Microgrid Integration of Smart facades

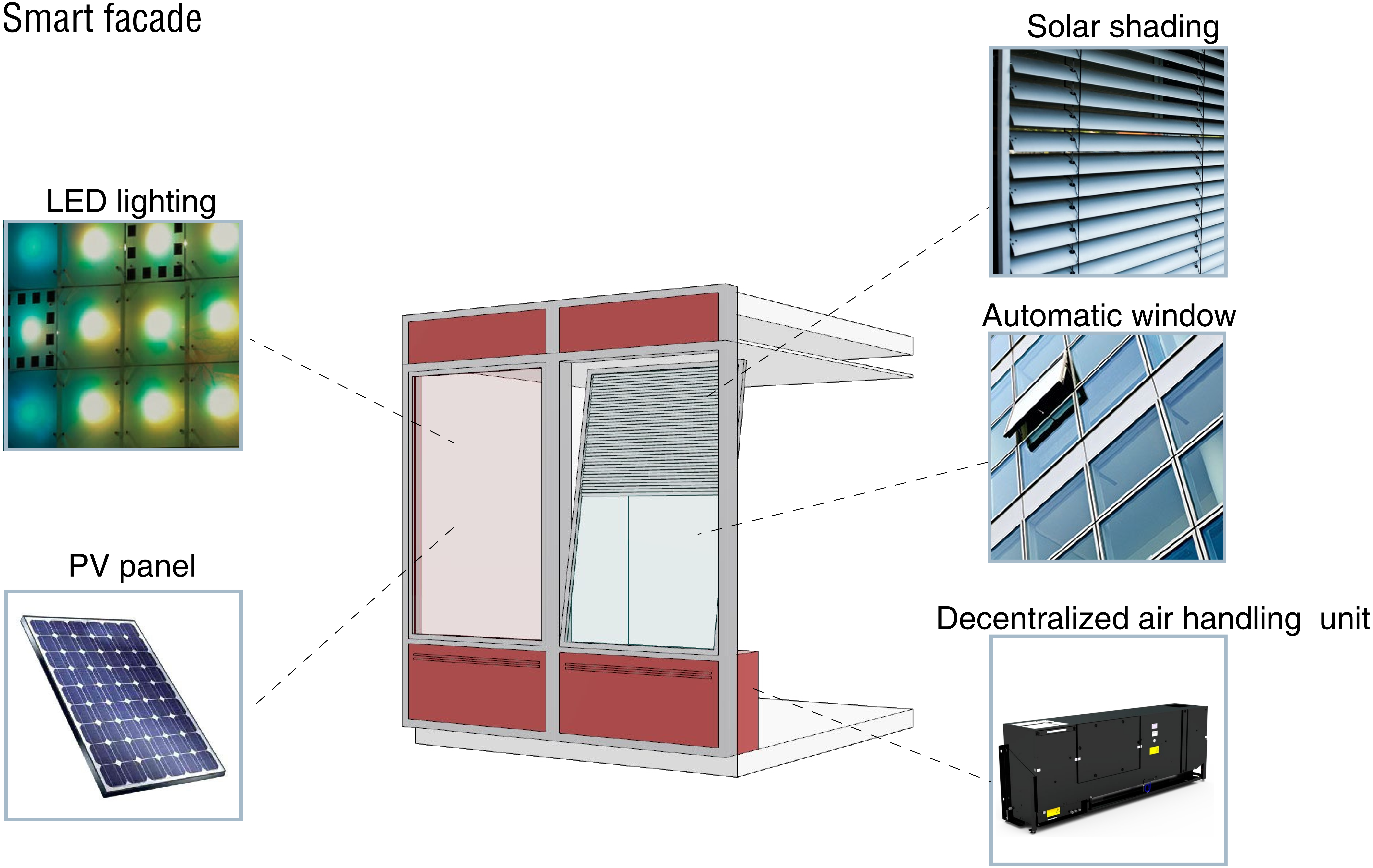
Integrated control of shading & operable window for CEG building

Graduation presentation by Jiahui Cai

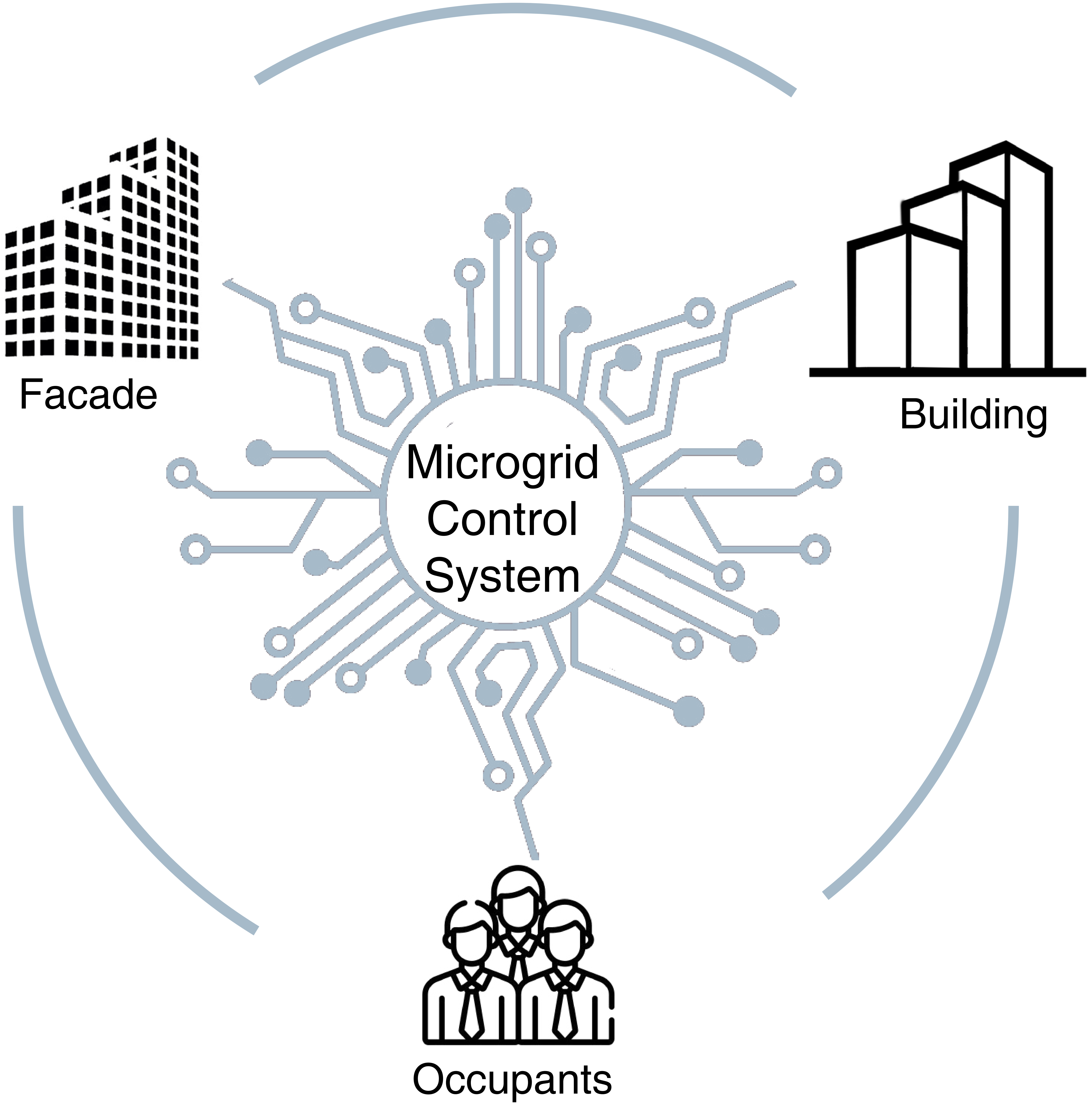
Content

Introduction

Introduction| Smart facade



Introduction| Microgrid integration



Smart Facade

Heating
Ventilation
Cooling
Lighting
Shading
Noise
Window open
PV

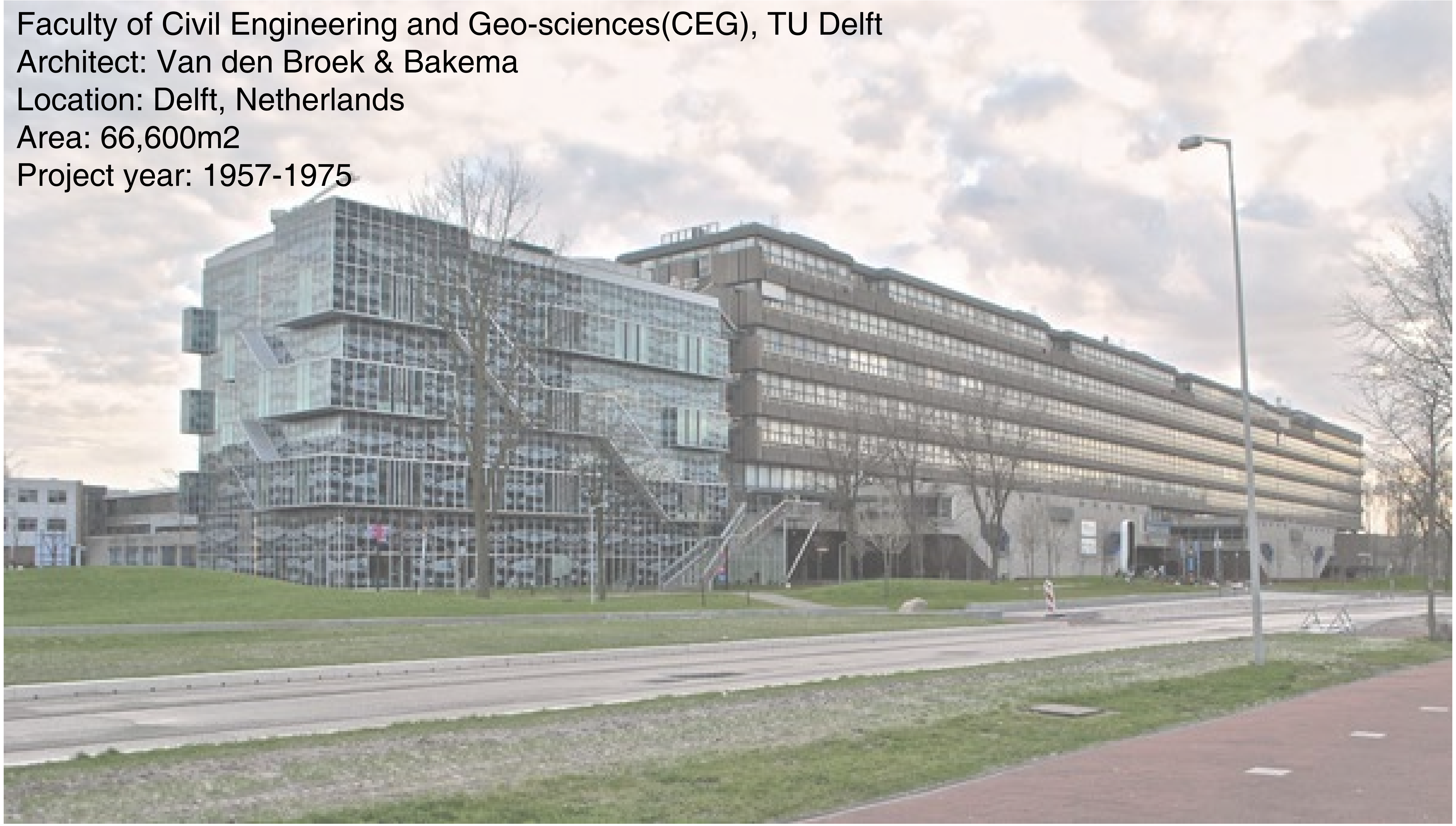
Human Comfort

Temperature
IAQ
Humidity
Acoustic comfort
Visual comfort

Others

Energy performance
Occupancy
Maintenance
Safety
Life span

Introduction| Project base



source: https://www.tudelft.nl/citg/

North

Heating

source: http://campusdevelopment.tudelft.nl/en/project/heating-network-transition-programme/

West

East

?

Facade Leasing Demonstrator Project (FLDP)
-> 2017 Began
-> 2018.11 East facade analysis, monitoring, prototyping

Problem statement

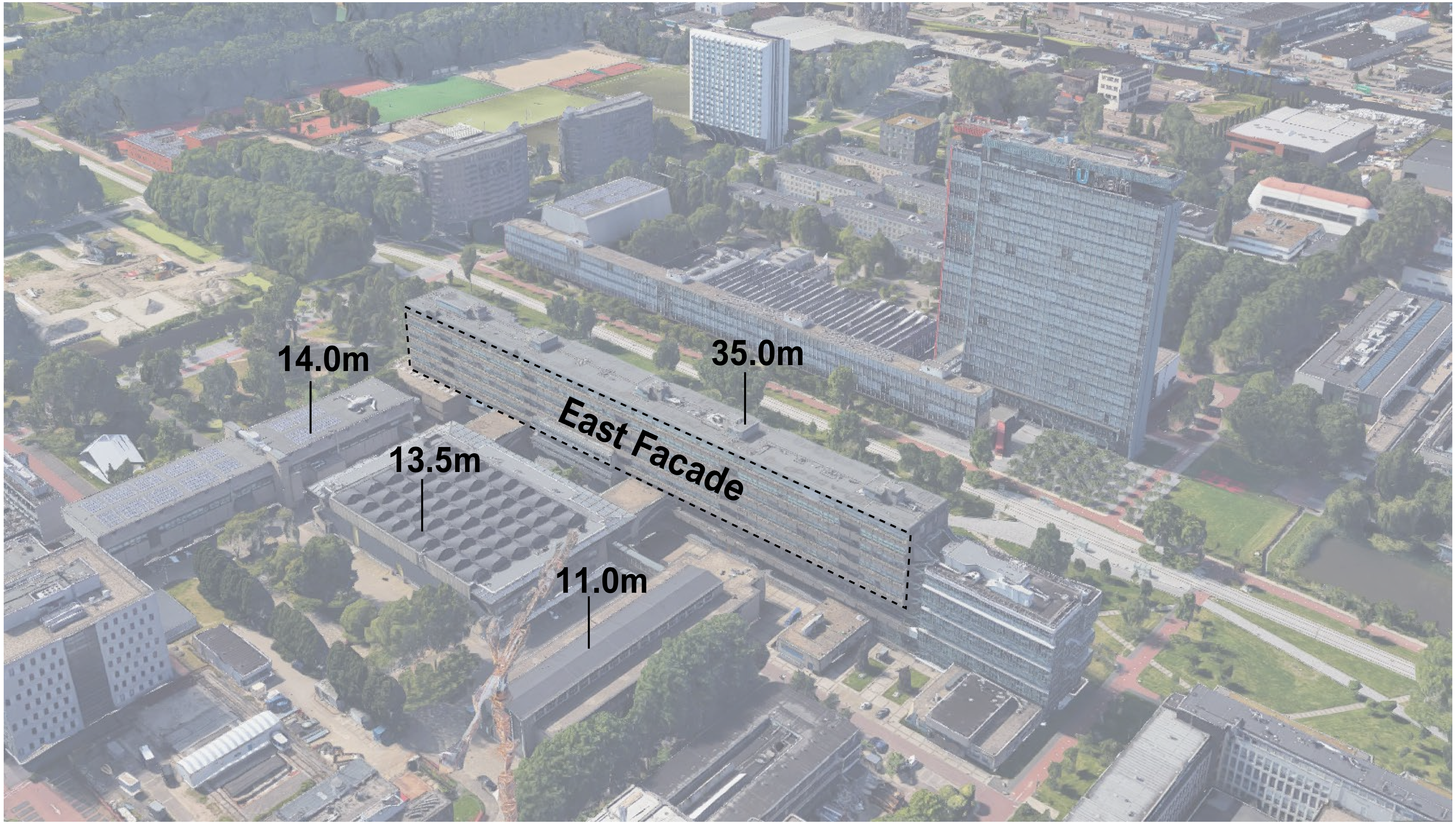
The CEG east facade has poor thermal performance and energy con-sumption and needs a solution to fulfill the indoor comfort requirement.

Reseach question

How can the integrated control of smart facade contribute to the indoor comfort for the east of CEG?

CEG east facade

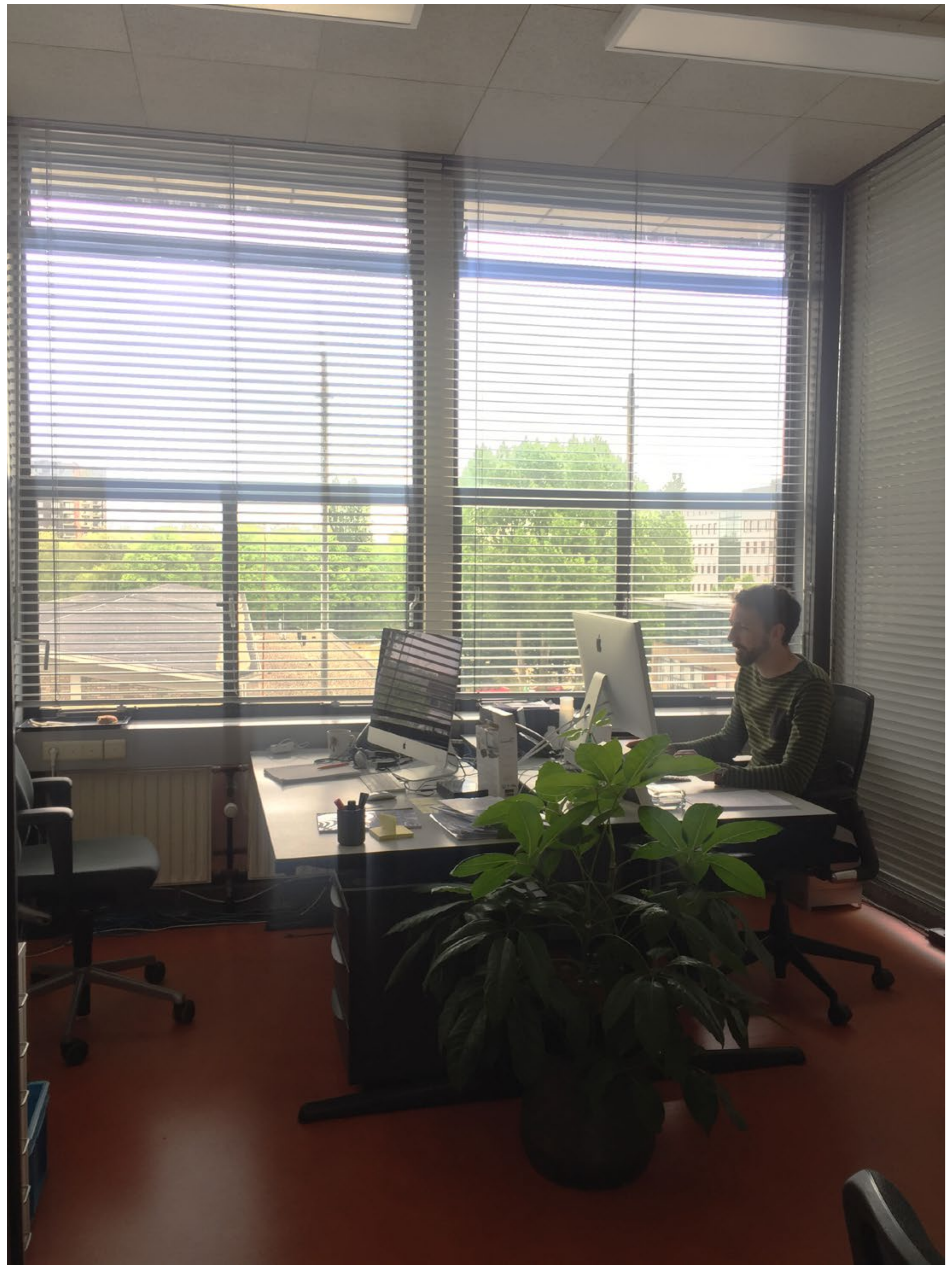
CEG east facade| Surroundings



CEG east facade| Settings

East facade

East Room



2th-5th floors: Office

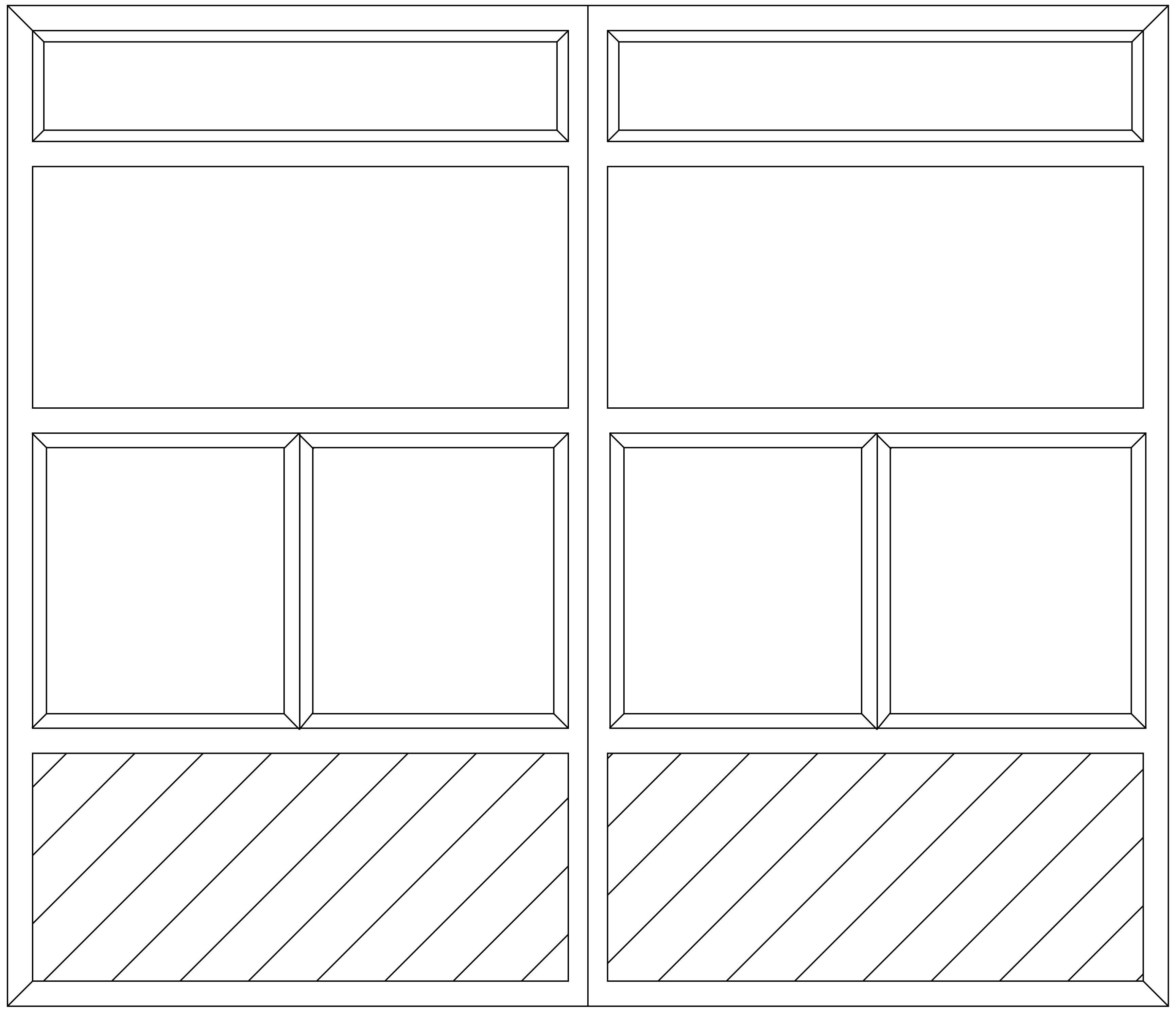
No air conditioning
No heating in summer

CEG 2017: 107.60 kWh/m2
BENG: 50 kWh/m2

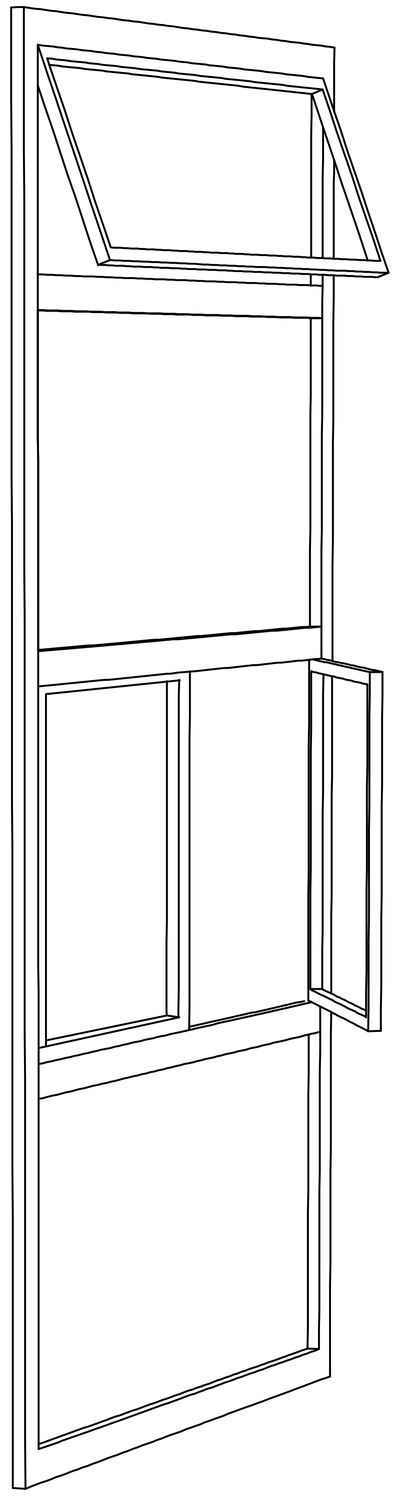
Construction

Single glazing

Ug=5.42 W/m²K   Uf=2.2 W/m²K   g=0.81

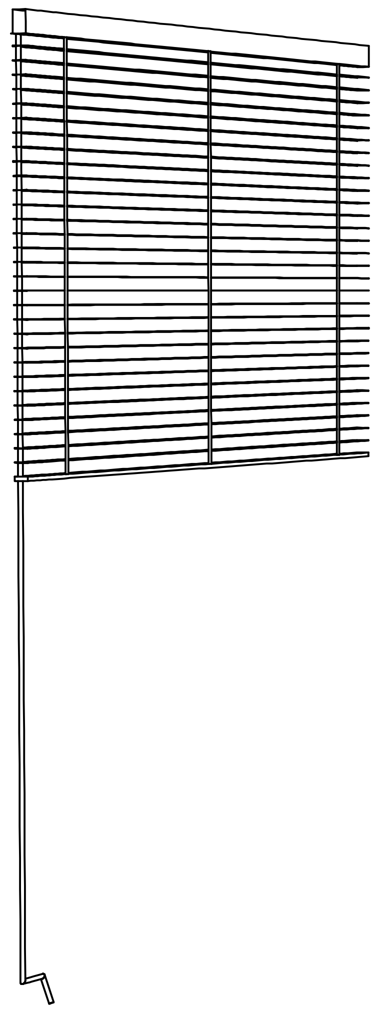


Manual control



Top:
tilt outwards

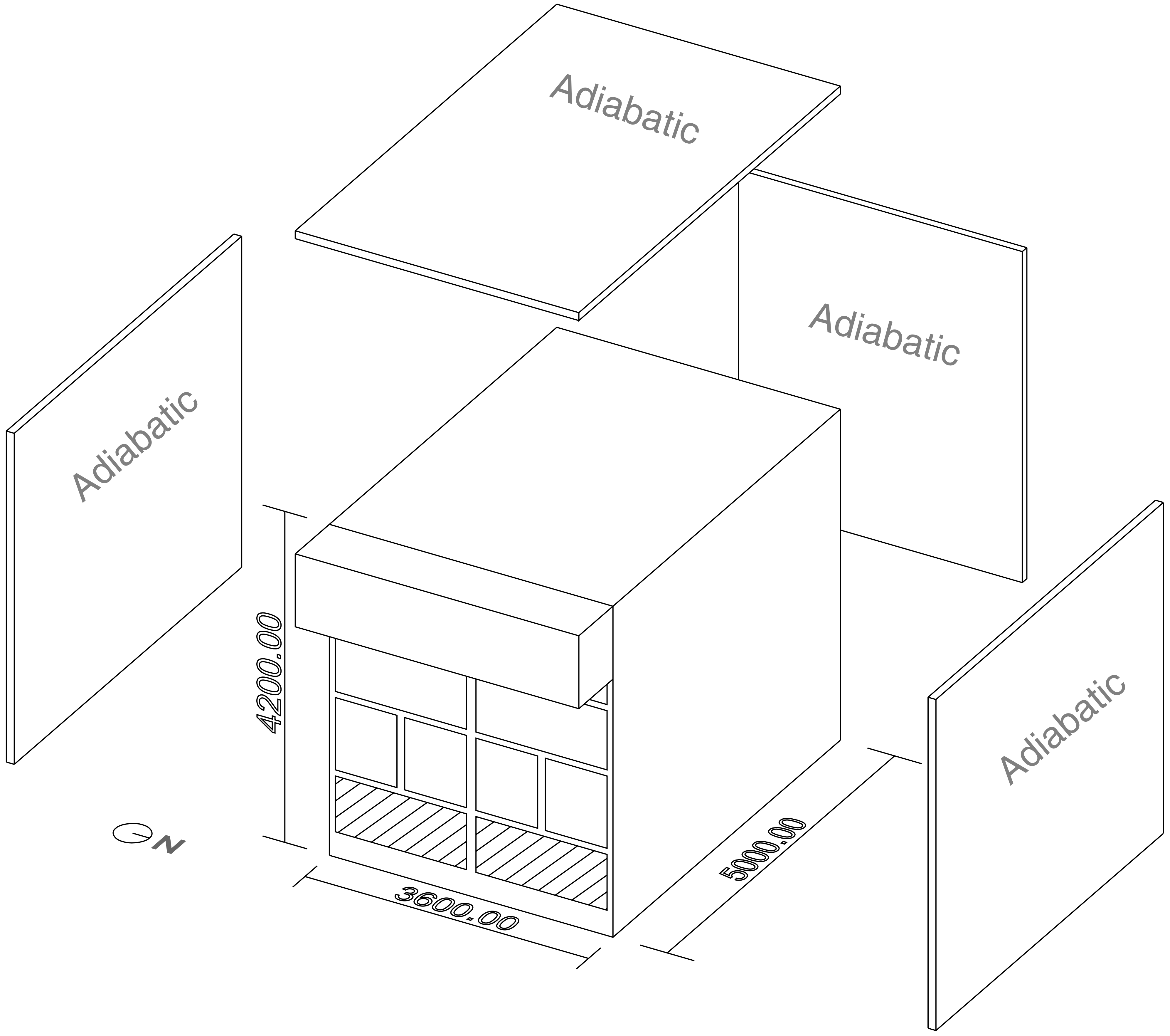
Bottom:
turn ourwards



Blinds:
adjust height
Slats:
horizontal
vertical

CEG east facade| Performance

DesignBuilder
Base model



OfficeVitae
monitoring data

Annual performance

	Old constrcution
Discomfort	259.5 hrs
Heating	108.2 kWh/m2
Lighting	9.7 kWh/m2

CEG 2017: 107.60 kWh/m2

Design logic

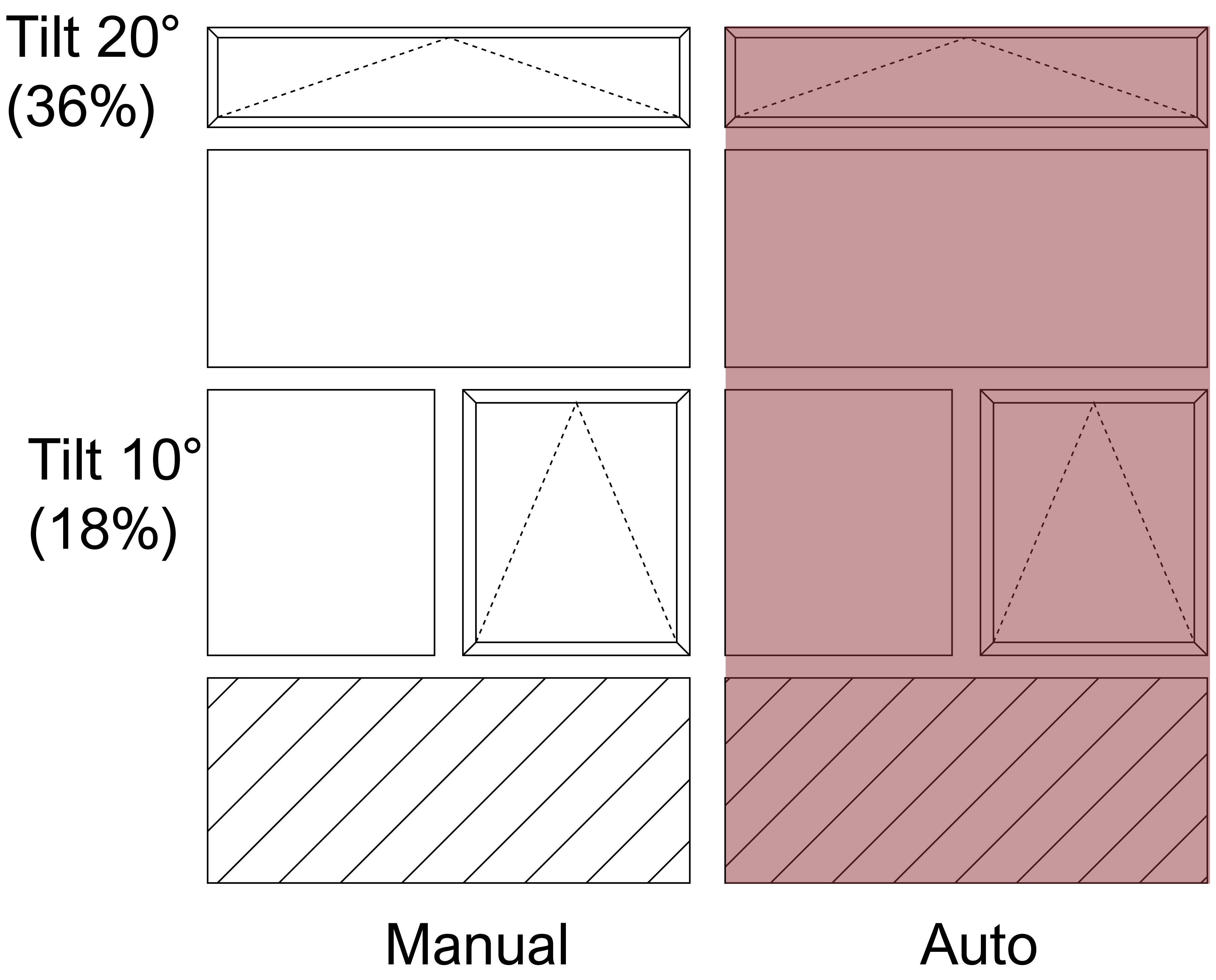
New construction

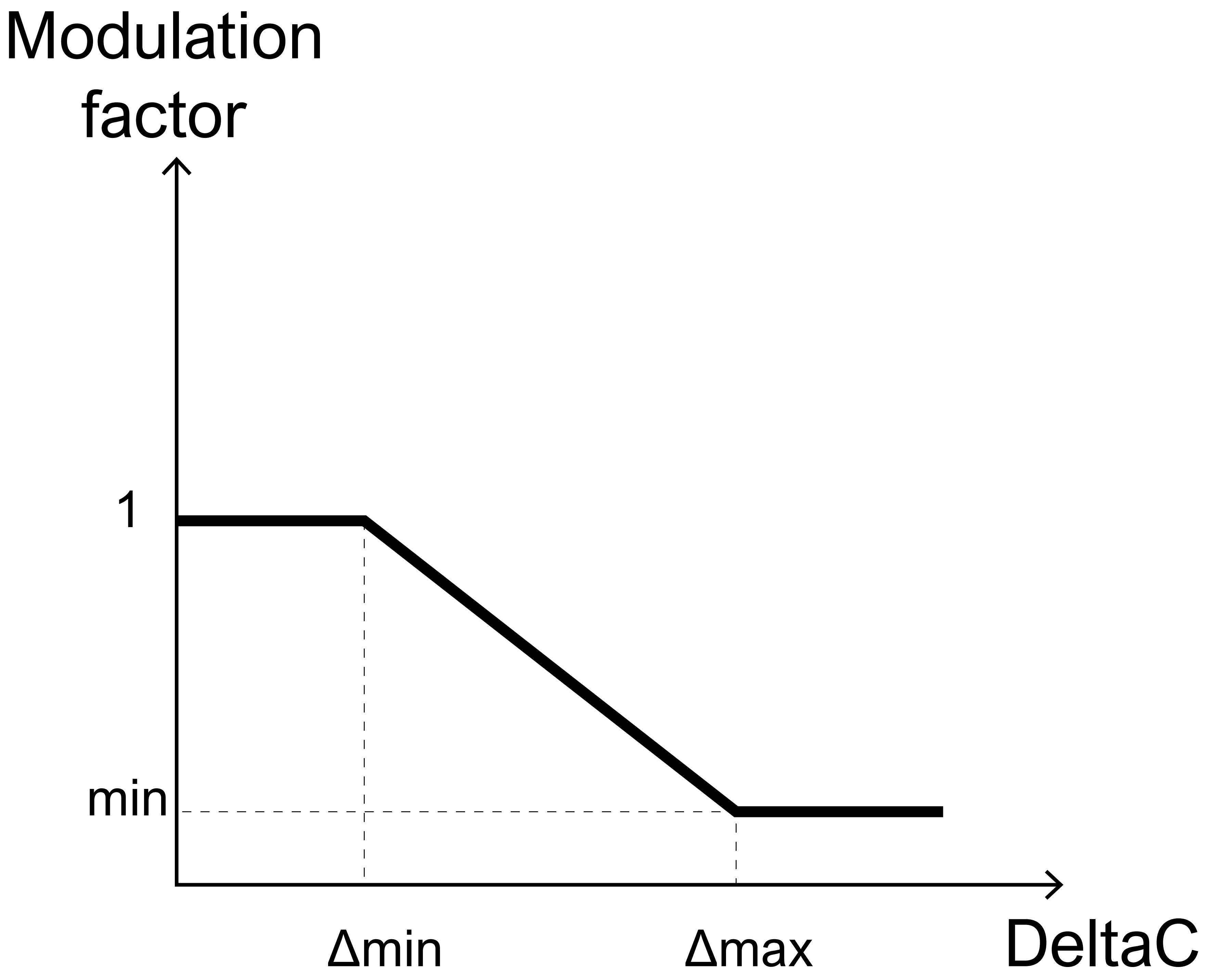
Ug=0.7 W/m²K
g=0.53
Lt=0.698
Uf=1.1W/m²K
Us=0.8W/m2K

Old construction

Ug=5.42 W/m2K
g=0.81
Lt=0.88
Uf=1.1W/m²K
Us=0.8W/m2K

Design logic | Control variables





Window control

Tin

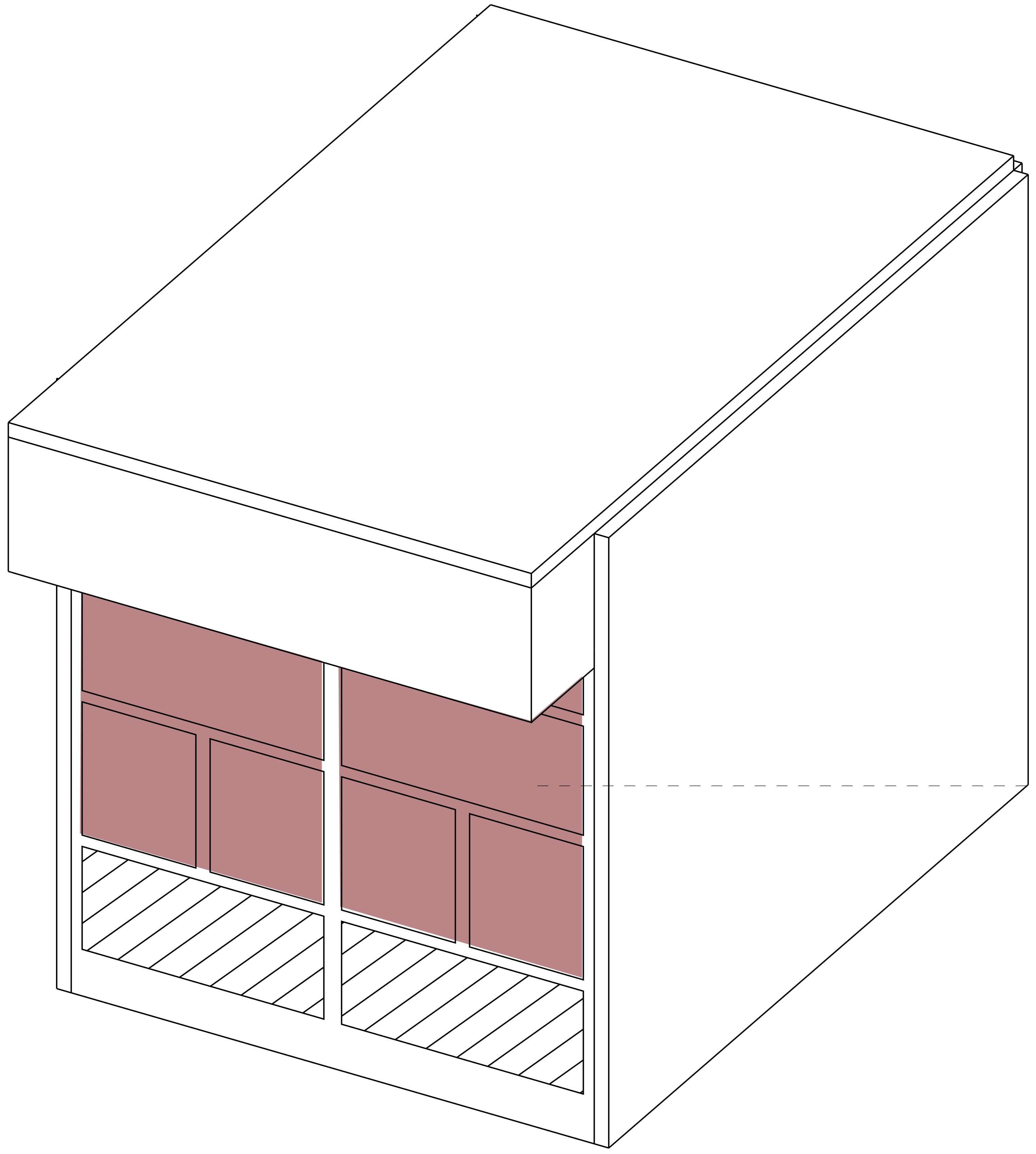
DeltaC

Opening number

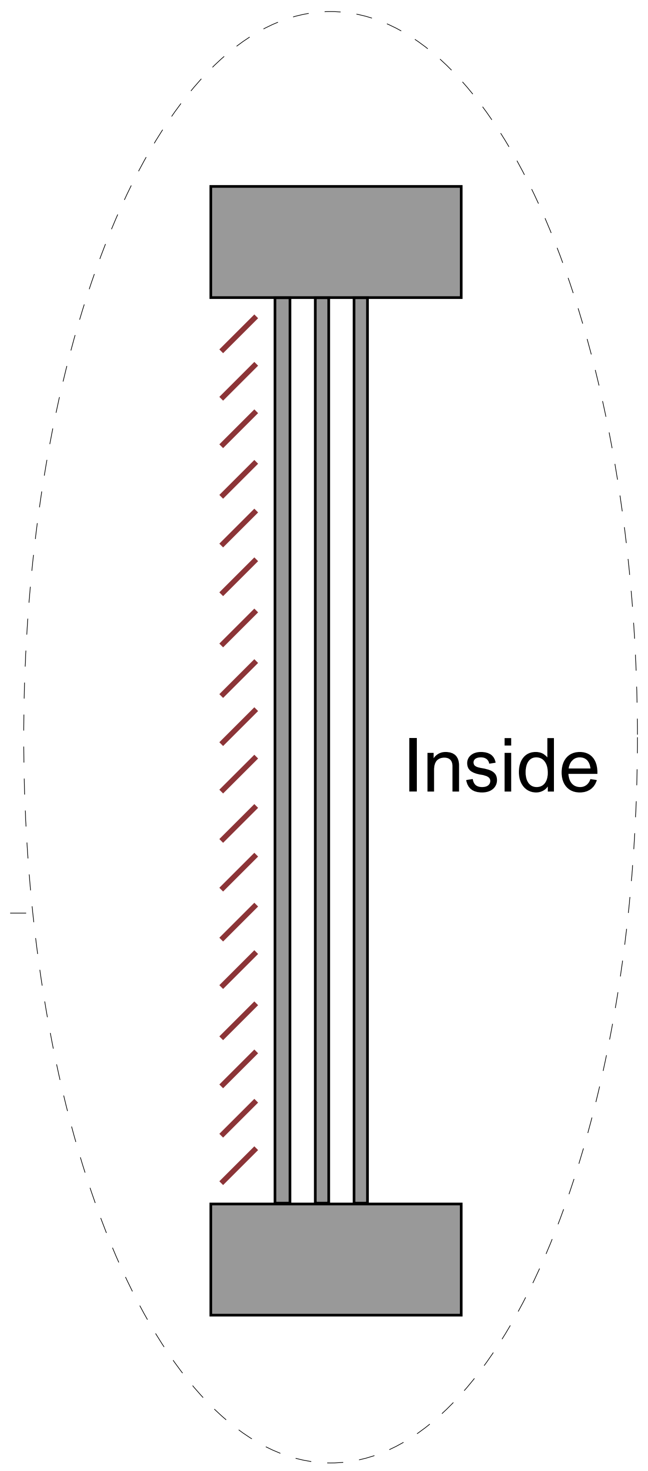
Opening size

Schedule

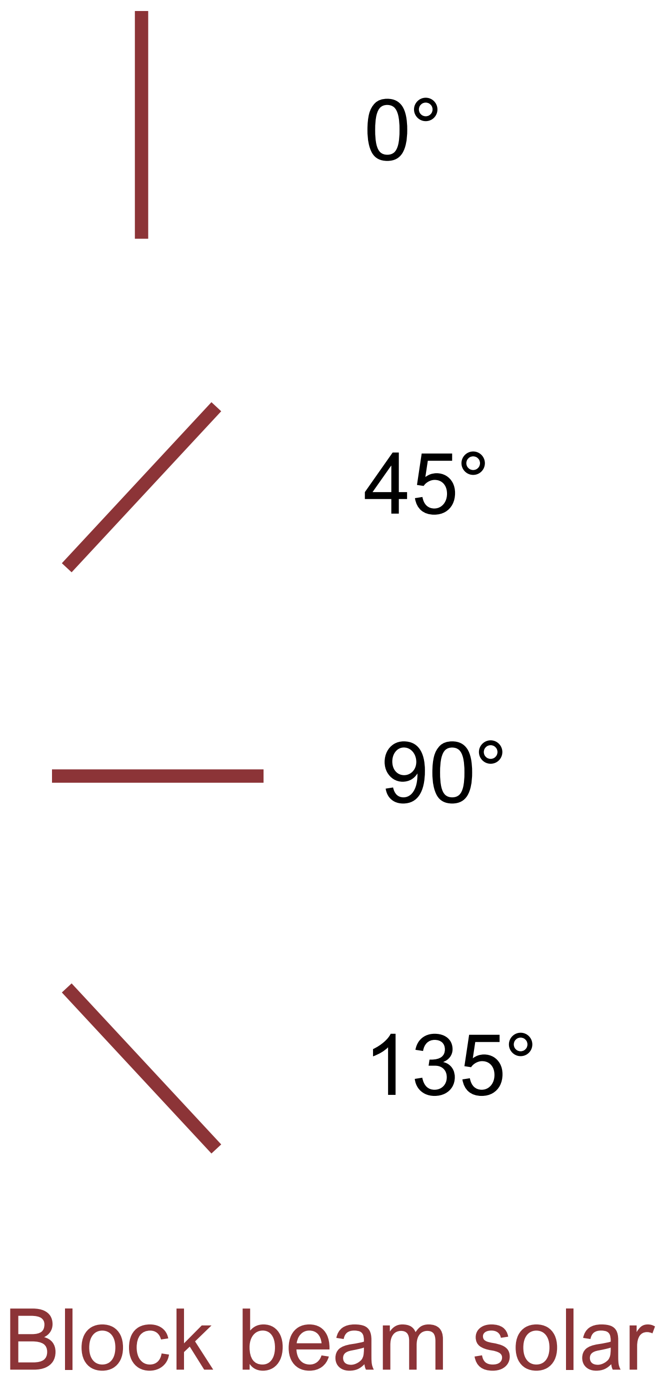
Design logic | Control variables



Blinds covered area



Slatted blinds



Slat angle

Shading control

Blinds	Slats
Tin	0°
Horizontal solar irradiance	45°
Solar radiation	90°
Night Tin	135°
Schedule	Block beam solar

Control requirement

Illuminance $\geqslant$ 500lux

Air change rate $\geqslant$ 0.66ach

Tin $\in$ [20, 26]

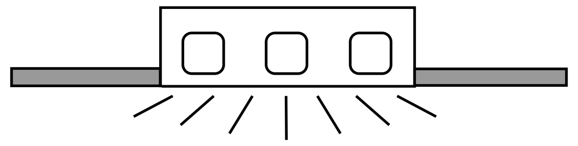
Control requirement

Illuminance ⩾ 500lux

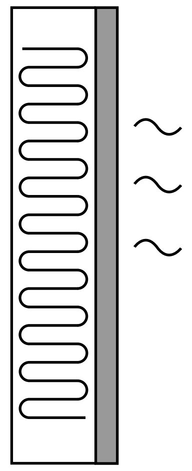
Air change rate ⩾ 0.66ach

Tin ∈ [20, 26]

Blank group



Illuminance ⩾ 500lux



Heating Tin>20℃

Design logic| Basic process

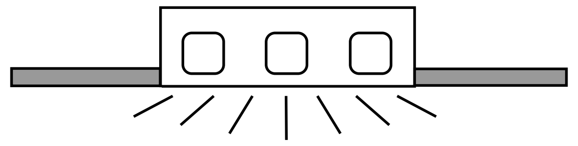
Control requirement

Illuminance ⩾ 500lux

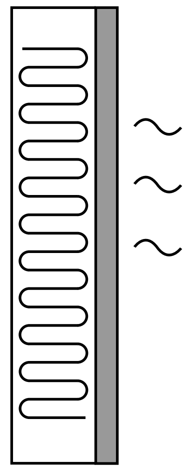
Air change rate ⩾ 0.66ach

Tin ∈ [20, 26]

Blank group

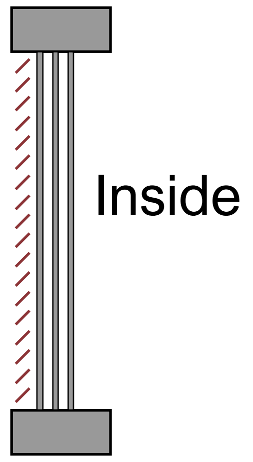


Illuminance ⩾ 500lux



Heating Tin>20℃

Shading group



Hot day : Tin ∈ [20, 26]

Cold day : Less energy

Design logic| Basic process

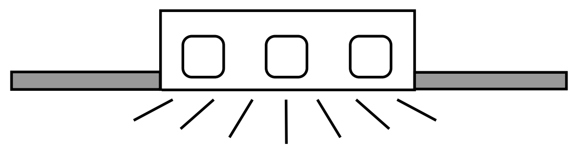
Control requirement

Illuminance ⩾ 500lux

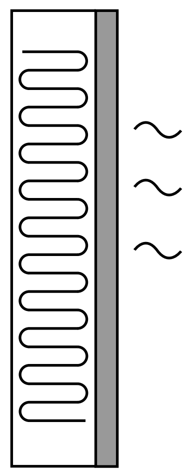
Air change rate ⩾ 0.66ach

Tin ∈ [20, 26]

Blank group

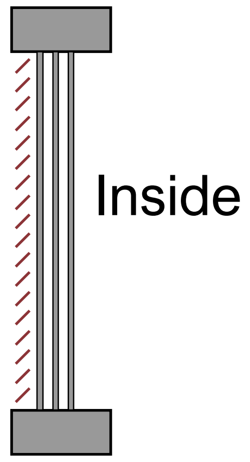


Illuminance ⩾ 500lux



Heating Tin>20℃

Shading group

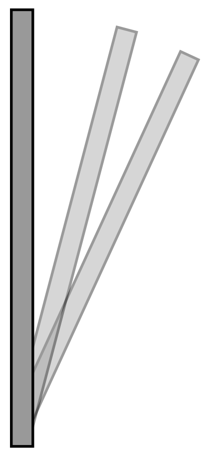


Hot day : Tin ∈ [20, 26]

Cold day : Less energy

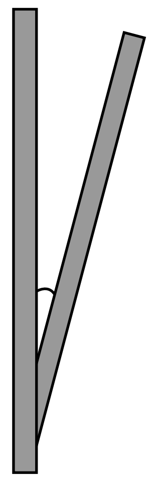
Vent group

Hot day



Tin ∈ [20, 26]

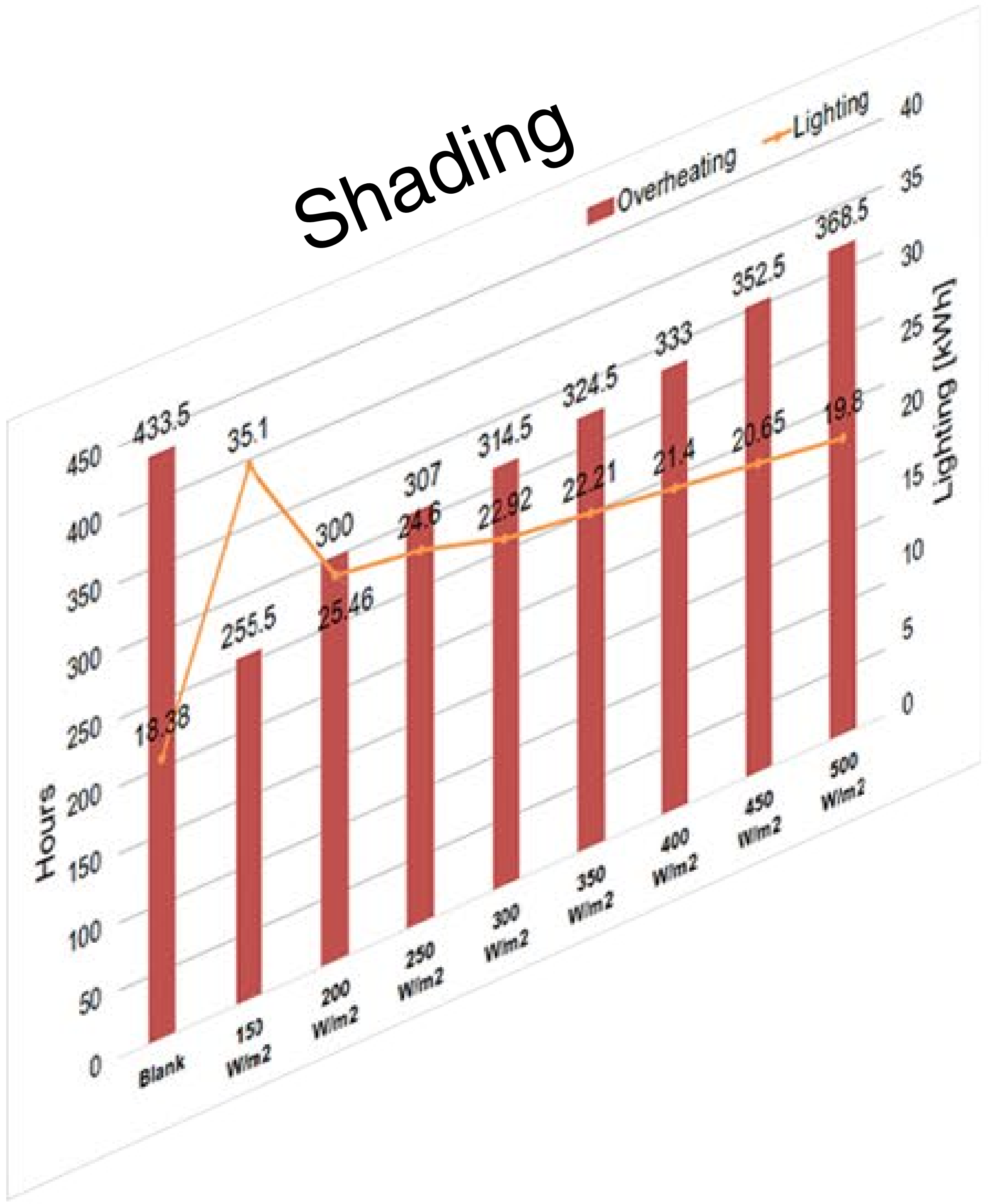
Cold day



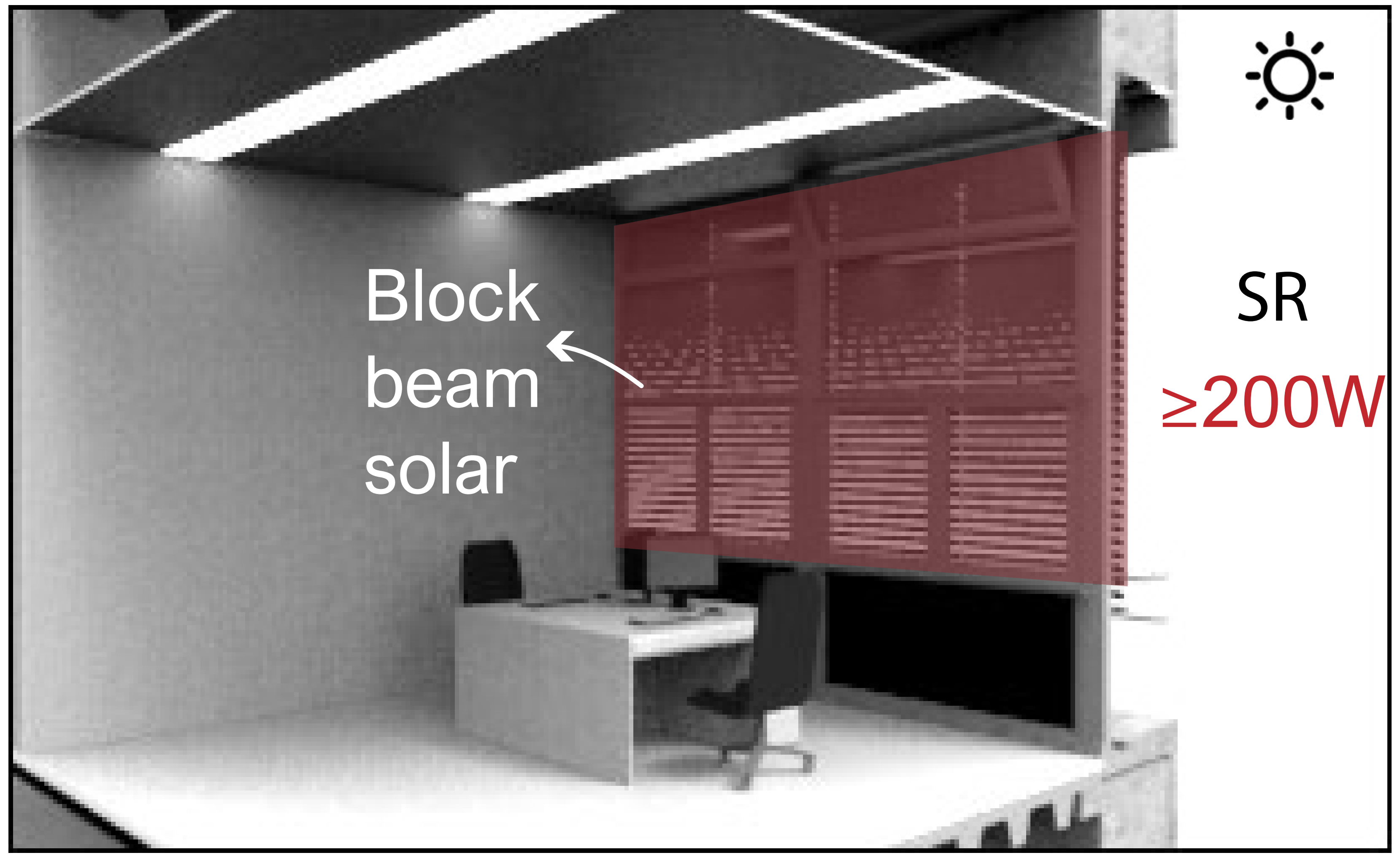
Air change rate ≥ 0.66ach

Design proposals

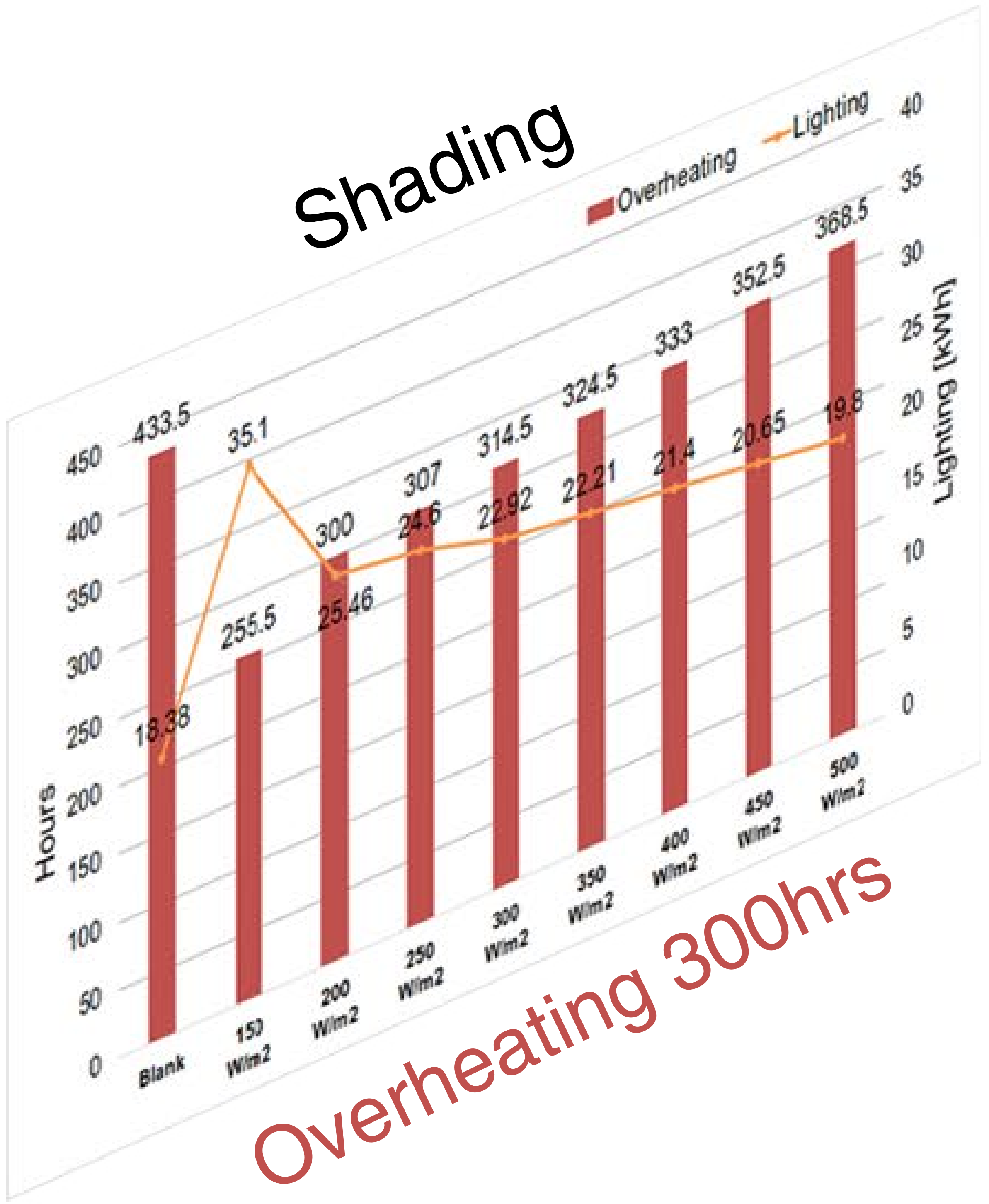
Summer

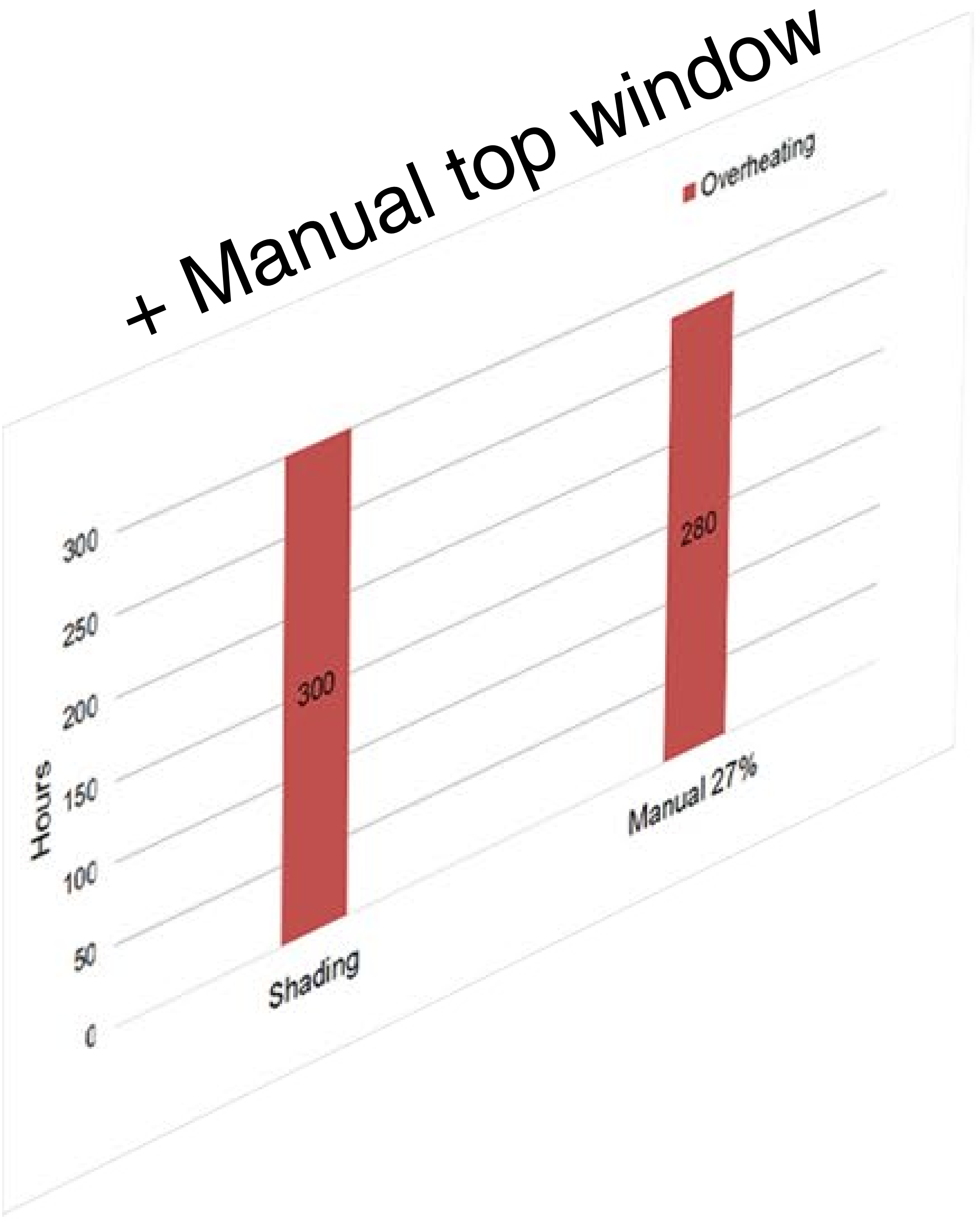


Overheating 300hrs

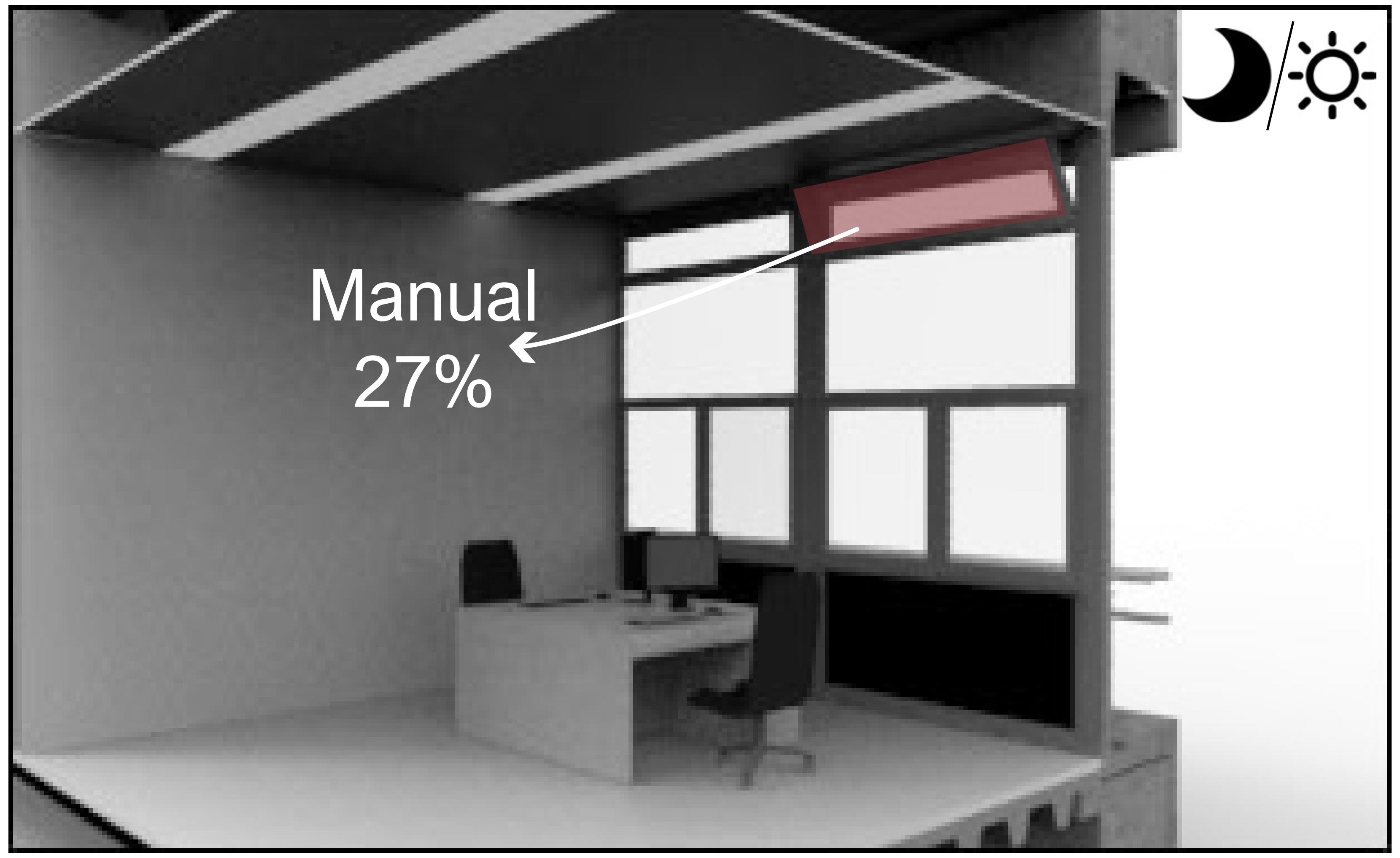


Summer

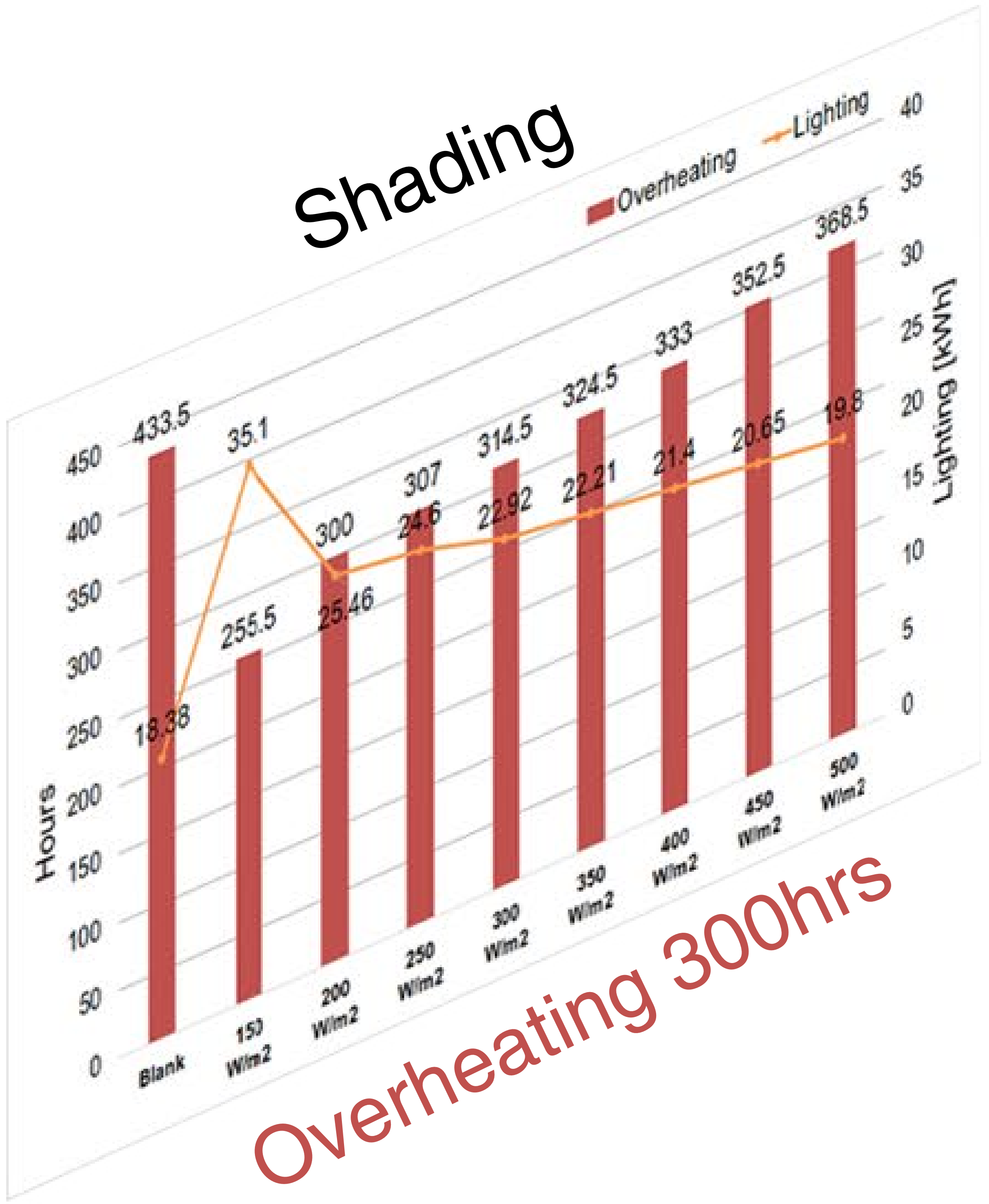


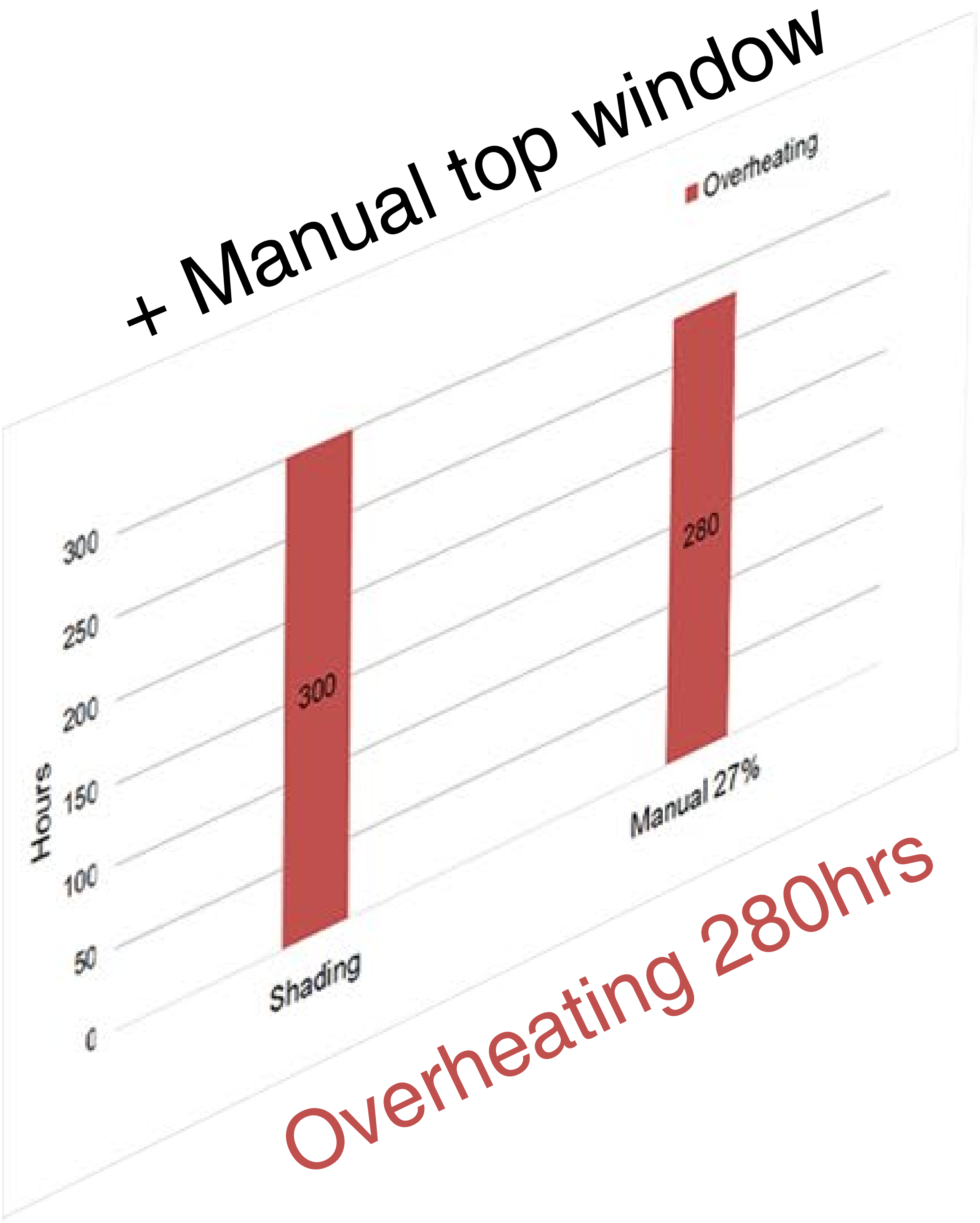


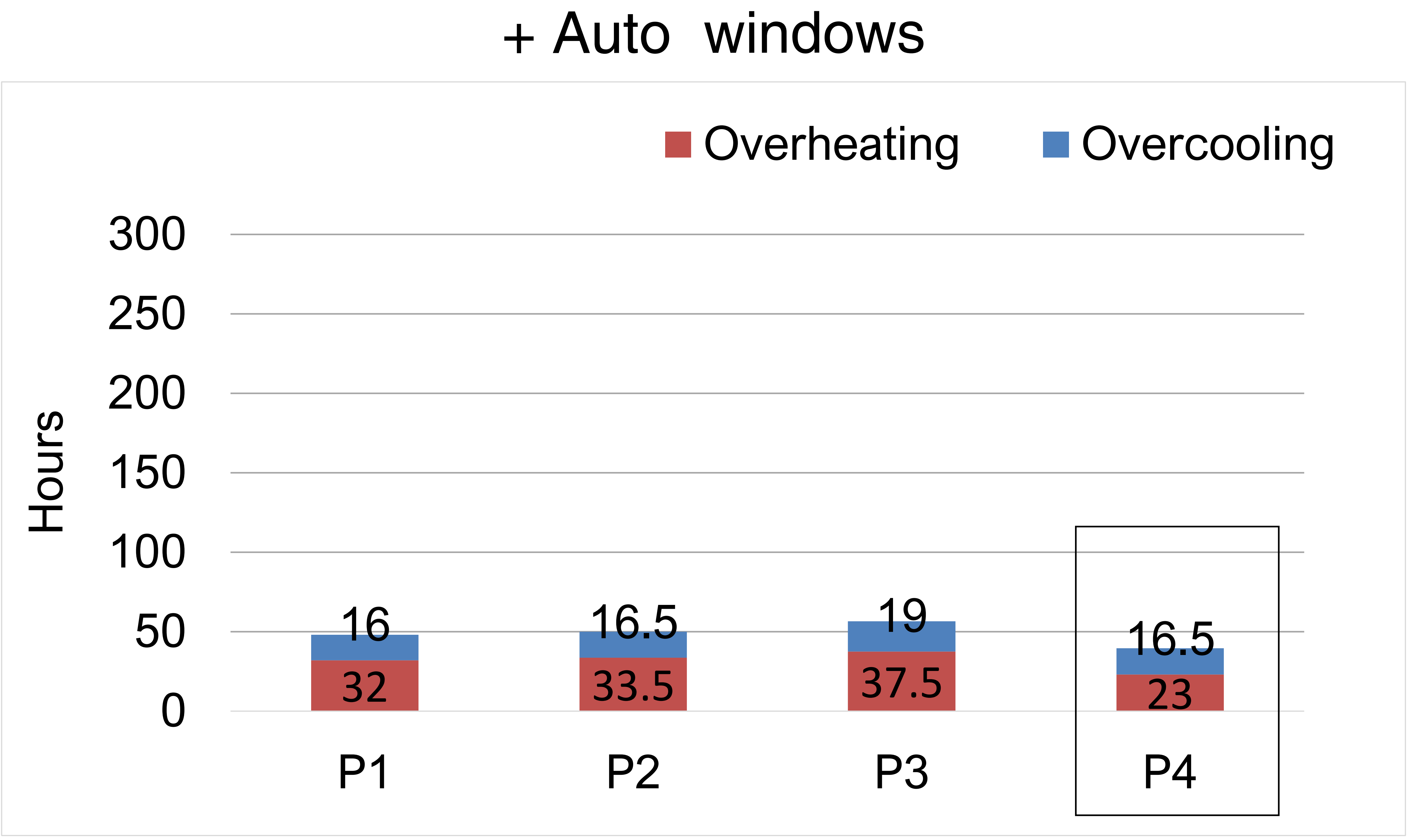
Overheating 280hrs



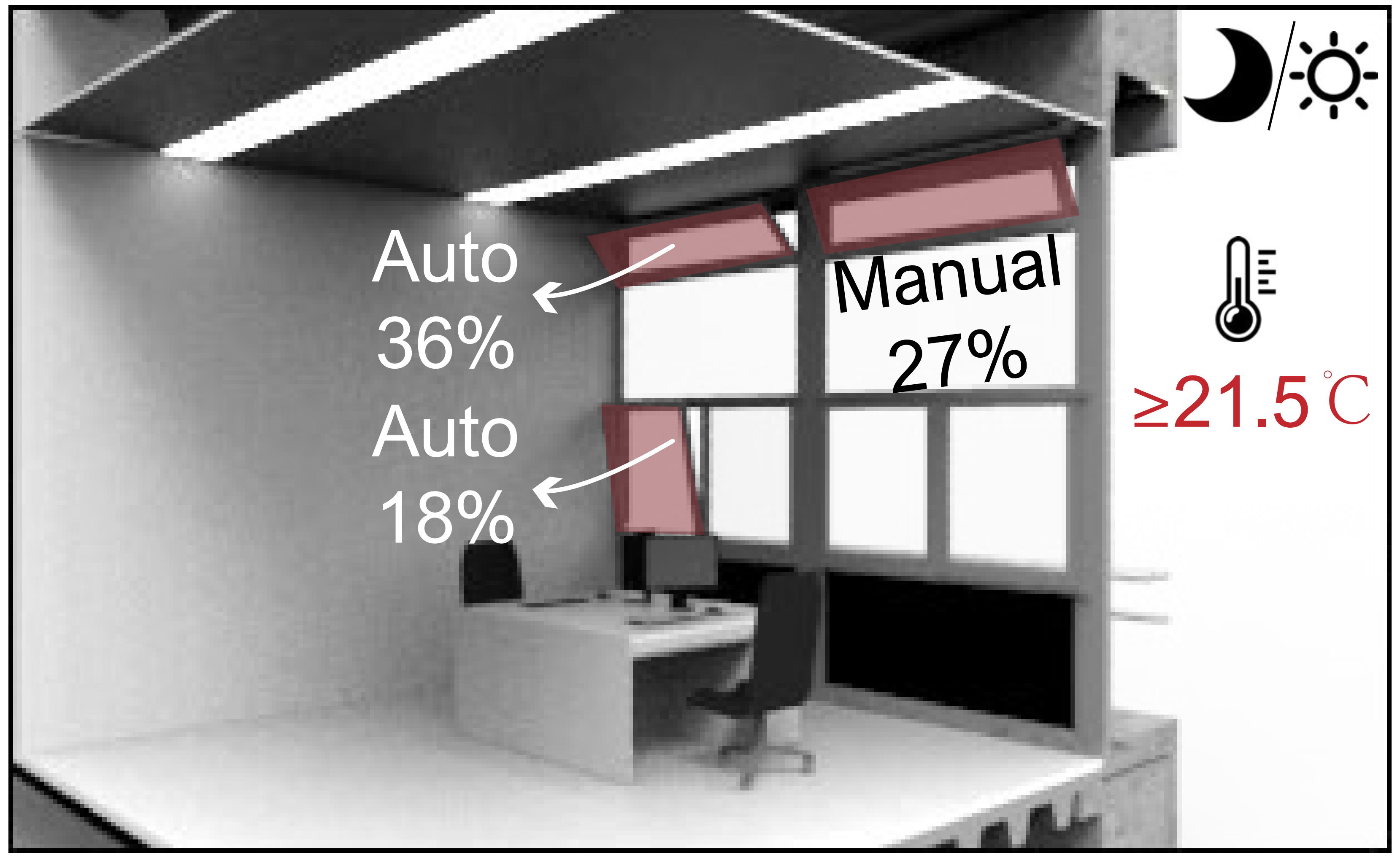
Summer

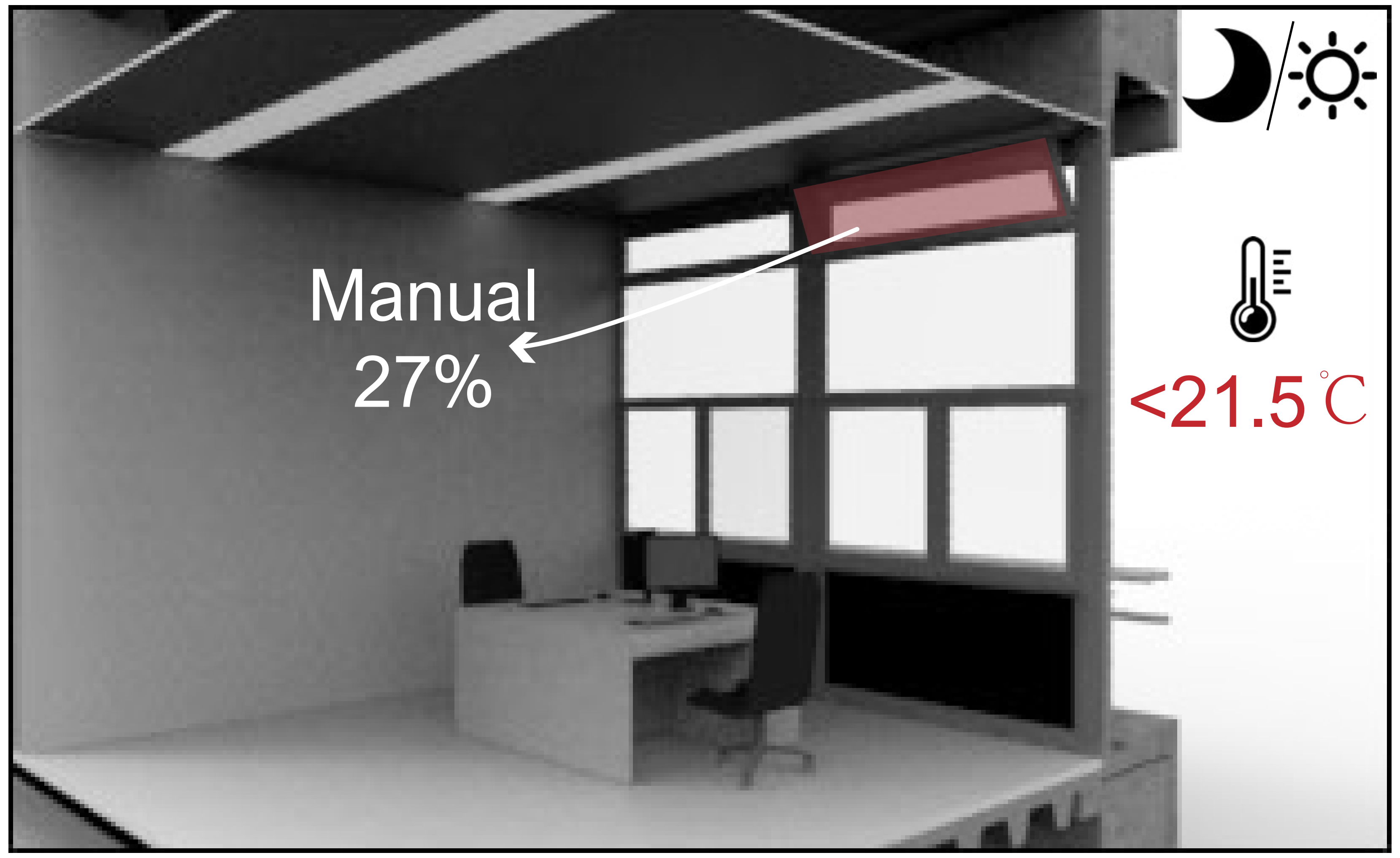

Shading
Overheating
Lighting
Hours
Lighting [kWh]
433.5
35.1
255.5
300
307
314.5
324.5
333
352.5
368.5
18.38
25.46
24.6
22.92
22.21
21.4
20.65
19.8
Blank
150 W/m2
200 W/m2
250 W/m2
300 W/m2
350 W/m2
400 W/m2
450 W/m2
500 W/m2
Overheating 300hrs

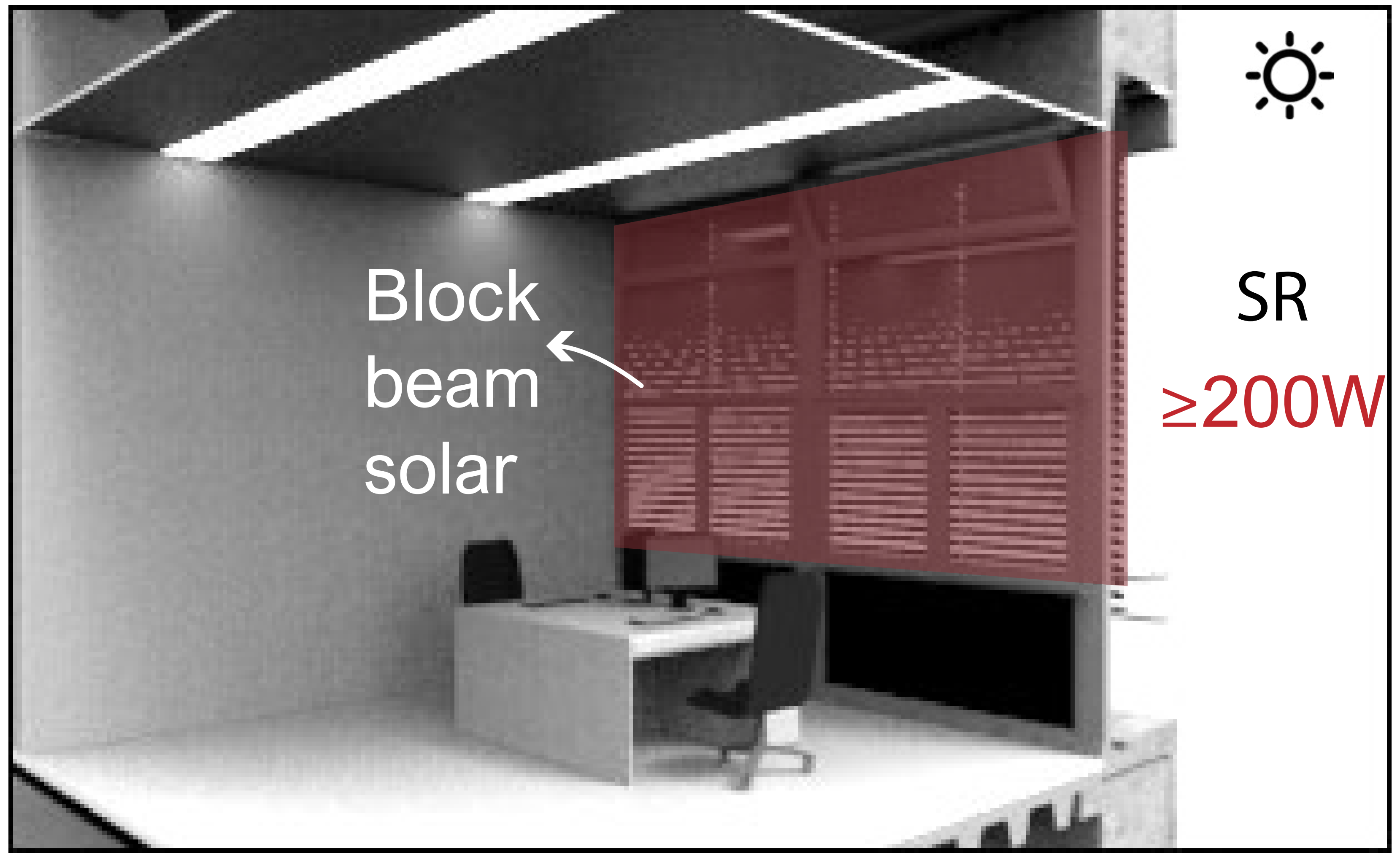

+ Manual top window
Overheating
Hours
300
280
Shading
Manual 27%
Overheating 280hrs


+ Auto windows
Overheating
Overcooling
Hours
300
250
200
150
100
50
0
16
32
16.5
33.5
19
37.5
16.5
23
P1
P2
P3
P4

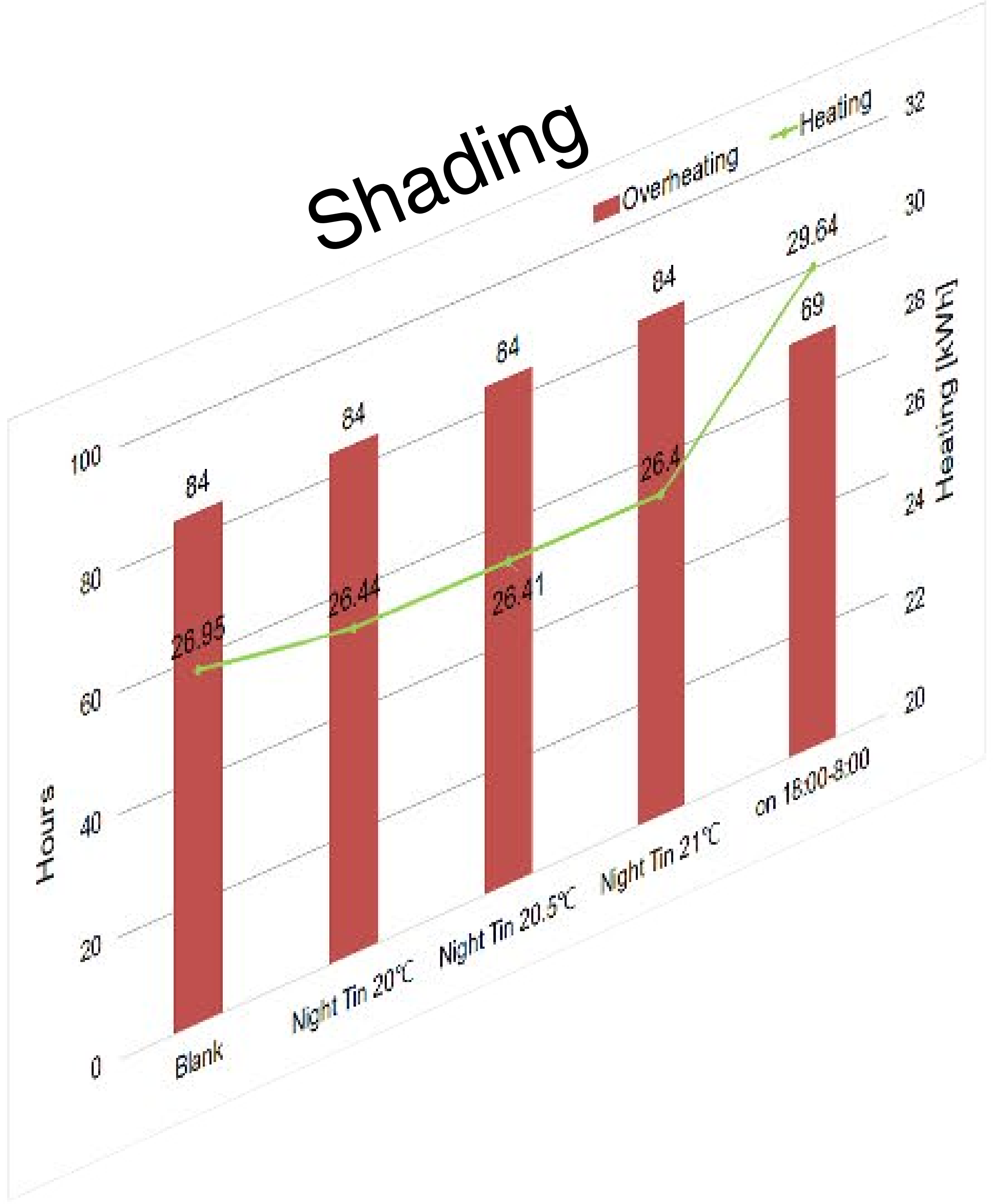
Summer


Auto
36%
Manual
27%
Auto
18%
≥21.5℃


Manual
27%
<21.5℃


Block
beam
solar
SR
≥200W

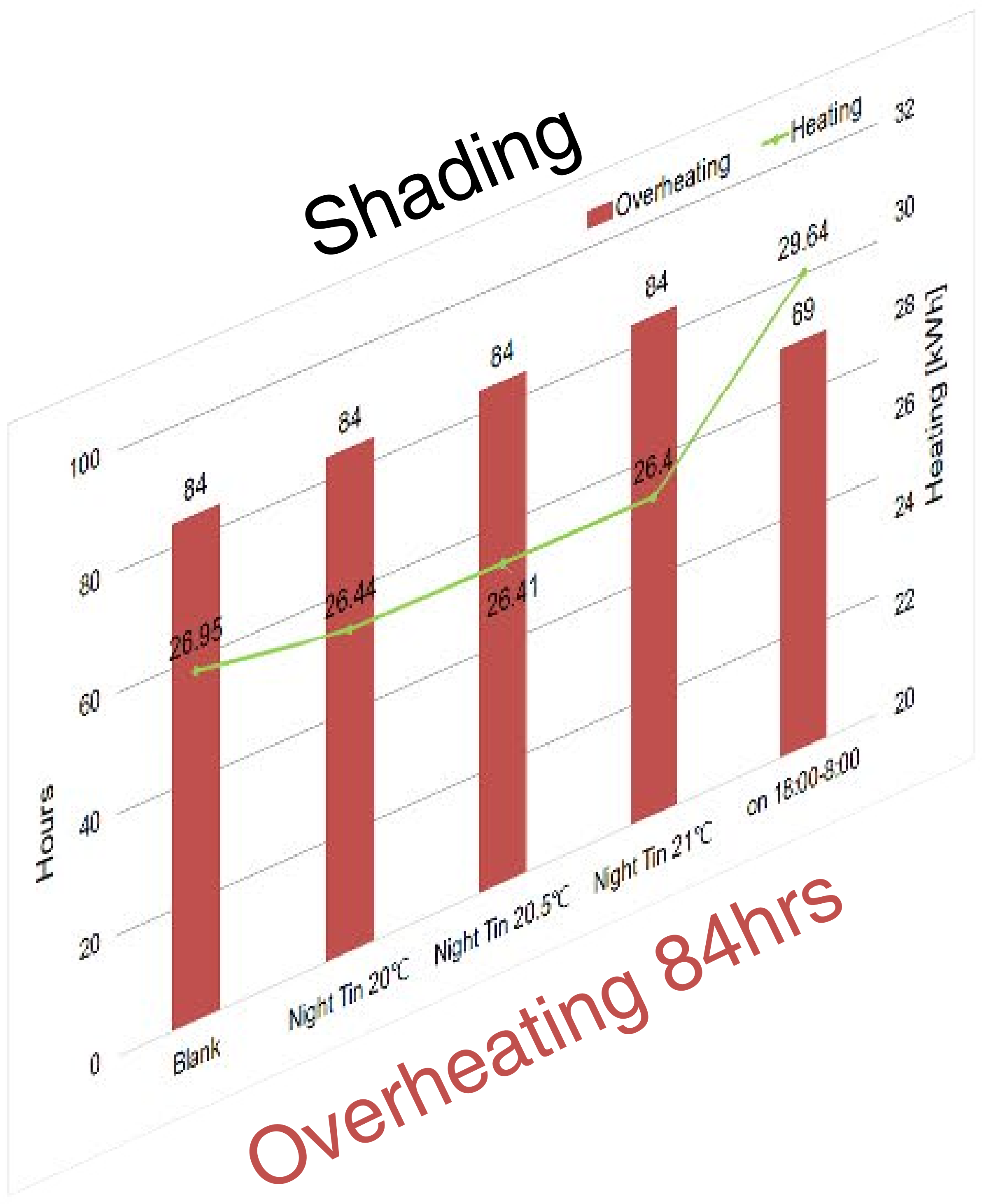
Spring

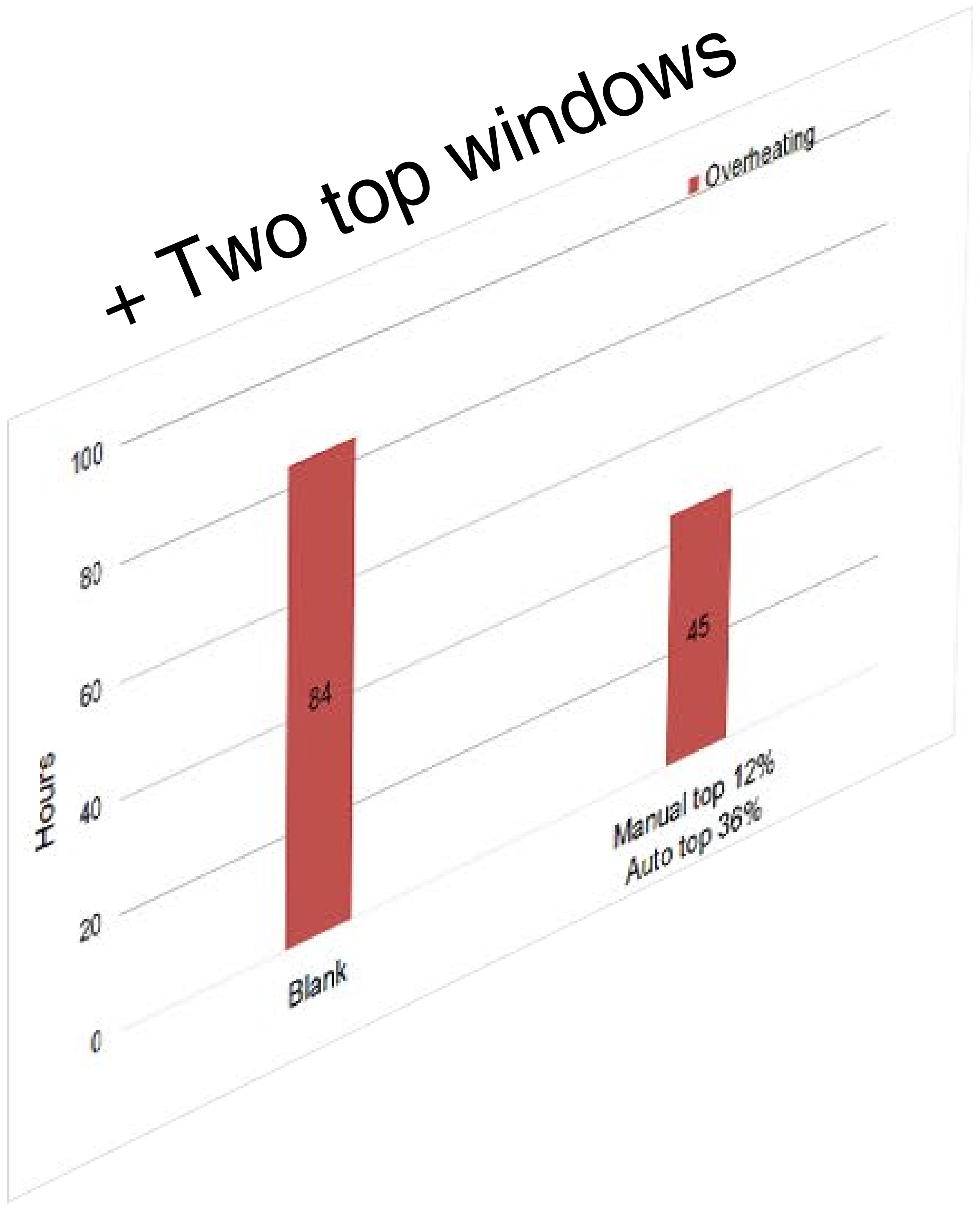


No shading
Overheating 84hrs
Heating 26.96kWh

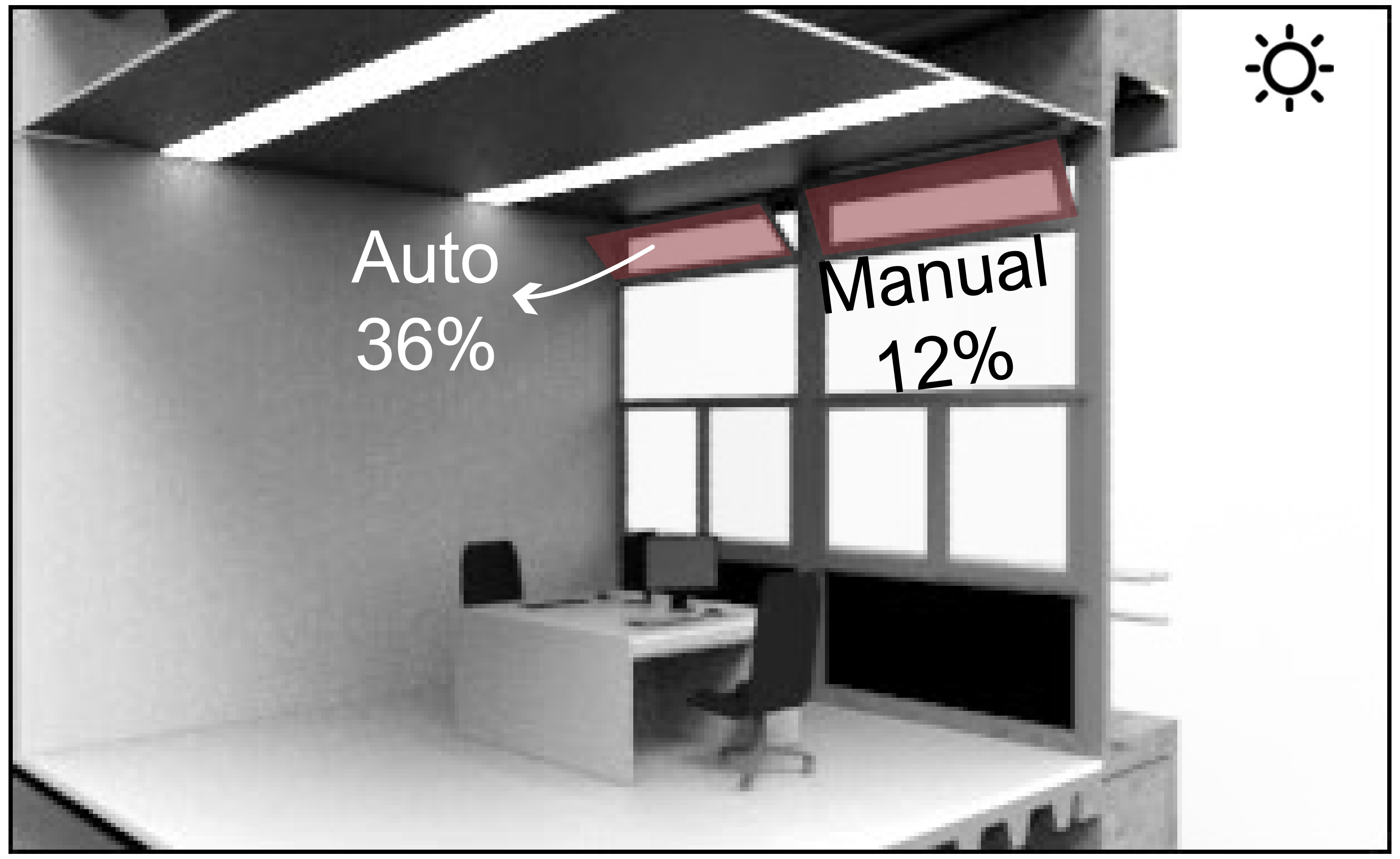
Shading 18:00-8:00
Overheating 69hrs
Heating 29.64kWh

Spring



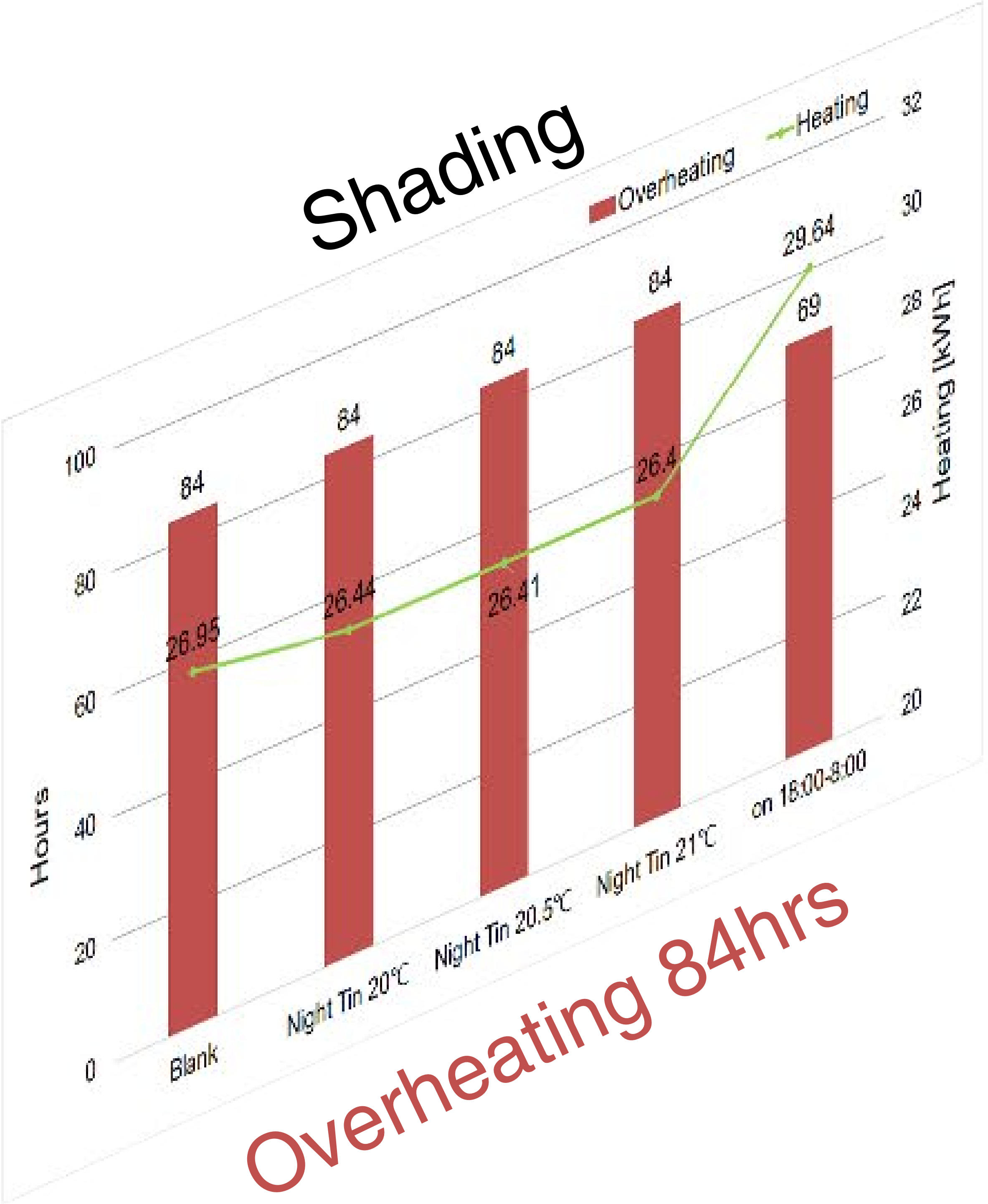


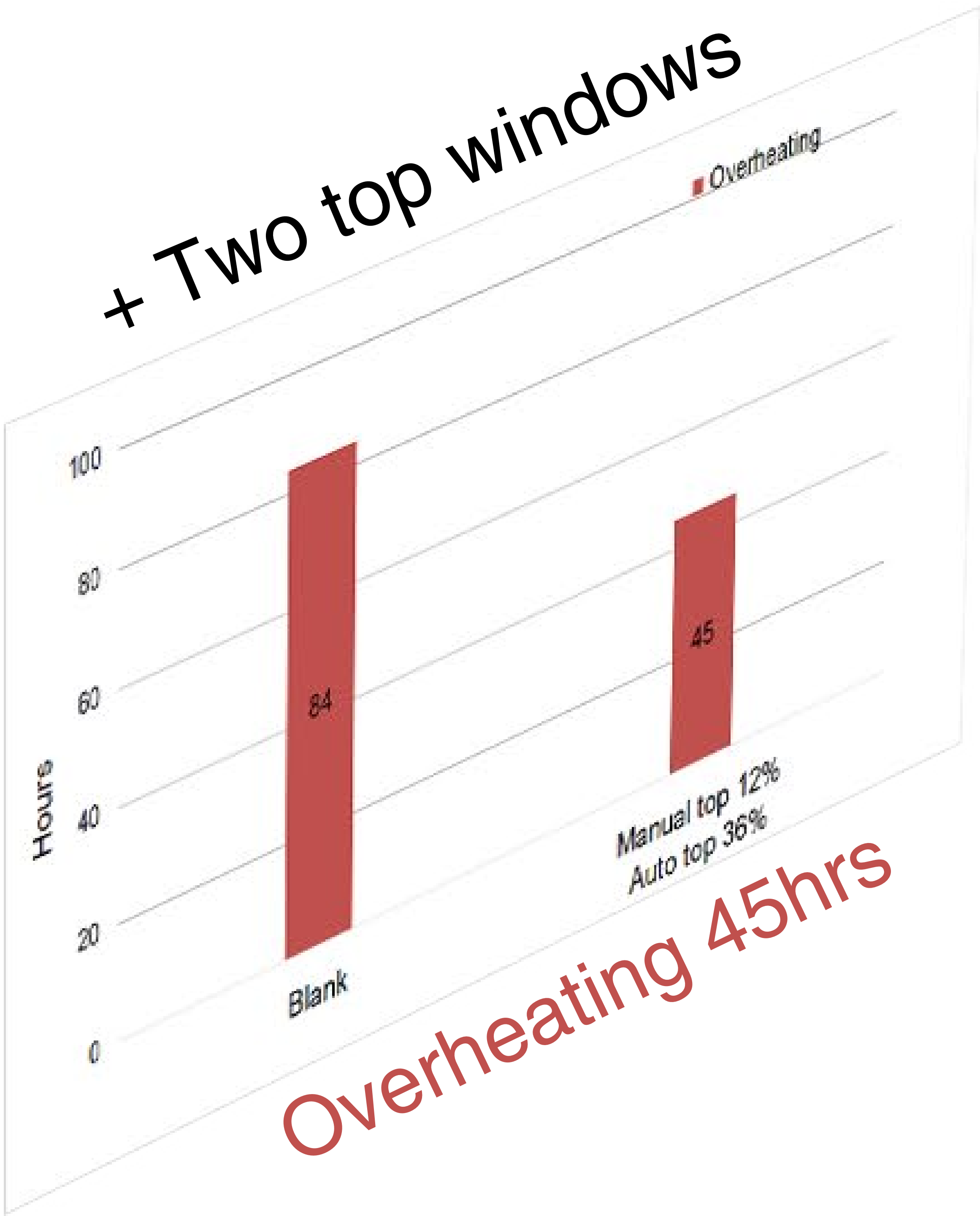
Overheating 45hrs

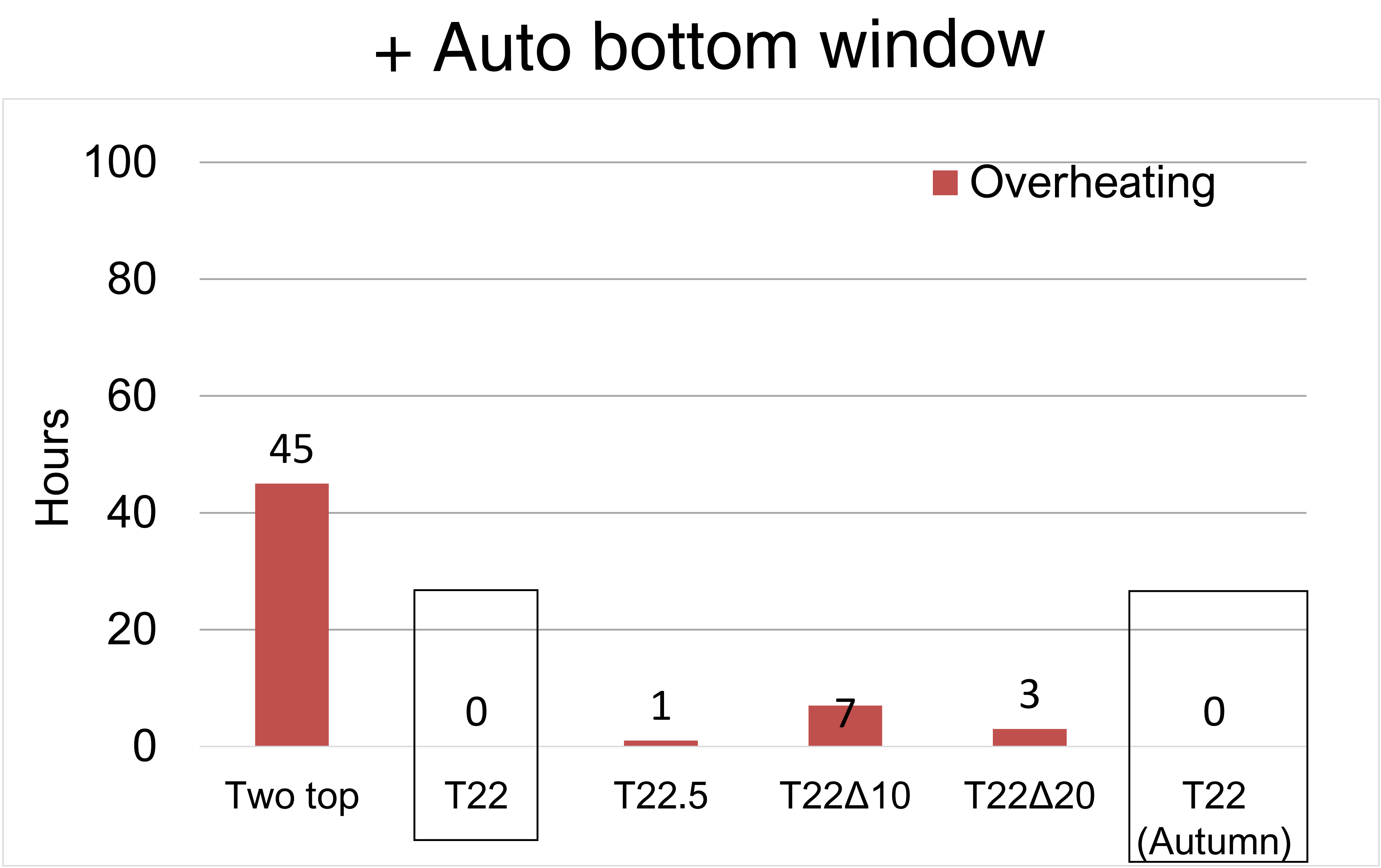


Design proposals | New construction

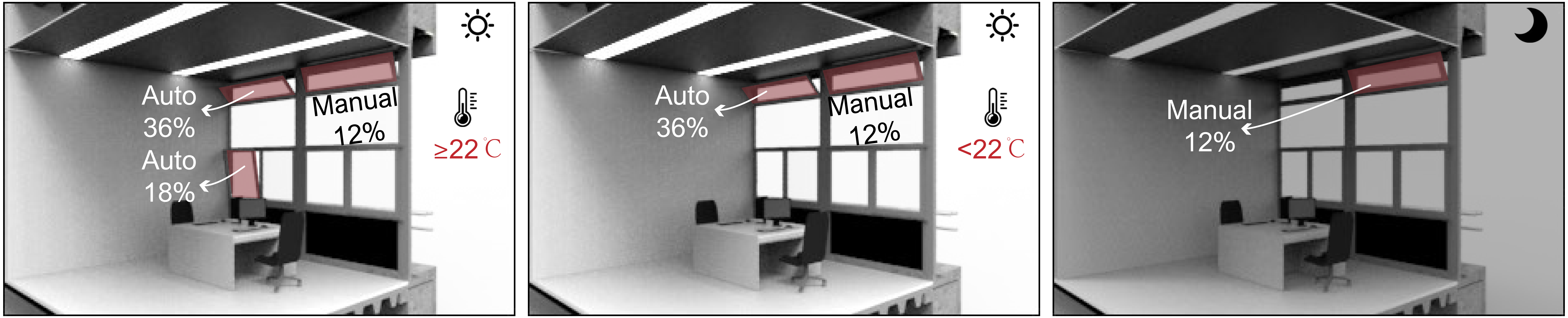
Spring & Autumn



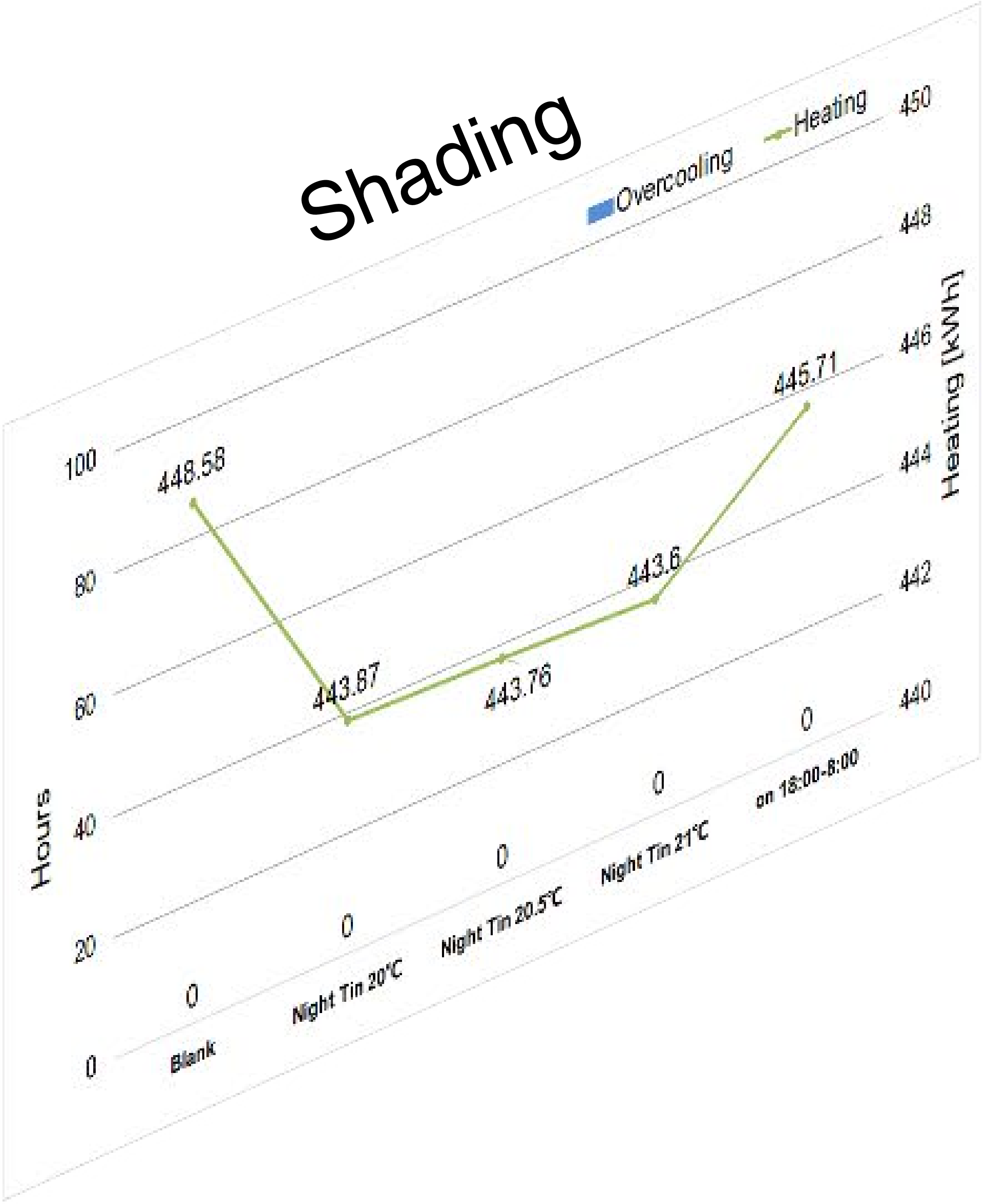




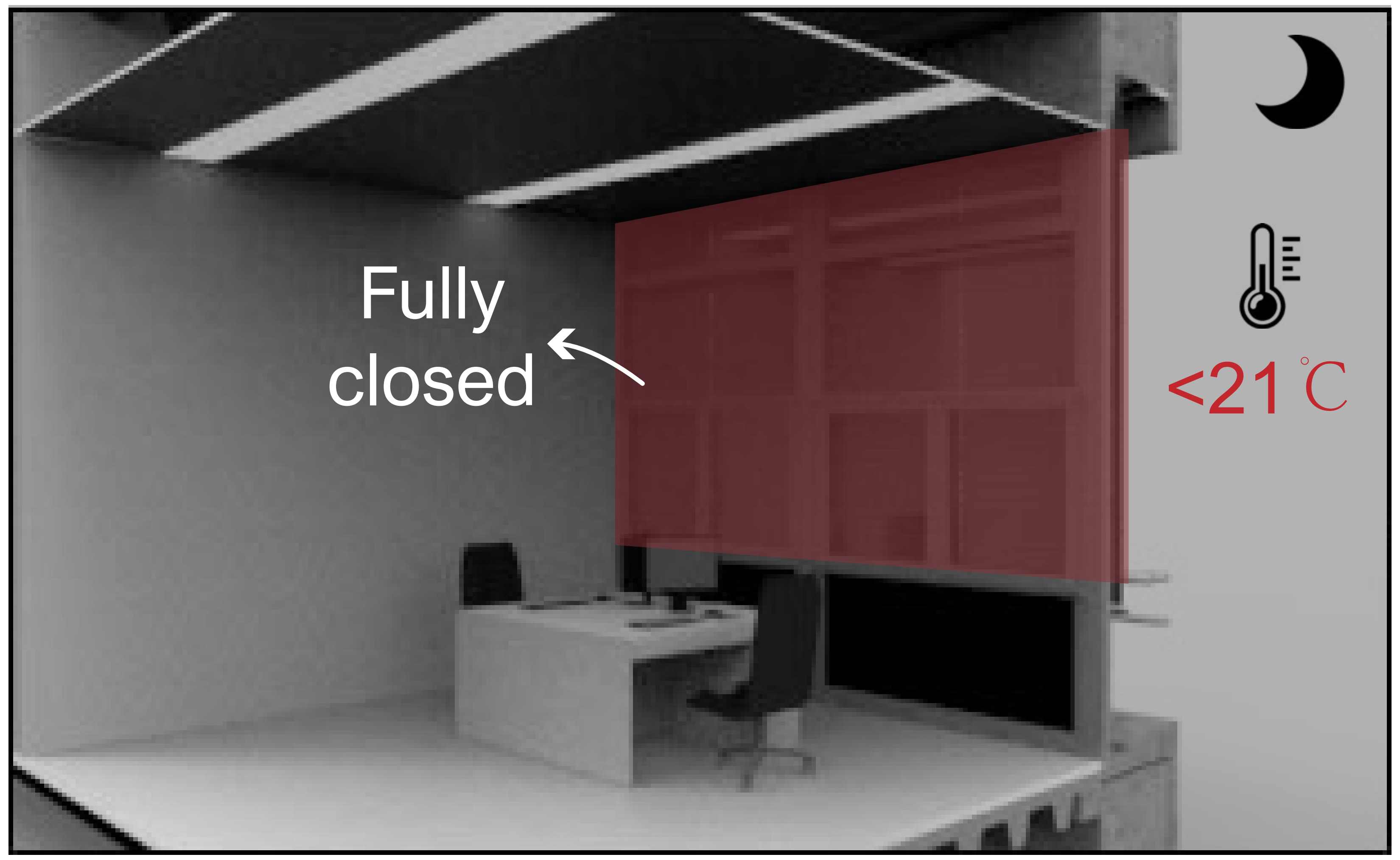
Spring & Autumn



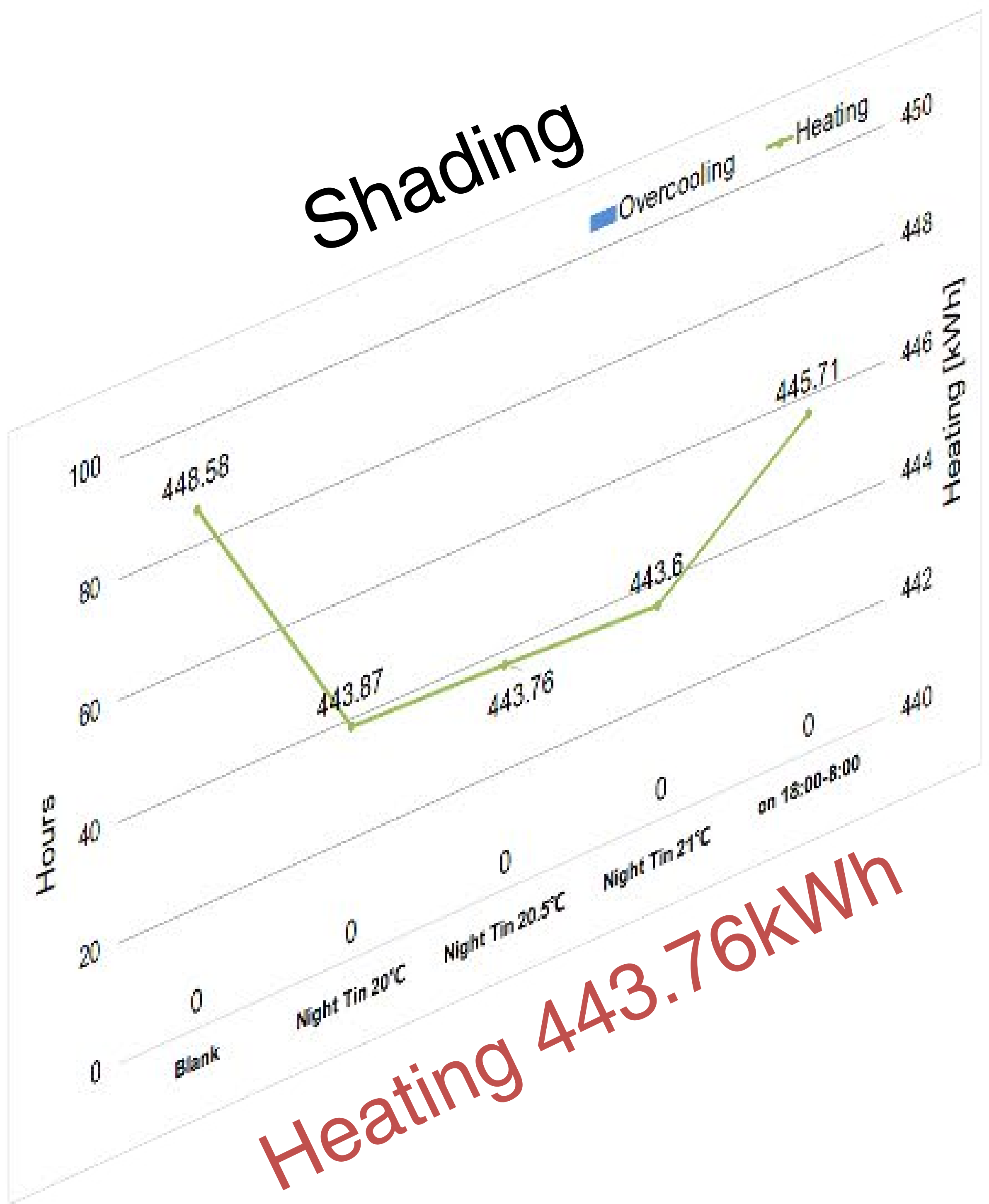
Winter



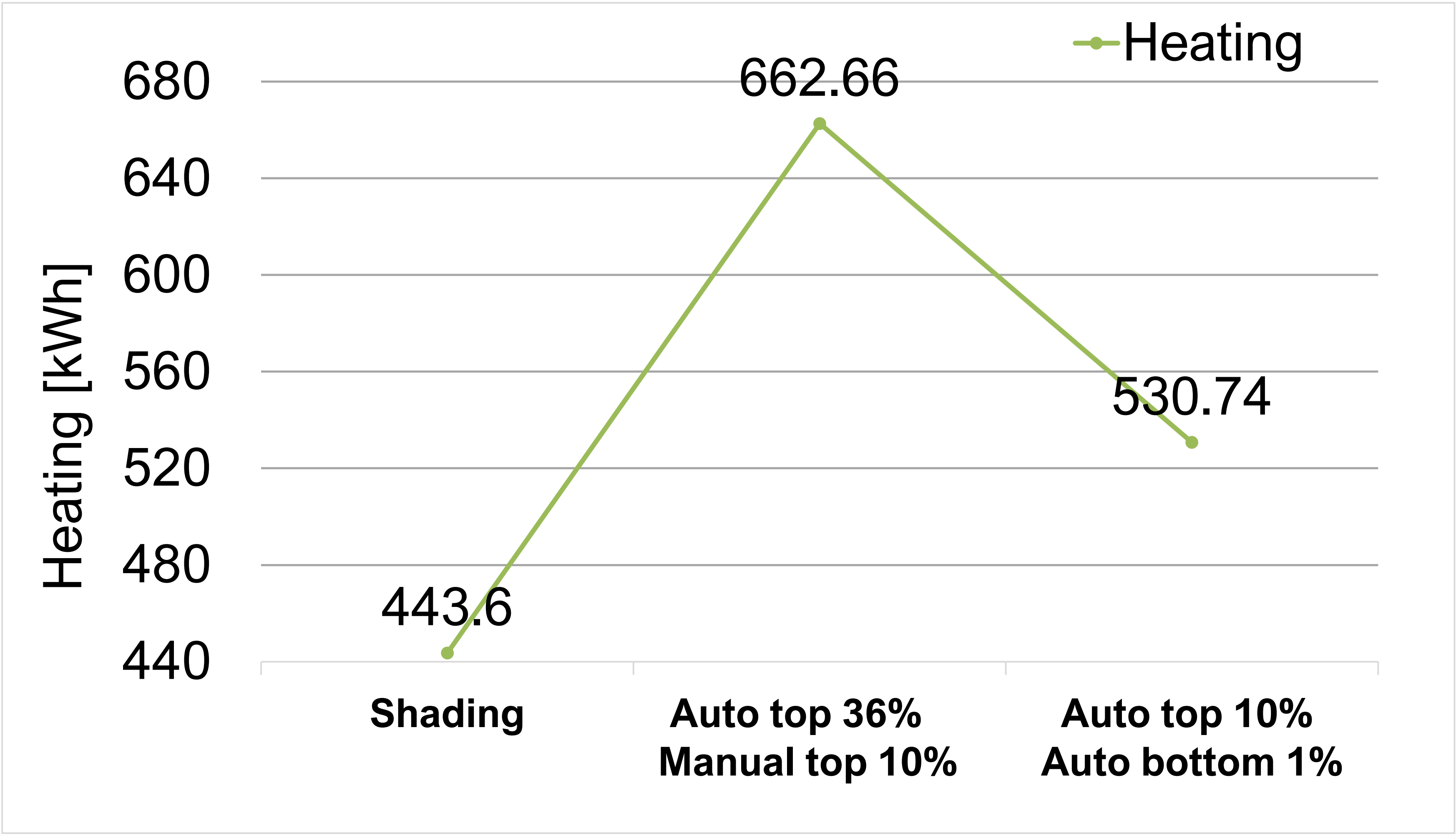
Heating 443.76kWh



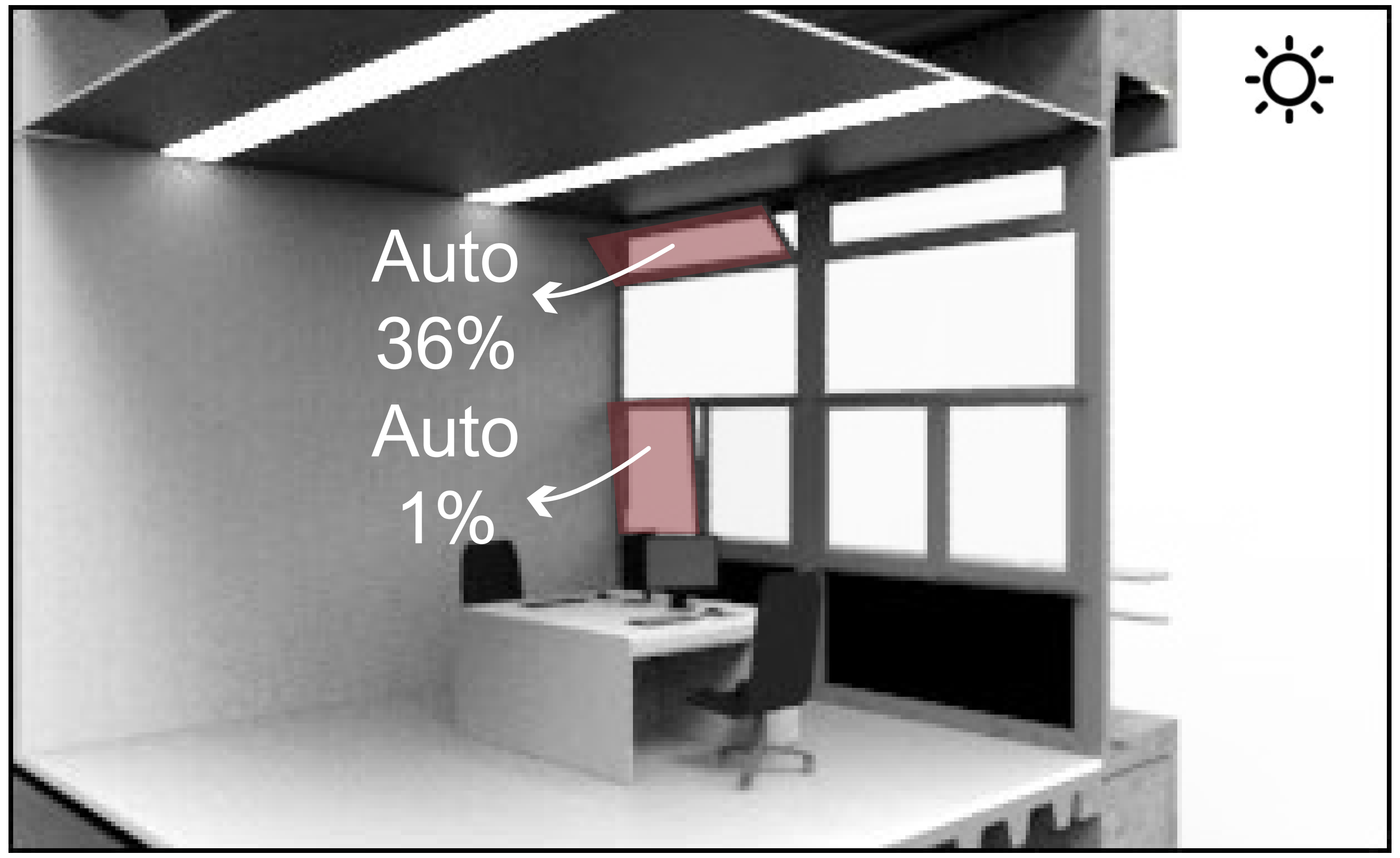
Winter

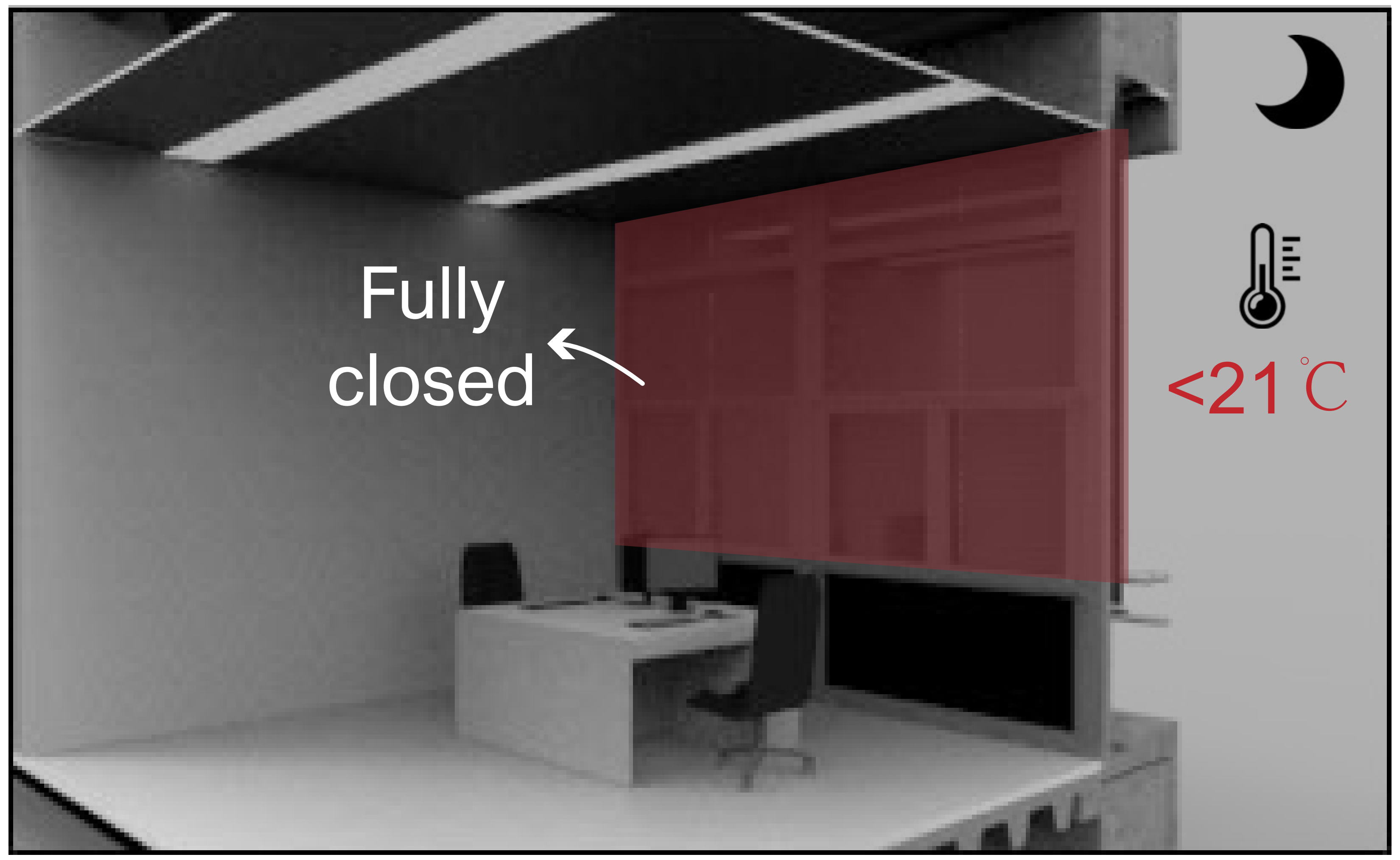


+ Two windows



Winter



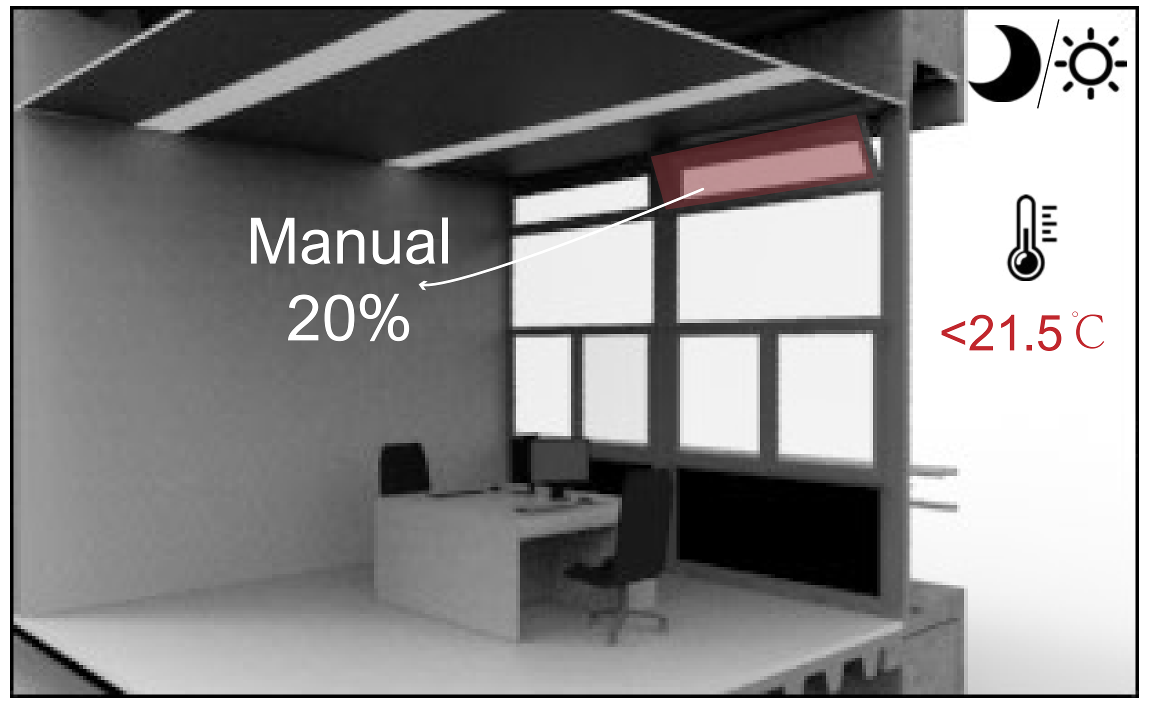


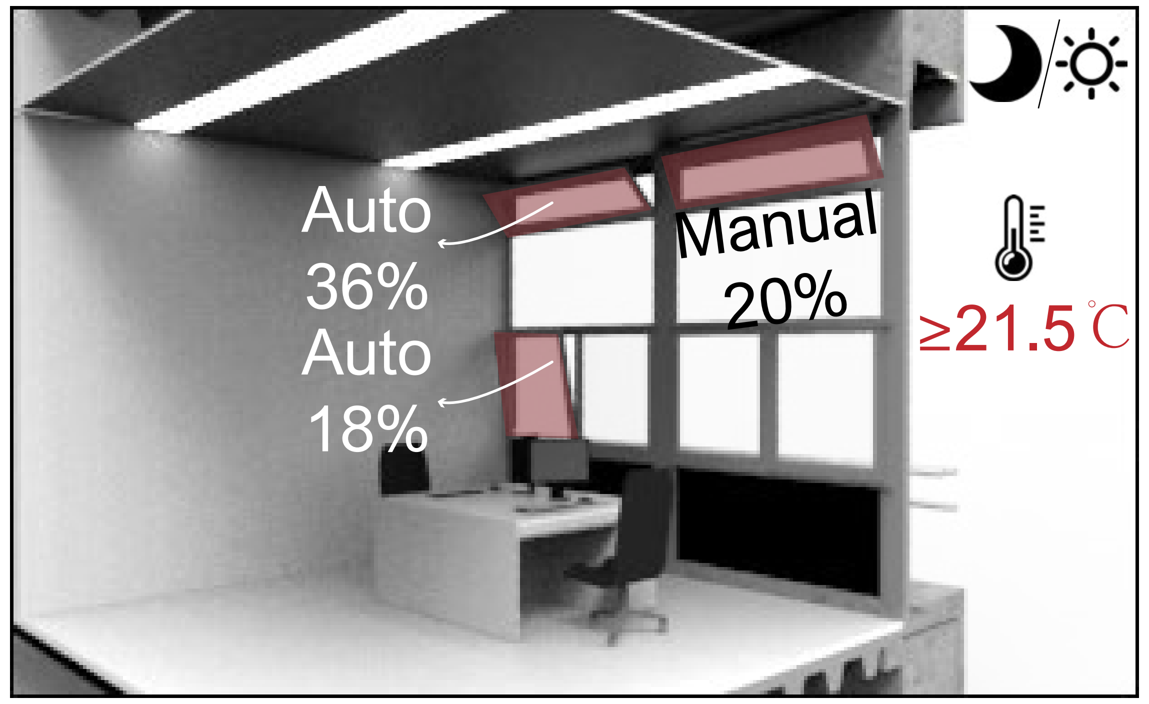
Annual performance

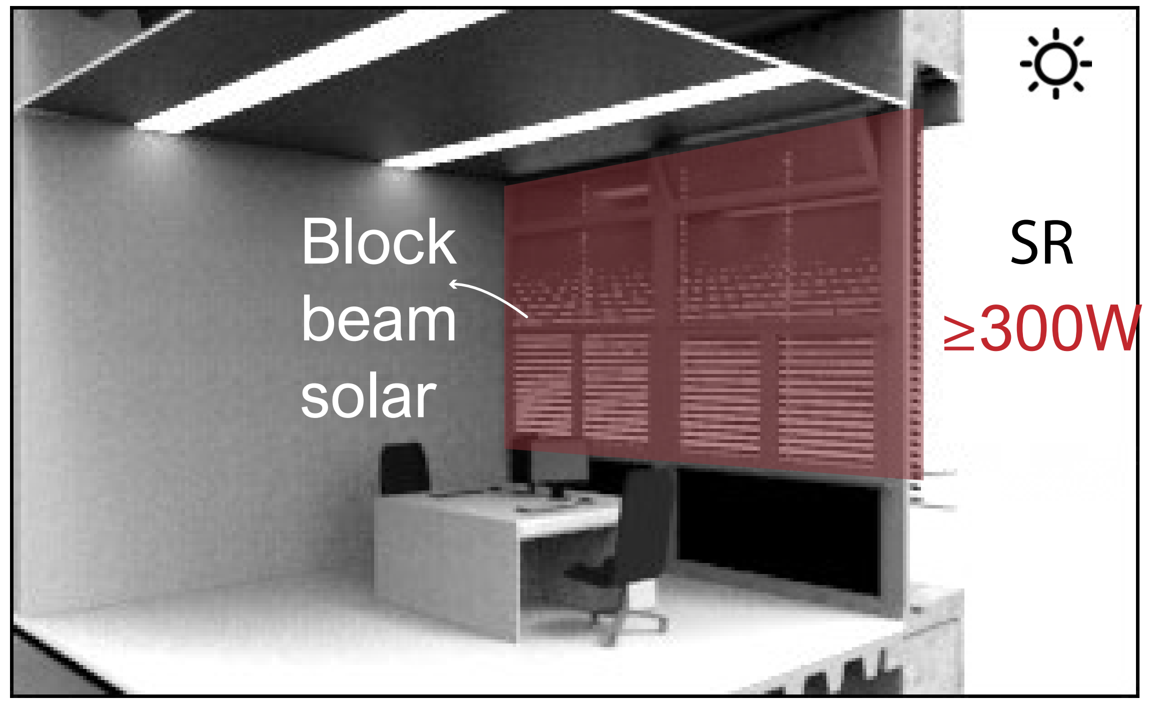
	Without control	With control
Discomfort	185.0 hrs	39.5 hrs
Heating	58.5 kWh/m2	36.1 kWh/m2
Lighting	10.8 kWh/m2	11.2 kWh/m2
Discomfort / Energy	100% / 100%	-78.7% / -31.7%

Design proposals | Old construction

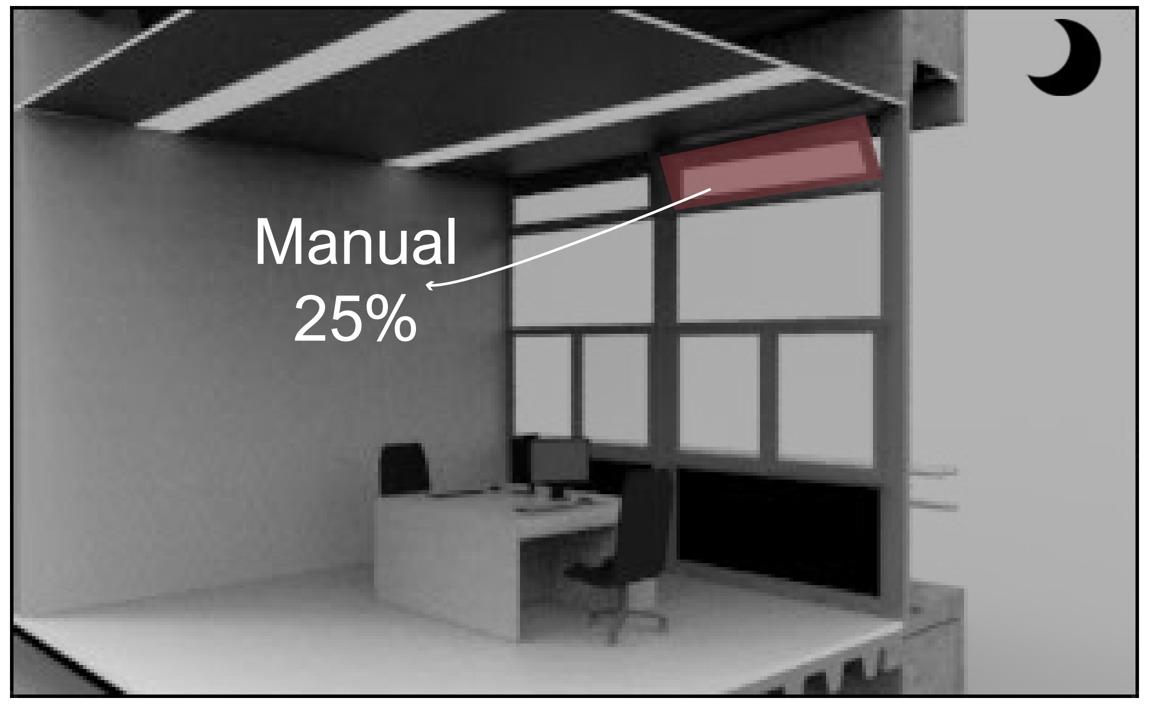
Summer

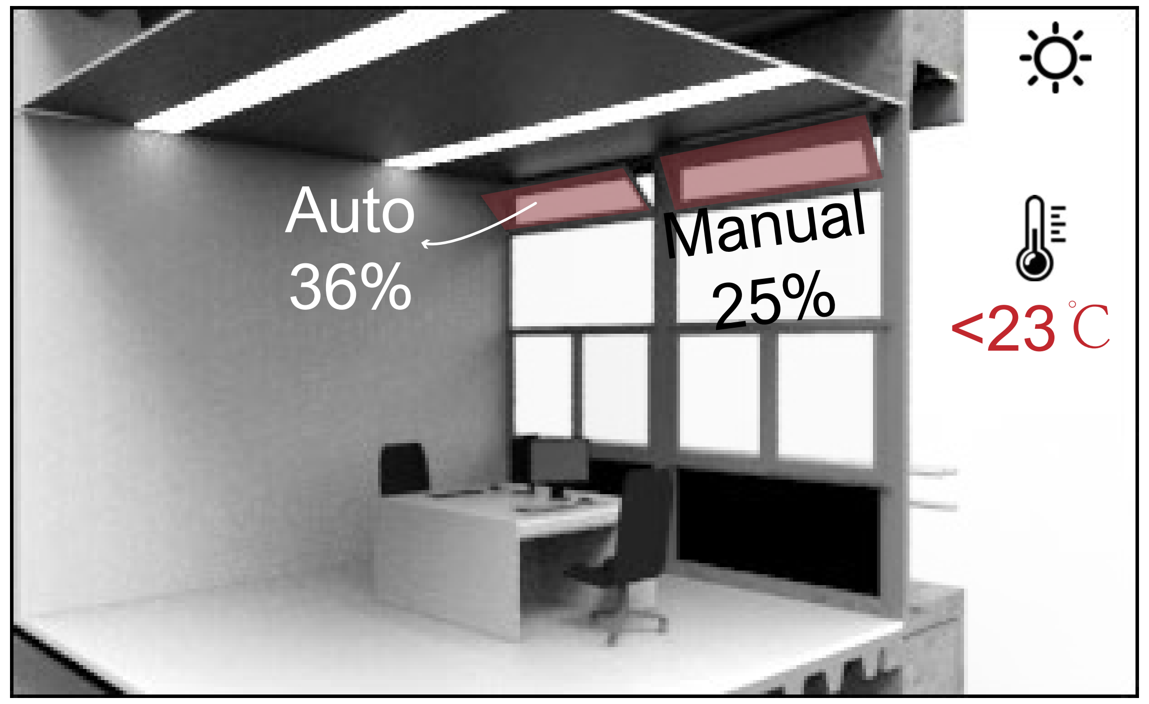


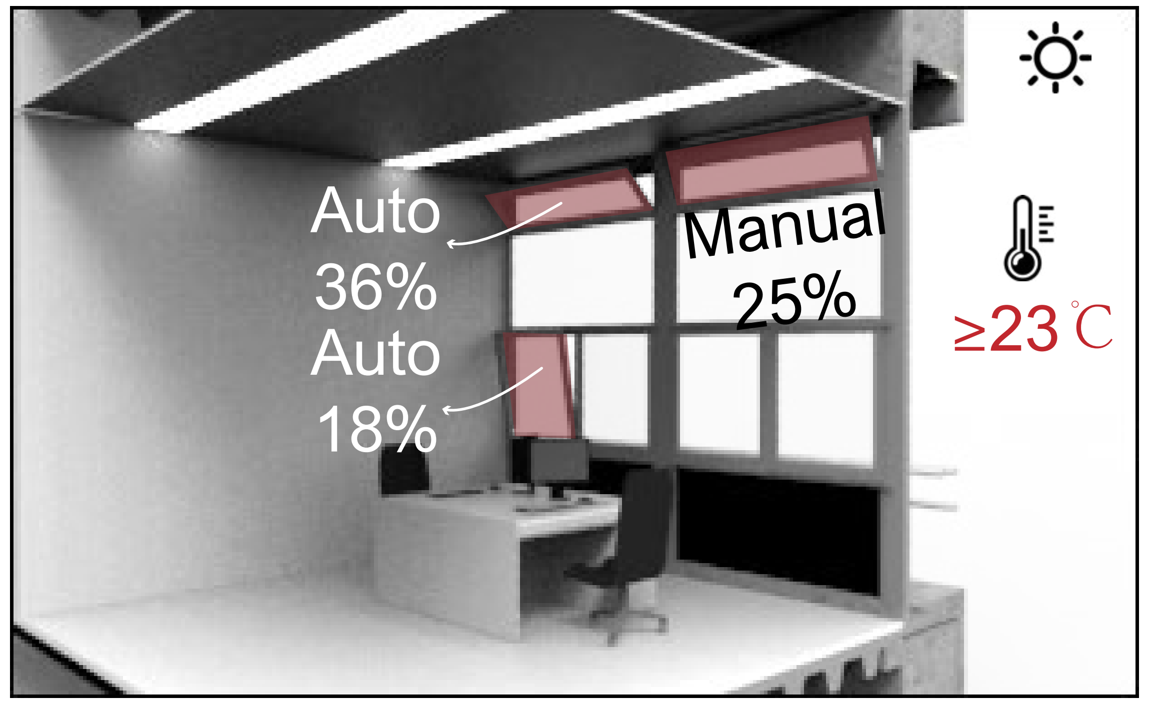




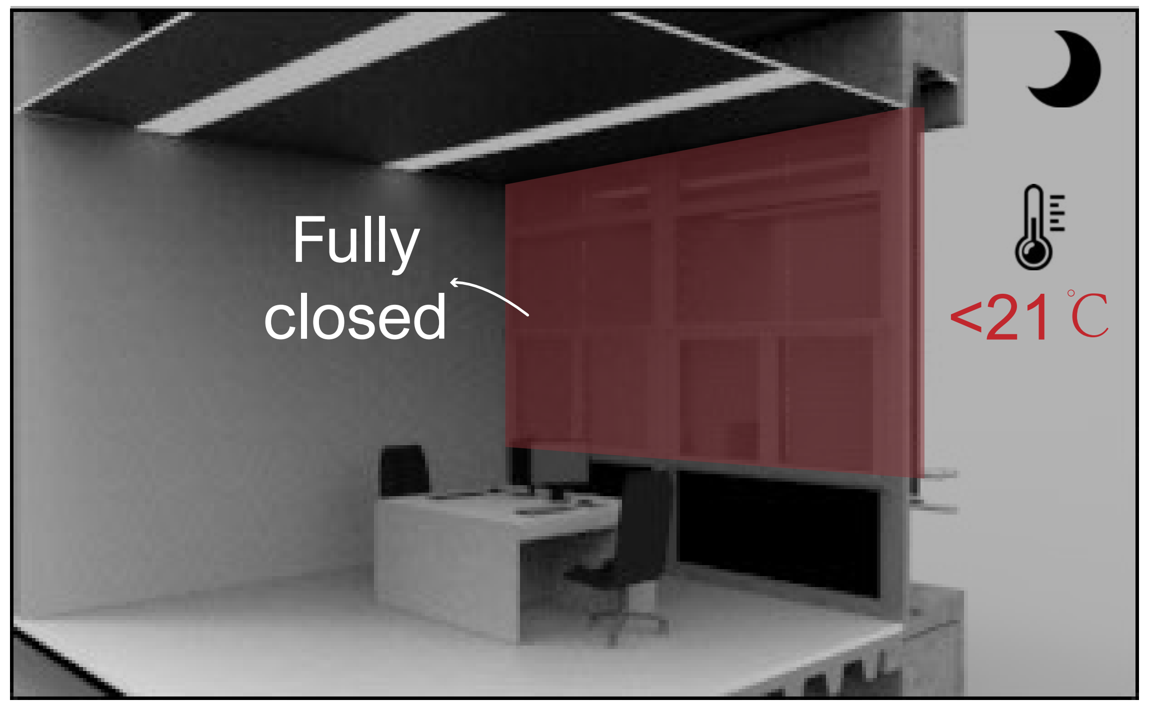
Spring&Autumn

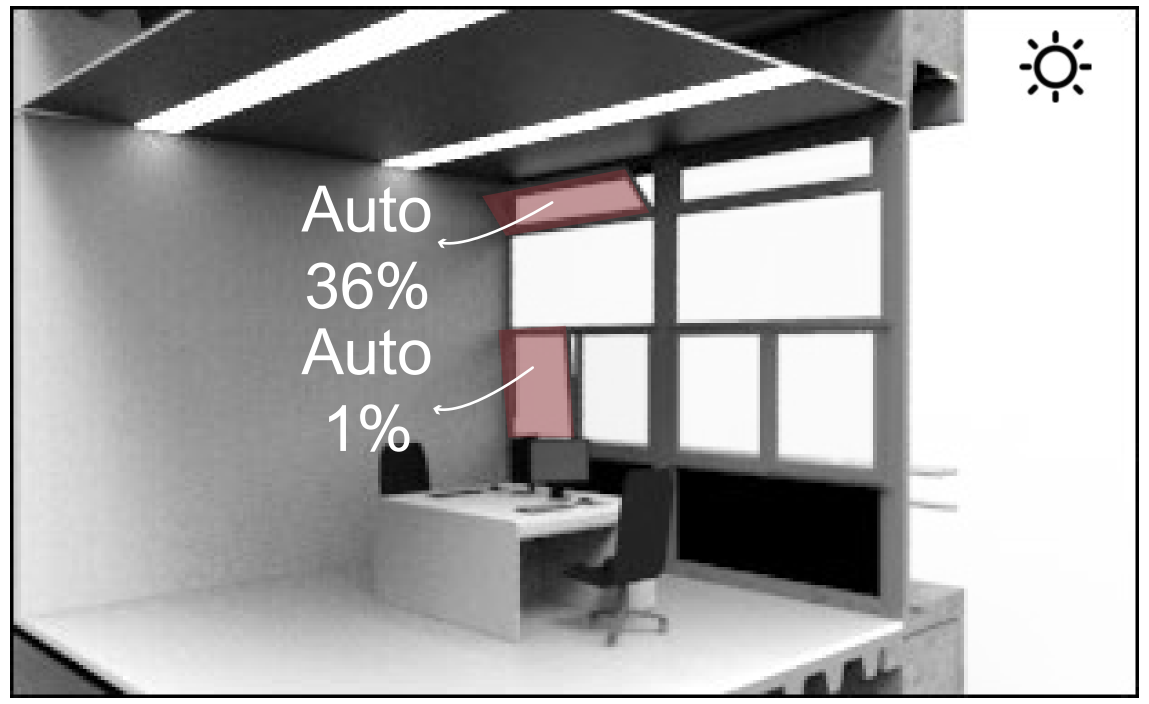






Winter





Annual performance

	Without control	With control
Discomfort	259.5 hrs	98.5 hrs
Heating	108.2 kWh/m2	63.0 kWh/m2
Lighting	9.7 kWh/m2	9.8 kWh/m2
Discomfort / Energy	100% / 100%	-62.0% / -38.3%

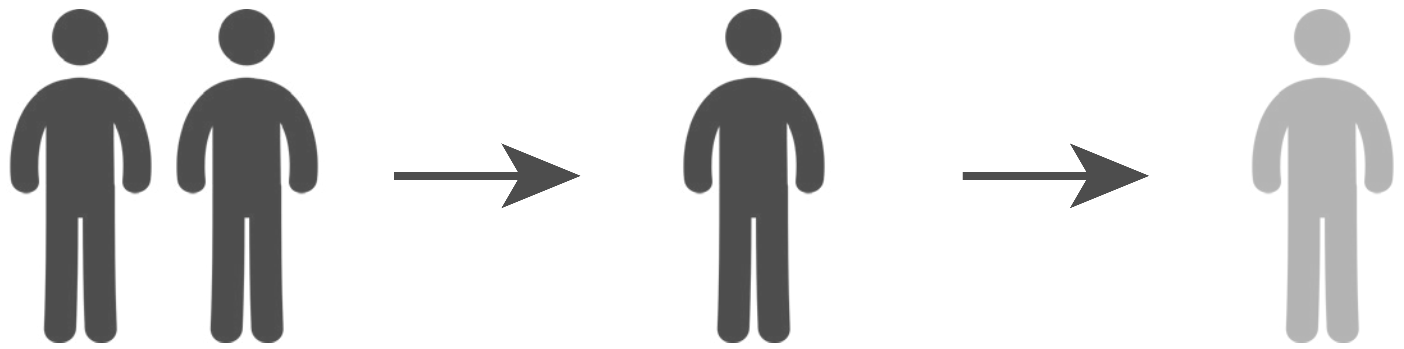
Annual performance comparison

	Old construction	New construction	
Without control	100% / 100%	-28.7% / -41.6%	Discomfort / Energy
With control	-62.0% / -38.7%	-84.8% / -60.2%	Discomfort / Energy

Refinement

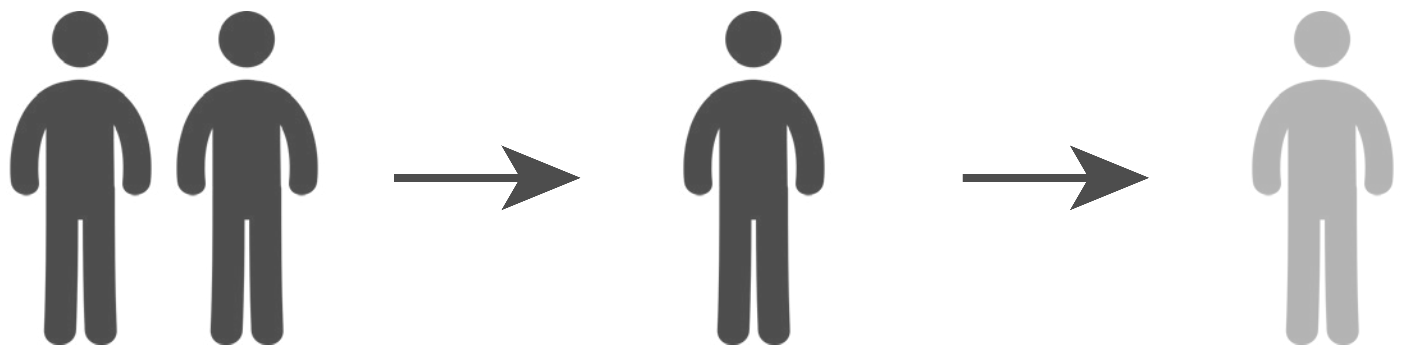
Refinement | Occupancy control

Opening modulation

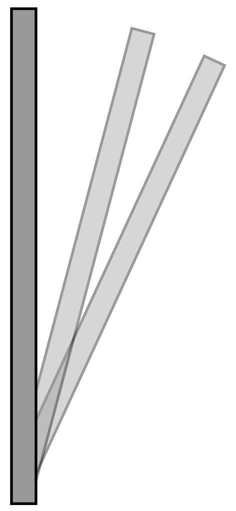


Requirement	0.66ach → 0.33ach → 0.00ach

Opening modulation

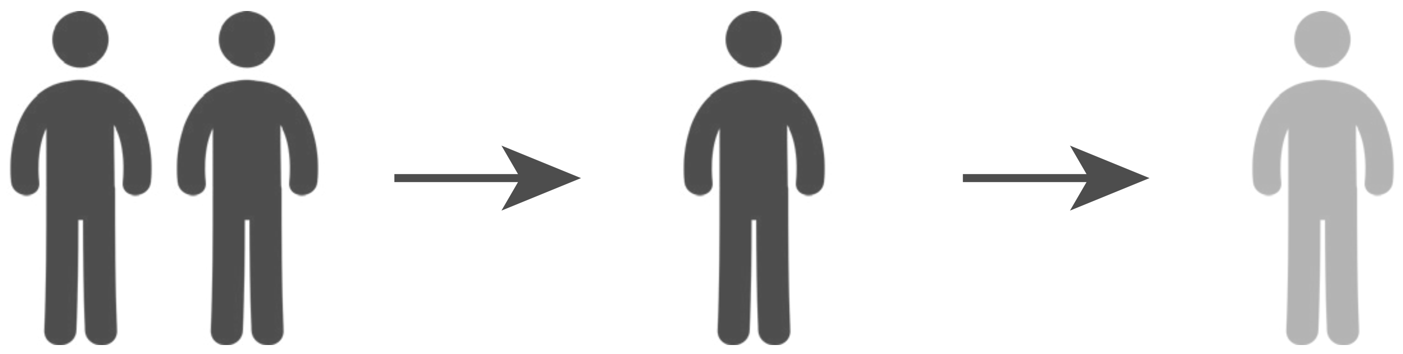


Requirement	0.66ach →	0.33ach →	0.00ach
Spring & Autumn	Manual 12% Auto top 36% →	Manual 12% →	Manual 12%
Winter	Auto top 36% Auto bottom 1% →	Auto top 15% →	Vent off

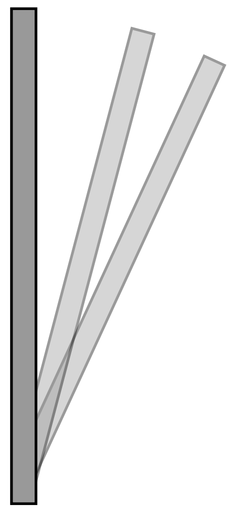


Refinement | Occupancy control

Opening modulation



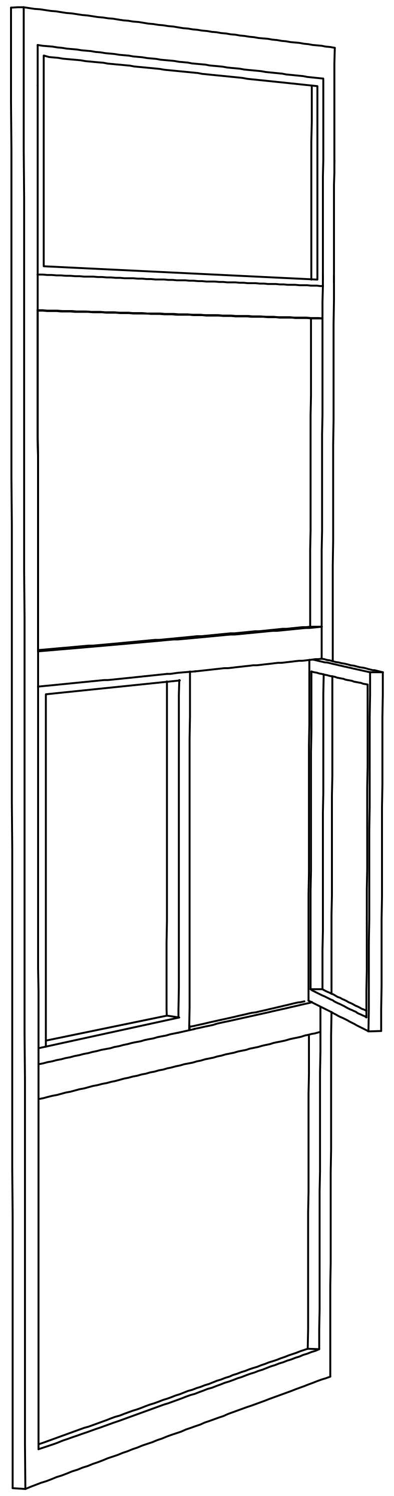
Requirement	0.66ach →	0.33ach →	0.00ach
Spring & Autumn	Manual 12% Auto top 36% →	Manual 12% →	Manual 12%
Winter	Auto top 36% Auto bottom 1% →	Auto top 15% →	Vent off



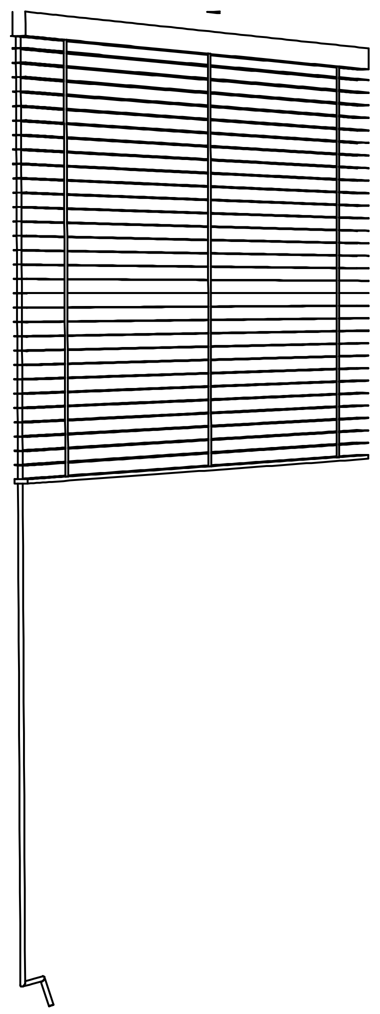
Absent at 12:00-14:00

Heating saved [kWh]	Spring Apr 15th	Autumn Oct 25th	Winter Jan 6th
	-0.22	-0.12	0.08
	-0.03	0.11	0.06

Manual windows



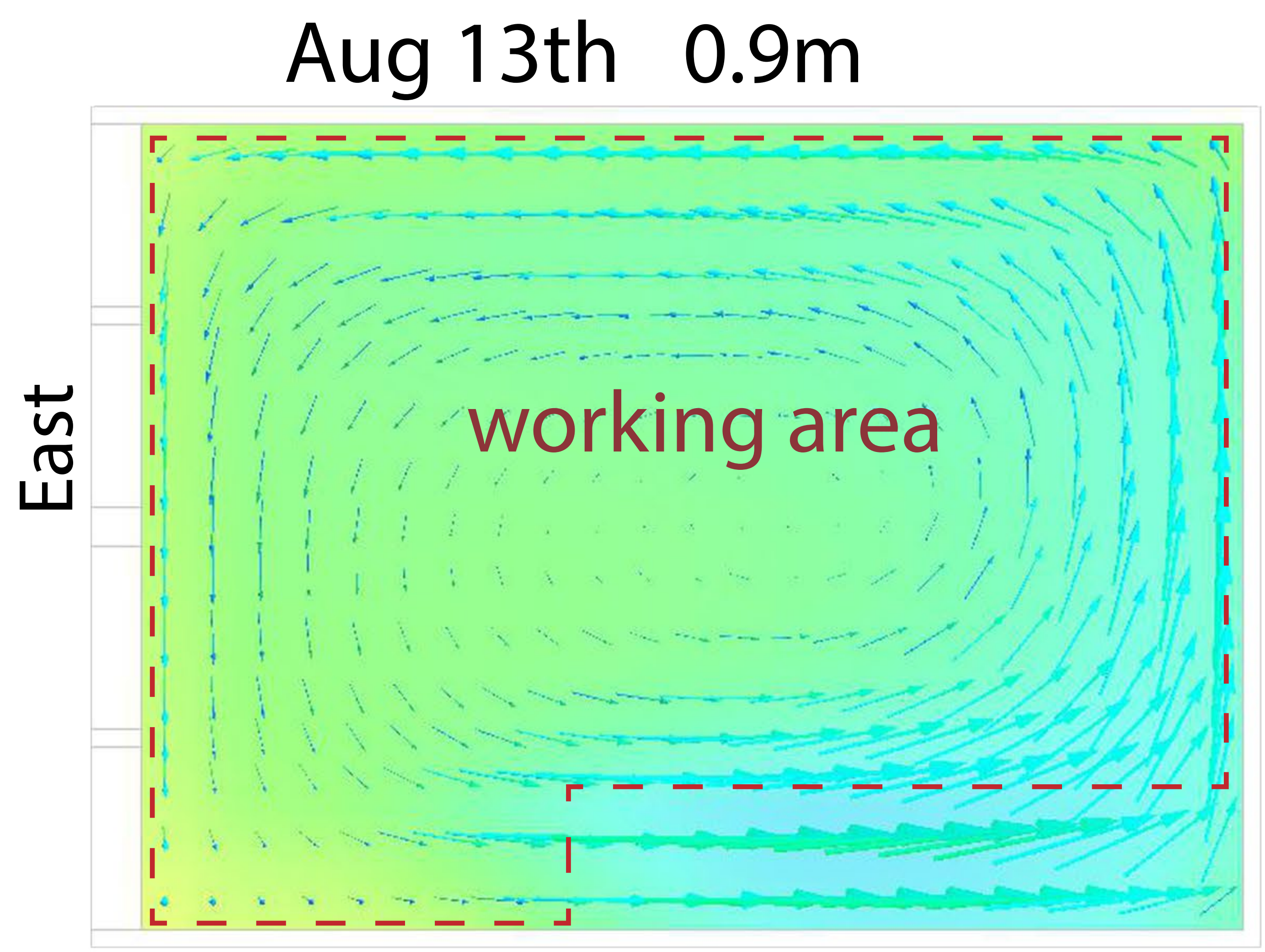
Shading

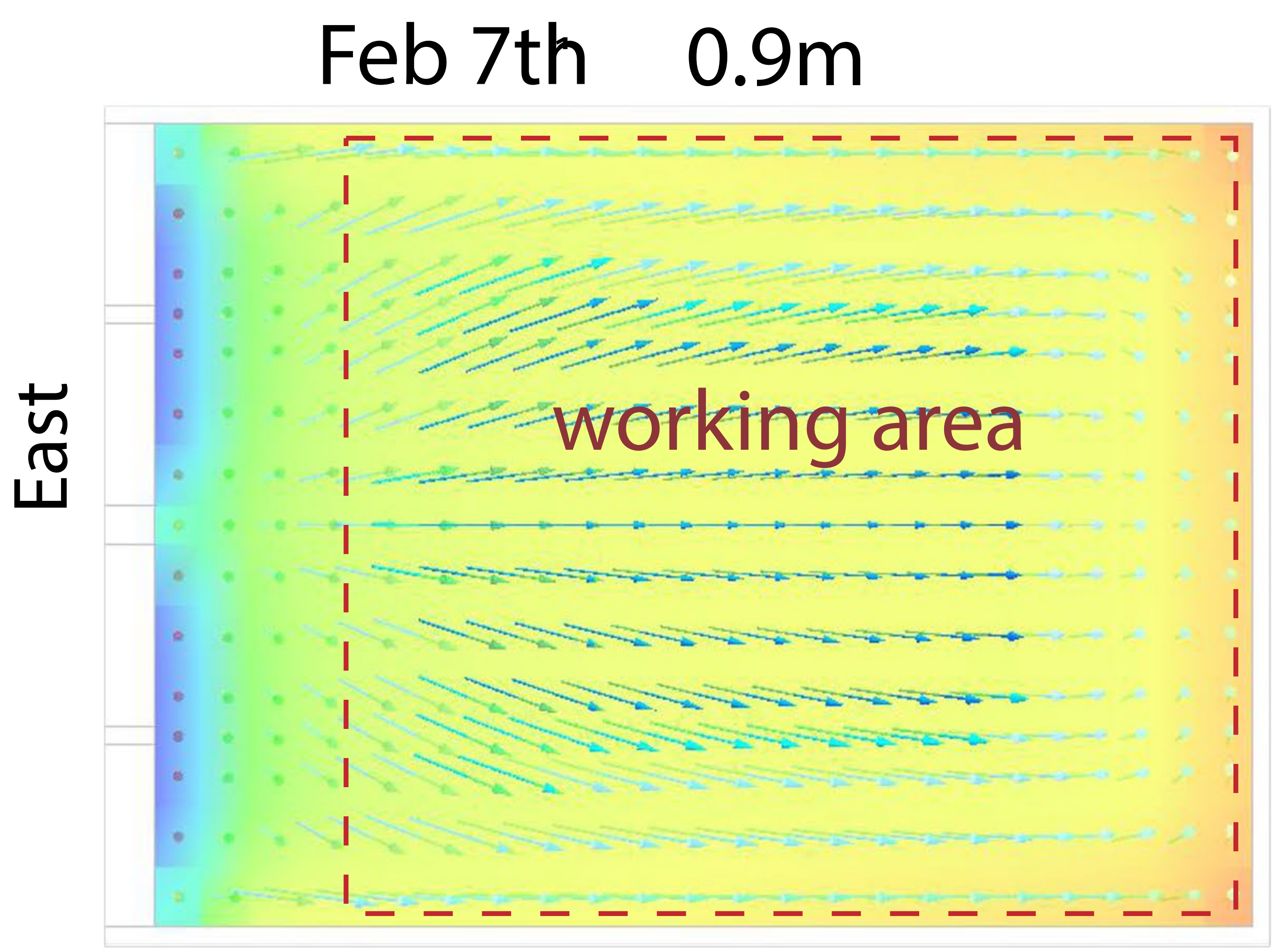


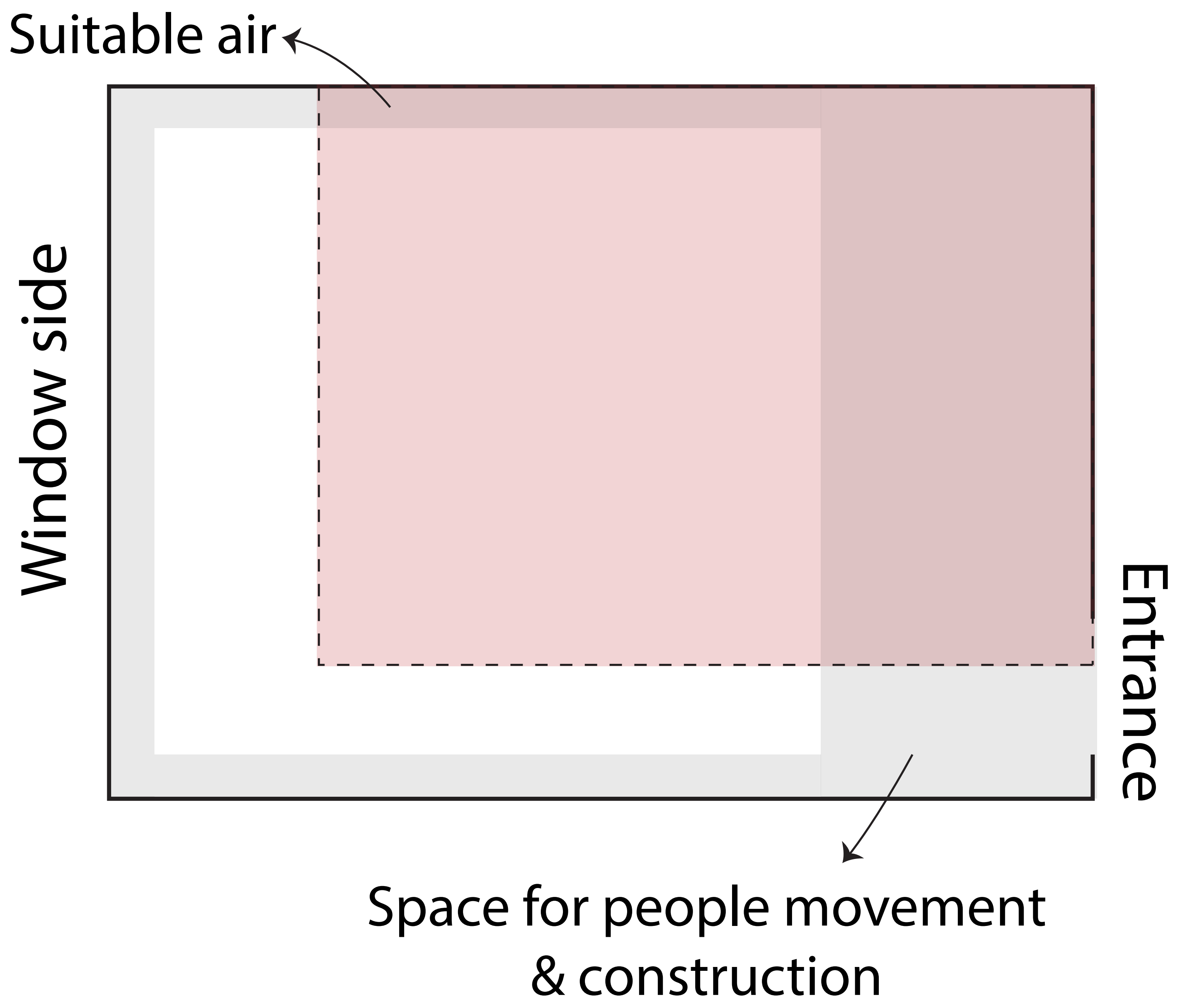
Blinds:
- adjust height

Slats:
- horizontal
- vertical

Refinement | Working area

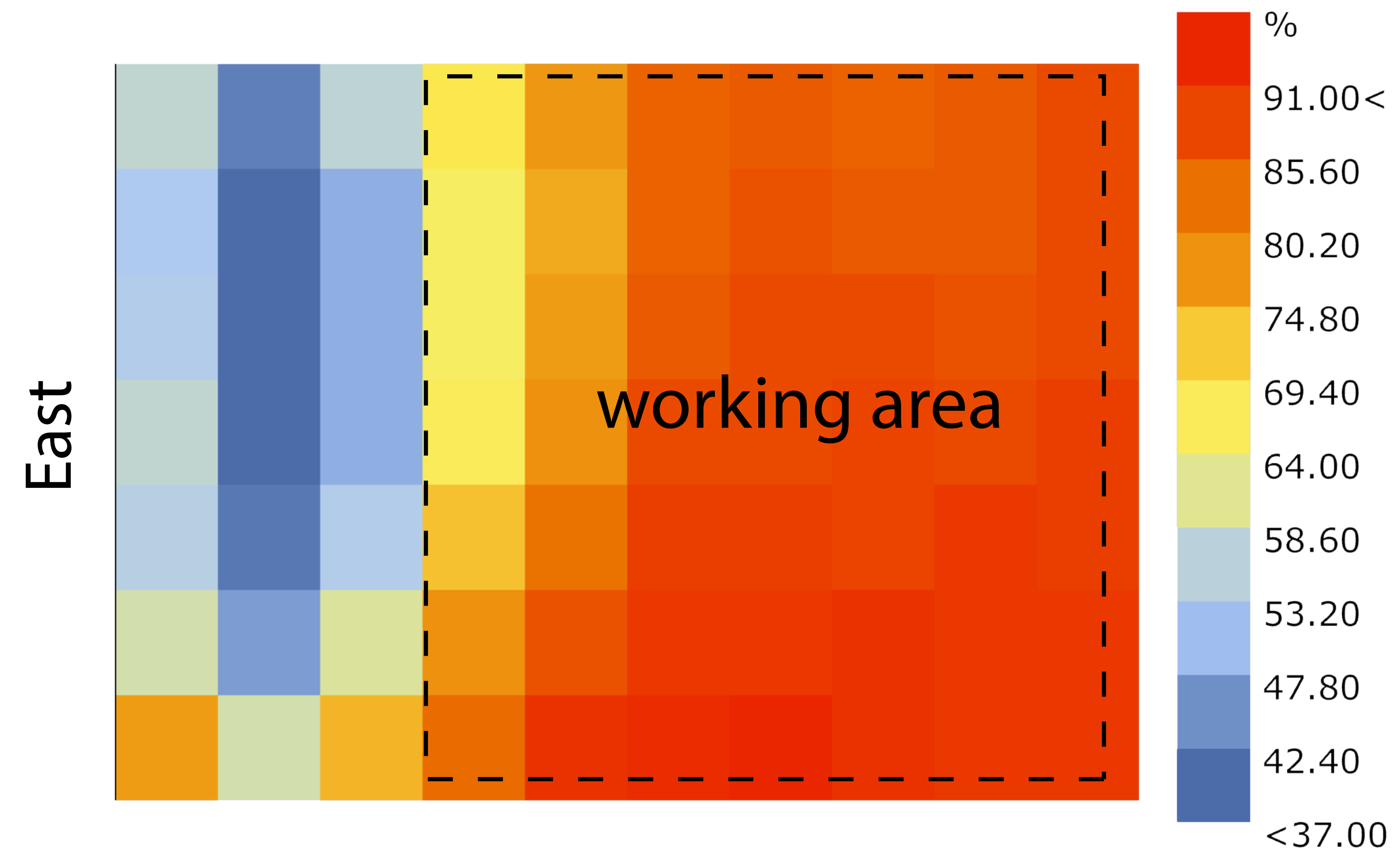


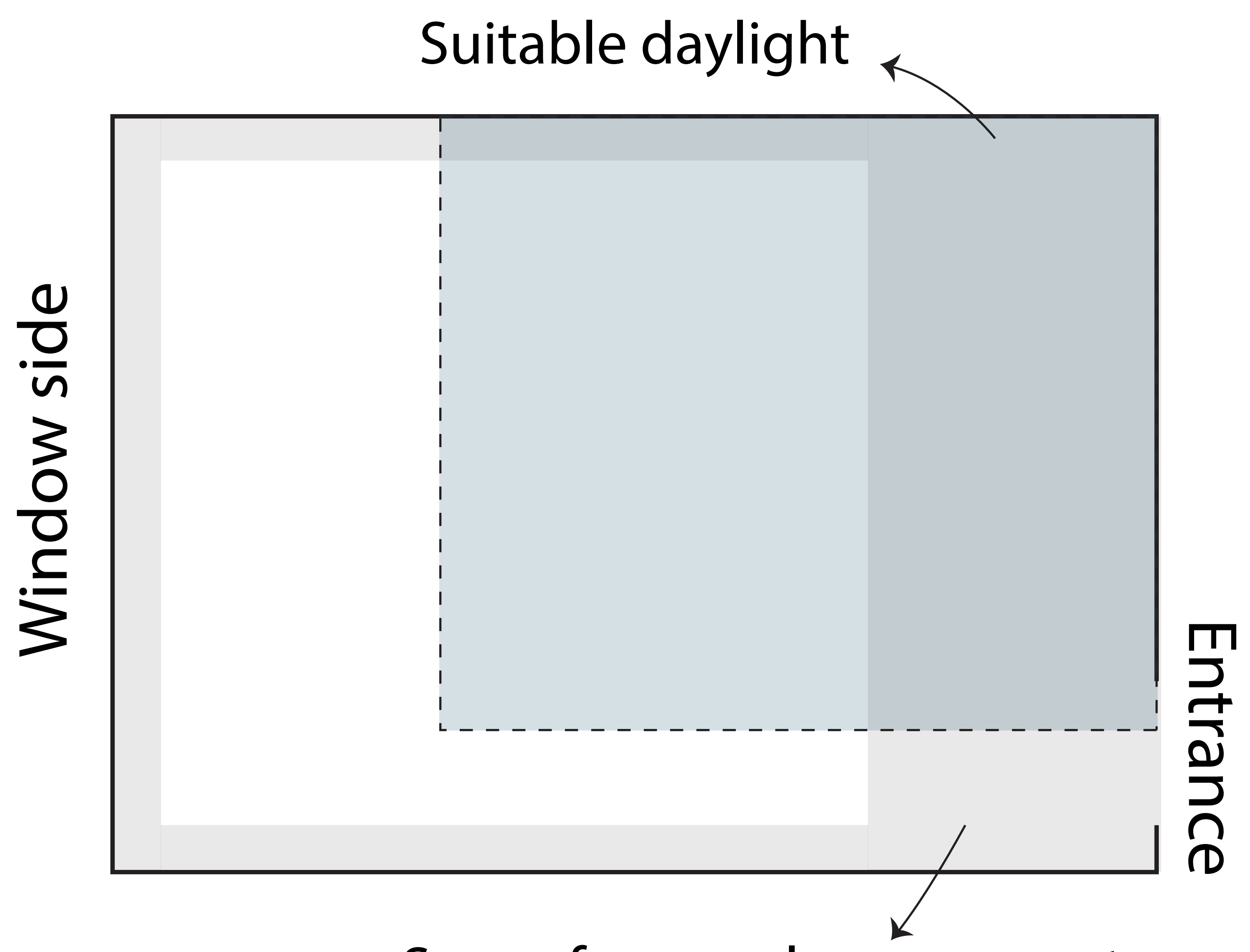


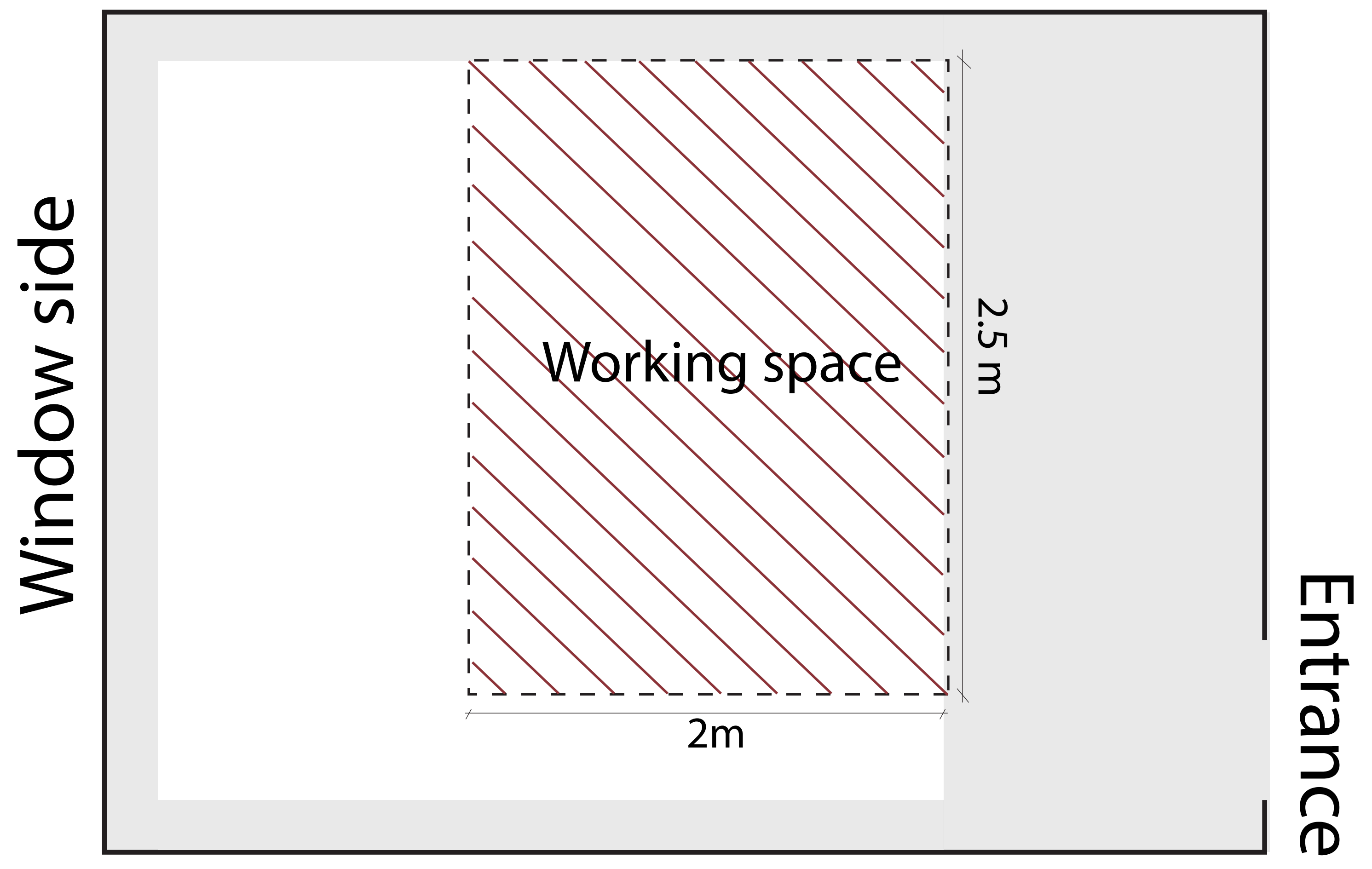


Refinement | Working area

Percentage of time during occupied that UDI fell in between 100lux and 2000lux

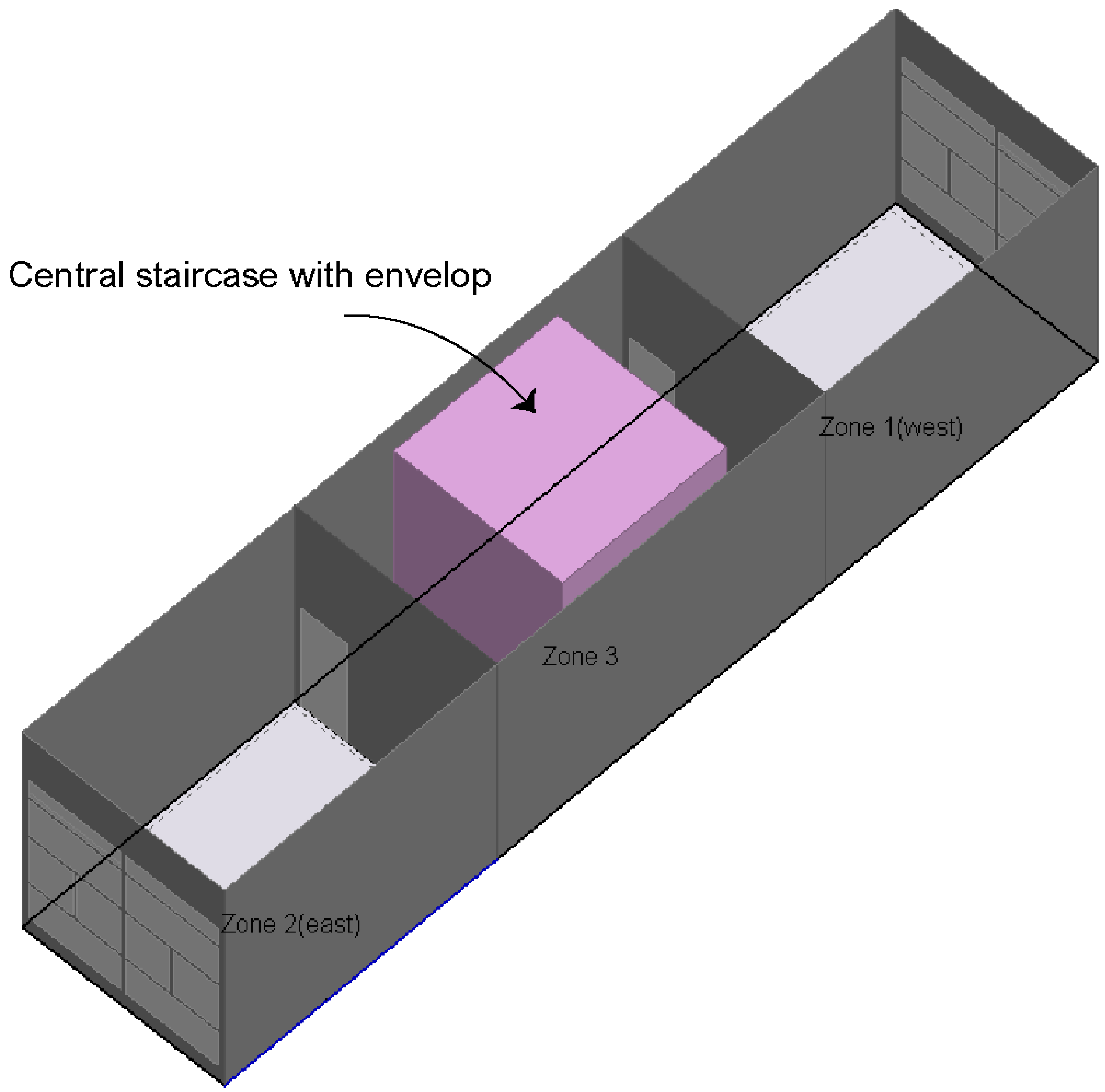






Estimation

Keeping the door opened 8:00-18:00



Annual performance

Discomfort / Energy	Single-sided	Cross vent
Discomfort	100%	172.2%
Energy	100%	-2.8%

Estimation

Operating internal shading at 16:00-18:00

	Spring Apr 15th	Autumn Oct 25th	Winter Jan 6th	Summer Aug 13th
Heating saved [kWh]	0.17	0.10	-0.07	-
Lighting saved [kWh]	-0.49	-0.10	-0.01	-0.53

Opening manual window at 8:00-9:00

Heating saved [kWh]	Spring Apr 15th	Autumn Oct 25th	Winter Jan 6th
	-3.84	-4.15	-13.89
	-3.11	-3.36	-14.52

Conclusion

Integrated control for CEG east facade

-SR, Tin & Schedule for shading control
-Tin & Schedule for window control

-Reduced occupant discomfort 84.8%
-Saved energy 60.2%

Recommendations for future research

-On-site test of the integrated control
-Comprehensive evaluation of the control

Thank you