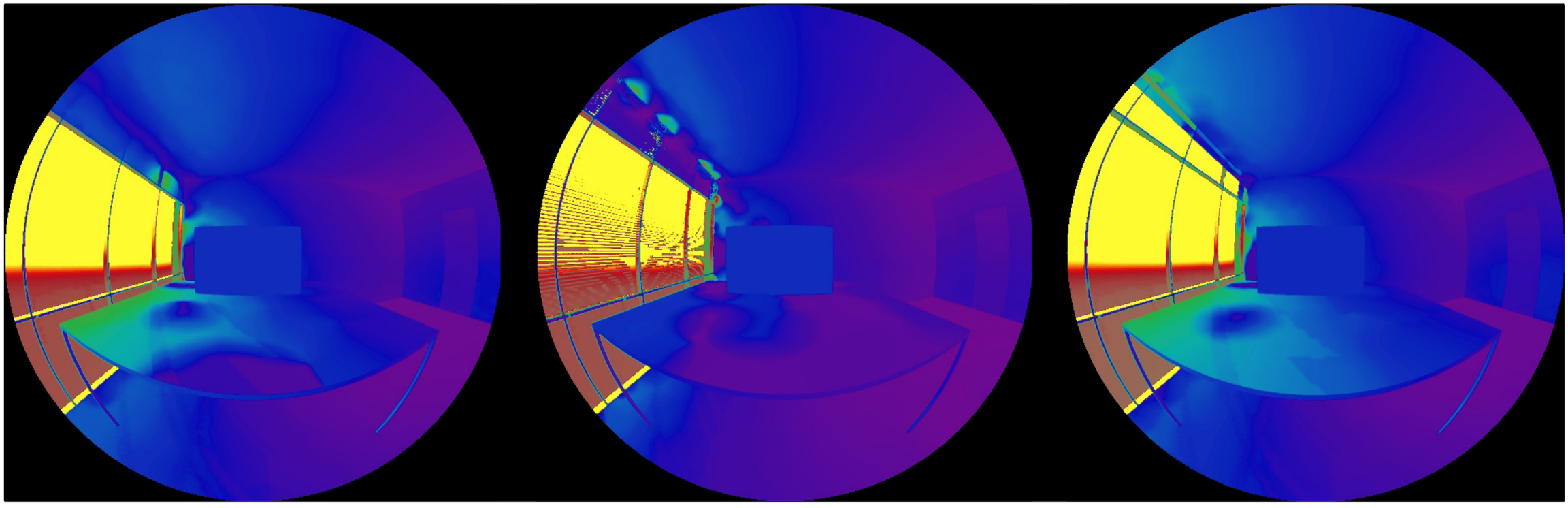
Results

21st March 16:00

Roller shading

Venetian blinds

Smart window



Roller shading	Venetian blinds	Smart window
100-300 lux	100-200 lux	300-500 lux
		Infrared control: 100%
25.5 °C	25.5 °C	22.5 °C
0.40 kWh	0.34 kWh	0.26 kWh

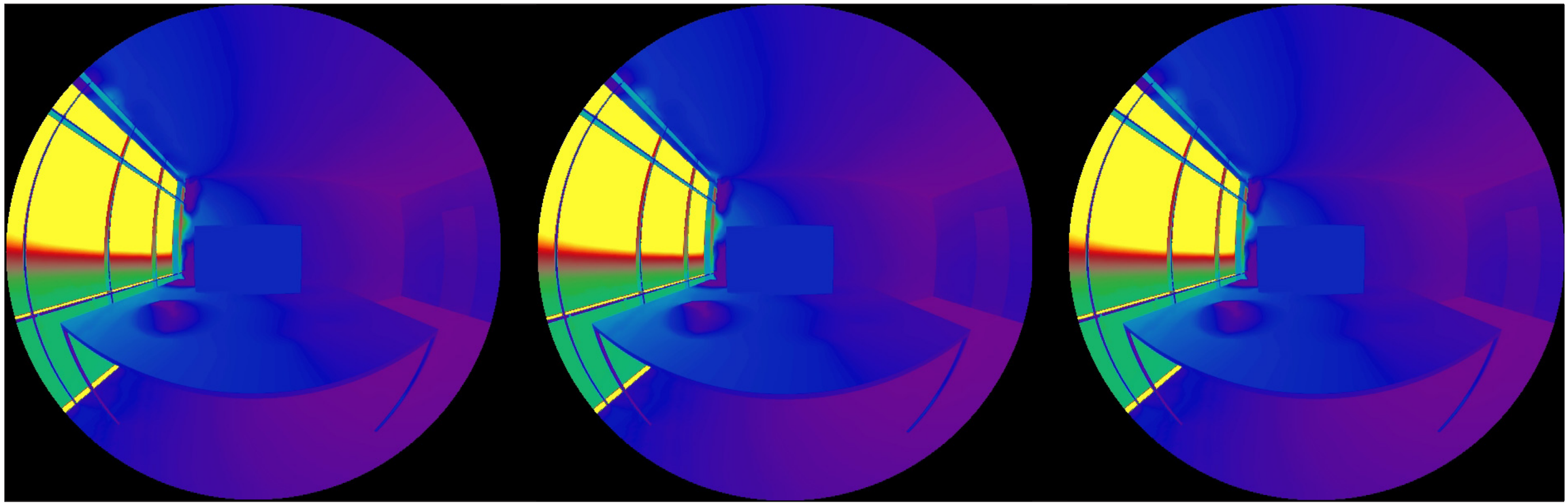
Results

21st March 17:00

Roller shading

Venetian blinds

Smart window



Roller shading	Venetian blinds	Smart window
300 lux	300 lux	300 lux
		Infrared control: 100%
25.5 °C	25.4 °C	22.6 °C
0.38 kWh	0.31 kWh	0.26 kWh

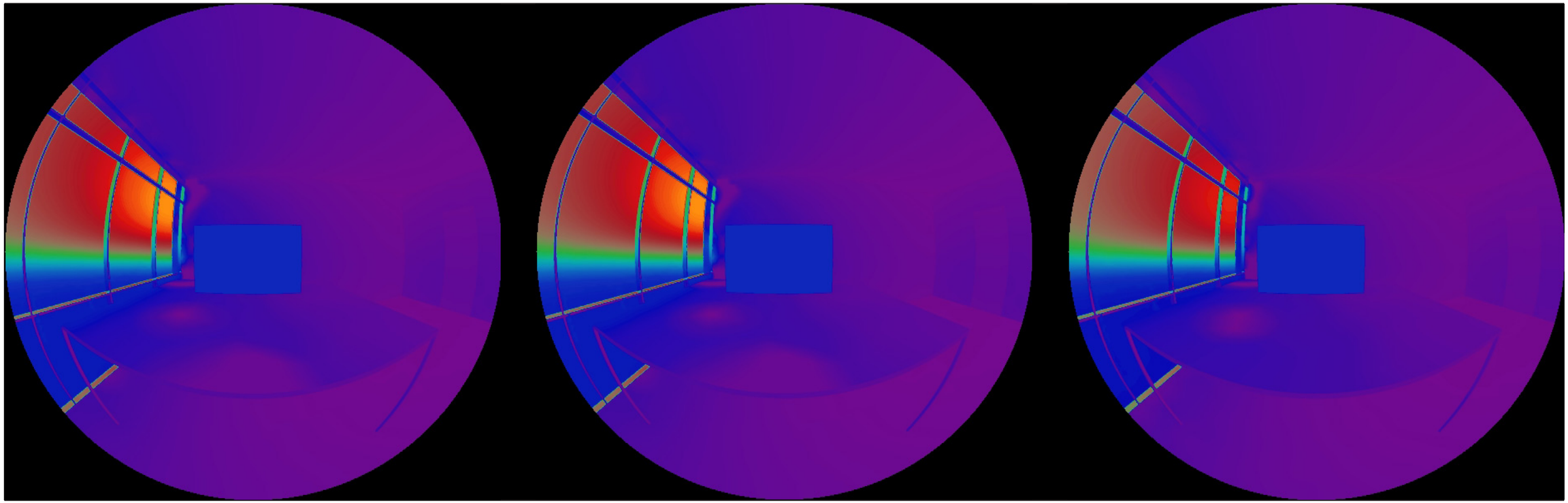
Results

21st March 18:00

Roller shading

Venetian blinds

Smart window



Roller shading	Venetian blinds	Smart window
100-200 lux	100-200 lux	100-200 lux
		Infrared control: 100%
25.5 °C	25 °C	22 °C
0.32 kWh	0.30 kWh	0.26 kWh

Results

21st June

	Shading schedule				Illuminance [lux]			Temperature [°C]		Energy demand [kWh]		
9:00	-			100%	500			25,5	23,5	0,4		0,2
10:00	-			100%	600			25,5	23,5	0,4		0,2
11:00	-			100%	600			25,5	24	0,5		0,2
12:00	-			100%	500			25,5	24	0,6		0,2
13:00	-			100%	700			26	24	0,7	0,6	0,2
14:00	-			100%	200			26	24	0,6	0,5	0,2
15:00	full	45°|45°	half-full	100%	100	200	500	26	24,5	0,7		0,2
16:00	top	0°| 0°	half-top	100%	300	400	400	26	24,5	0,7	0,6	0,2
17:00	-			100%	200			26	24,5	0,7	0,5	0,2
18:00	-			50%	200			26	25,5	0,1		-

Results

21st June

	Shading schedule				Illuminance [lux]			Temperature [°C]		Energy demand [kWh]		
9:00	-			100%	500			25,5	23,5	0,4		0,2
10:00	-			100%	600			25,5	23,5	0,4		0,2
11:00	-			100%	600			25,5	24	0,5		0,2
12:00	-			100%	500			25,5	24	0,6		0,2
13:00	-			100%	700			26	24	0,7	0,6	0,2
14:00	-			100%	200			26	24	0,6	0,5	0,2
15:00	full	45°|45°	half-full	100%	100	200	500	26	24,5	0,7		0,2
16:00	top	0°| 0°	half-top	100%	300	400	400	26	24,5	0,7	0,6	0,2
17:00	-			100%	200			26	24,5	0,7	0,5	0,2
18:00	-			50%	200			26	25,5	0,1		-

Results

21st June

	Shading schedule				Illuminance [lux]			Temperature [°C]		Energy demand [kWh]		
9:00	-			100%	500			25,5	23,5	0,4		0,2
10:00	-			100%	600			25,5	23,5	0,4		0,2
11:00	-			100%	600			25,5	24	0,5		0,2
12:00	-			100%	500			25,5	24	0,6		0,2
13:00	-			100%	700			26	24	0,7	0,6	0,2
14:00	-			100%	200			26	24	0,6	0,5	0,2
15:00	full	45°|45°	half-full	100%	100	200	500	26	24,5	0,7		0,2
16:00	top	0°| 0°	half-top	100%	300	400	400	26	24,5	0,7	0,6	0,2
17:00	-			100%	200			26	24,5	0,7	0,5	0,2
18:00	-			50%	200			26	25,5	0,1		-

Results

21st June

	Shading schedule				Illuminance [lux]			Temperature [°C]		Energy demand [kWh]		
9:00	-			100%	500			25,5	23,5	0,4		0,2
10:00	-			100%	600			25,5	23,5	0,4		0,2
11:00	-			100%	600			25,5	24	0,5		0,2
12:00	-			100%	500			25,5	24	0,6		0,2
13:00	-			100%	700			26	24	0,7	0,6	0,2
14:00	-			100%	200			26	24	0,6	0,5	0,2
15:00	full	45°|45°	half-full	100%	100	200	500	26	24,5	0,7		0,2
16:00	top	0°| 0°	half-top	100%	300	400	400	26	24,5	0,7	0,6	0,2
17:00	-			100%	200			26	24,5	0,7	0,5	0,2
18:00	-			50%	200			26	25,5	0,1		-

Results

21st June

	Shading schedule				Illuminance [lux]			Temperature [°C]		Energy demand [kWh]		
9:00	-			100%	500			25,5	23,5	0,4		0,2
10:00	-			100%	600			25,5	23,5	0,4		0,2
11:00	-			100%	600			25,5	24	0,5		0,2
12:00	-			100%	500			25,5	24	0,6		0,2
13:00	-			100%	700			26	24	0,7	0,6	0,2
14:00	-			100%	200			26	24	0,6	0,5	0,2
15:00	full	45°|45°	half-full	100%	100	200	500	26	24,5	0,7		0,2
16:00	top	0°| 0°	half-top	100%	300	400	400	26	24,5	0,7	0,6	0,2
17:00	-			100%	200			26	24,5	0,7	0,5	0,2
18:00	-			50%	200			26	25,5	0,1		-

-1.5/2°C

1/2-1/3

Results

23rd December

	Shading schedule		Illuminance [lux]	Temperature [°C]			Energy demand [kWh]		
9:00	-	0%	100	20			0,2	0,2	0,2
10:00	-	0%	100	20			0,2	0,2	0,1
11:00	-	0%	100	20,0			0,2	0,1	0,1
12:00	-	0%	200	20	20,5	20,5	0,1	0,02	0,03
13:00	-	50%	300	20,5			0,01	0,04	0,01
14:00	-	100%	300	20,5	21	20,5	0,02	0,1	0,01
15:00	-	100%	200	20,5	21	20,5	0,03	0,04	0,01
16:00	-	100%	100	20,5	21	21	0,03	0,01	-
17:00	-	100%	100	20,5	21	21	0,03	-	-
18:00	-	50%	100	20,5	21	21	0,03	-	0,01

Results

23rd December

	Shading schedule		Illuminance [lux]	Temperature [°C]			Energy demand [kWh]		
9:00	-	0%	100	20			0,2	0,2	0,2
10:00	-	0%	100	20			0,2	0,2	0,1
11:00	-	0%	100	20			0,2	0,1	0,1
12:00	-	0%	200	20	20,5	20,5	0,1	0,02	0,03
13:00	-	50%	300	20,5			0,01	0,04	0,01
14:00	-	100%	300	20,5	21	20,5	0,02	0,1	0,01
15:00	-	100%	200	20,5	21	20,5	0,03	0,04	0,01
16:00	-	100%	100	20,5	21	21	0,03	0,01	-
17:00	-	100%	100	20,5	21	21	0,03	-	-
18:00	-	50%	100	20,5	21	21	0,03	-	0,01

Results

23rd December

	Shading schedule		Illuminance [lux]	Temperature [°C]			Energy demand [kWh]		
9:00	-	0%	100	20			0,2	0,2	0,2
10:00	-	0%	100	20			0,2	0,2	0,1
11:00	-	0%	100	20			0,2	0,1	0,1
12:00	-	0%	200	20	20,5	20,5	0,1	0,02	0,03
13:00	-	50%	300	20,5			0,01	0,04	0,01
14:00	-	100%	300	20,5	21	20,5	0,02	0,1	0,01
15:00	-	100%	200	20,5	21	20,5	0,03	0,04	0,01
16:00	-	100%	100	20,5	21	21	0,03	0,01	-
17:00	-	100%	100	20,5	21	21	0,03	-	-
18:00	-	50%	100	20,5	21	21	0,03	-	0,01

Results

23rd December

	Shading schedule		Illuminance [lux]	Temperature [°C]			Energy demand [kWh]		
9:00	-	0%	100	20			0,2	0,2	0,2
10:00	-	0%	100	20			0,2	0,2	0,1
11:00	-	0%	100	20			0,2	0,1	0,1
12:00	-	0%	200	20	20,5	20,5	0,1	0,02	0,03
13:00	-	50%	300	20,5			0,01	0,04	0,01
14:00	-	100%	300	20,5	21	20,5	0,02	0,1	0,01
15:00	-	100%	200	20,5	21	20,5	0,03	0,04	0,01
16:00	-	100%	100	20,5	21	21	0,03	0,01	-
17:00	-	100%	100	20,5	21	21	0,03	-	-
18:00	-	50%	100	20,5	21	21	0,03	-	0,01

Results overview

	Reference project 1 Roller shading	Reference project 2 Venetian blinds	Design option Ch-LC + LC
Daylight Autonomy	83%	86%	85%
View availability	low	medium	high
Energy consumption lighting	45,5 kWh/y	37,5 kWh/y	38,2 kWh/y
Energy heating & cooling	127,1 kWh/y	113,7 kWh/y	41,3 kWh/y

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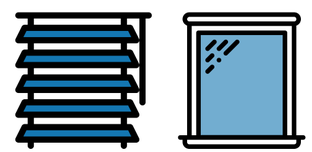
Pros & cons

2 levels of adaptation

Low maintainance

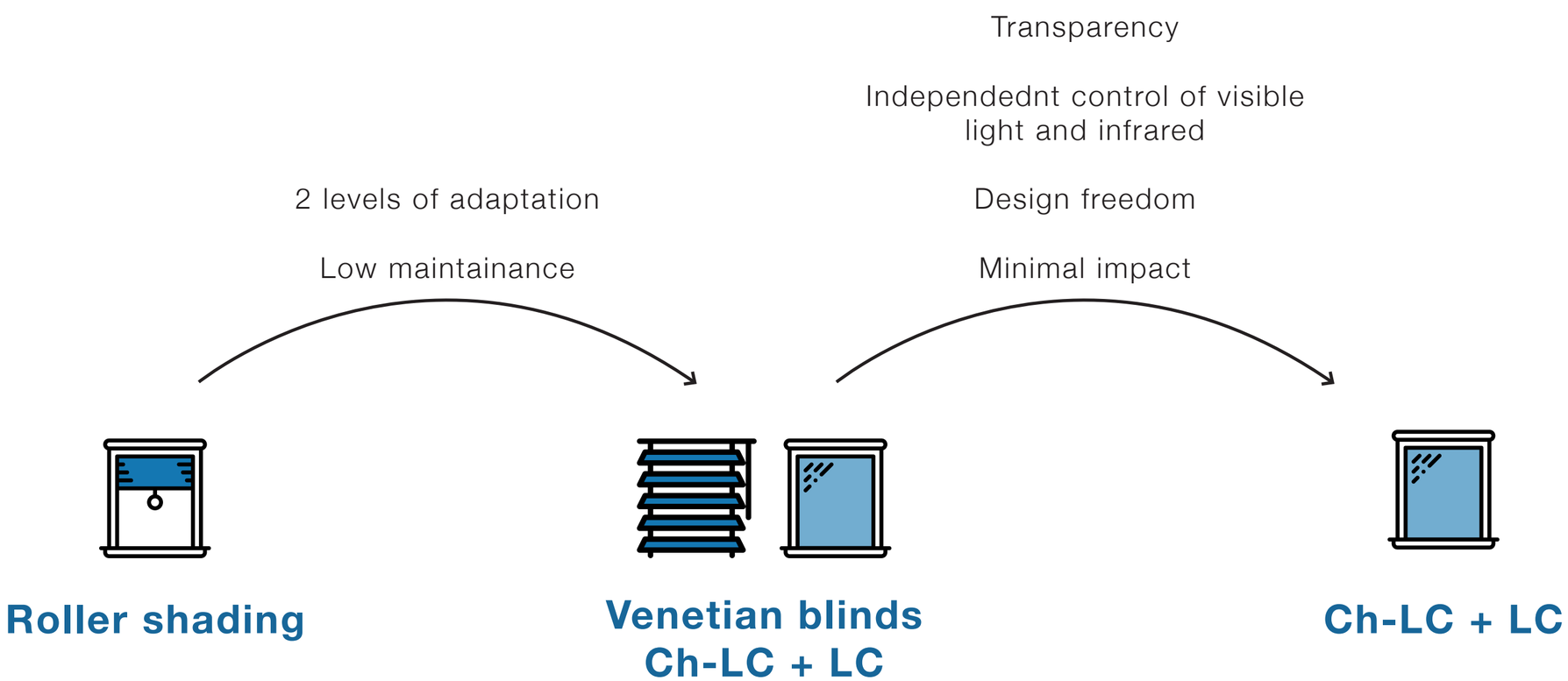
Roller shading



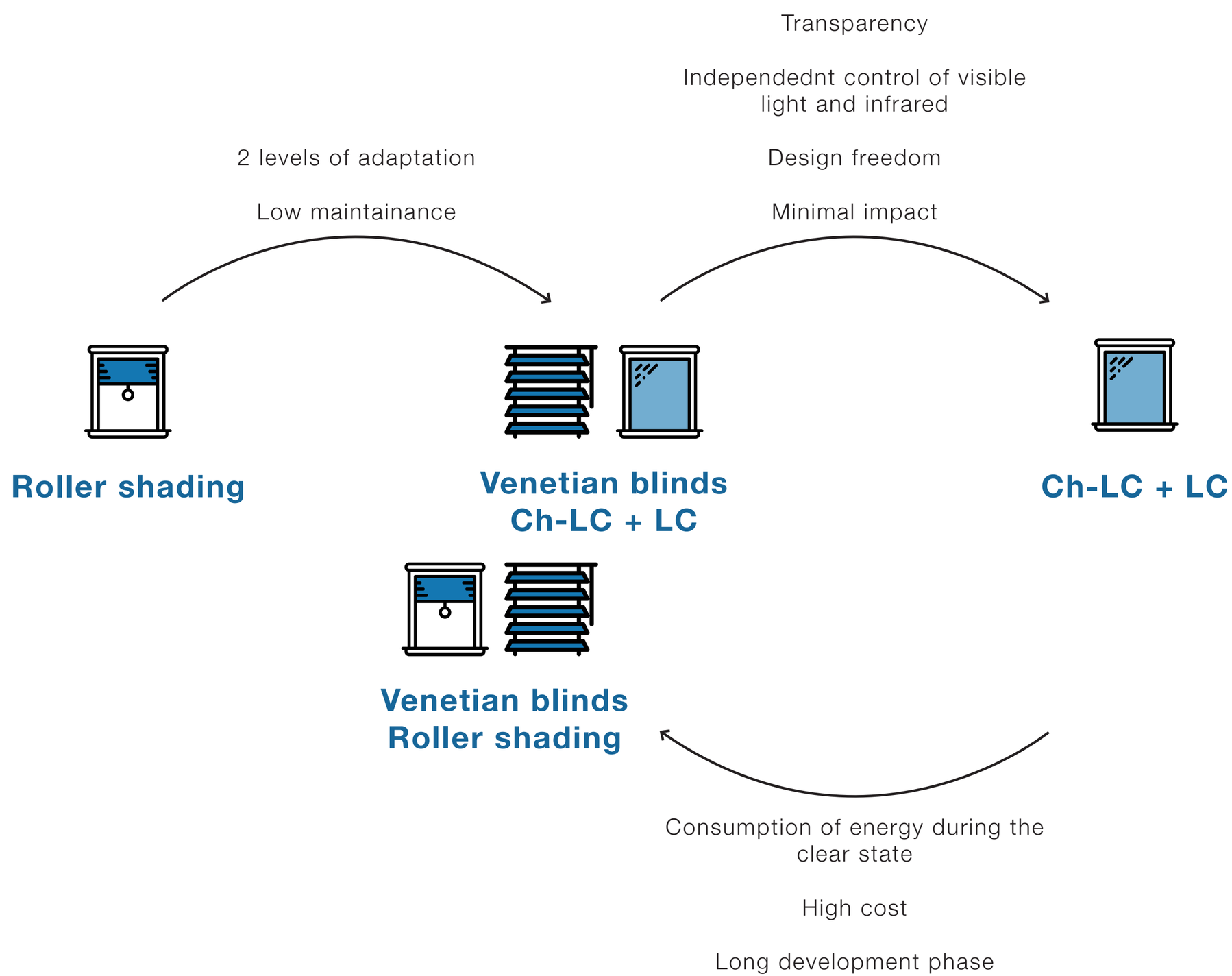
Venetian blinds

Ch-LC + LC

Pros & cons


2 levels of adaptation
Low maintainance
Transparency
Independednt control of visible light and infrared
Design freedom
Minimal impact
Roller shading
Venetian blinds
Ch-LC + LC
Ch-LC + LC

Pros & cons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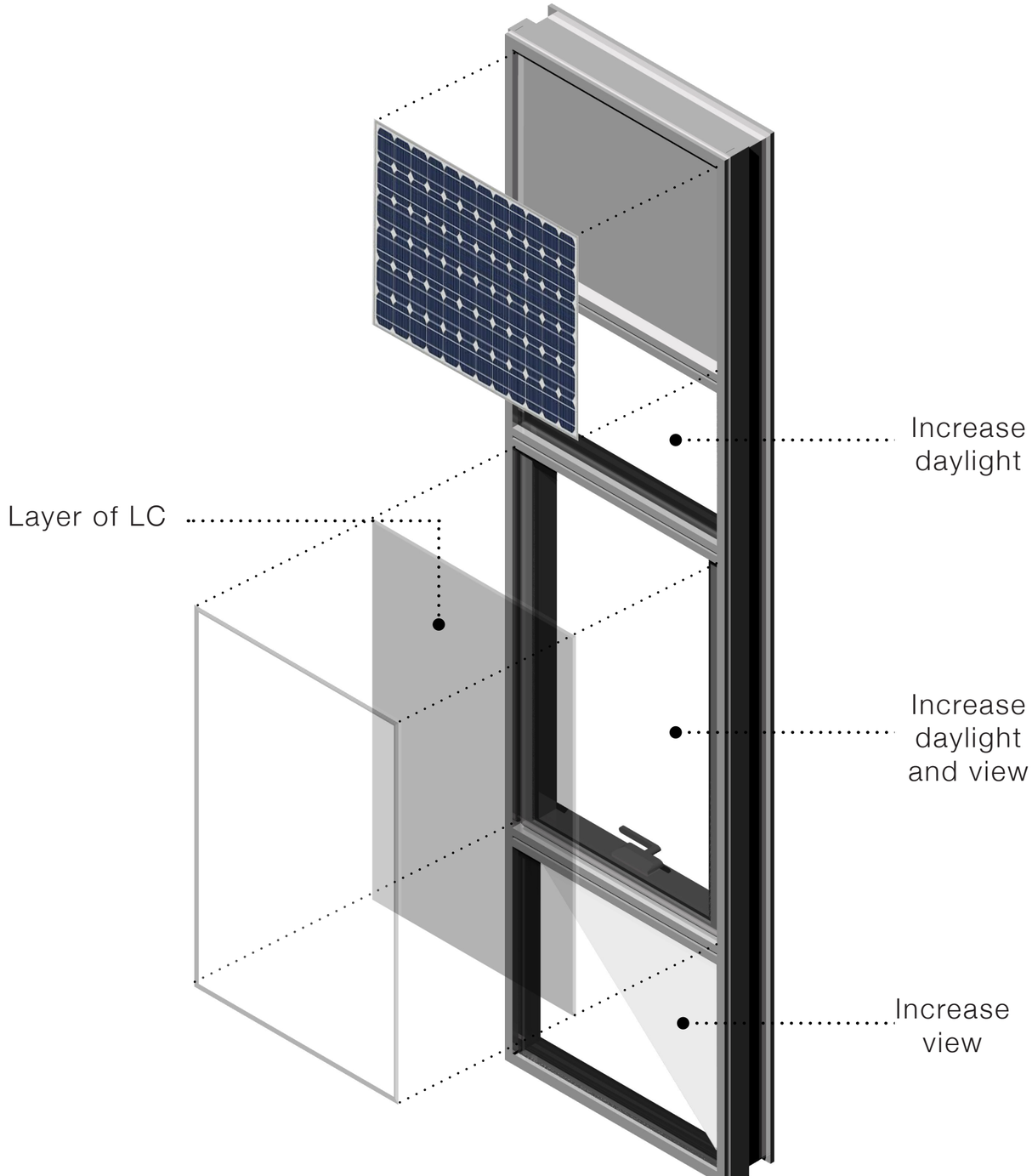
Venetian blinds
Ch-LC + LC
Ch-LC + LC
Venetian blinds
Roller shading
Consumption of energy during the clear state
High cost
Long development phase

Design

Unitised system

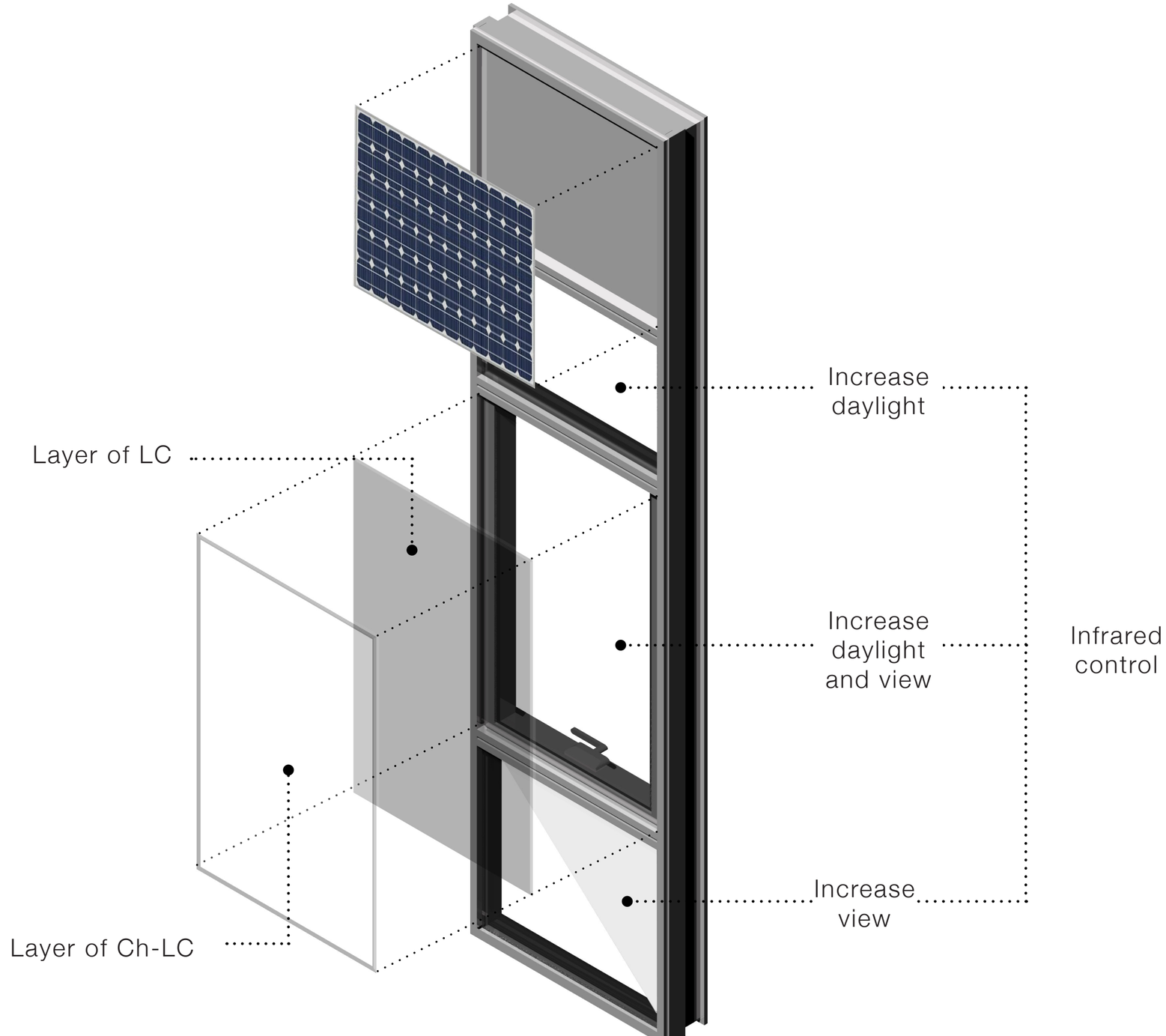
standard product



Design

Unitised system

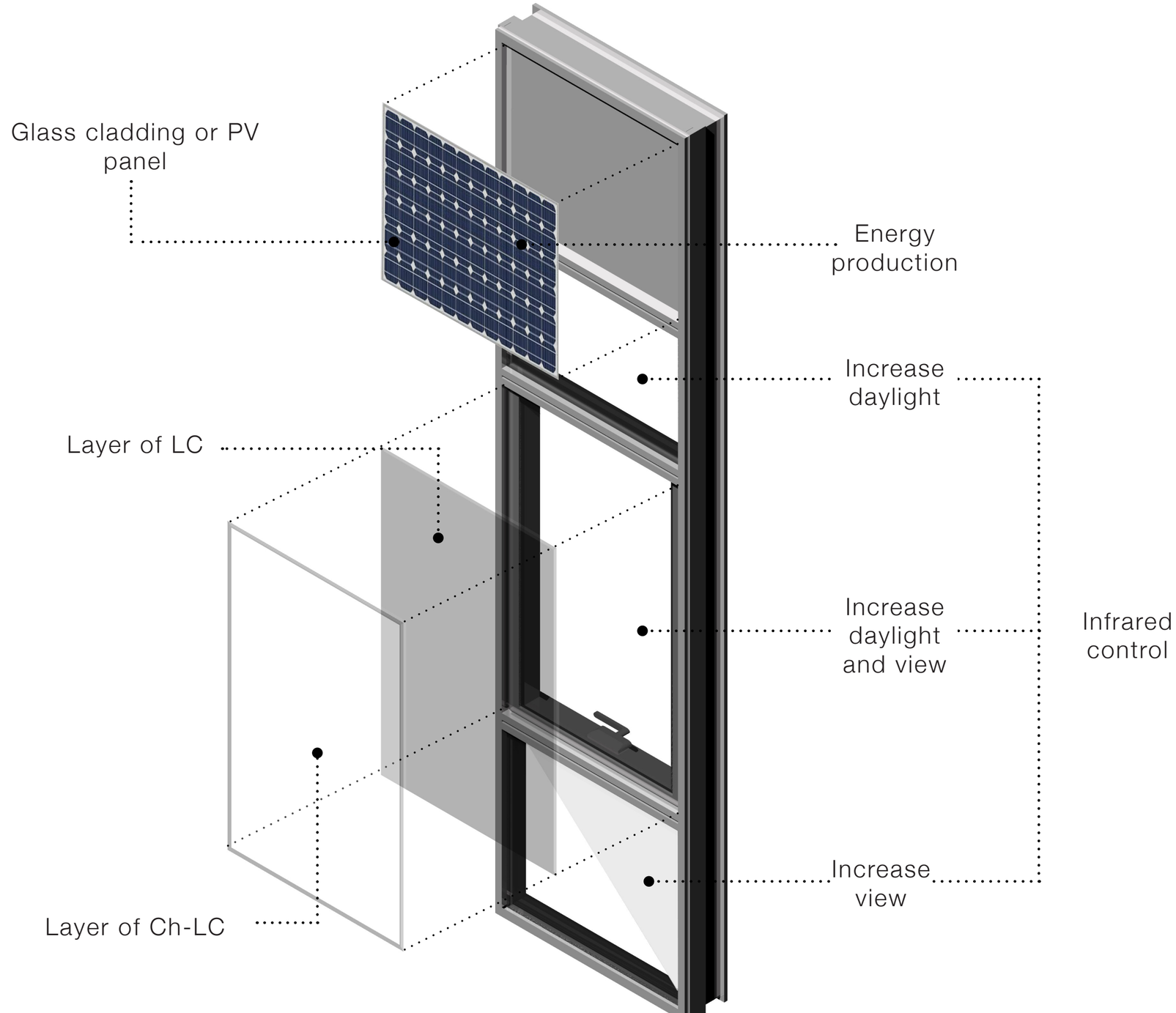
standard product



Design

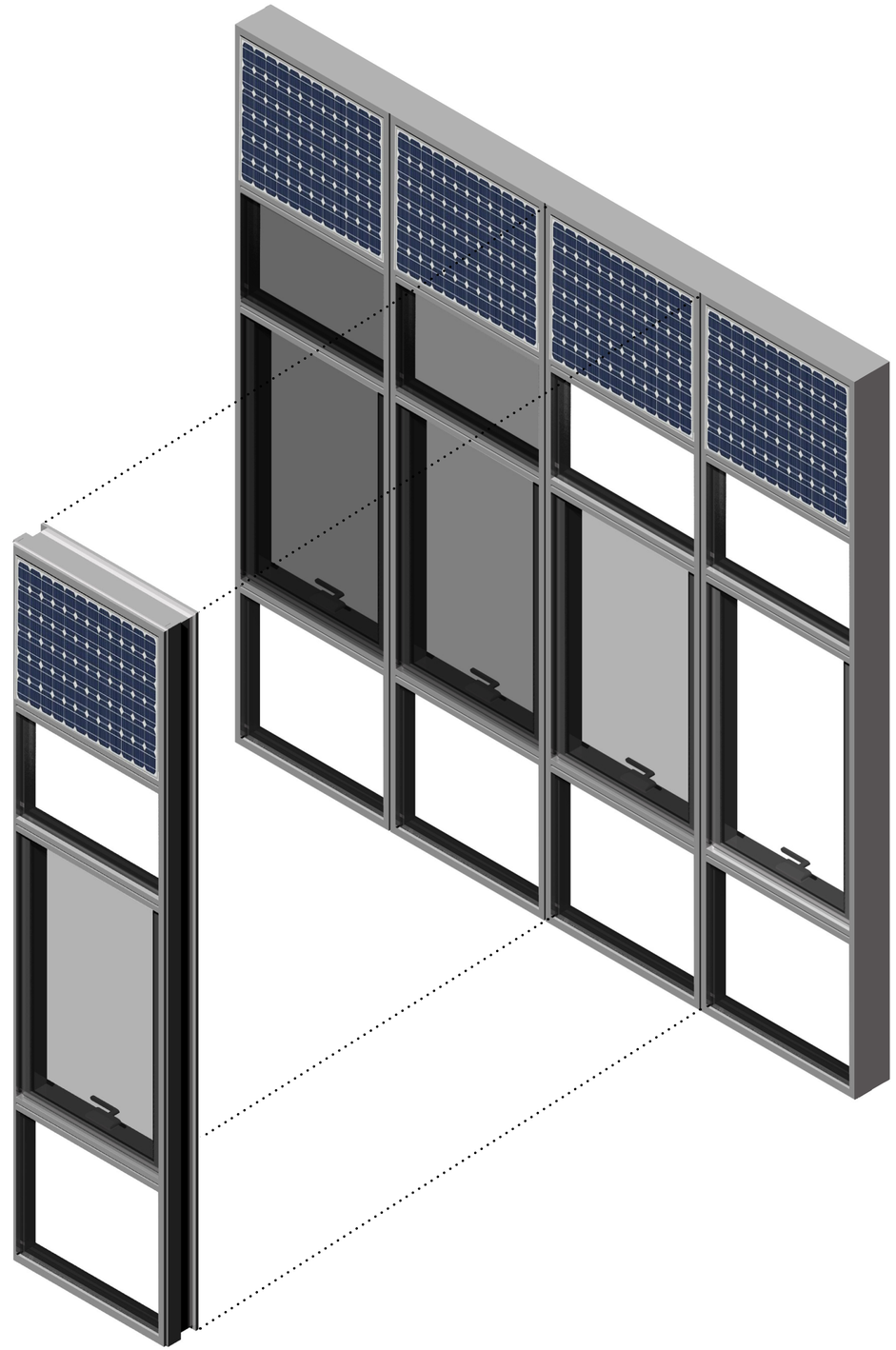
Unitised system

standard product

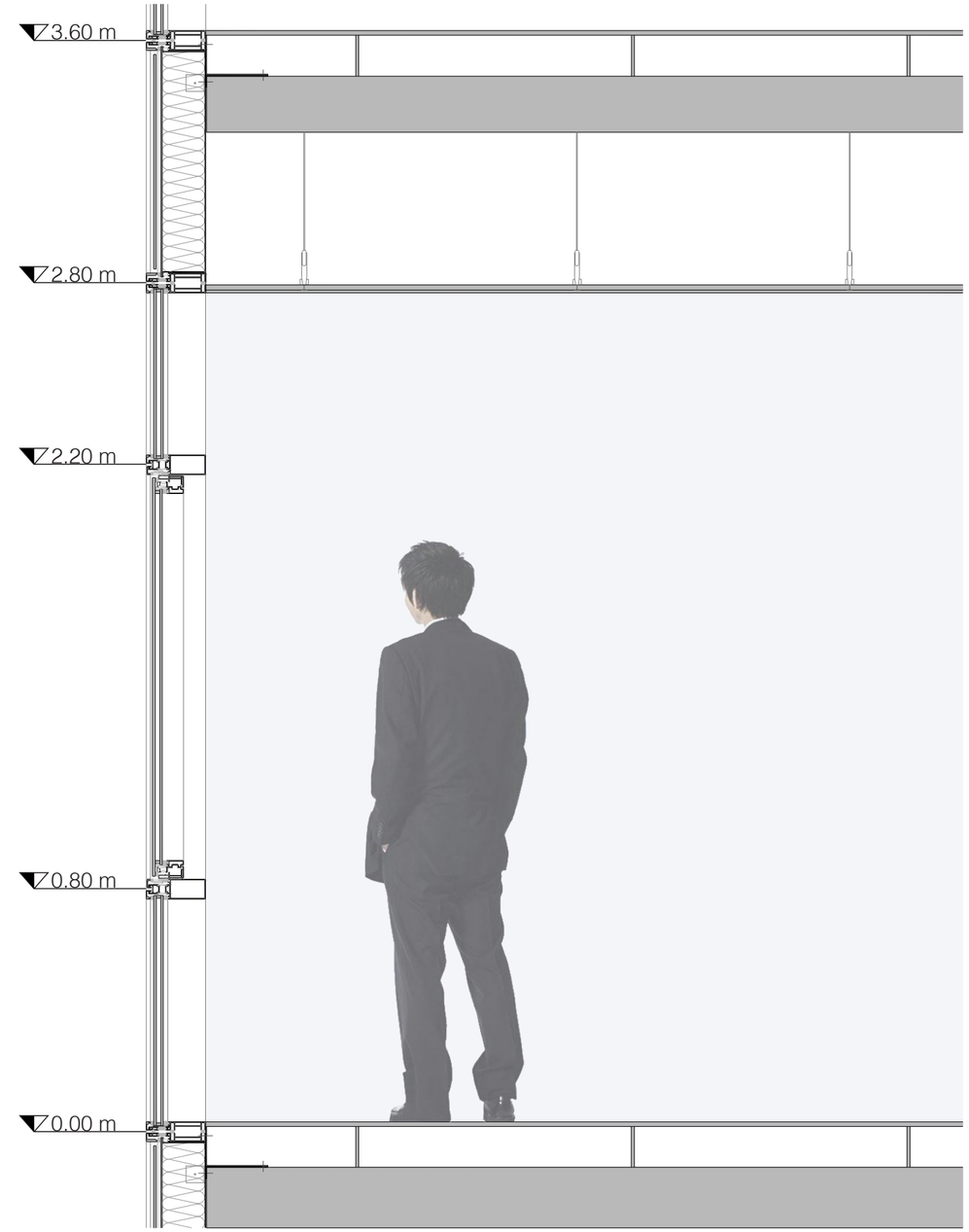


Unitised system

standard product



Design



Further developments

Different facade systems

Different dimension

Different shapes

Different colours

Different functions

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Different facade systems

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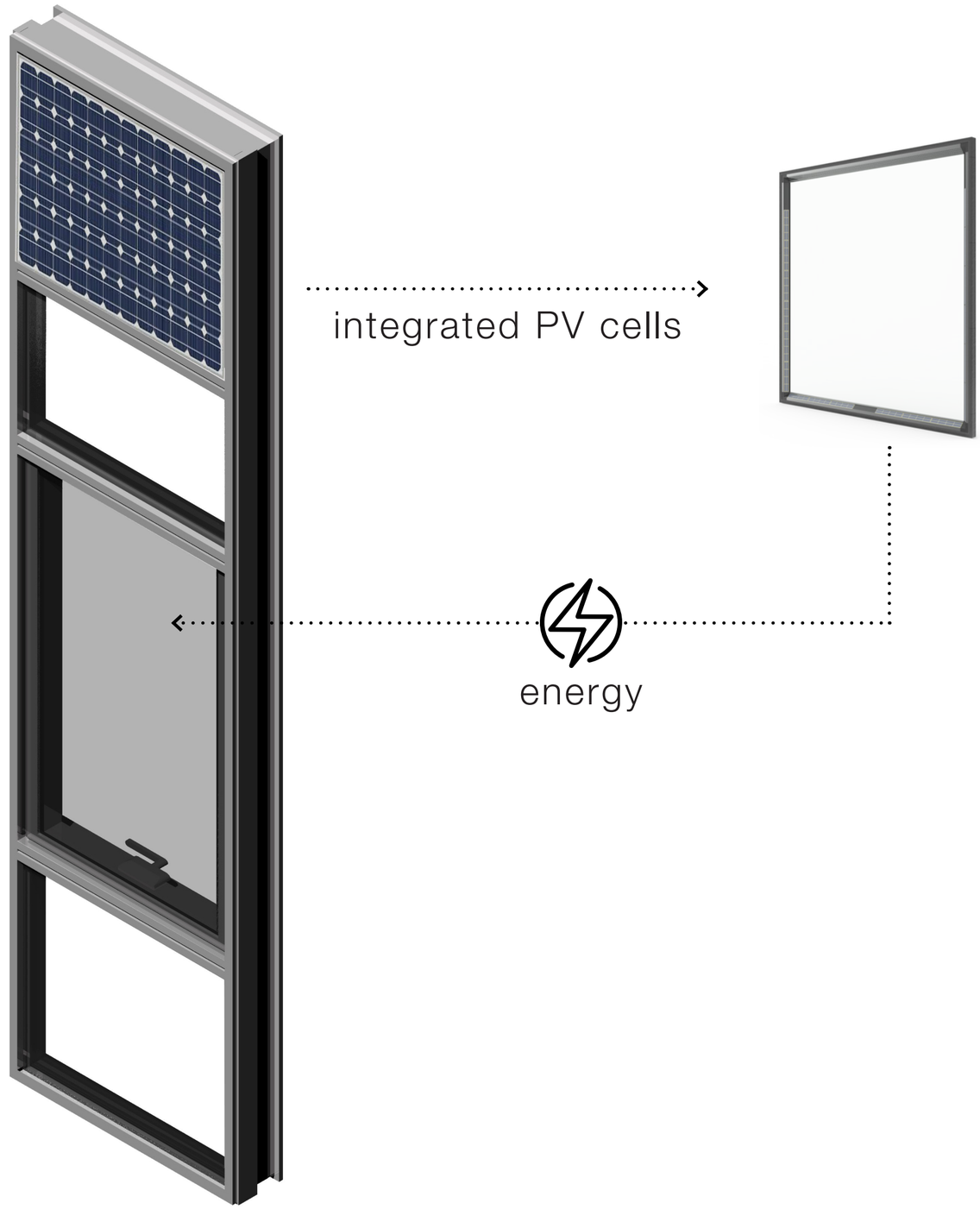


Further developments

Different facade systems

Different dimension

Different shapes

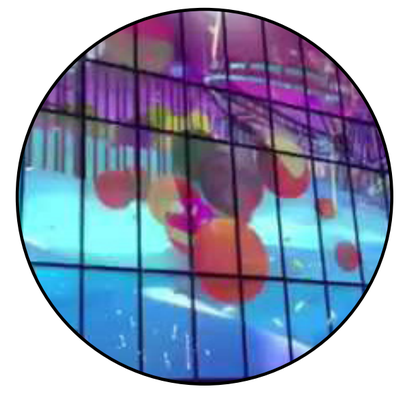
Different colours

Different functions

integrated PV cells

energy

projection



outdoor

Advertisment
interesting for leasing facade

indoor

Presentation
or group work
flexibility of interiors

THANK YOU