TEM HEAT DISSIPATION SYSTEM

Increasing performance of a thermoelectrical integrated facade through the heat dissipation system

P5 - GRADUATION PRESENTATION

Yarai Mariam Zenteno Montemayor

1ST OF JULY, 2020

01 INTRODUCTION

+BACKGROUND

+FOCUS

+OBJECTIVES

+RESEARCH QUESTIONS

+METHODOLOGY

01 INTRODUCTION

+BACKGROUND

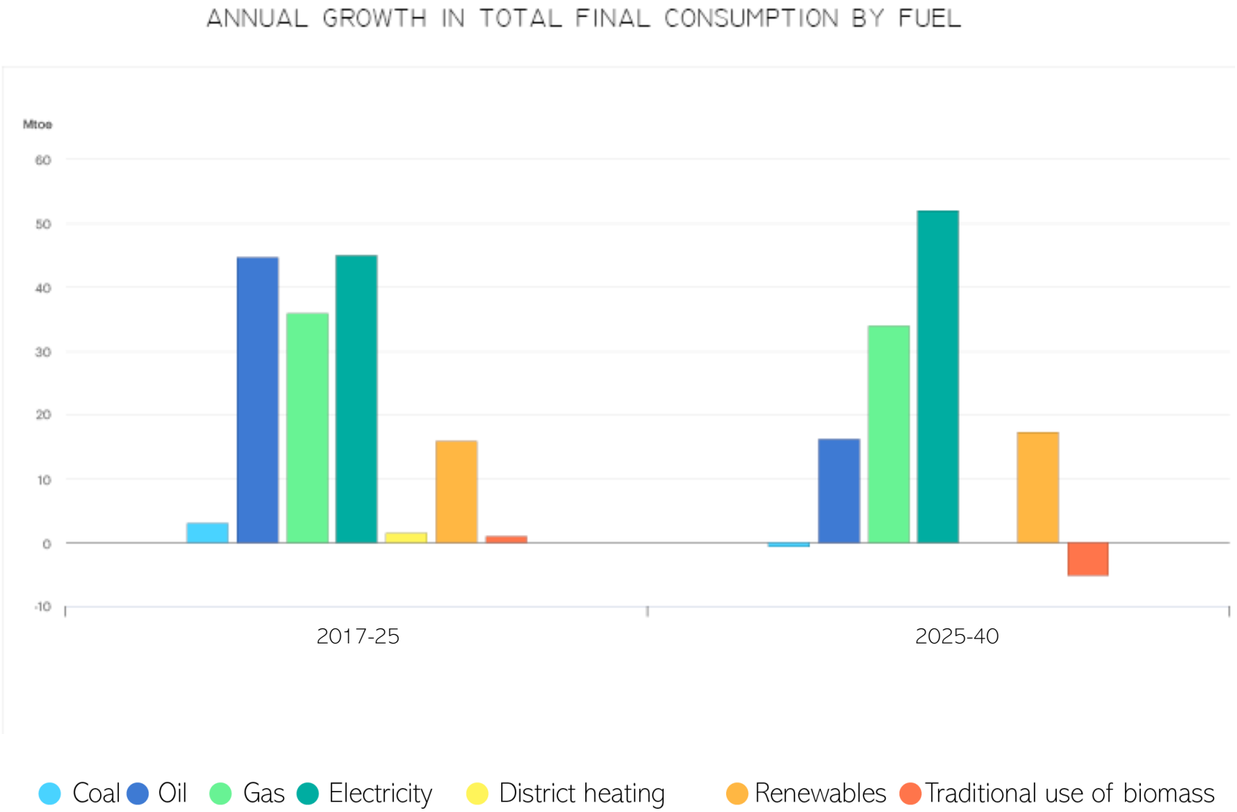
+FOCUS

+OBJECTIVES

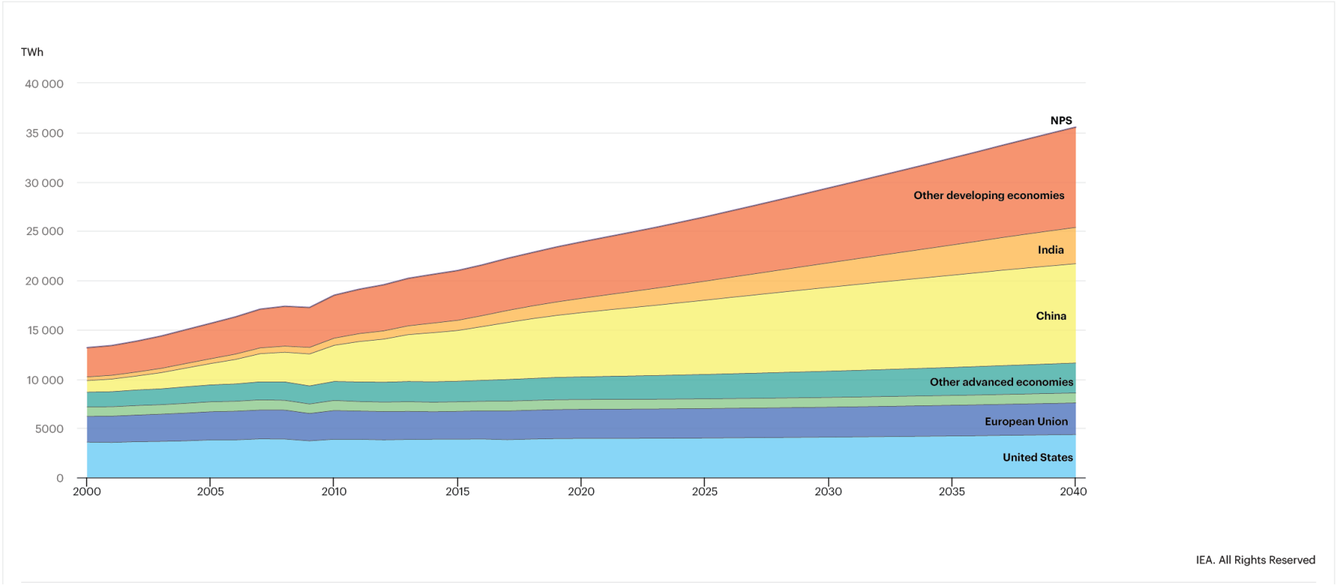
+RESEARCH QUESTIONS

+METHODOLOGY

+BACKGROUND GLOBAL TREND

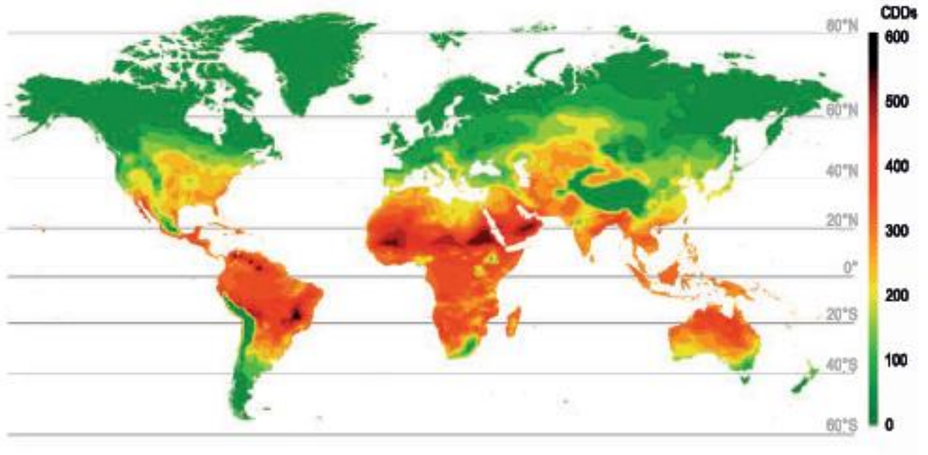


+BACKGROUND DEVELOPING COUNTRIES

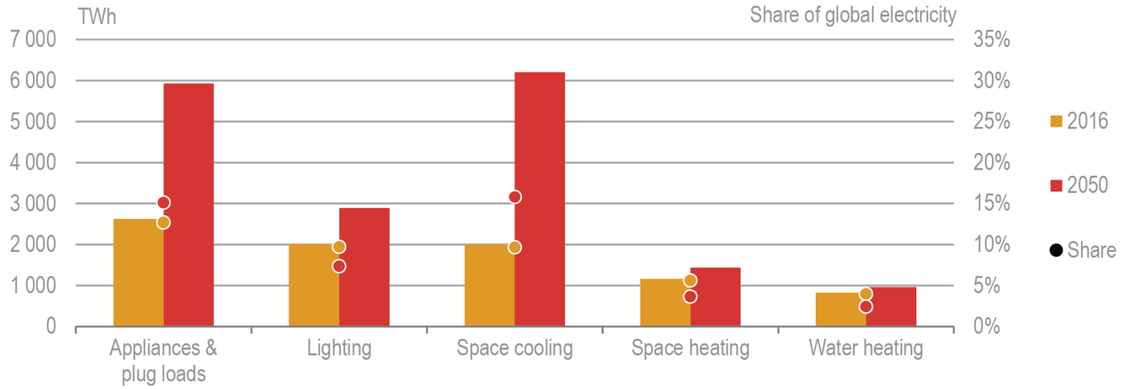


+BACKGROUND SPACE COOLING

increase in cdds (compared to historical data)



building electricity demand by end-use



01 INTRODUCTION

+BACKGROUND

+FOCUS

+OBJECTIVES

+RESEARCH QUESTIONS

+METHODOLOGY

+FOCUS

Climate

hot-arid climate

+FOCUS

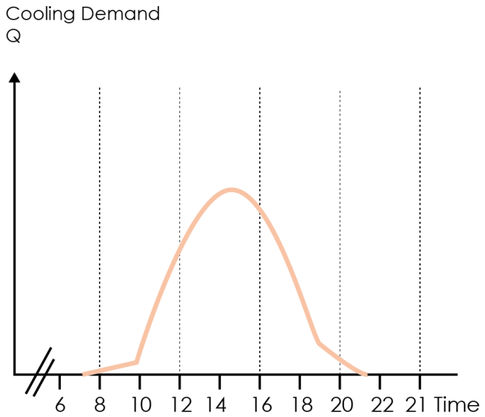
Building Typology

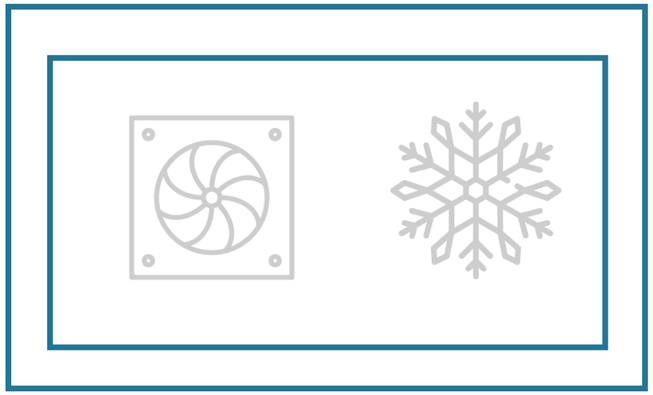
office building
(case-study)

+FOCUS

Building System

cooling system

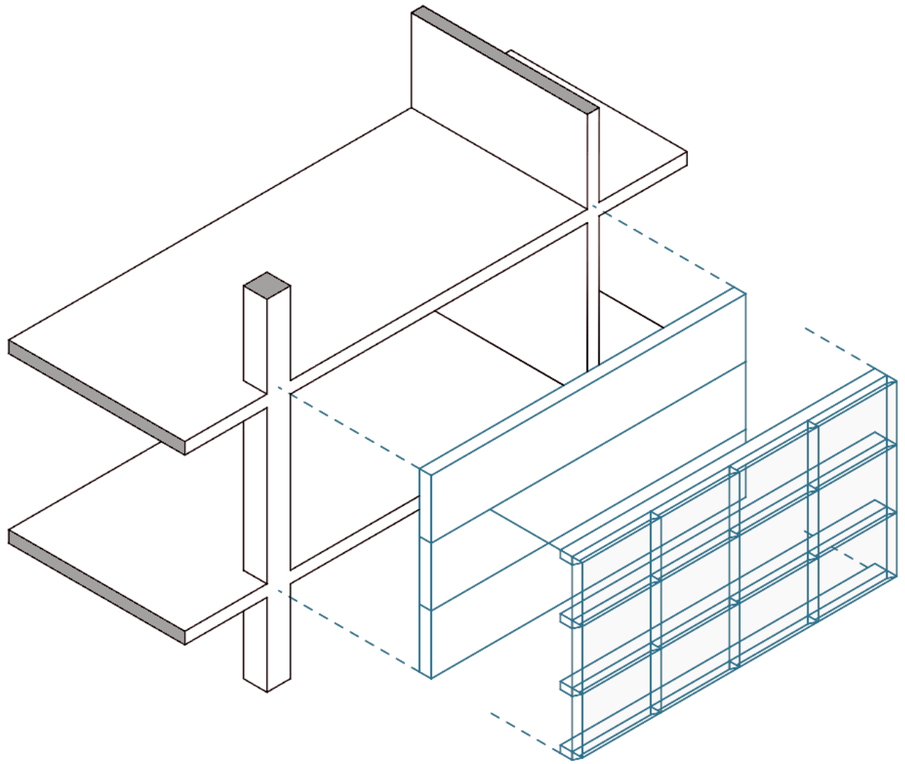




+FOCUS

Building Element

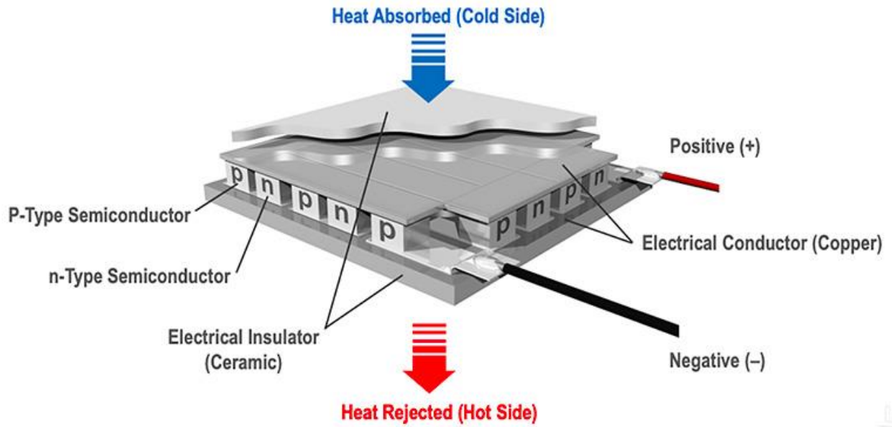
facade system



+FOCUS

System component

heat dissipation for Peltier Module



01 INTRODUCTION

+BACKGROUND

+FOCUS

+RESEARCH QUESTIONS

+METHODOLOGY

01 INTRODUCTION

+BACKGROUND

+FOCUS

+RESEARCH QUESTION

+METHODOLOGY

+RESEARCH QUESTION

How could a heat dissipation system for an integrated façade with TE active cooling be designed, for it to cover the cooling loads of a typical office building?

01 INTRODUCTION

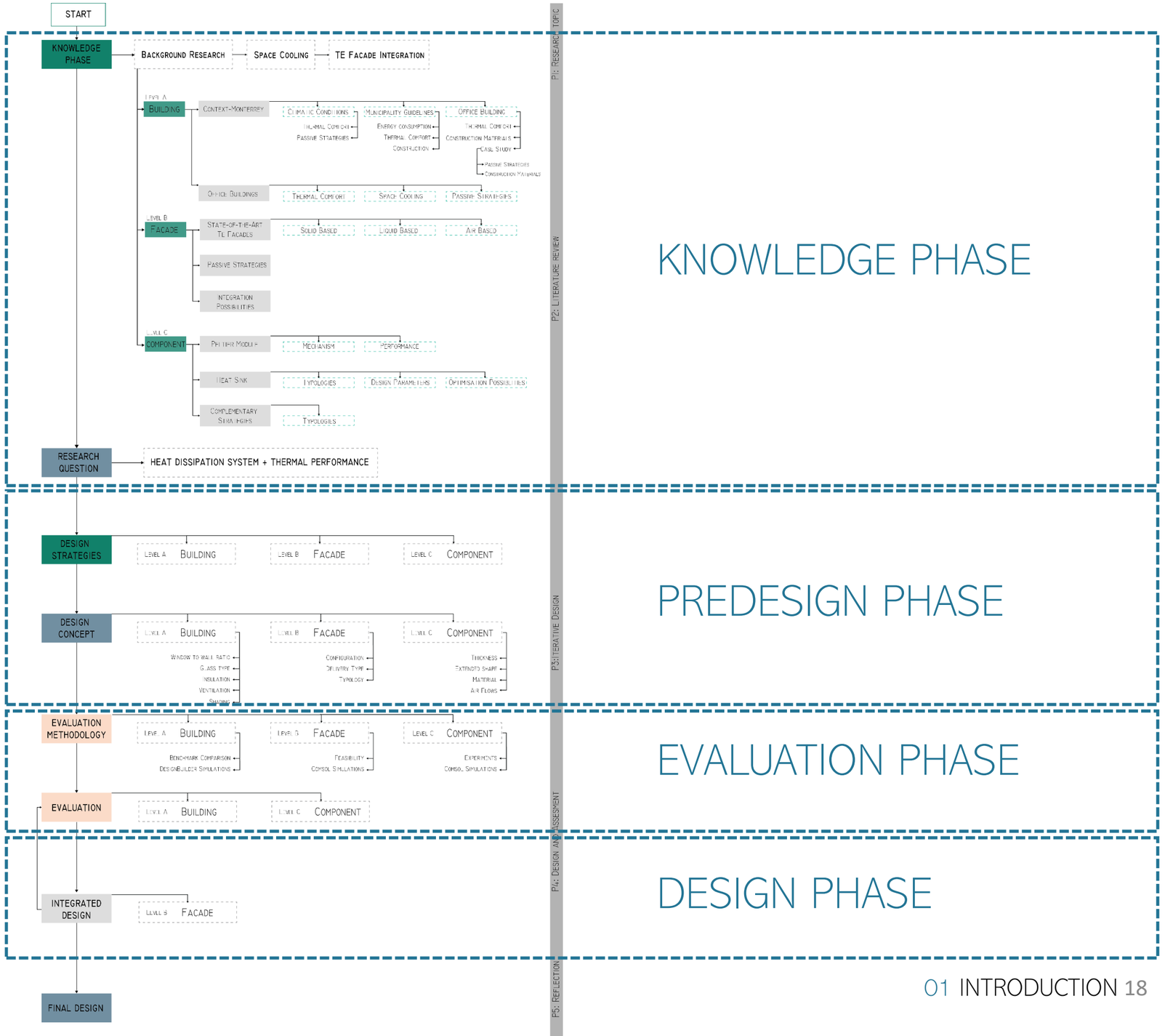
+BACKGROUND

+FOCUS

+RESEARCH QUESTIONS

+METHODOLOGY

+METHODOLOGY



02 KNOWLEDGE

+TE TECHNOLOGY

+TE FACADES

+HEAT DISSIPATION

+CONTEXT

02 KNOWLEDGE

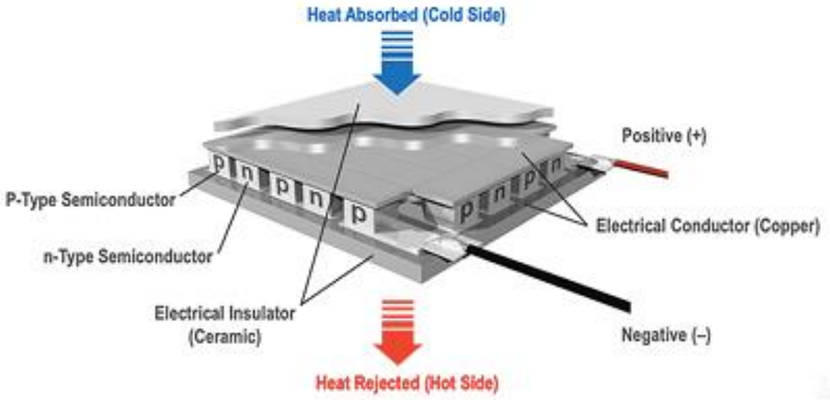
+TE TECHNOLOGY

+TE FACADES

+HEAT DISSIPATION

+CONTEXT

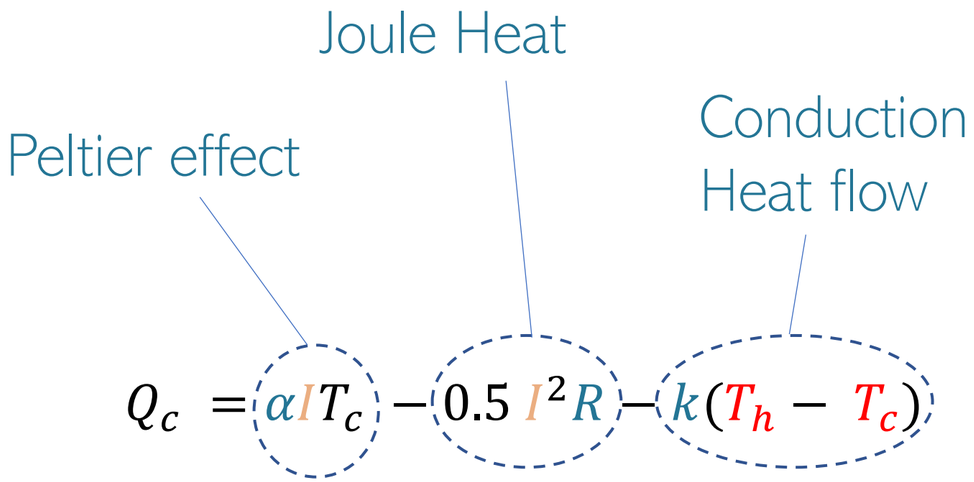
+TE TECHNOLOGY
(TE=THERMOELECTRIC)



! EXCESS HEAT TRANFER TO COLD SIDE

+TE TECHNOLOGY PERFORMANCE BOOST

Material design
Current intensity & Voltage
Decrease in temperature difference



$$Q_h = \alpha I T_h + 0.5\, I^2 R - k(T_h - T_c)$$

$$COP_c = Q_c / P$$

$$COP_h = Q_h / P$$

k : thermal conductivity, $Wm\text{-}1K\text{-}1$
α: Seebeck coefficient, $VK\text{-}1$
R: electrical resistance, ohm
I: current, A
P: electric power, W

02 KNOWLEDGE

+TE TECHNOLOGY

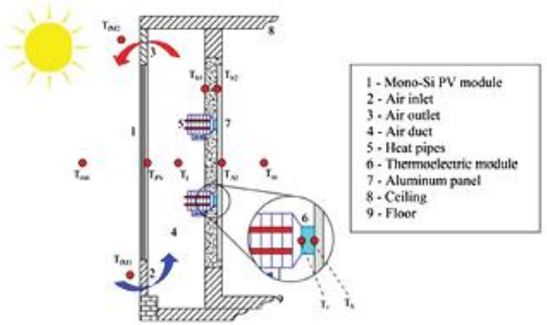
+TE FACADES

+HEAT DISSIPATION

+CONTEXT

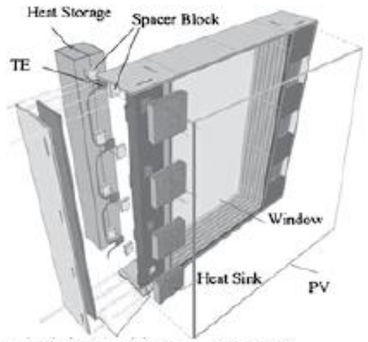
+TE FACADES

SOLID-BASED



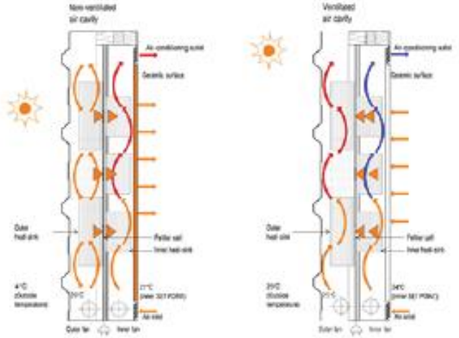
CONCEPT BY LUO ET AL.(2016)

LIQUID-BASED



CONCEPT BY XU ET AL.(2007)

AIR-BASED



CONCEPT BY IBANEZ PUY ET AL.(2016)

	SOLID-BASED	LIQUID-BASED	AIR-BASED
INTEGRATION	x	x	x
WALL	x		x
WINDOW		x	
VENTILATION			x
HEAT DISSIPATION	x	x	x
HEAT PIPES	x	x	
WATER STORAGE		x	
HEAT SINKS	x	x	x

02 KNOWLEDGE

+TE TECHNOLOGY

+HEAT DISSIPATION

+TE FACADES

+HEAT DISSIPATION

+CONTEXT

+HEAT DISSIPATION PERFORMANCE BOOST

Lower thermal resistance through:
Base plate thickness
Fin shape/profile
Heat sink material
Cross-cut patters

02 KNOWLEDGE

+TE TECHNOLOGY

+HEAT DISSIPATION

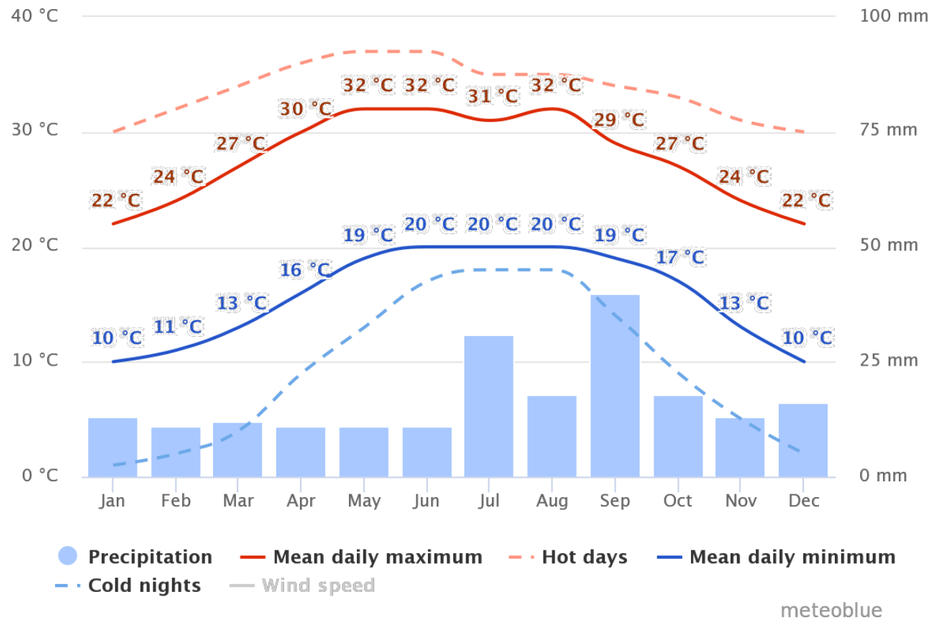
+TE FACADES

+HEAT DISSIPATION

+CONTEXT

+CONTEXT

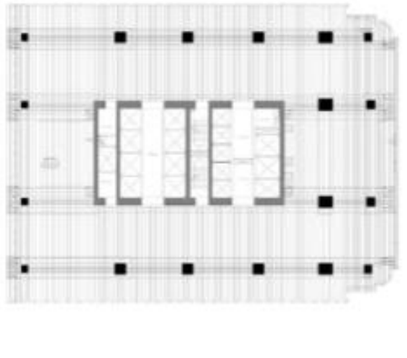
HOT ARID CLIMATE



+CONTEXT

CASE STUDY

Koi Tower,
Monterrey



03 PROCESS

+CONCEPT

+EVALUATION – Component

+EVALUATION – Building

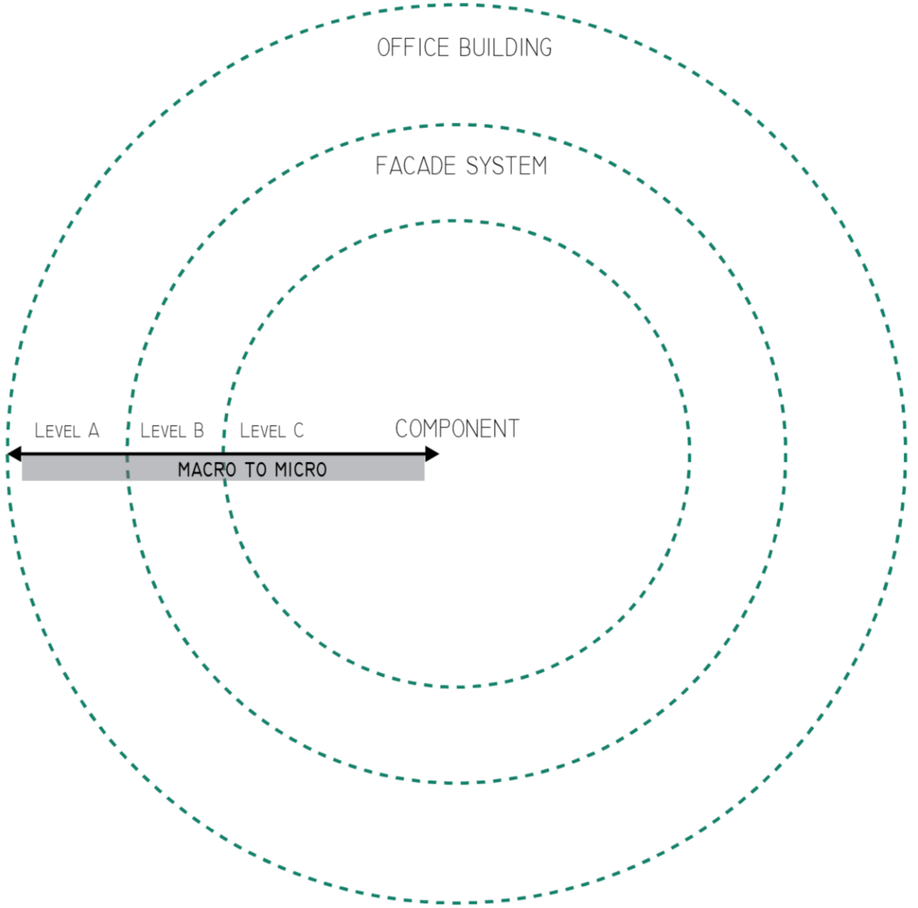
03 PROCESS

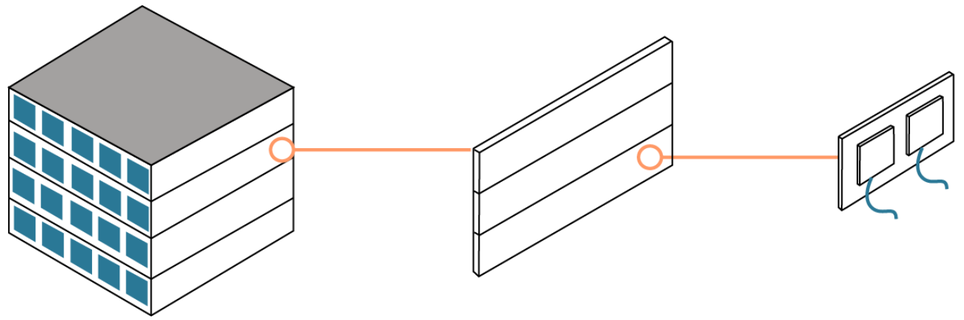
+CONCEPT

+EVALUATION – Component

+EVALUATION – Building

+CONCEPT Design Levels

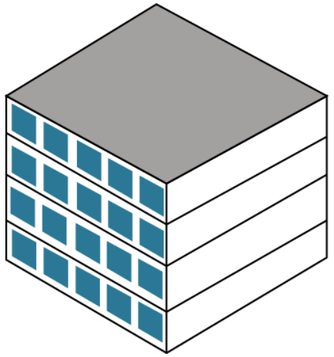




+CONCEPT

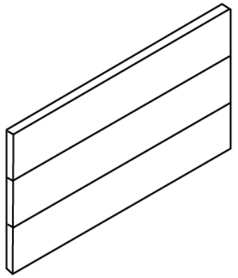
Parameters

LEVEL A



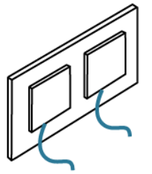
1 Glazing
2 Insulation
3 Glass Type
4 Shading
5 Ventilation

LEVEL B



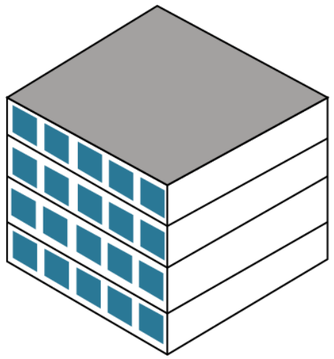
1 Configuration
2 Integration

LEVEL C



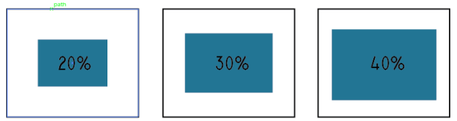
1 Thickness
2 Extended Surface
3 Material
4 Air flows

+CONCEPT

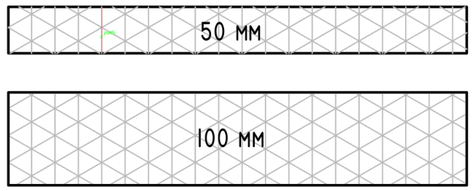


Design Strategies

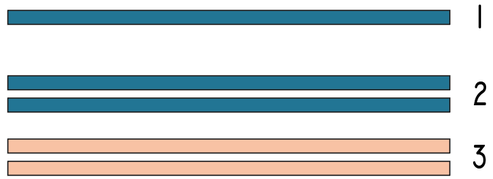
Building



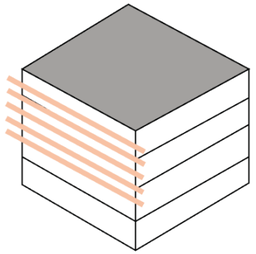
1 WWR: variations
(20%,30% and 40%)



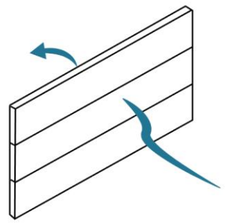
2 Insulation: thickness
50 mm and 100 mm



3 Glass type:
Clear single glazing, clear double glazing, low-e double glazing



4 Shading: internal and external

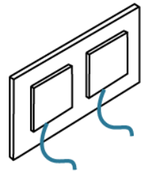


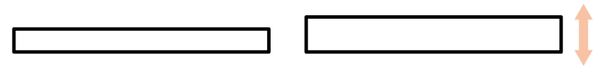
5 Ventilation:
Natural ventilation, Night free cooling

+CONCEPT

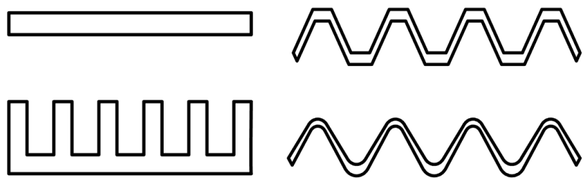
Design Strategies

Component

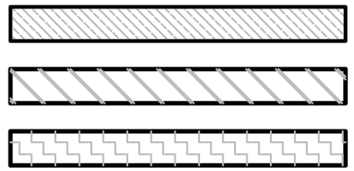




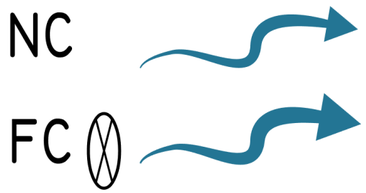
1 HS Thickness



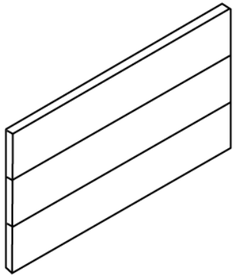
2 HS Extended Surface



3 HS Material

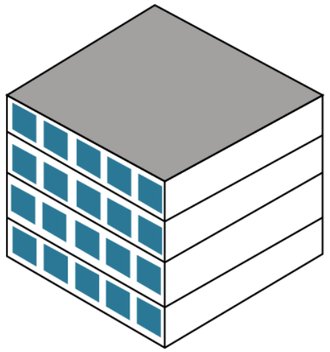


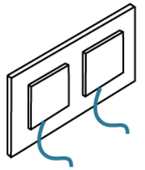
4 Air Flow

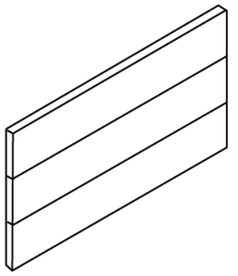


+CONCEPT Design Strategies

Façade







1 Configuration
2 Delivery Method

03 PROCESS

+CONCEPT

+EVALUATION – Component

+Methodology

+Strategies

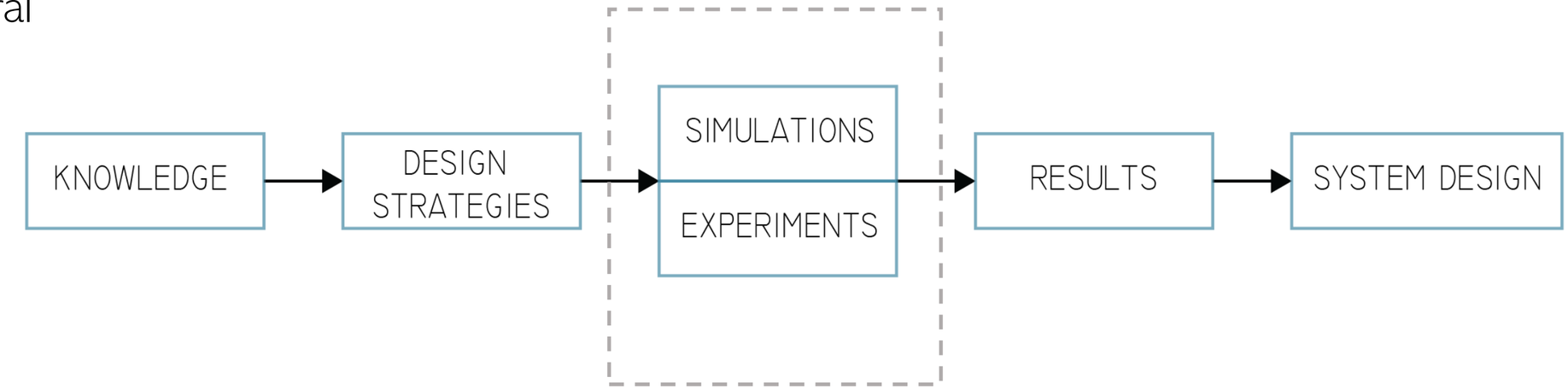
+Results

+EVALUATION – Building

+EVALUATION – Component

+Methodology

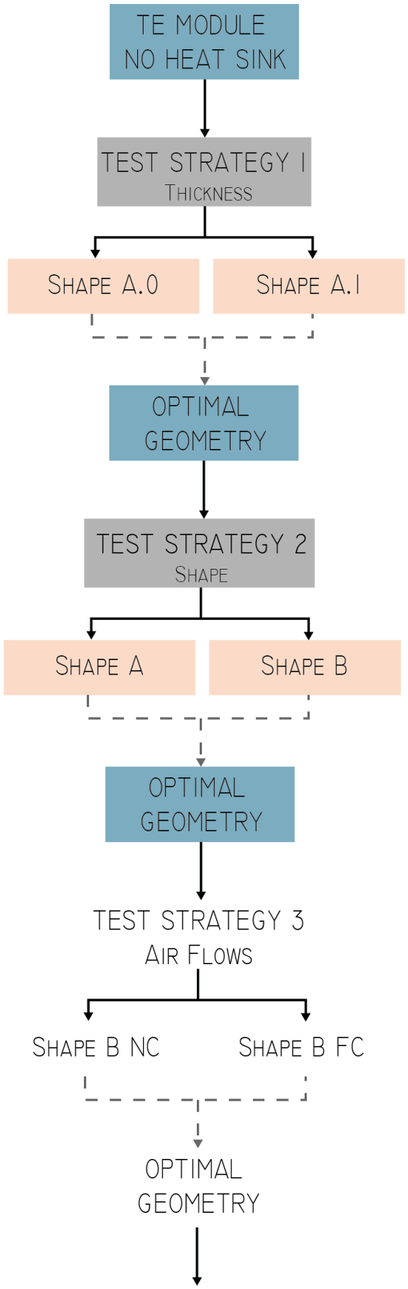
General



+EVALUATION – Component

+Methodology

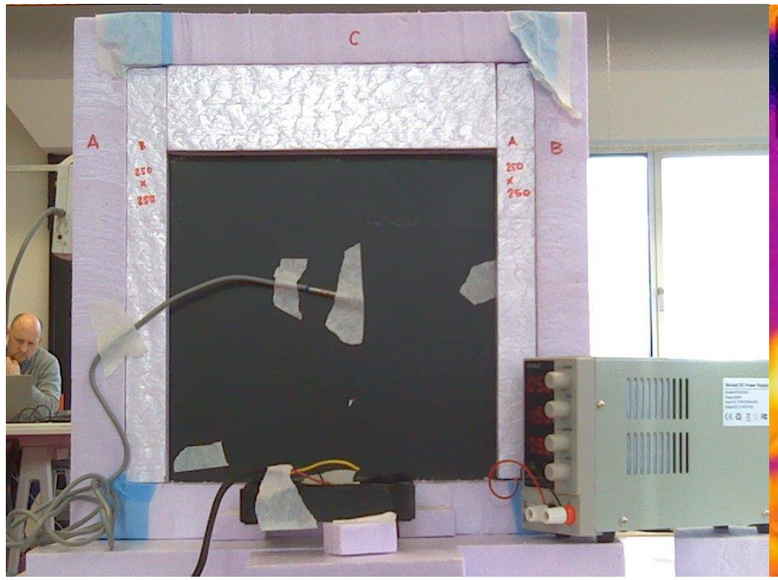
Stepped Methodology

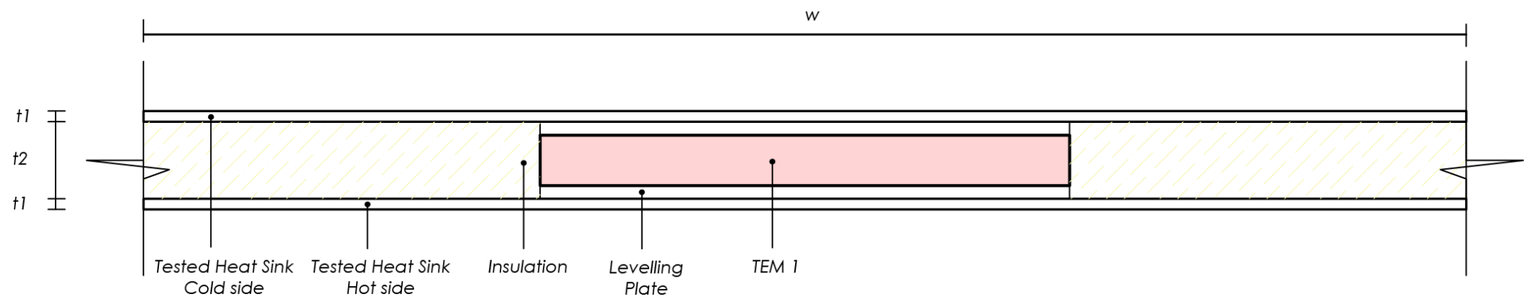


+EVALUATION – Component

+Methodology

Experiments



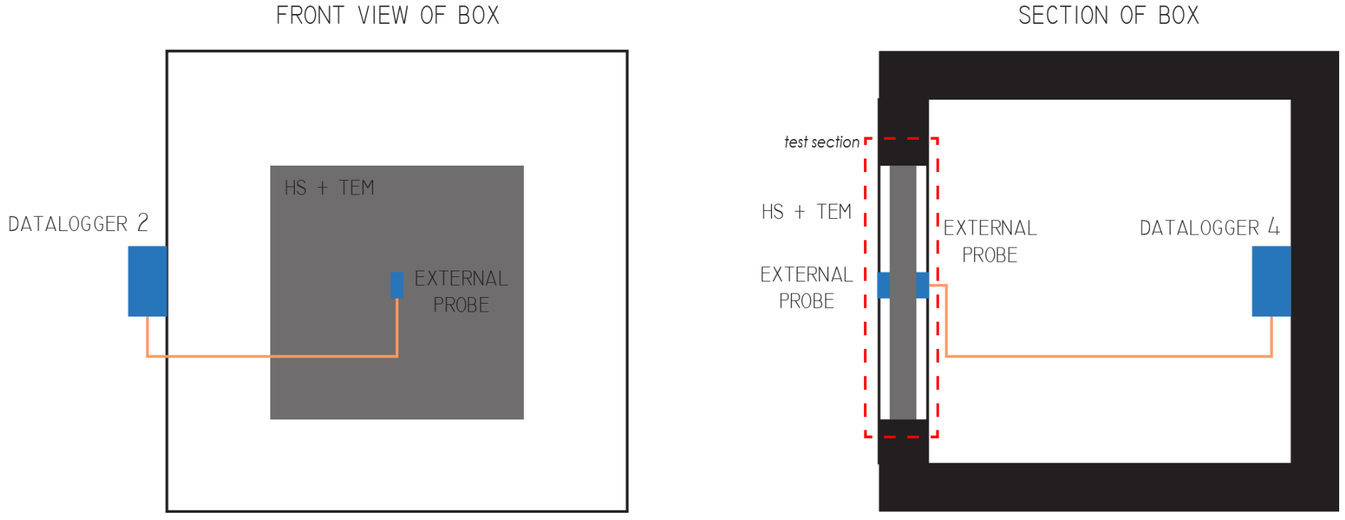


Tested Component Layer Composition

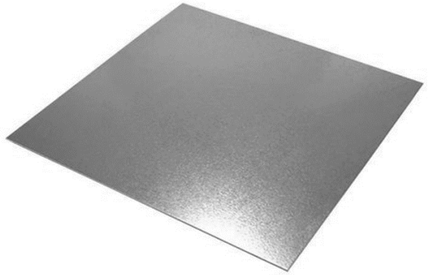
+EVALUATION – Component

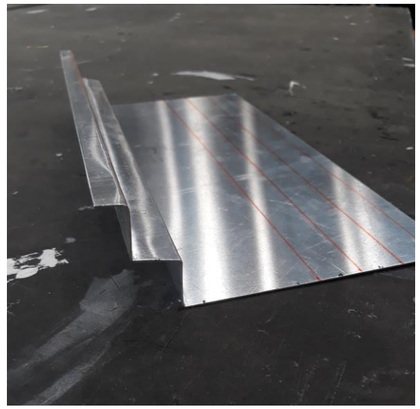
+Methodology

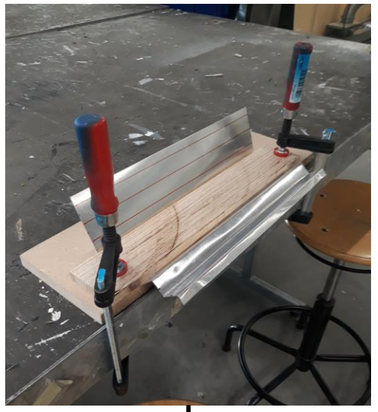
Experiment Setup



Hot Box Composition / Probe Locations



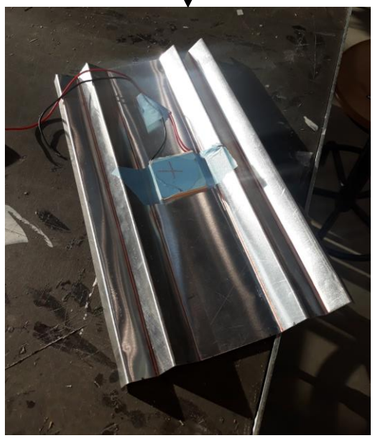




+EVALUATION – Component

+Methodology

Specimen construction

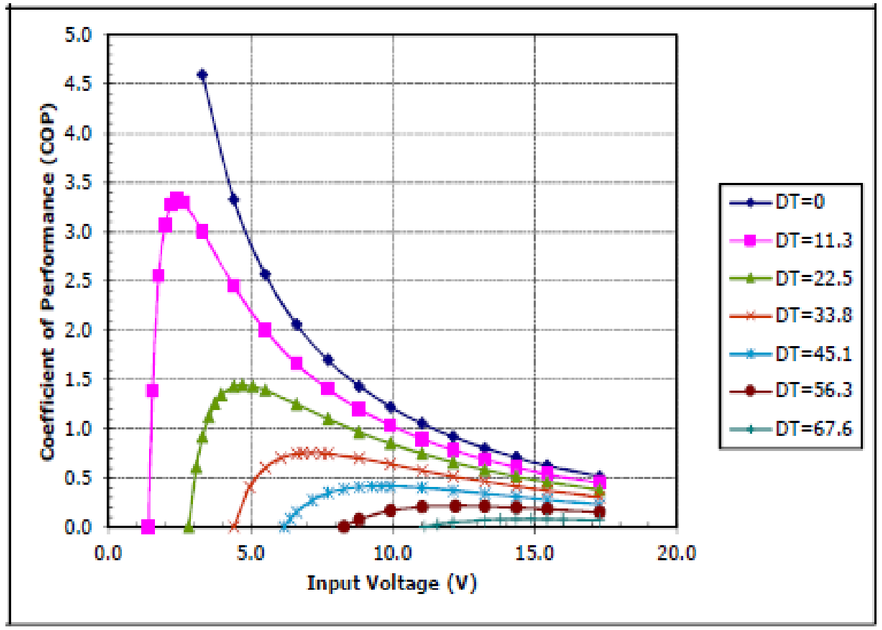


+EVALUATION – Component

+Methodology

+Strategies

Experiment Baseline



TEC1 - 12706 Module		
I max	6.4	6.4
V max	14.4	16.4
ΔT	66	75
T hot	25	50
Q max	50	57
AC resistance	1.98	2.3
Number of couples	127	
Dimensions	40*40*3.8	

+EVALUATION – Component

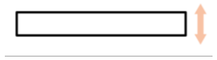
+Methodology

+Strategies

Frozen parameters

Experiment Set-Up: Strategy 1

num	TE module	TE quantity	Voltage (V)	Current (amps)	Power (W)	HS shape	Physical Parameter tested	Dimensions(mm)	Volume (mm3)
1	TEM1	1	5	1.23	6.1	Aluminium Plate	thickness	250x250x0.8	50000
2	TEM1	1	6	1.37	8.16	Aluminium Plate	thickness	250x250x0.8	50000
3	TEM1	1	5	1.22	6.05	Aluminium Plate	thickness	250x250x1.0	62500
4	TEM1	1	6	1.41	8.4	Aluminium Plate	thickness	250x250x1.0	62500



Experiment Set-Up : Strategy 2

num	TE module	TE quantity	Voltage (V)	Current (amps)	Power (W)	HS shape	Physical Parameter tested	Dimensions (mm)	Volume (mm3)
3	TEM1	1	5	1.22	6.05	A: Aluminium Plate	thickness	250x250x1.0	62500
4	TEM1	1	6	1.41	8.4	A: Aluminium Plate	thickness	250x250x1.0	62500
5	TEM1	1	5	1.51	7.55	B: Origami	Shape	250x250x1.0	62500
6	TEM1	1	6	1.77	10.6	B: Origami	Shape	250x250x1.0	62500

Experiment Set-Up: Strategy 3

num	TE module	TE quantity	Voltage (V)	Current (amps)	Power (W)	HS shape	Parameter tested	Dimensions (mm)	Volume (mm3)	Air Flow	Velocity m/s
5	TEM1	1	5	1.51	7.55	Origami	Shape	250x250x 1.0	62500	NC	NA
6	TEM1	1	6	1.77	10.6	Origami	Shape	250x250x 1.0	62500	NC	NA
7	TEM1	1	5	1.49	7.45	Origami	Shape	250x250x 1.0	62500	FC	1.10-1.30
8	TEM1	1	6	1.75	10.2	Origami	Shape	250x250x 1.0	62500	FC	1.10-1.30

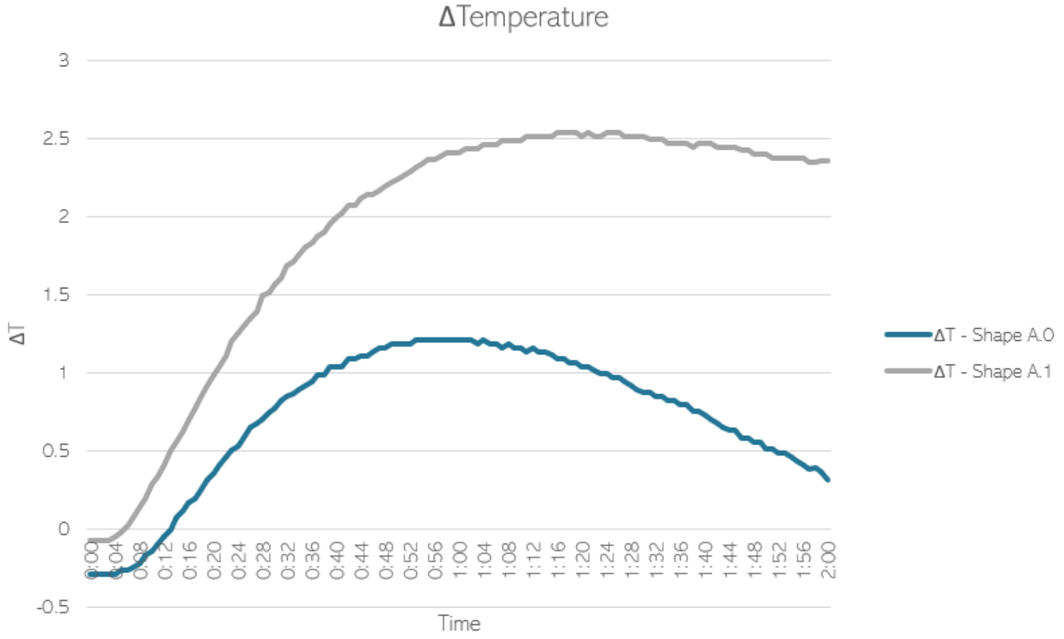
+EVALUATION – Component

+Methodology

+Strategies

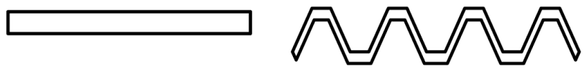
+Results

01 Thickness



0.8 mm
ΔT: 1.2 °C
HS Hot side: 25.04 °C
HS Cold side: 23.84 °C

1.0 mm
ΔT: 2.5 °C
HS Hot side: 26.54°C
HS Cold side: 24.04 °C



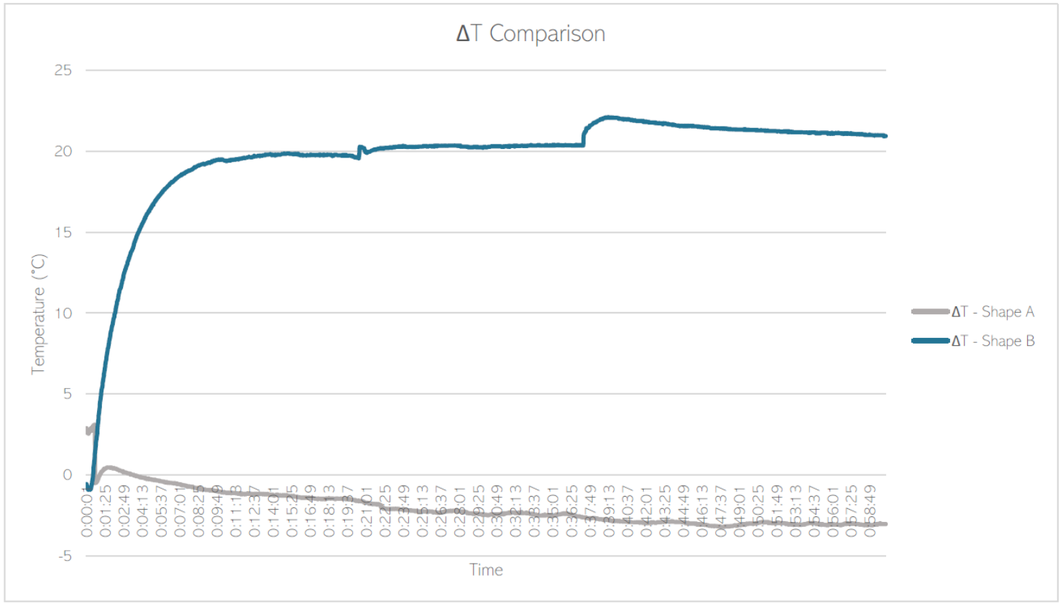
+EVALUATION – Component

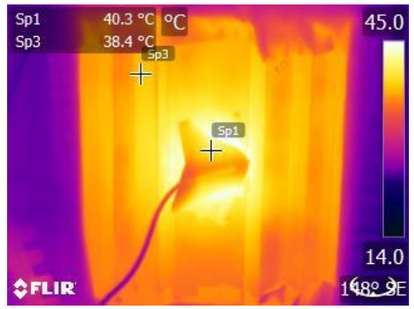
+Methodology

+Strategies

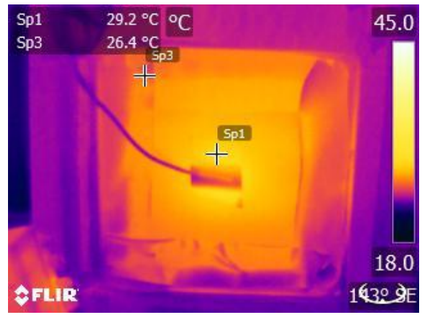
+Results

02 Shape





Shape B - Origami
ΔT: 20.25 °C
HS Hot side: 39.37 °C
HS Cold side: 19.13 °C



Shape A – Aluminium Plate
ΔT: 2.47 °C
HS Hot side: 28.90°C
HS Cold side: 31.46 °C

NC

FC

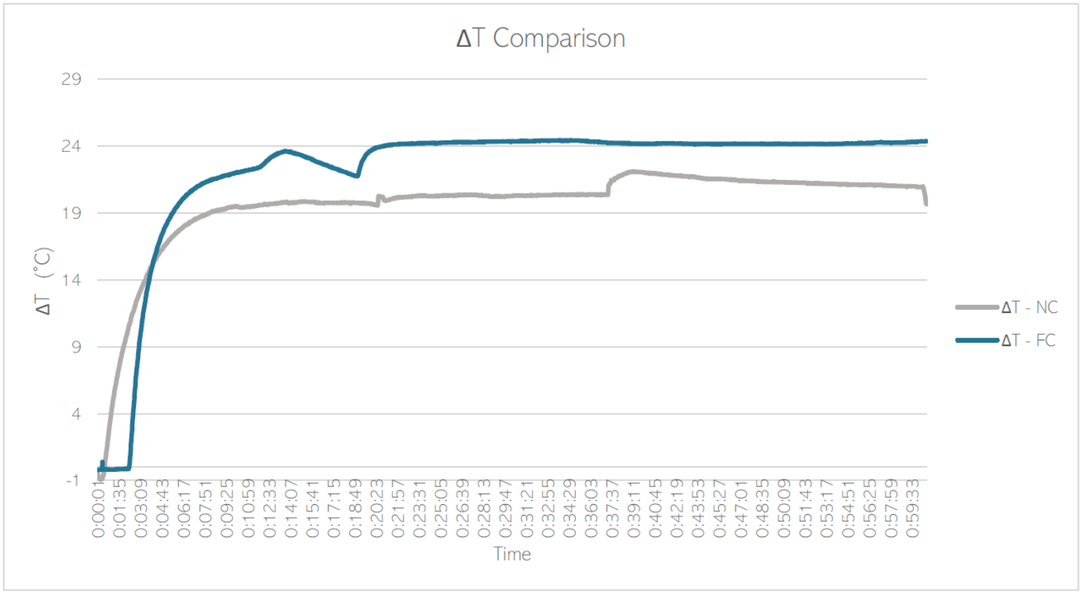
+EVALUATION – Component

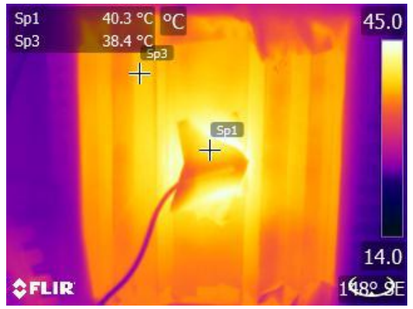
+Methodology

+Strategies

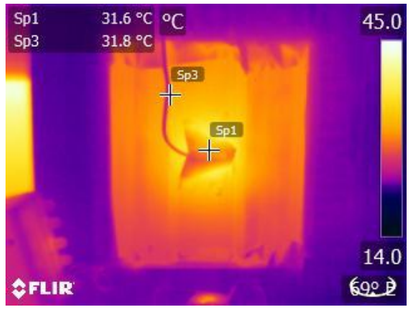
+Results

03 Air Flows





Natural Convection
ΔT: 20.13 °C
HS Hot side: 38.95 °C
HS Cold side: 18.82 °C



Forced Convection
ΔT: 24.13°C
HS Hot side: 39.72°C
HS Cold side: 15.58 °C

NC

FC

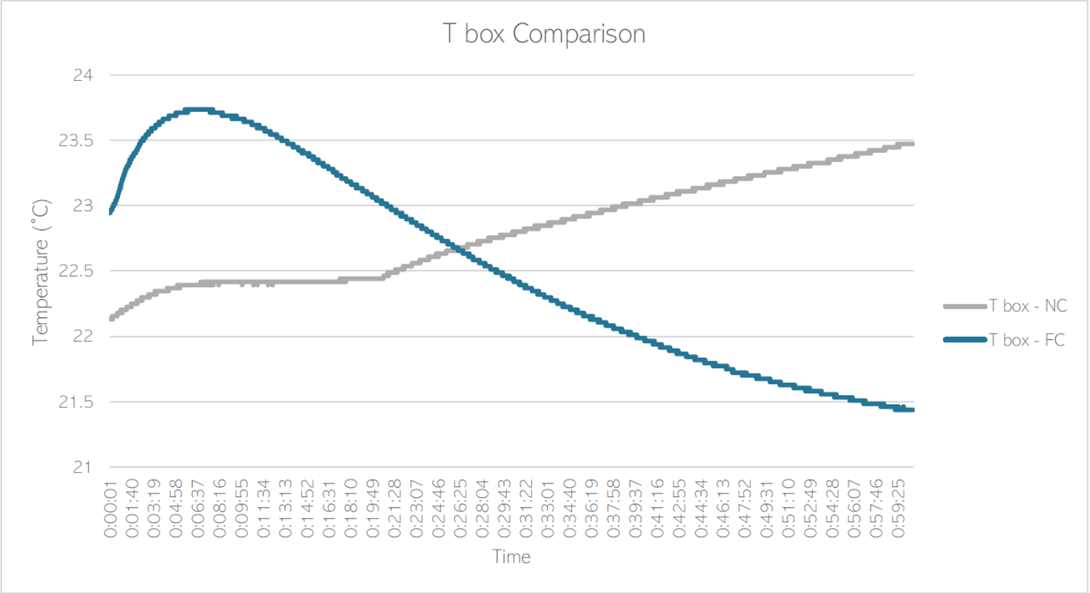
+EVALUATION – Component

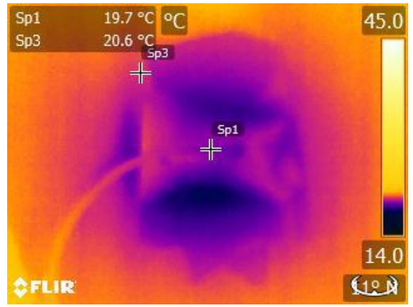
+Methodology

+Strategies

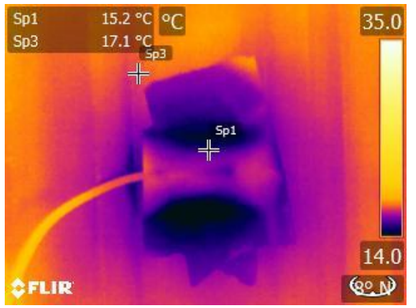
+Results

03 Air Flows





Natural Convection
Min T box: 22.13 °C



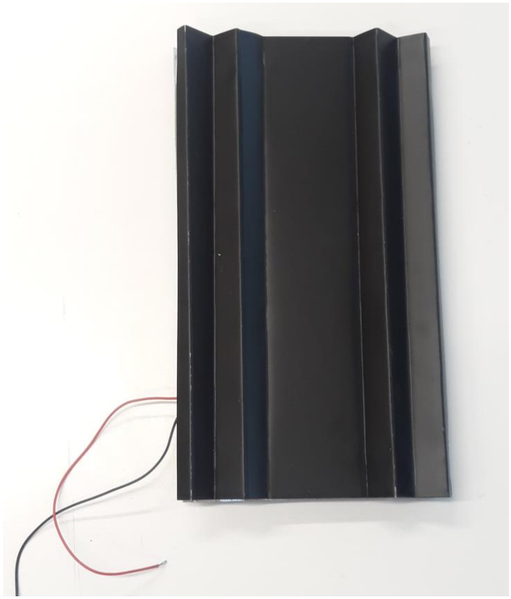
Forced Convection
Min T box: 21.44 °C

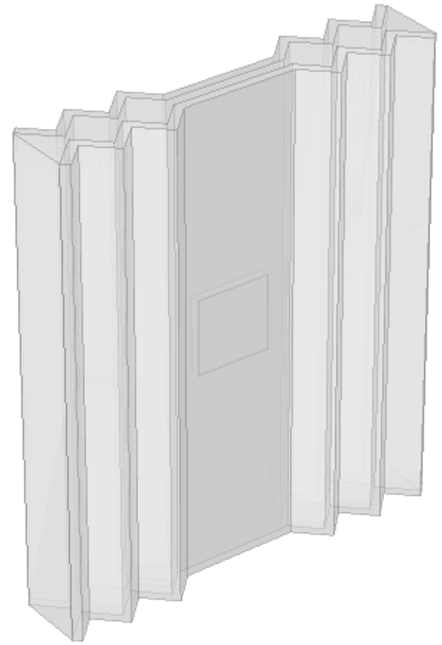
+EVALUATION – Component

+Methodology

+Strategies

Simulation Baseline





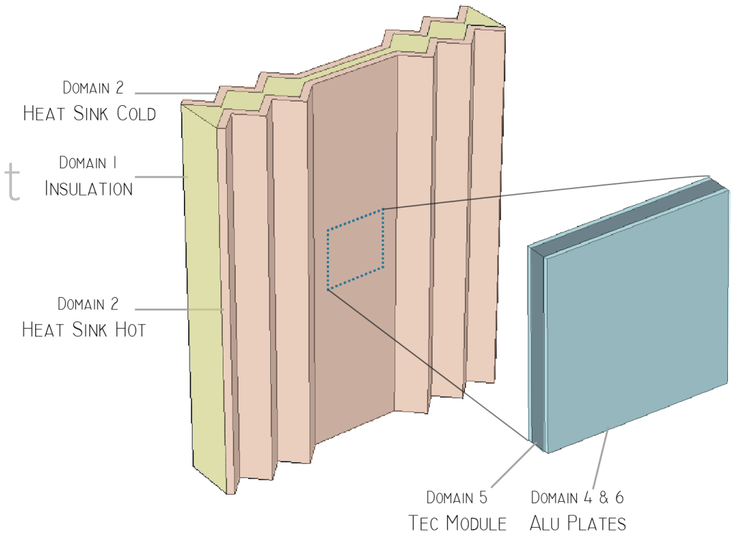
*when laminar flow was included simulation time was very long
*so an empirical *h* was used, based on research

+EVALUATION – Component

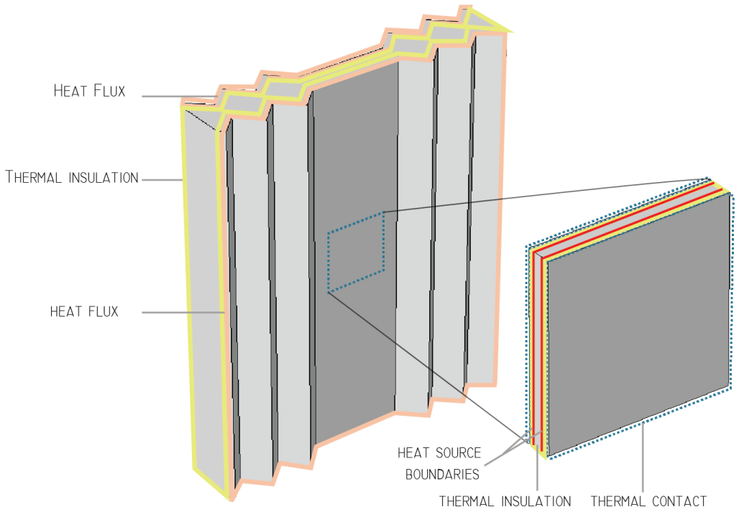
+Methodology

Boundary Conditions
Strategies 1-3

COMSOL DOMAINS (STRATEGIES 1-3)



COMSOL HEAT TRANSFER (STRATEGIES 1-3)

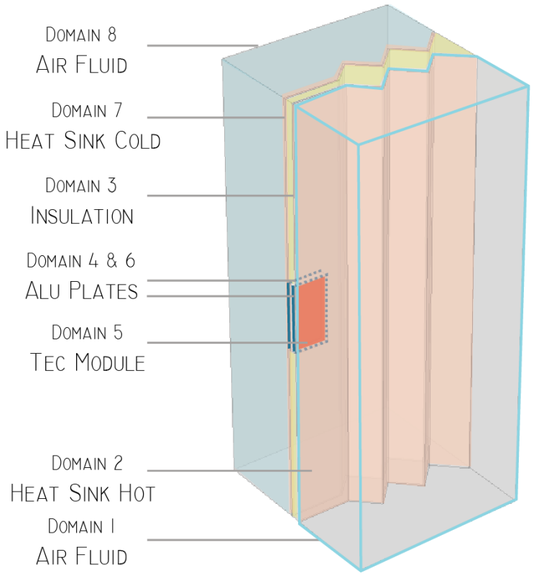


+EVALUATION – Component

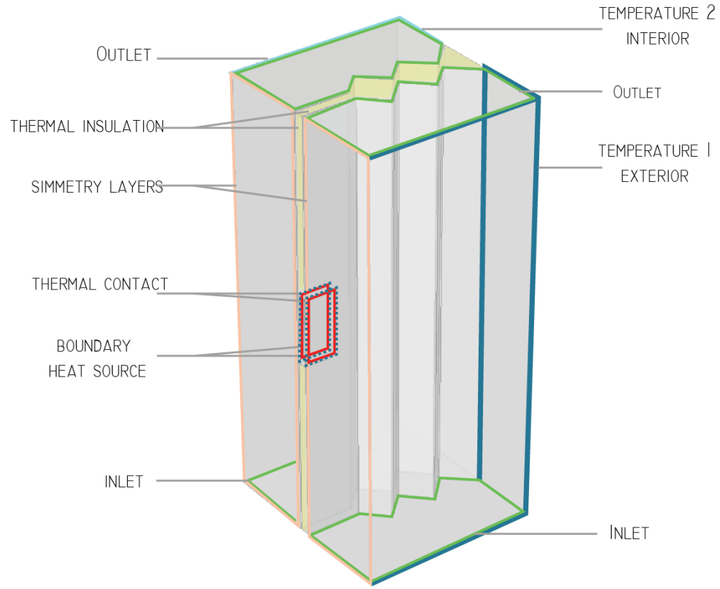
+Methodology

Boundary Conditions
Strategy 4

COMSOL DOMAINS (STRATEGY 4)



COMSOL HEAT TRANSFER (STRATEGY 4)



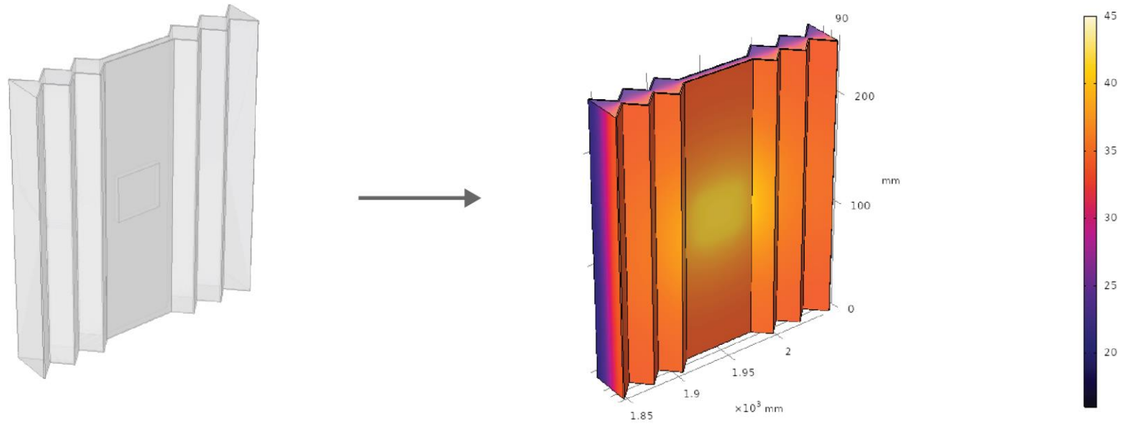
+EVALUATION – Component

+Methodology

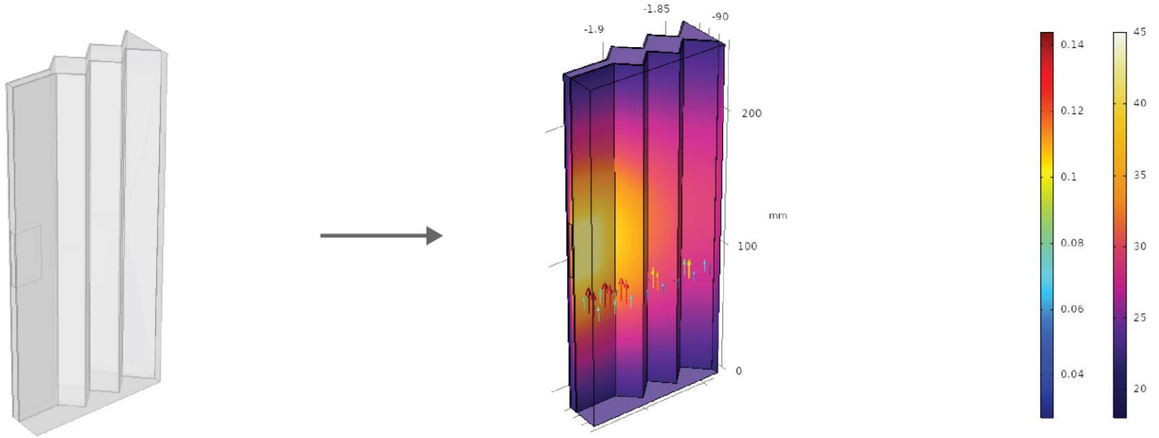
+Strategies

Simulations – 3D Heat Transfer

3D HEAT TRANSFER STUDY (STRATEGIES 1-3)



3D HEAT TRANSFER STUDY (STRATEGY 4)



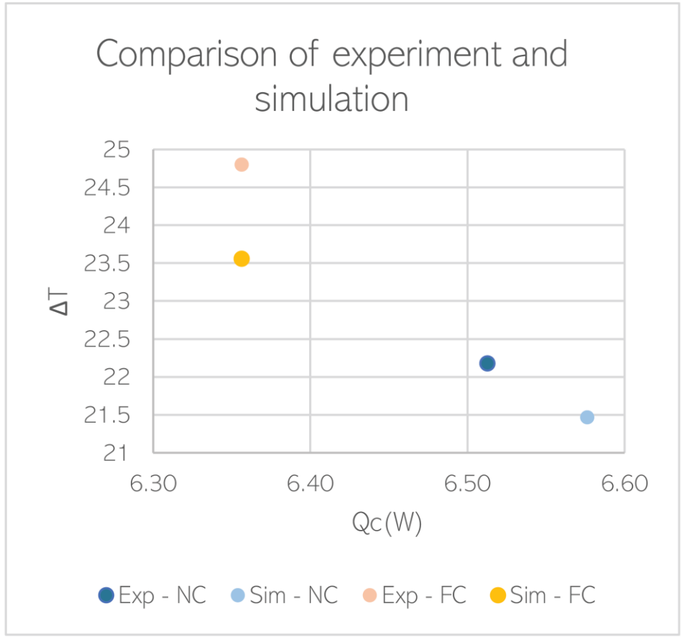
+EVALUATION – Component

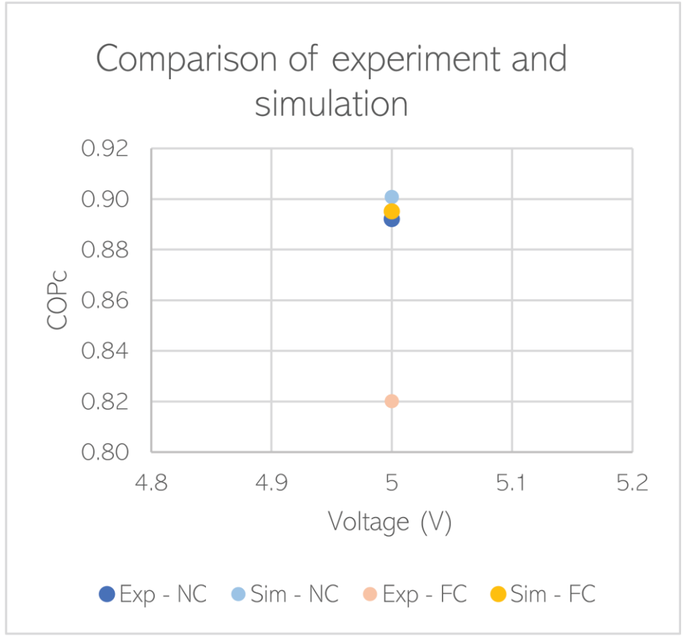
+Methodology

+Strategies

+Results

Simulation Base

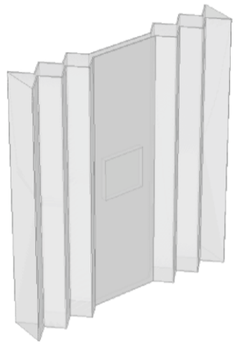




+Results 01 Thickness

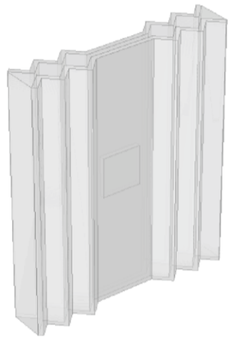
PEAK DAY IN SUMMER

1 MM



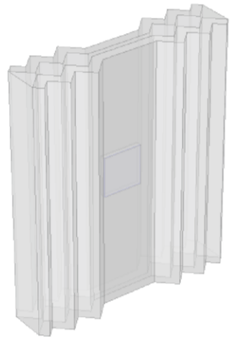
Qc 3.52 W
Qh 10.82 W
COPh 1.48
COPc 0.48

5 MM



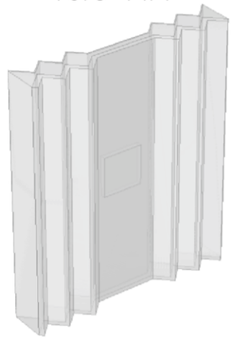
Qc 8.11 W
Qh 15.41 W
COPh 2.11
COPc 1.11

10 MM



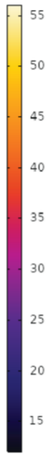
Qc 9.00 W
Qh 16.30 W
COPh 2.23
COPc 1.23

18&5 MM



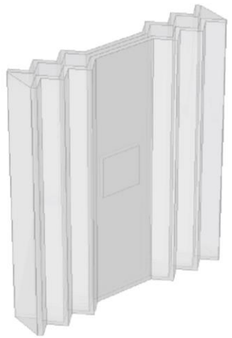
Qc 6.57 W
Qh 13.87 W
COPh 1.90
COPc 0.90

°C



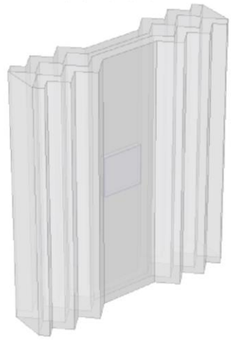
+Results 01 Thickness

5 MM



Qc 8.11 W
Qh 15.41 W
COPh 2.11
COPc 1.11

10 MM

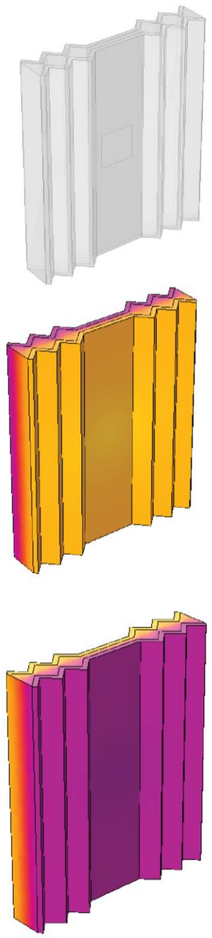


Qc 9.00 W
Qh 16.30 W
COPh 2.23
COPc 1.23

+Results 02 Extended Surface

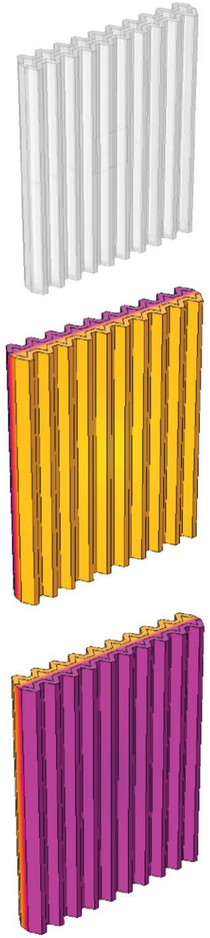
PEAK DAY IN SUMMER

SHAPE B



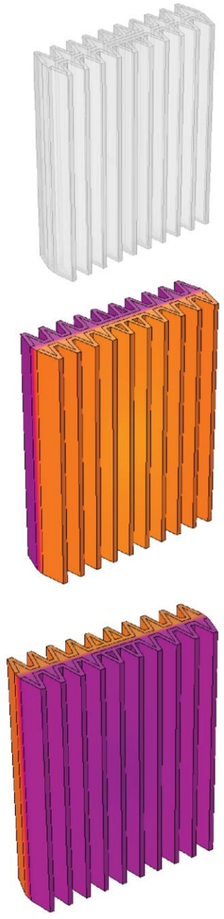
Qc 8.11 W
Qh 15.41 W
COPh 2.11
COPc 1.11
S.A 0.063 m2

SHAPE C



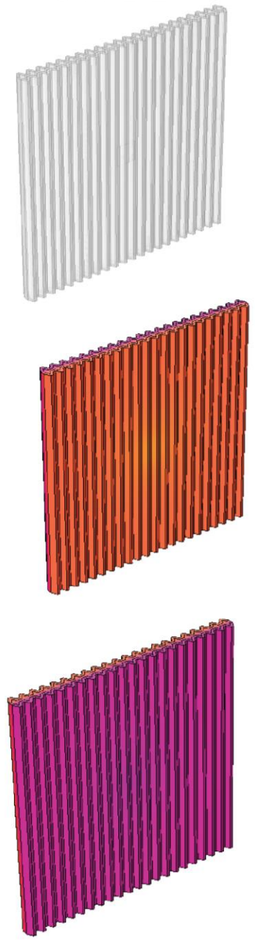
Qc 8.87 W
Qh 16.17 W
COPh 2.21
COPc 1.21
SA 0.076 m2

SHAPE D



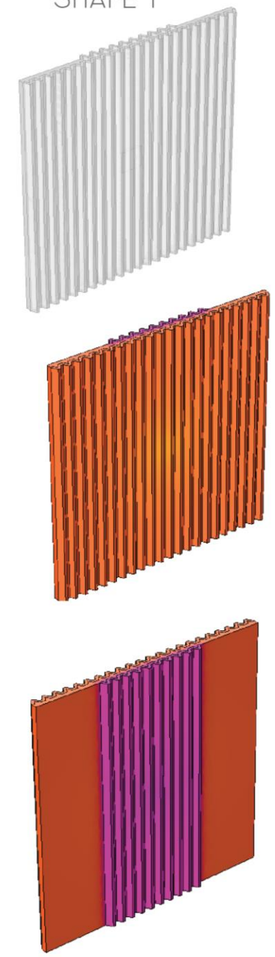
Qc 10.11 W
Qh 17.41 W
COPh 2.38
COPc 1.38
SA 0.142 m2

SHAPE E

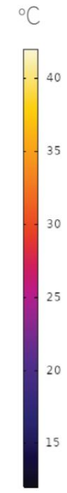


Qc 12.16 W
Qh 19.46 W
COPh 2.67
COPc 1.67
SA 1.500 m2

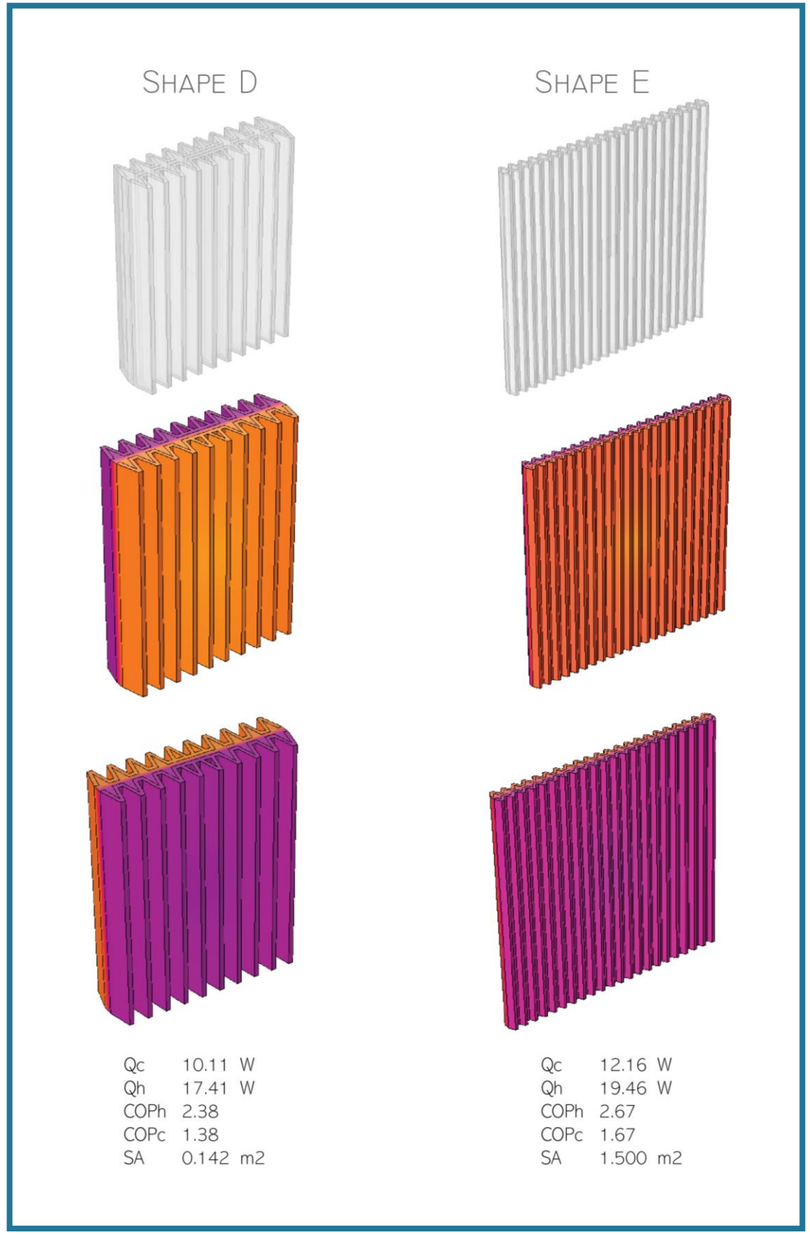
SHAPE F



Qc 11.39 W
Qh 18.69 W
COPh 2.56
COPc 1.56
SA 1.5/0.136 m2

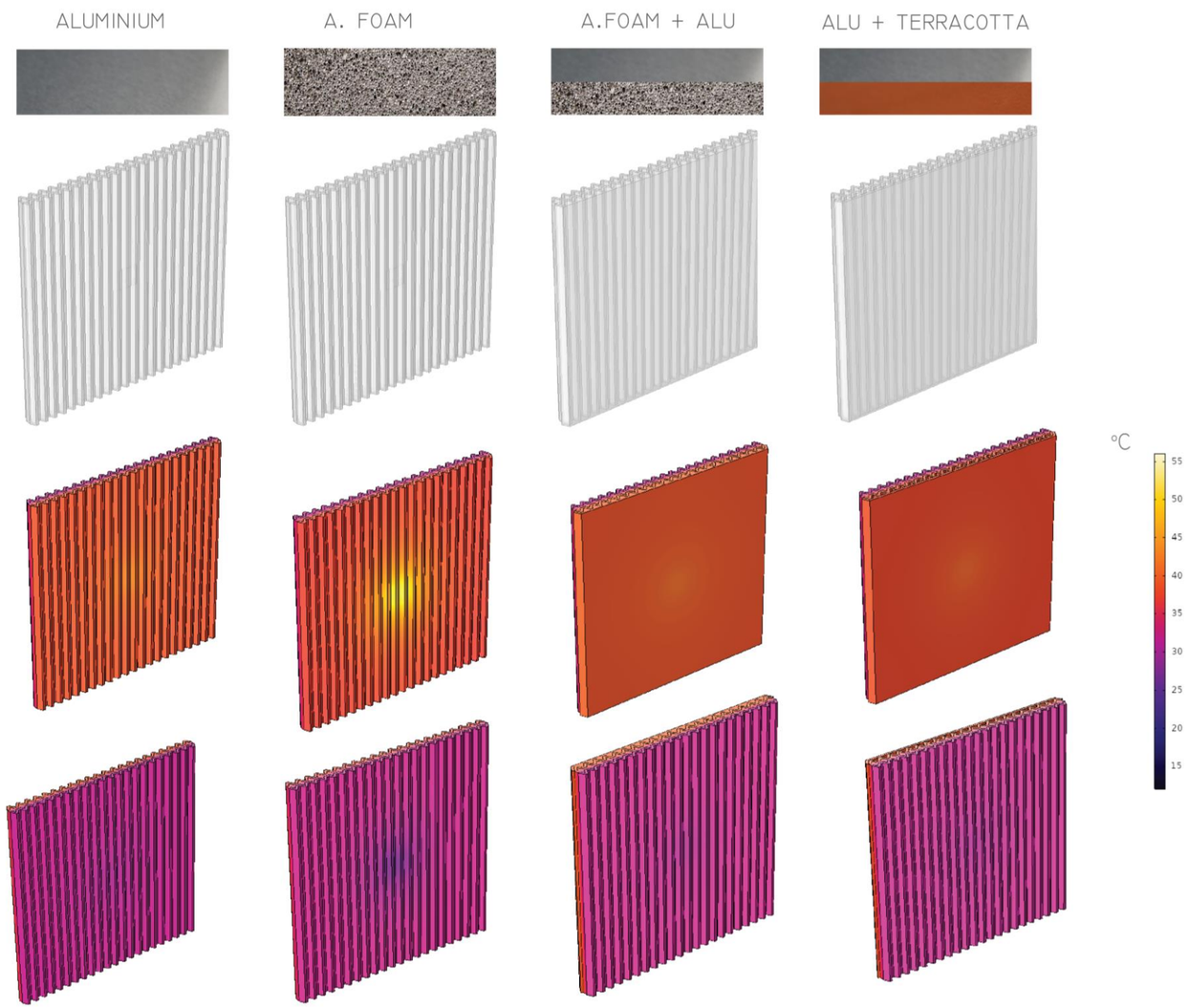


+Results 02 Extended Surface



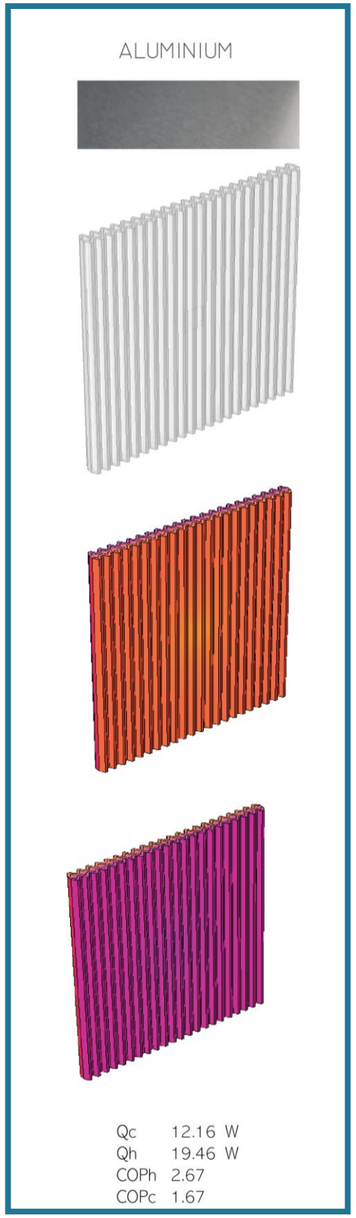
+Results 03 Material Exploration

PEAK DAY IN SUMMER



Qc 12.16 W	Qc 5.70 W	Qc 12.08 W	Qc 12.16 W
Qh 19.46 W	Qh 13.00 W	Qh 19.38 W	Qh 19.46 W
COPh 2.67	COPh 1.78	COPh 2.65	COPh 2.67
COPc 1.67	COPc 0.78	COPc 1.65	COPc 1.67

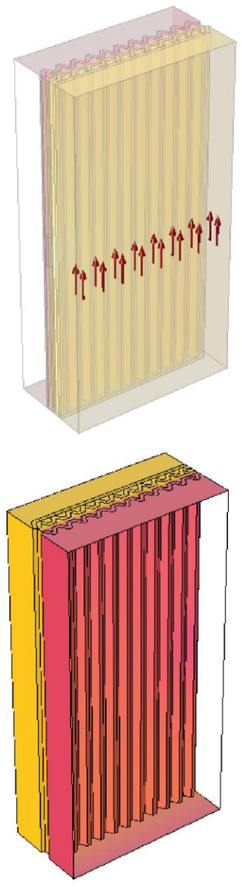
+Results 03 Material Exploration



+Results 04 Air flows

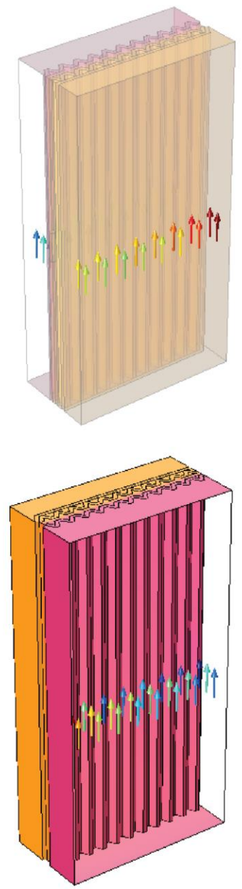
PEAK DAY IN SUMMER

NC BOTH



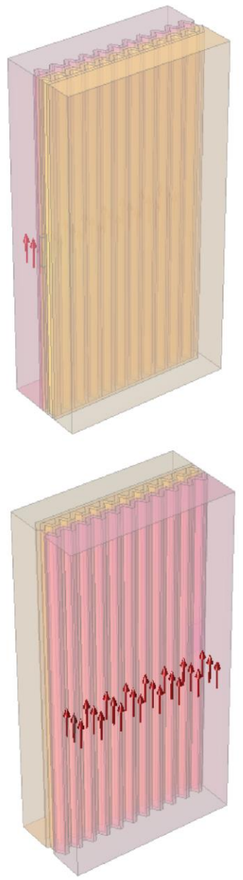
Qc 11.87 W
Qh 19.17 W
COPh 2.63
COPc 1.63

FC BOTH UP



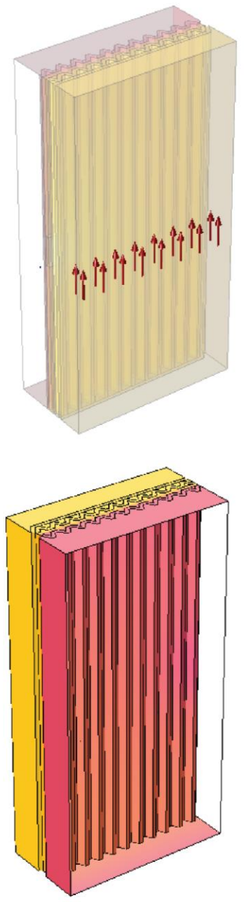
Qc 12.09 W
Qh 19.39 W
COPh 2.66
COPc 1.66

FC H UP / NC C



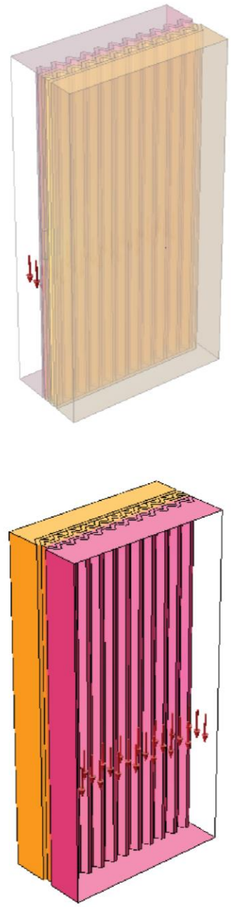
Qc 11.96 W
Qh 19.26 W
COPh 2.64
COPc 1.64

NC H / FC C UP

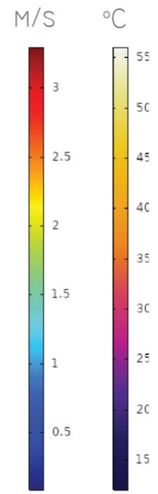


Qc 12.00 W
Qh 19.30 W
COPh 2.64
COPc 1.64

NC H / FC C DOWN



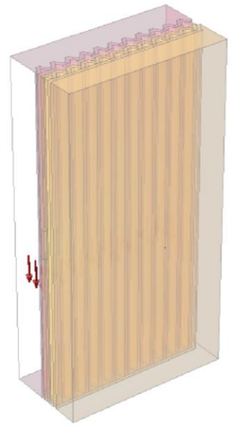
Qc 11.74 W
Qh 19.04 W
COPh 2.61
COPc 1.61

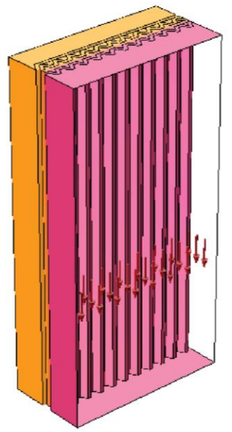


*Forc

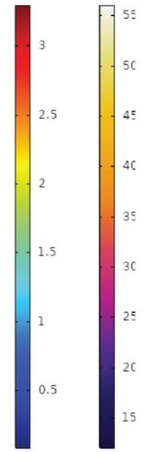
+Results 04 Air flows

NC H / FC C DOWN





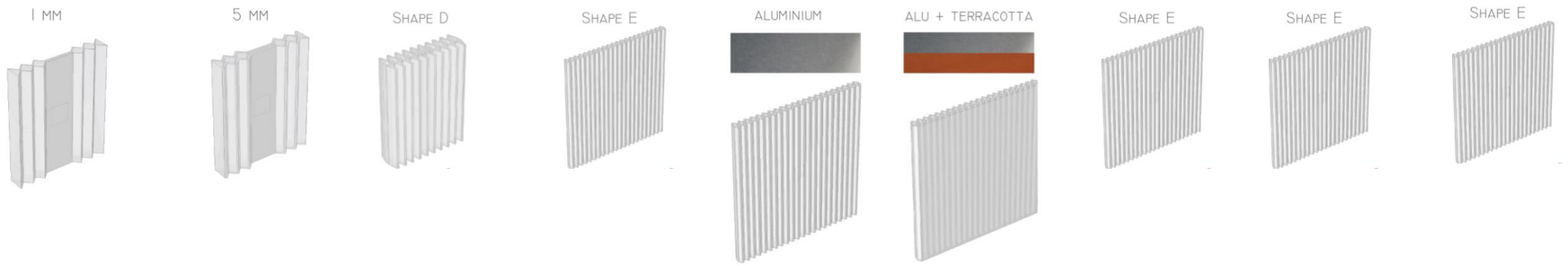
M/S °C



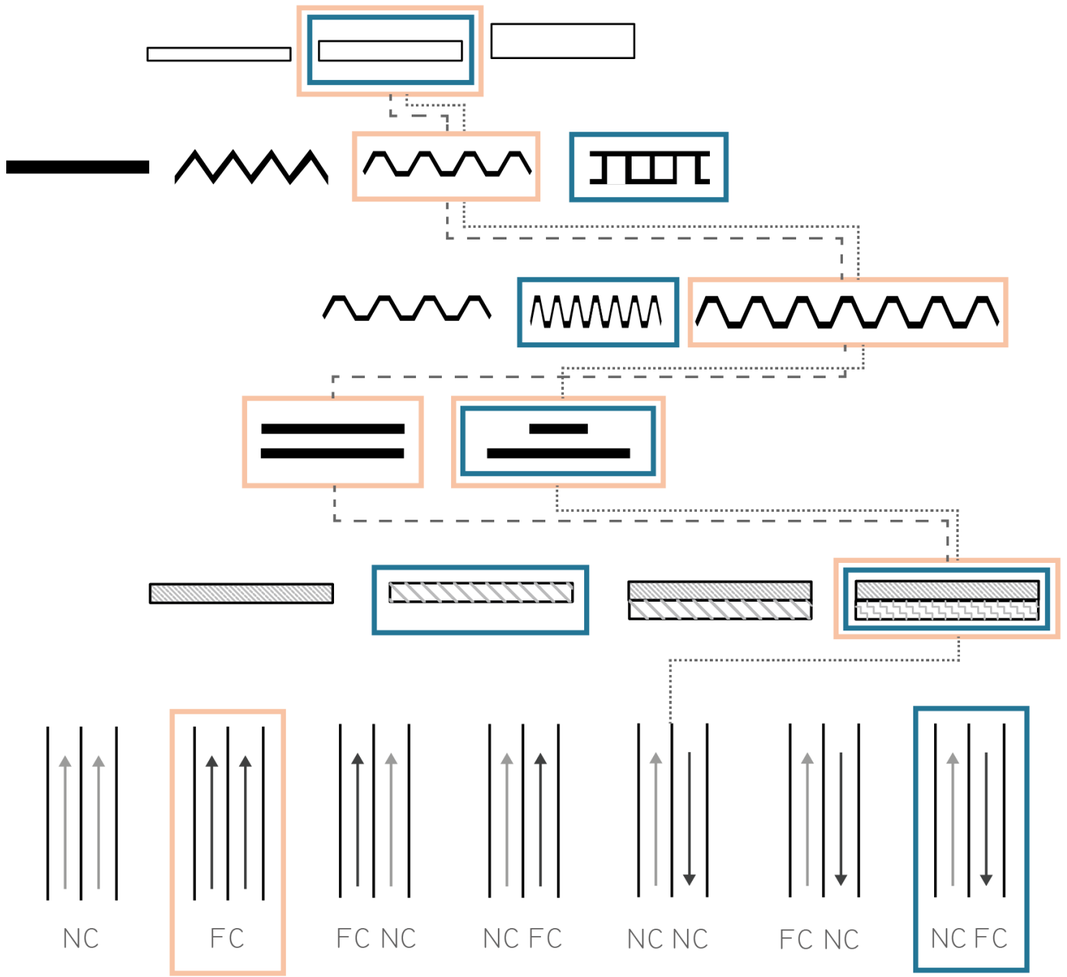
Qc 11.74 W
Qh 19.04 W
COPh 2.61
COPc 1.61

+Results Summary

INITIAL	STRATEGY	00	01	02	02	03	03	04	04	04
	Ambient Temperature	37.8	37.8	37.8	37.8	37.8	37.8	37.8	37.8	37.8
	Inside Temperature	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	Paramenter	Baseline	Thickness	Shape	Area Surface	Material	Material Combo	Airflows Base	Airflows	Airflows
COMPARISON	HS Hot	56.46	46.51	42.07	41.57	41.57	41.57	41.78	41.15	41.41
	TEC H	55.86	49.08	44.14	41.40	41.40	41.39	41.49	41.15	41.12
	TEC C	27.30	29.37	28.60	30.09	30.09	30.07	29.60	29.73	29.53
	ΔT	28.56	19.71	15.54	11.31	11.31	11.31	11.89	11.43	11.59
	COPc	0.48	1.11	1.38	1.67	1.67	1.67	1.63	1.66	1.64
	Detail	-	5 mm	250x200/S.D	450x450/S.E	Aluminium	Alu + Terracotta	NC/S.E	FC/S.E	FC C/NC H, S.E
	Summary	-	130%	24%	21%	No Change	No Change	-	1.8%	0.61%



+Results Conclusions



01

02

02

02

03

04

HOT SIDE

COLD SIDE

SIMULATION PATH

SELECTED PATH

03 PROCESS

+CONCEPT

+EVALUATION – Component

+EVALUATION – Building

+Methodology

+Strategies

+Results

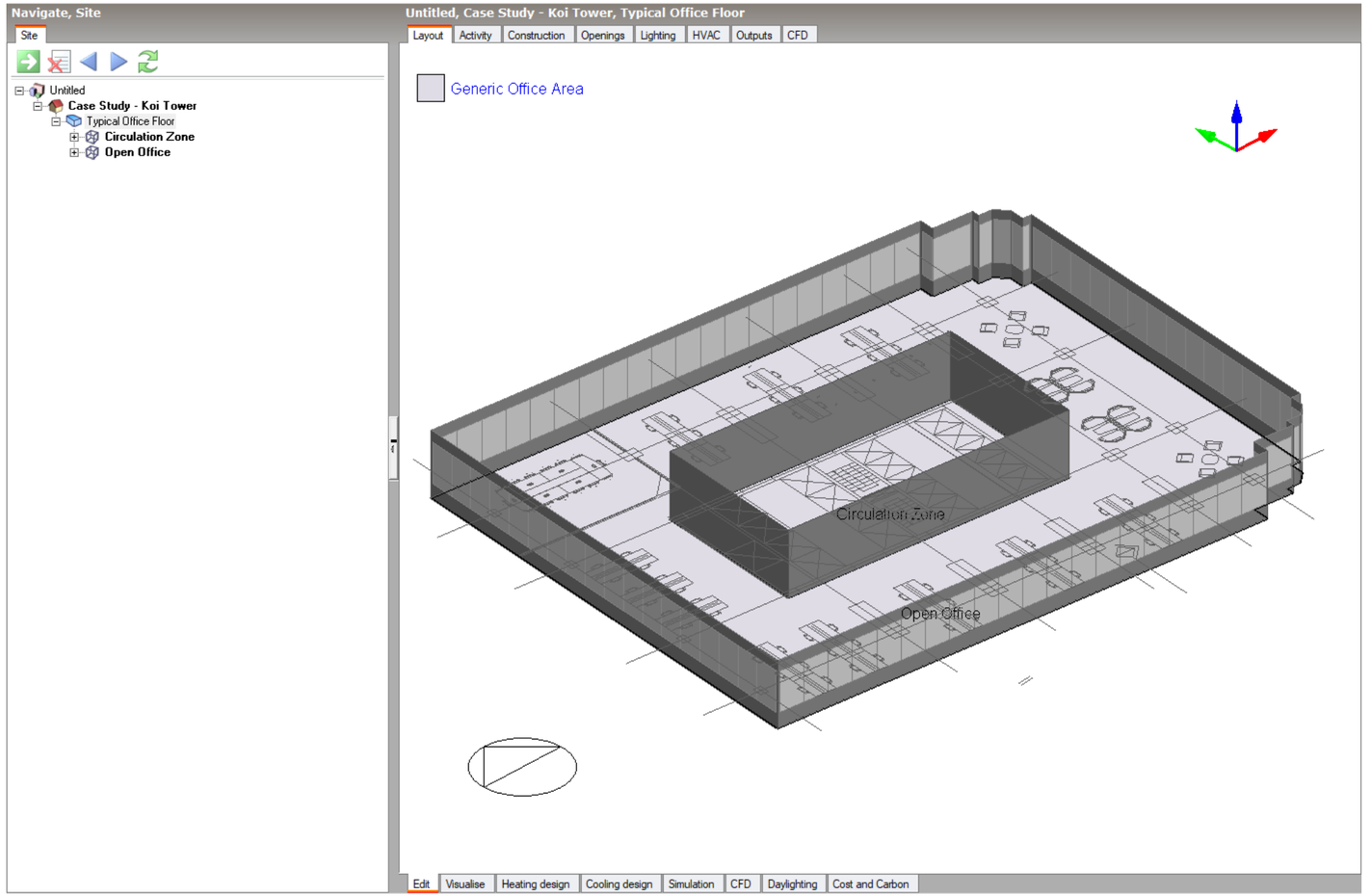
+EVALUATION – Building

+Methodology

+EVALUATION – Building

+Methodology

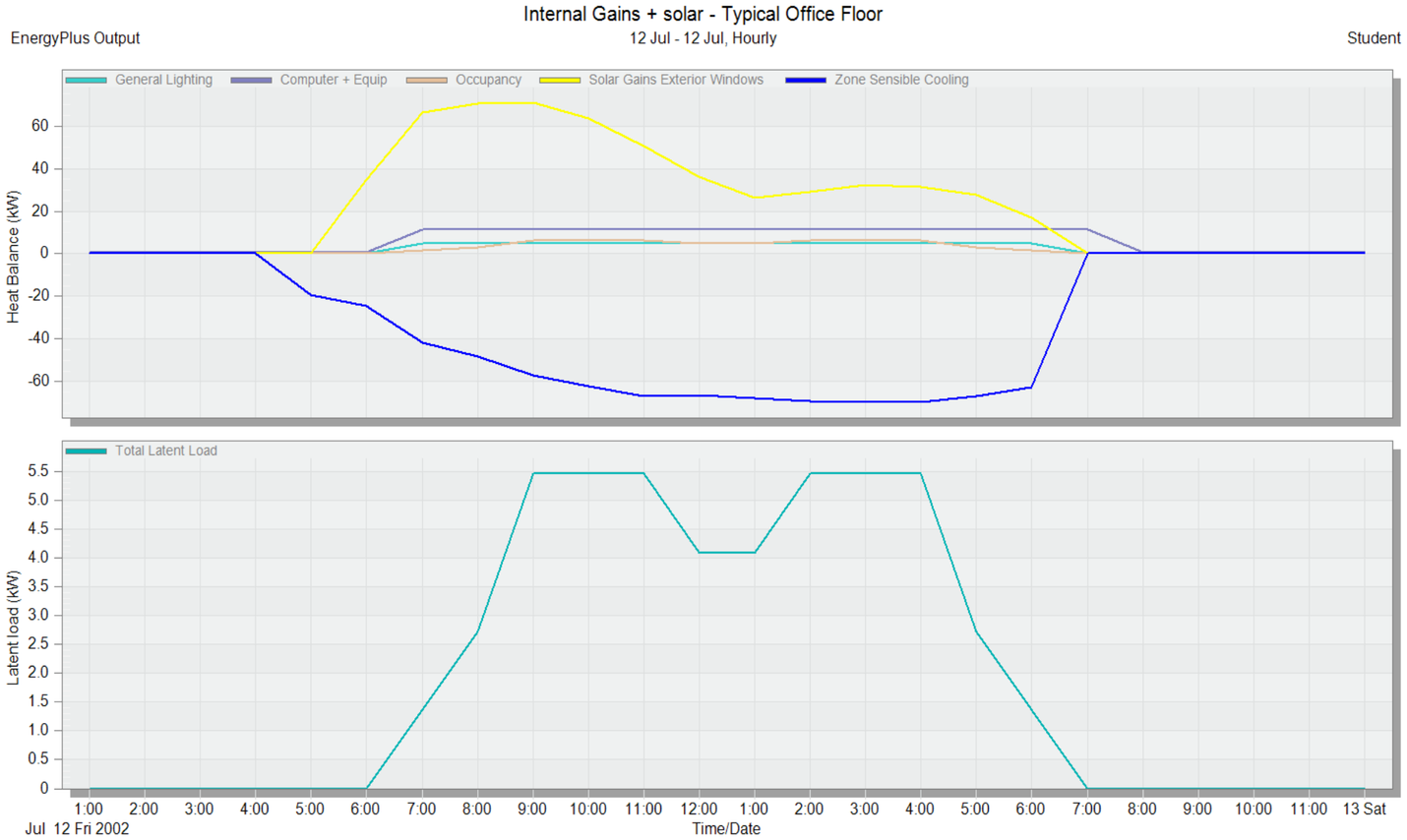
Design Builder



+EVALUATION – Building

+Methodology

Peak Gains
Summer



+EVALUATION – Building

+Methodology

+Strategies

Peak Gains - Summer

00 BASE	01 WWR	02 INSULATON	03 GLASS TYPE	04 SHADING	05 VENTILATION
	20%	50 mm	Solarban 3mm clear	Exterior	Natural Ventilation
	30%	75 mm	Double, Low-e reflective coating	Interior	Night Ventilation
	40%	100 mm	Double Low- e tint		

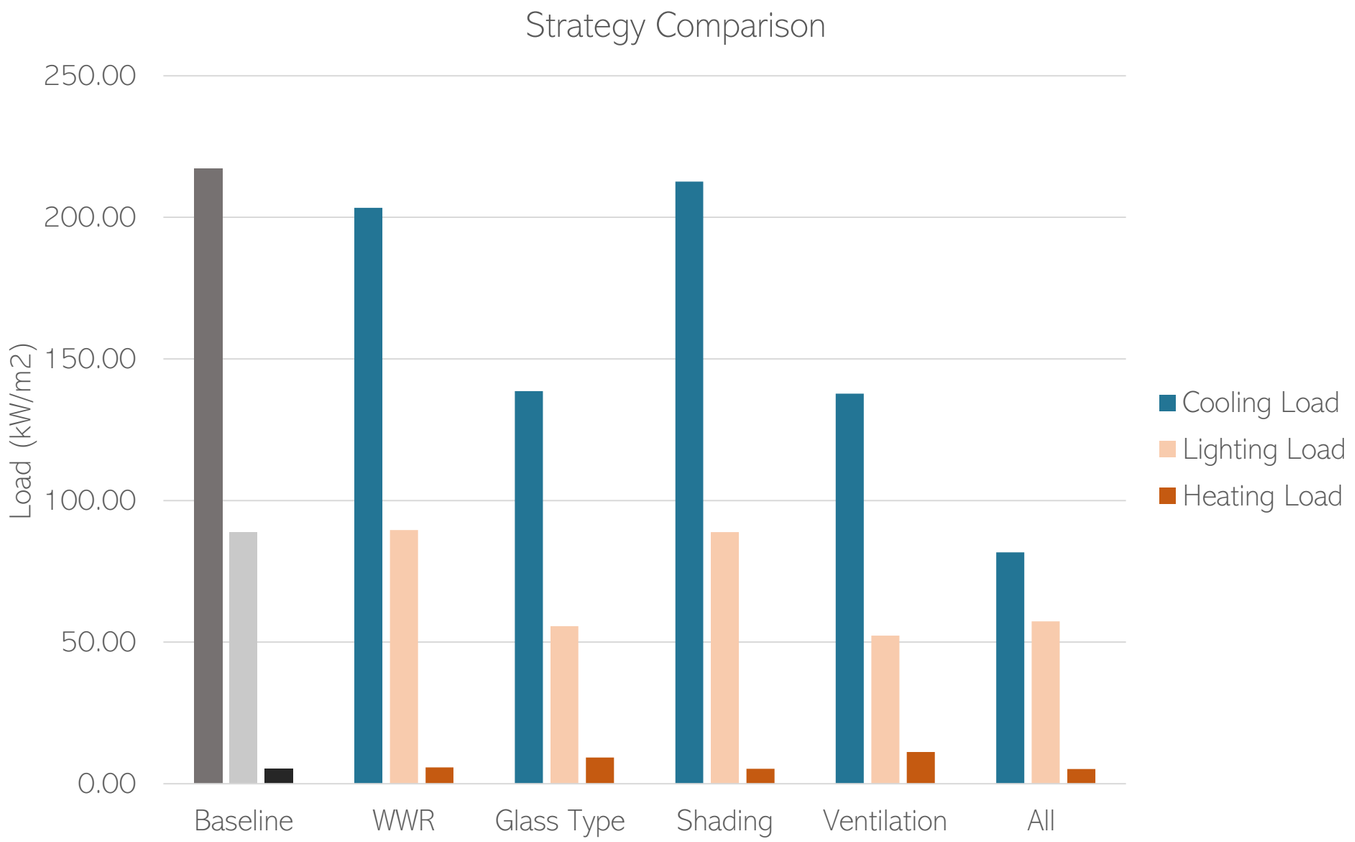
+EVALUATION – Building

+Methodology

+Strategies

+Results

Summary



+EVALUATION – Building

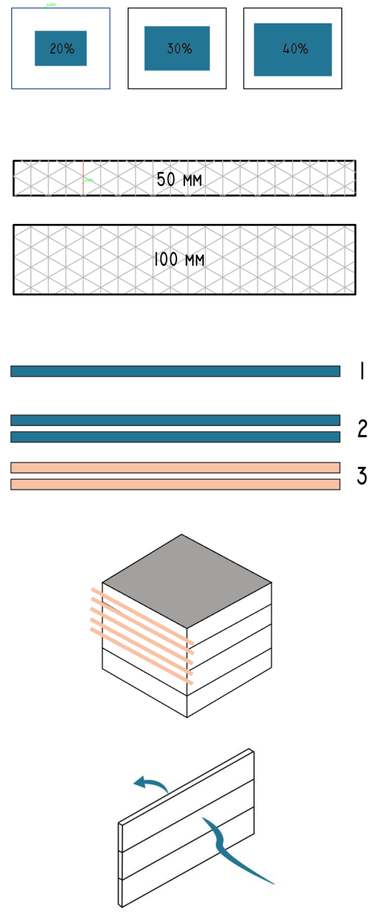
+Methodology

+Strategies

+Results

Summary

53.7% ENERGY SAVINGS



04 DESIGN

+CONCEPT

+GUIDELINES

+FAÇADE DEVELOPMENT

+FAÇADE TYPES

+EVALUATION

04 DESIGN

+CONCEPT

+GUIDELINES

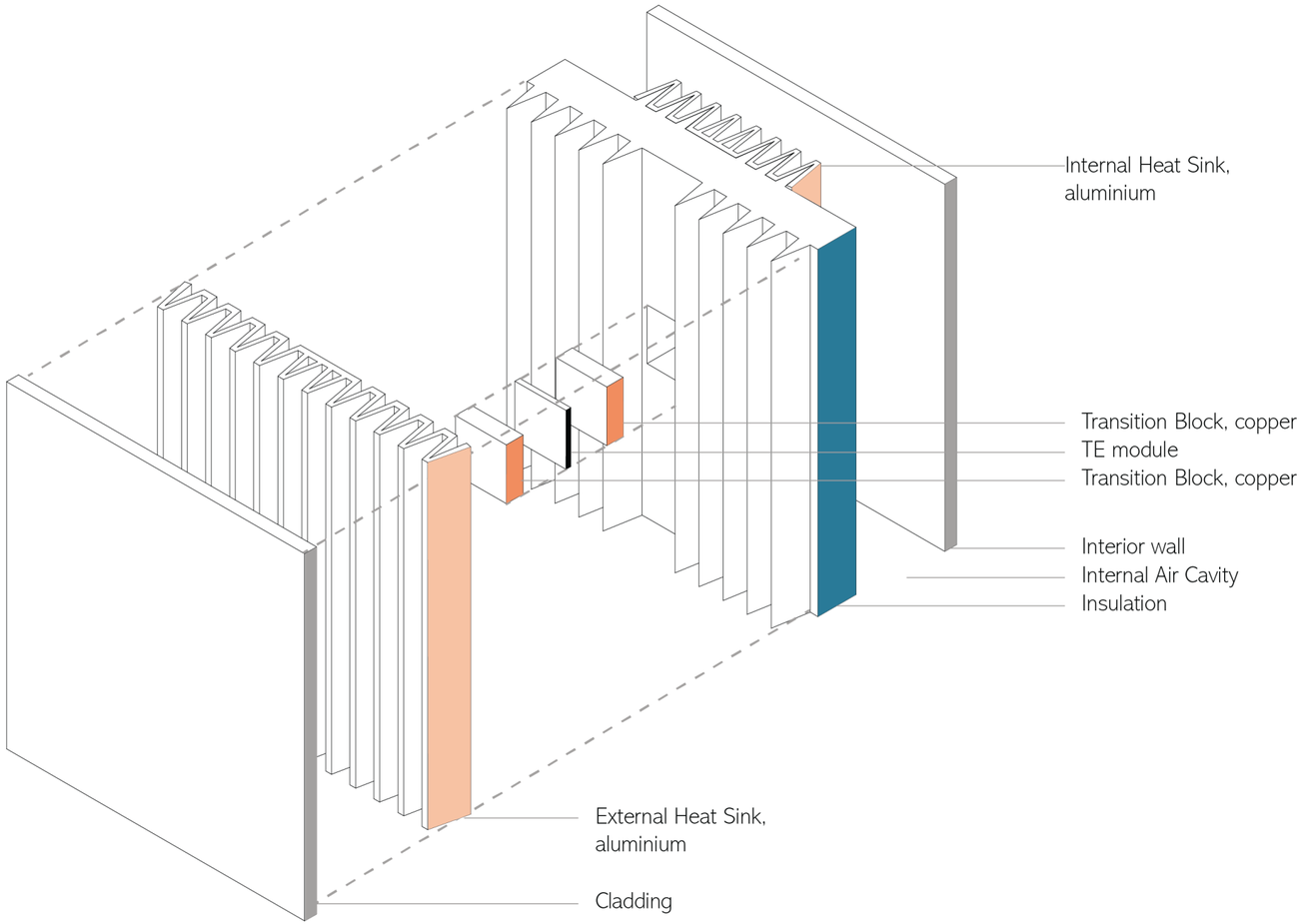
+FAÇADE DEVELOPMENT

+FAÇADE TYPES

+EVALUATION

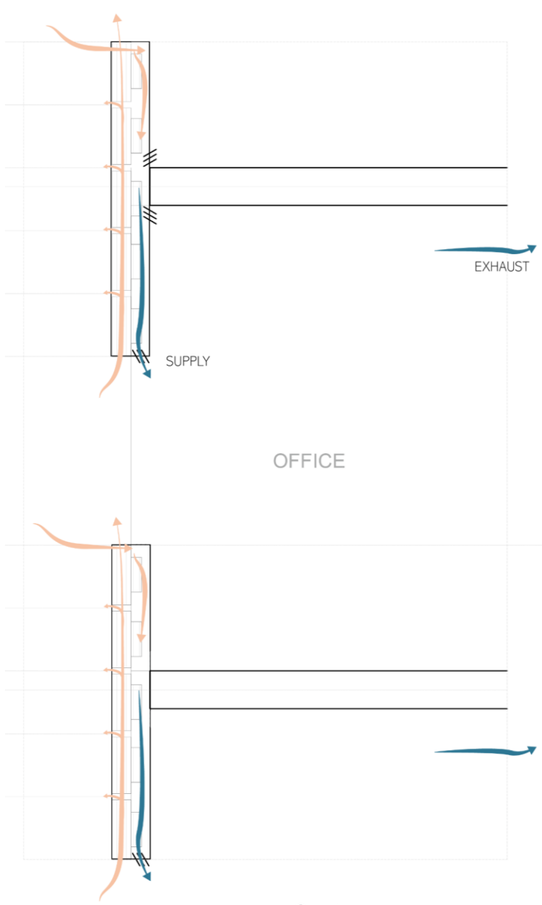
+CONCEPT

Chosen Configuration

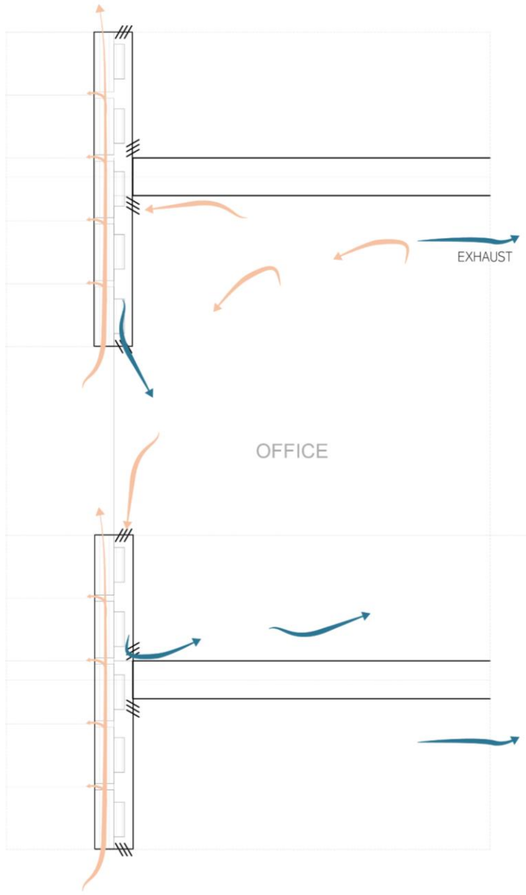


+CONCEPT

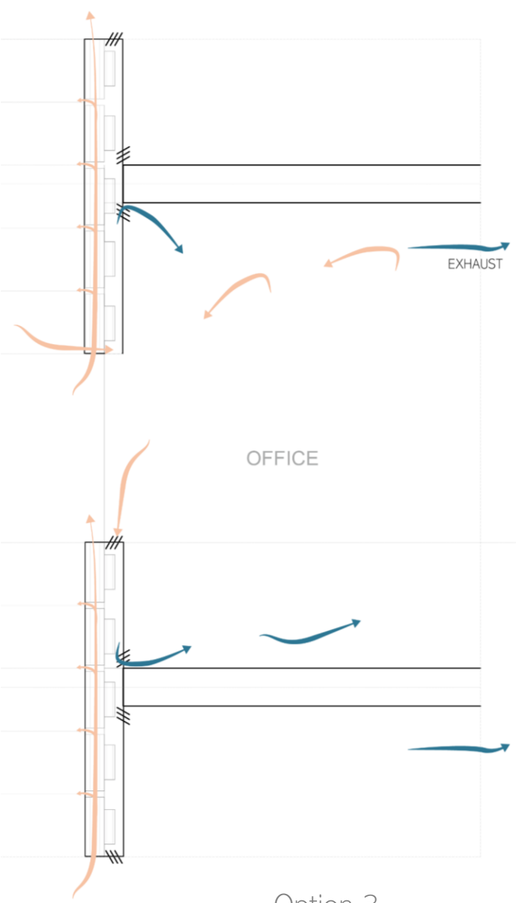
Cooling concept



Option 1



Option 2



Option 3

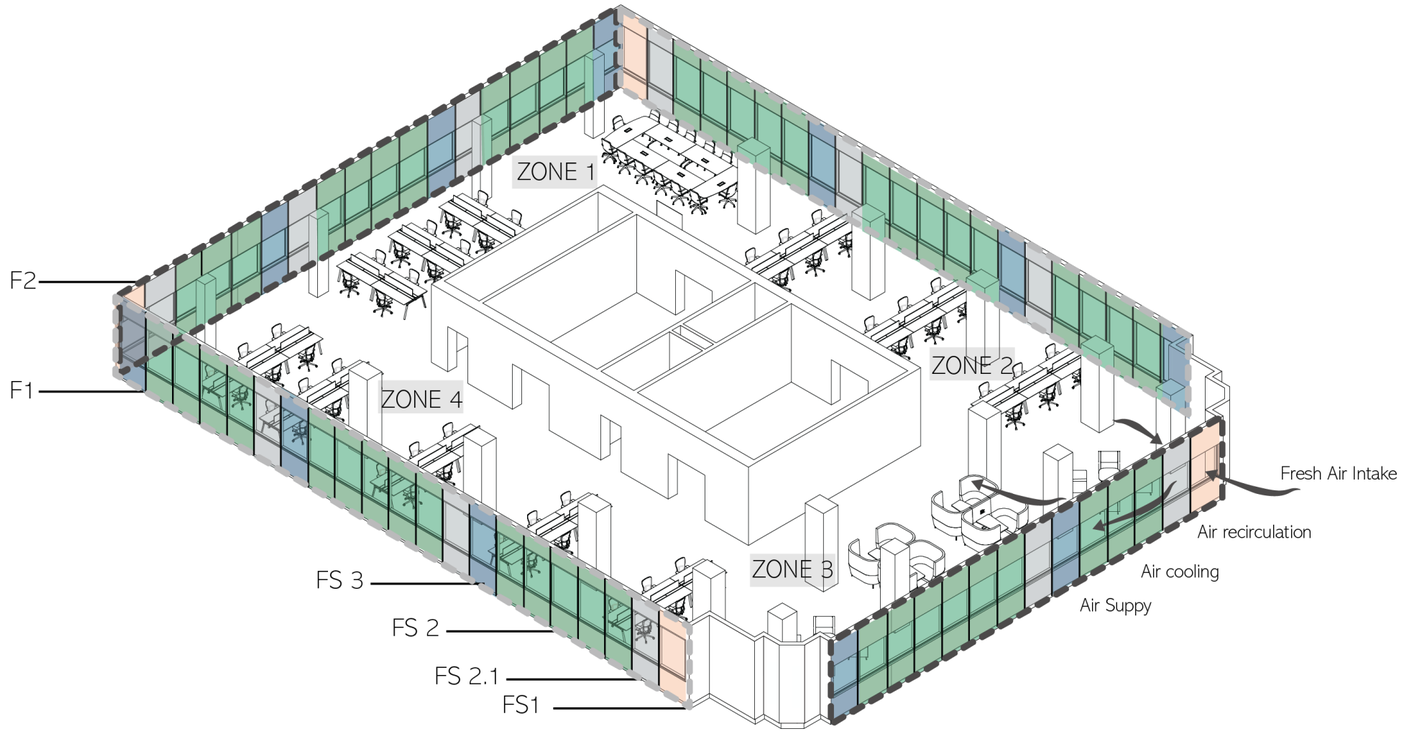
+RESULTS LEVEL B Facade modules

+CONCEPT

TEM Quantity based on:

Required fresh air
Required cooling power
Space Available

=3786 TEMs



04 DESIGN

+CONCEPT

+GUIDELINES

+FAÇADE DEVELOPMENT

+FAÇADE TYPES

+EVALUATION

+GUIDELINES

HOT DRY &
OFFICE CONTEXT

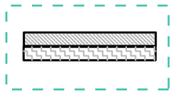
COMPONENT

LEVEL C

Balance between total material usage and functional thickness

Extended surface effective closer to heat source

Heat sink at cold side requires smaller dimensions



No limit in exterior cladding so long as heat sink is Aluminium

Forced convection towards the inside

Air flow velocity between 1.1 m/s and 3.0 m/s

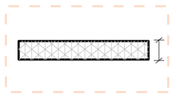
Less turbulence in the air flows with less abrubt direction change

+

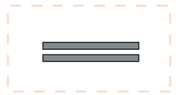
BUILDING

LEVEL A

EW Facades 40% WWR
NS Facades 62% WWR

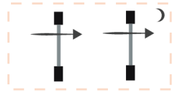


Insulation thickness of 50 mm



Double Low-E Glazing type

Exterior Shading



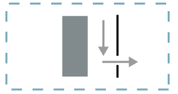
Natural Ventilation
+ Night ventilation

+

FACADE

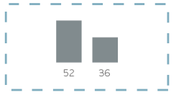
LEVEL B

Air cavity Requirements



Cooling Concept

Four different types of facade module (job based)



Two different panel size (orientation based)

04 DESIGN

+CONCEPT

+GUIDELINES

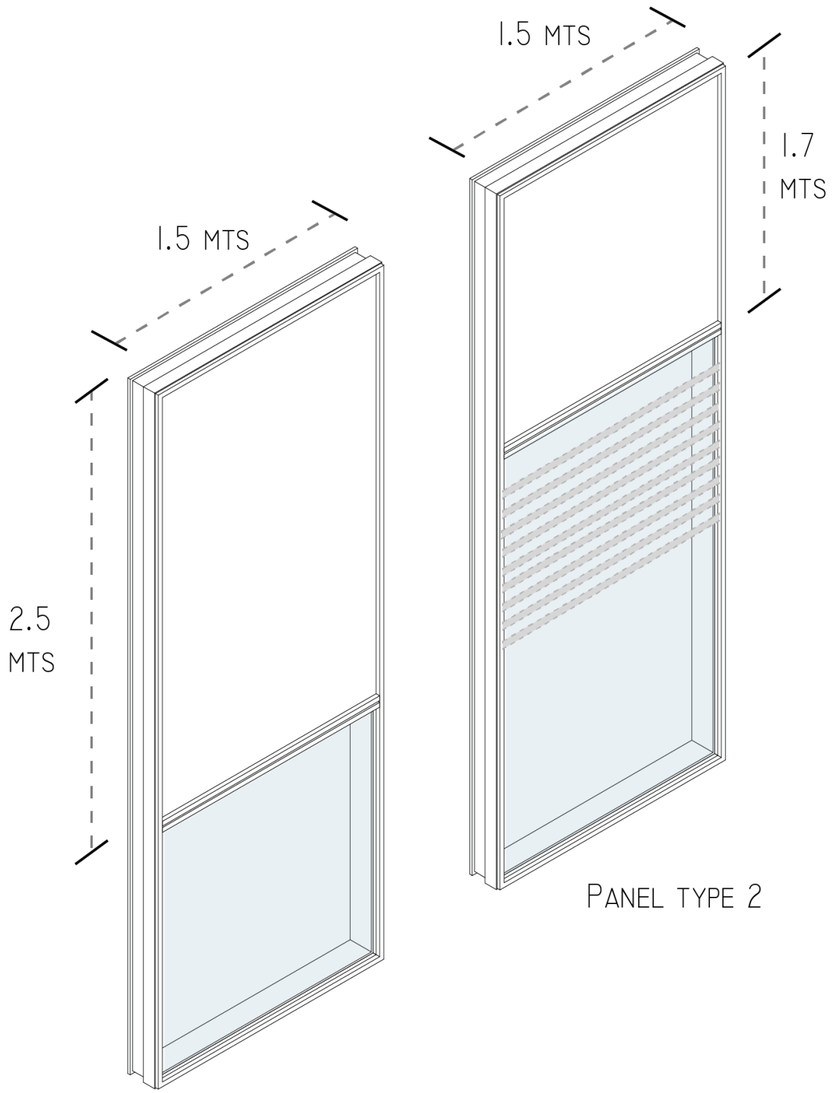
+FAÇADE DEVELOPMENT

+FAÇADE TYPES

+EVALUATION

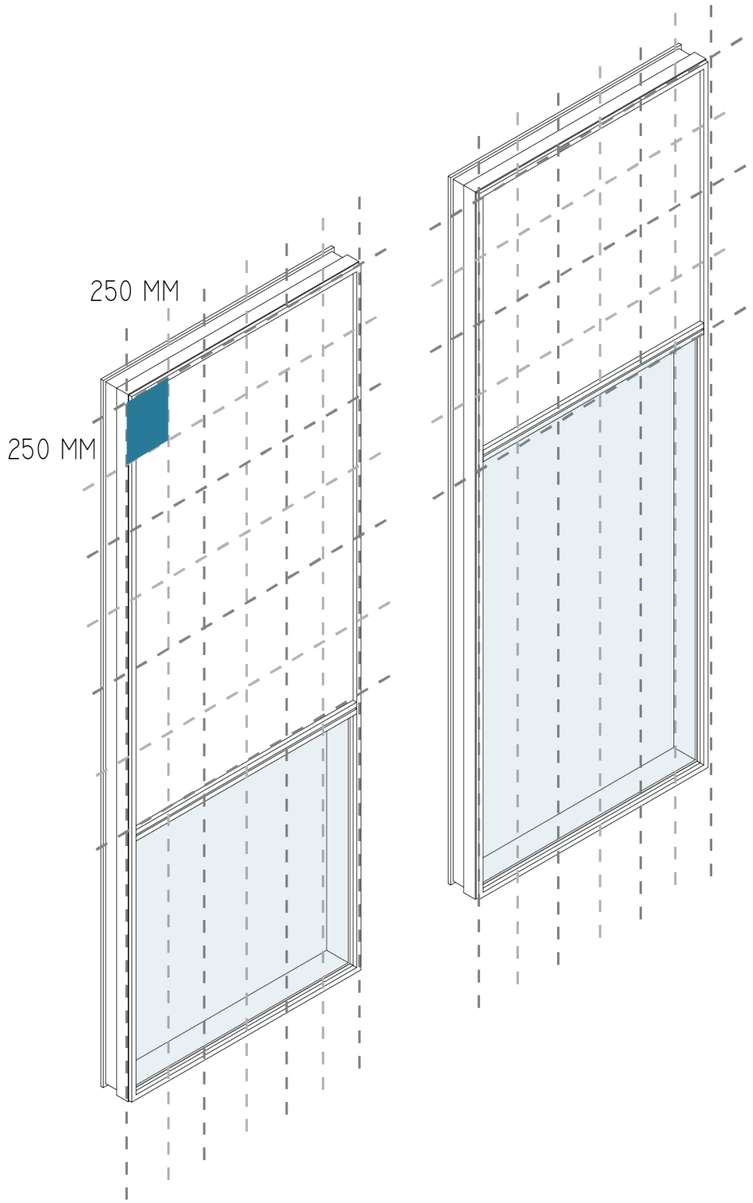
+FACADE DEVELOPMENT

01
FAÇADE MODULE TYPES BY SIZE



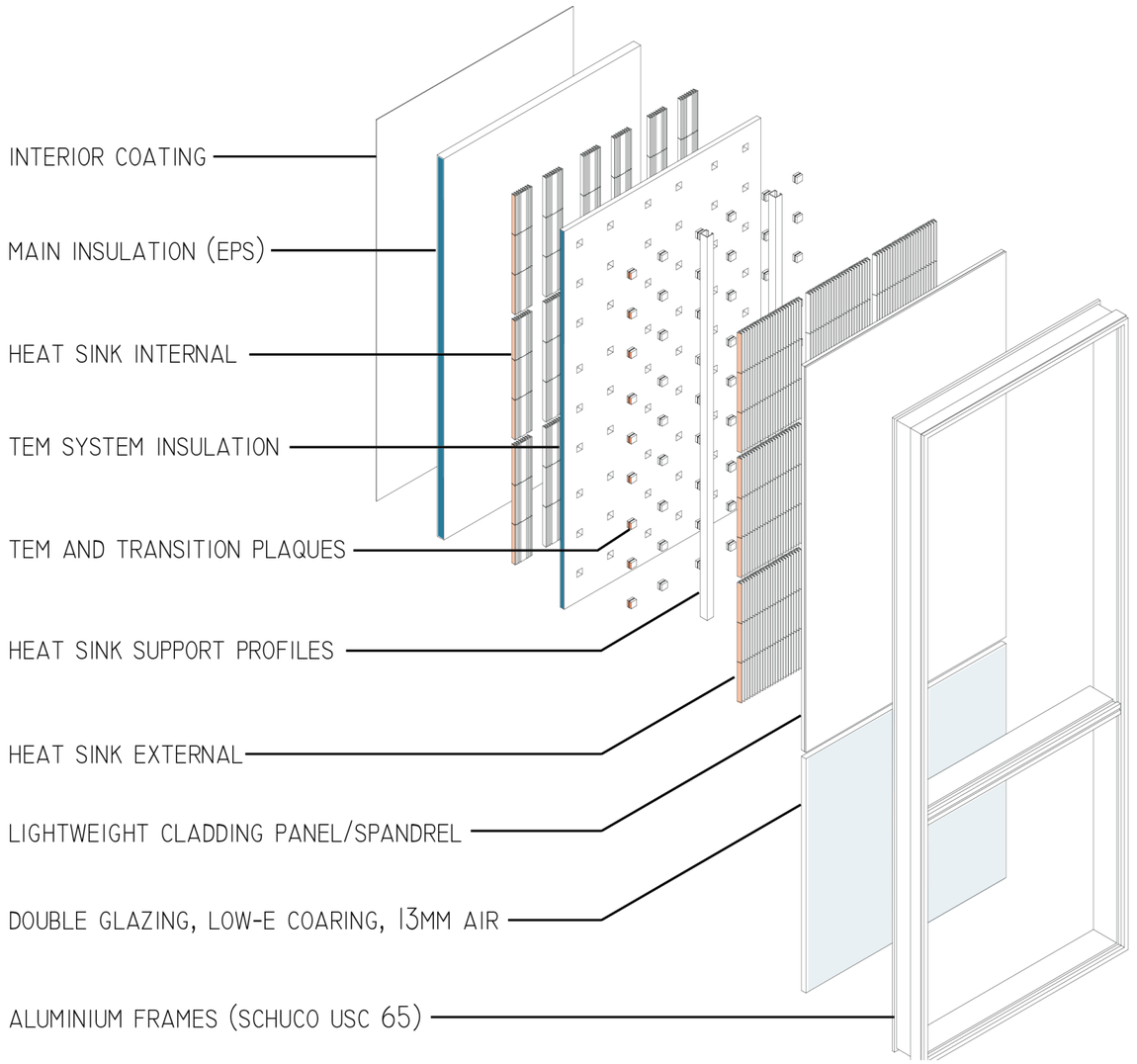
+FACADE DEVELOPMENT

02
FAÇADE PANEL GRID BY SPACE



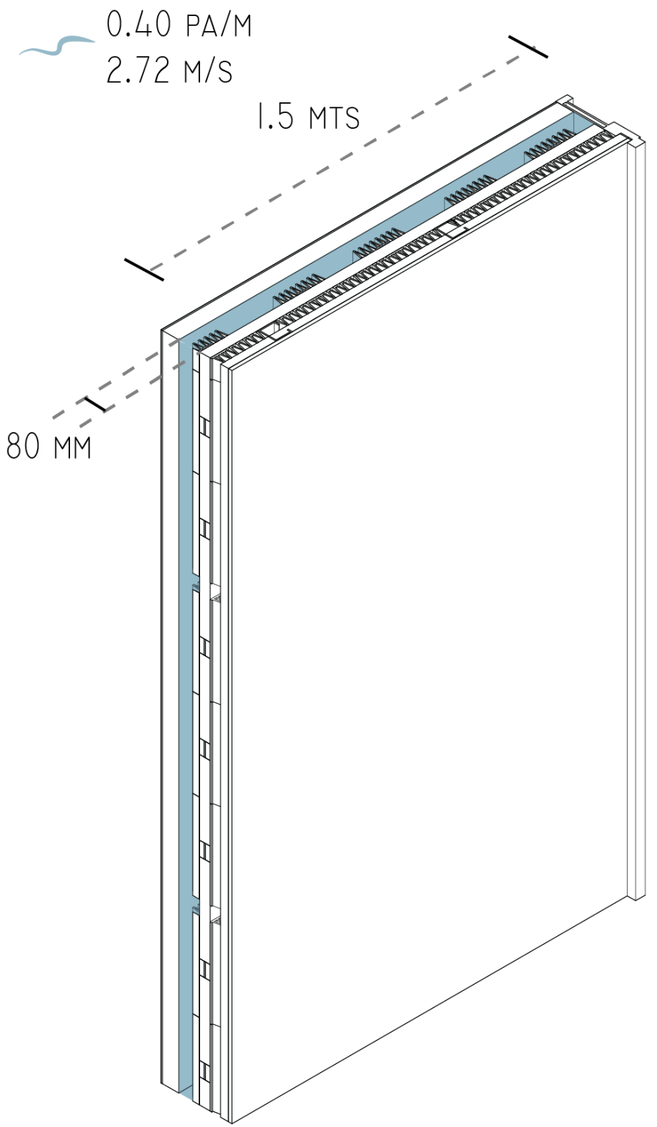
+FACADE DEVELOPMENT

03
FAÇADE MODULE LAYER
TEM SYSTEM



+FACADE DEVELOPMENT

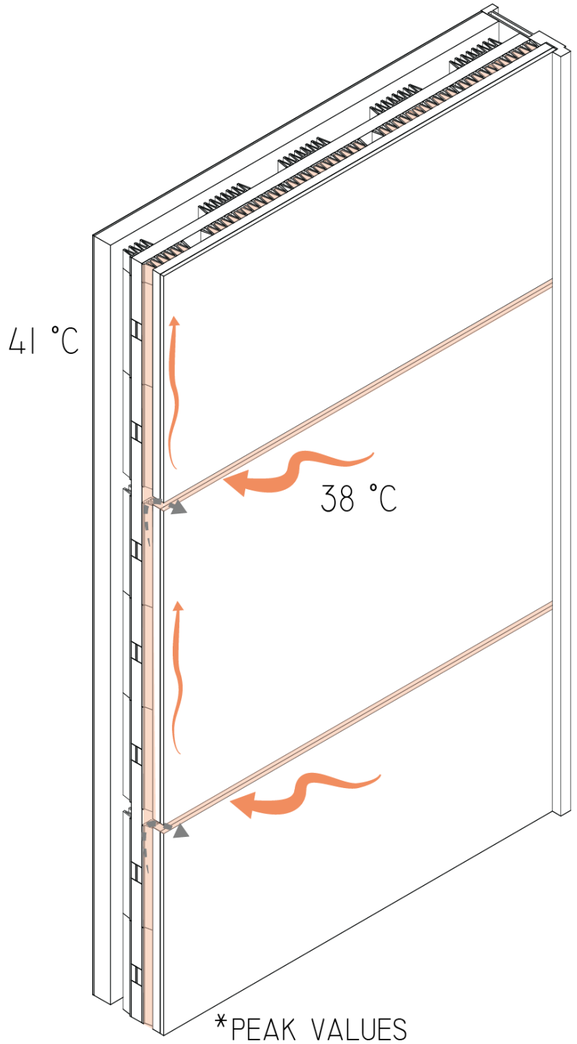
04
FAÇADE AIR CAVITY
INTERNAL



+FACADE DEVELOPMENT

05

FAÇADE EXTERNAL
HEAT SINK VENTILATION



04 DESIGN

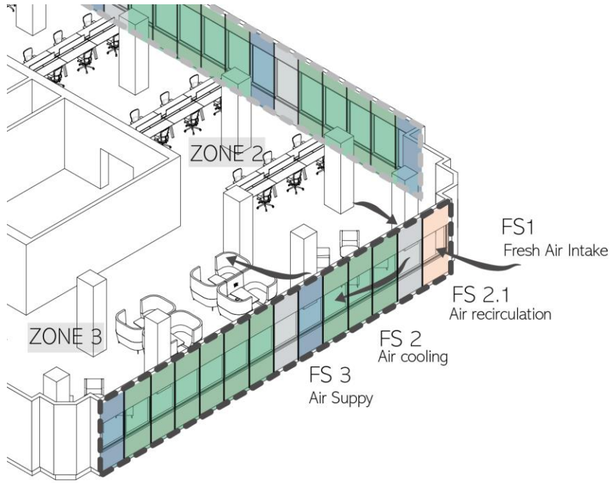
+CONCEPT

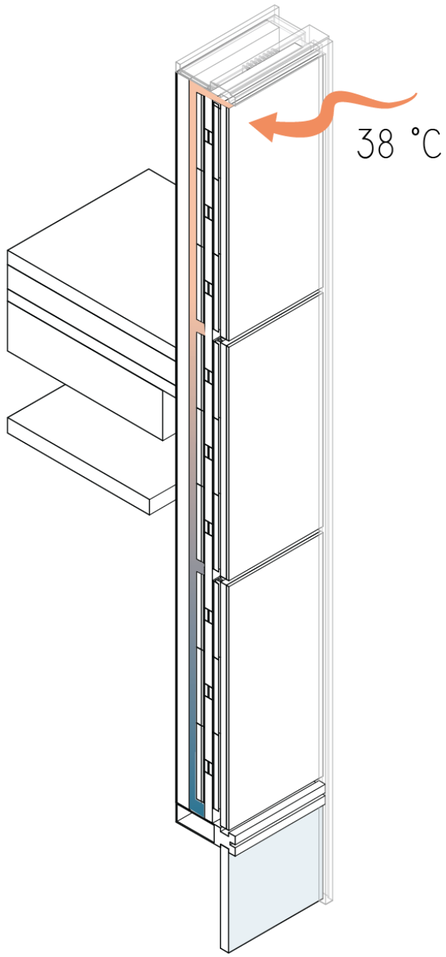
+GUIDELINES

+FAÇADE DEVELOPMENT

+FAÇADE TYPES

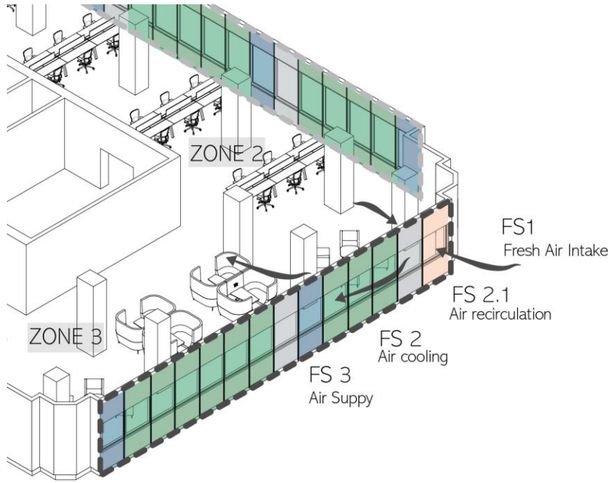
+EVALUATION

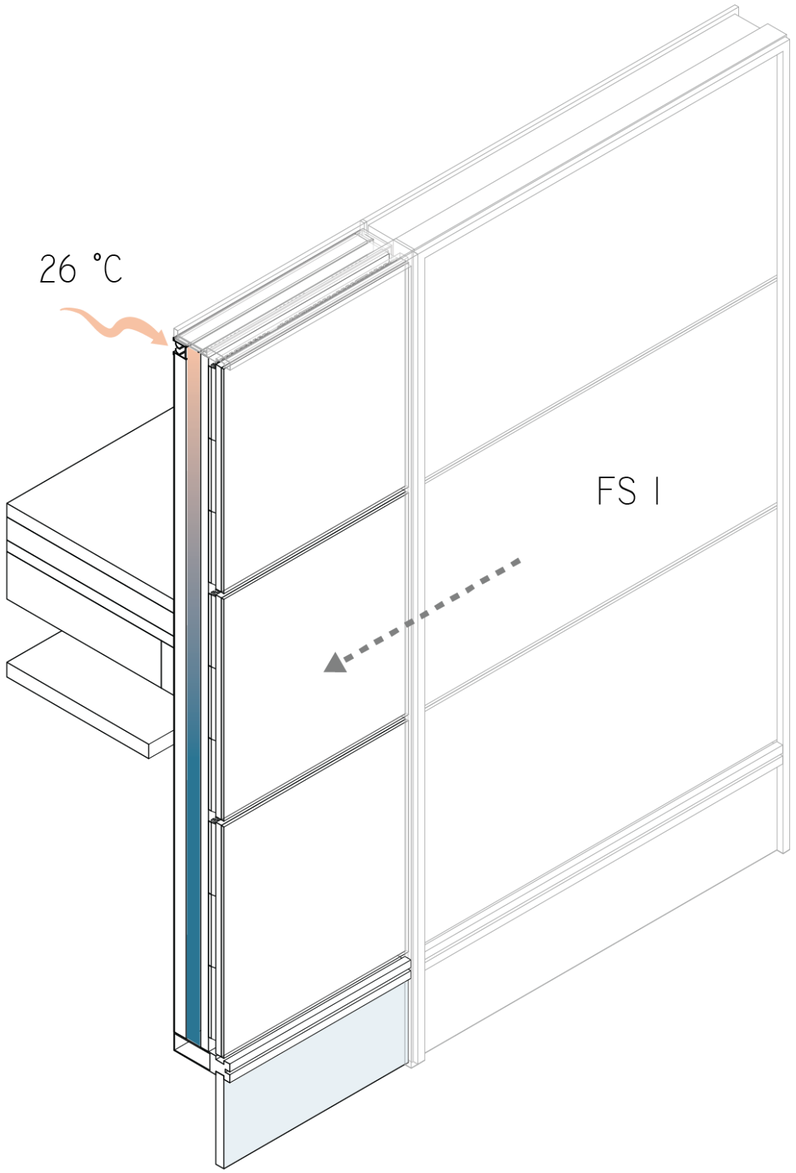




+FACADE TYPES

06
FACADE MODULE BY FUNCTION
FRESH AIR INTAKE

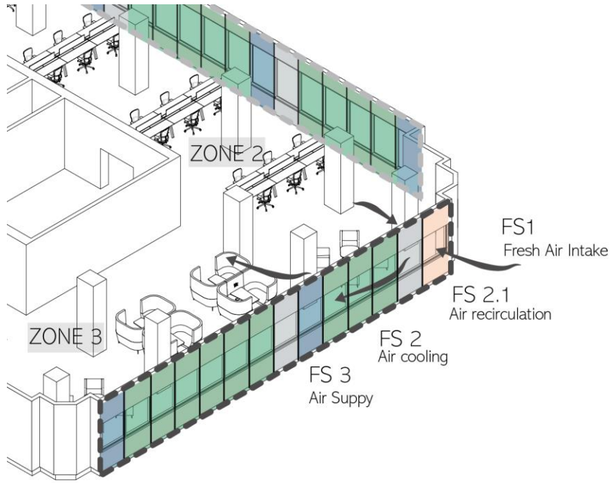


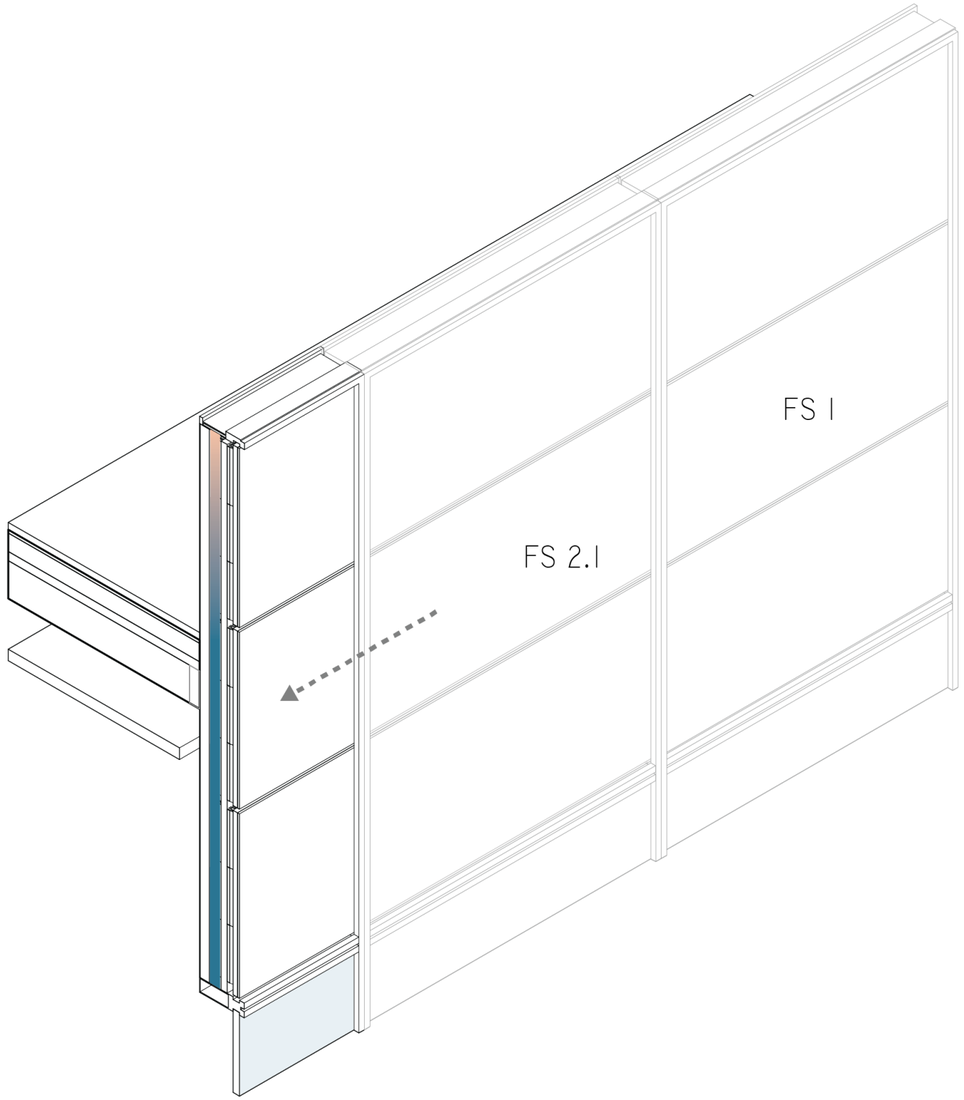


+FACADE TYPES

07

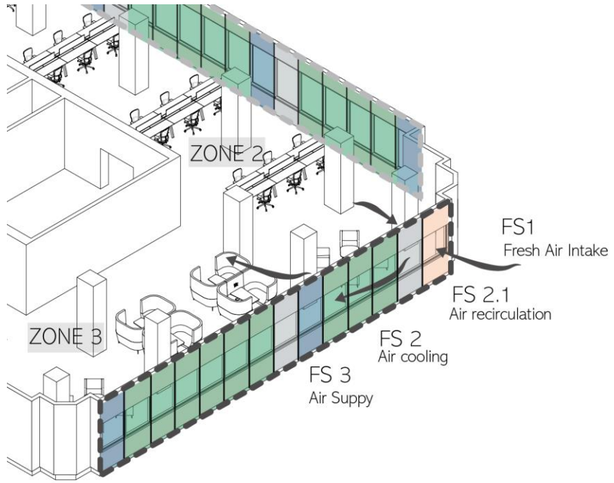
FACADE MODULE BY FUNCTION
OFFICE AIR INTAKE





+FACADE TYPES

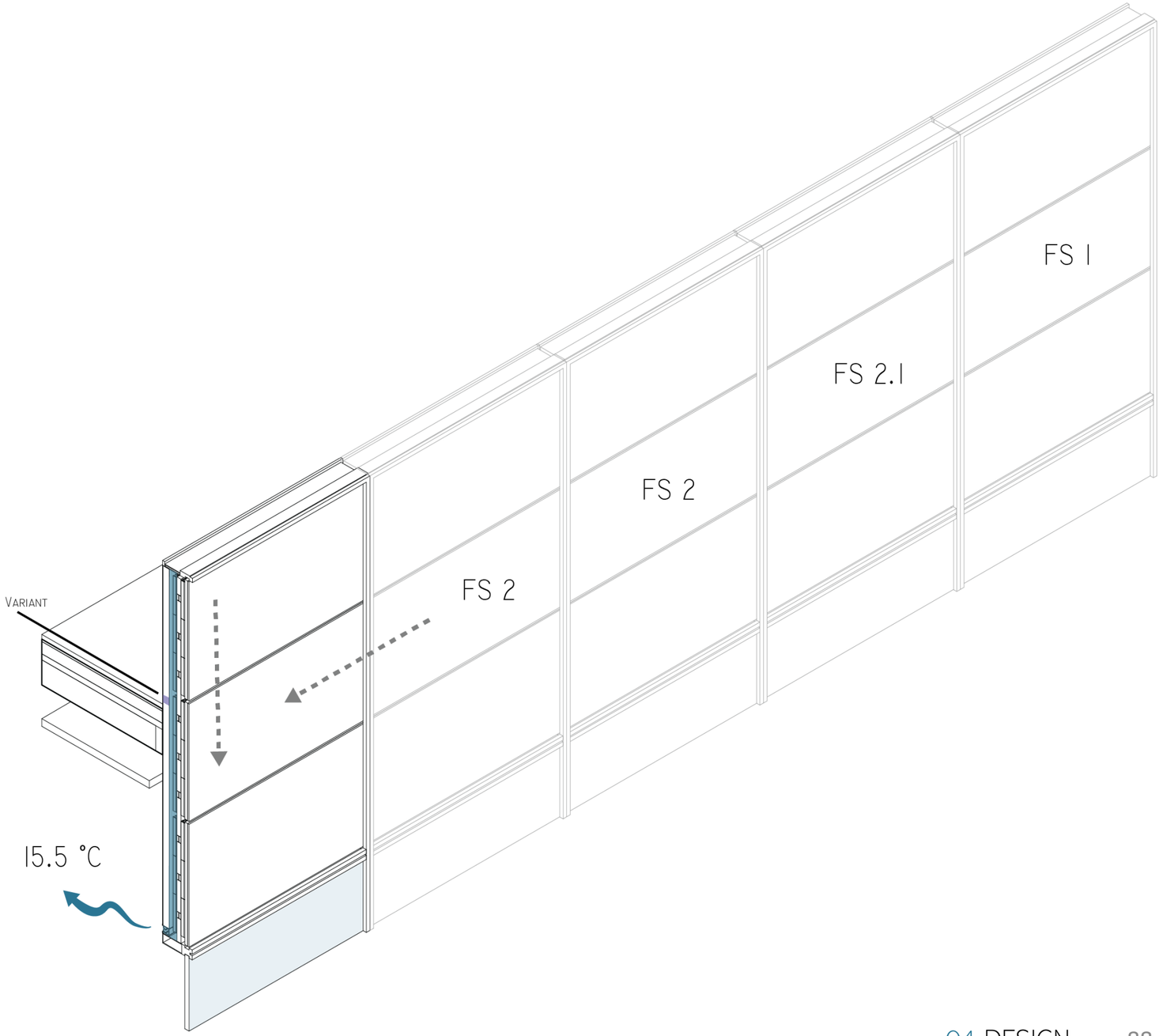
08
FACADE MODULE BY FUNCTION
AIR CONDITIONING

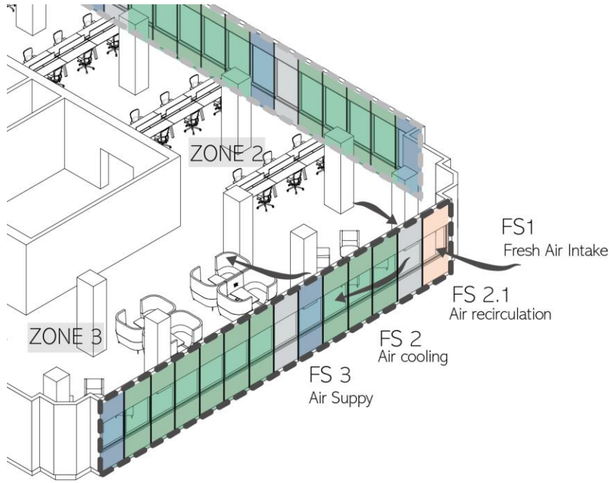


+FACADE TYPES

09

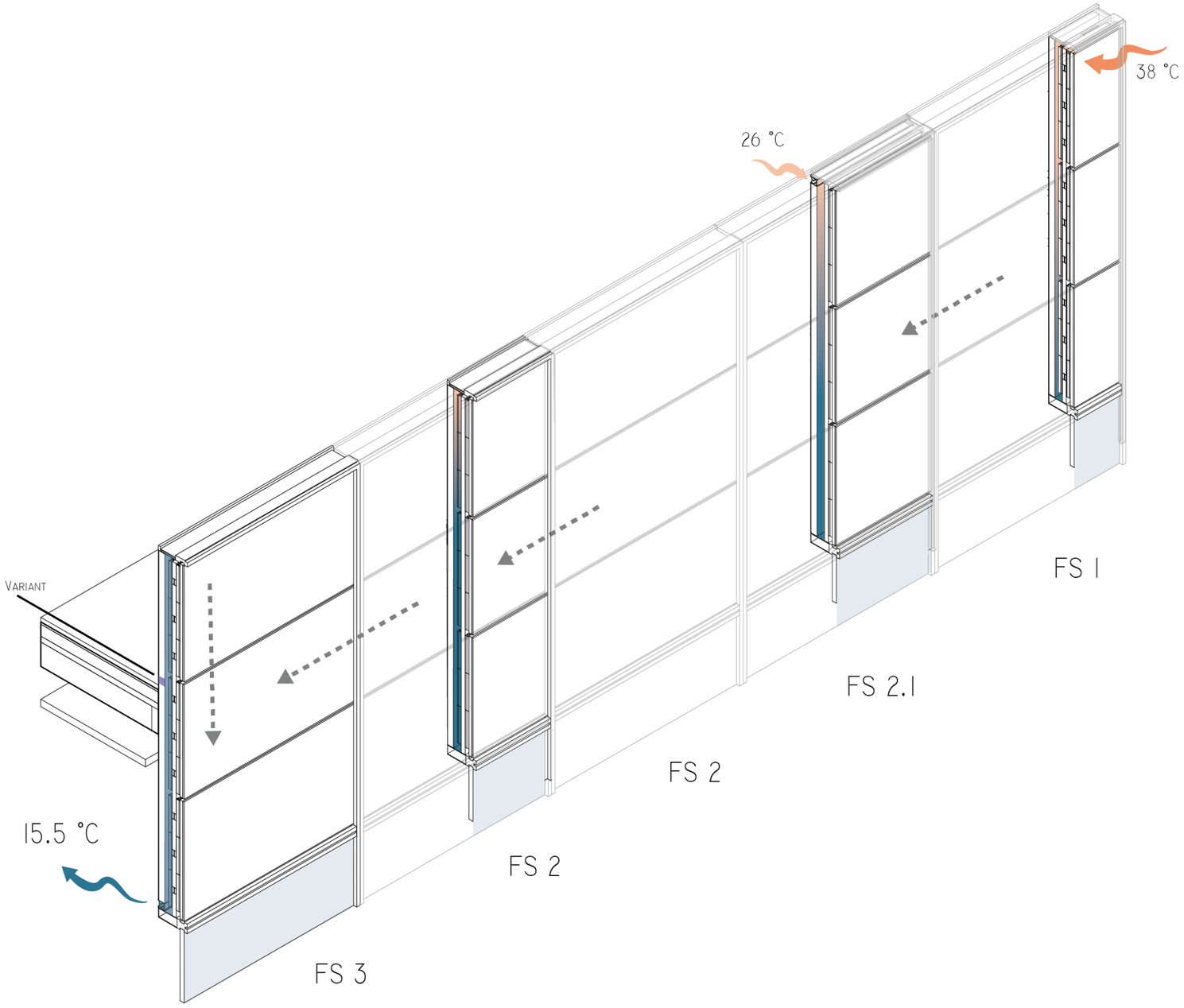
FACADE MODULE BY FUNCTION
AIR SUPPY TO INTERIOR

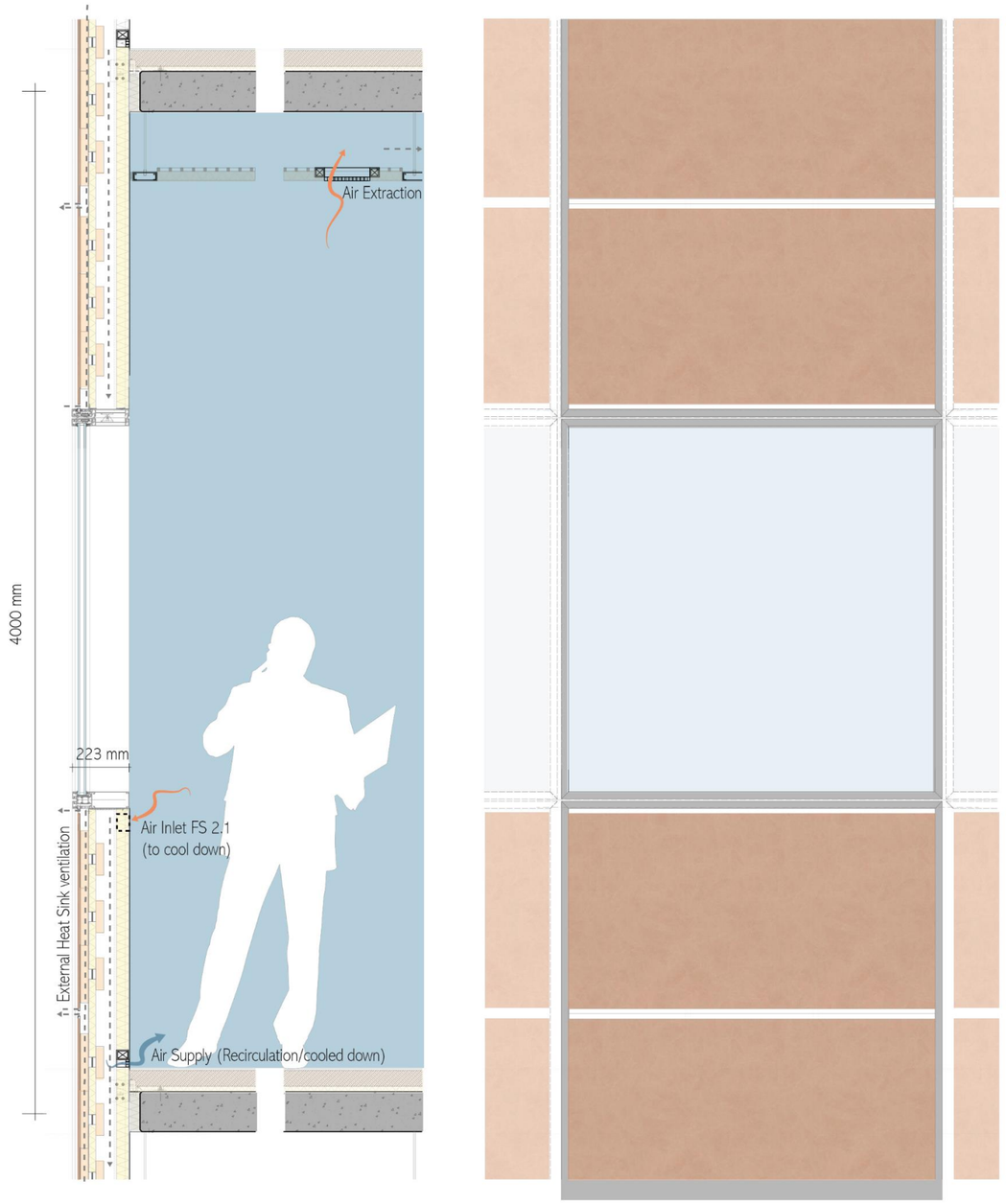


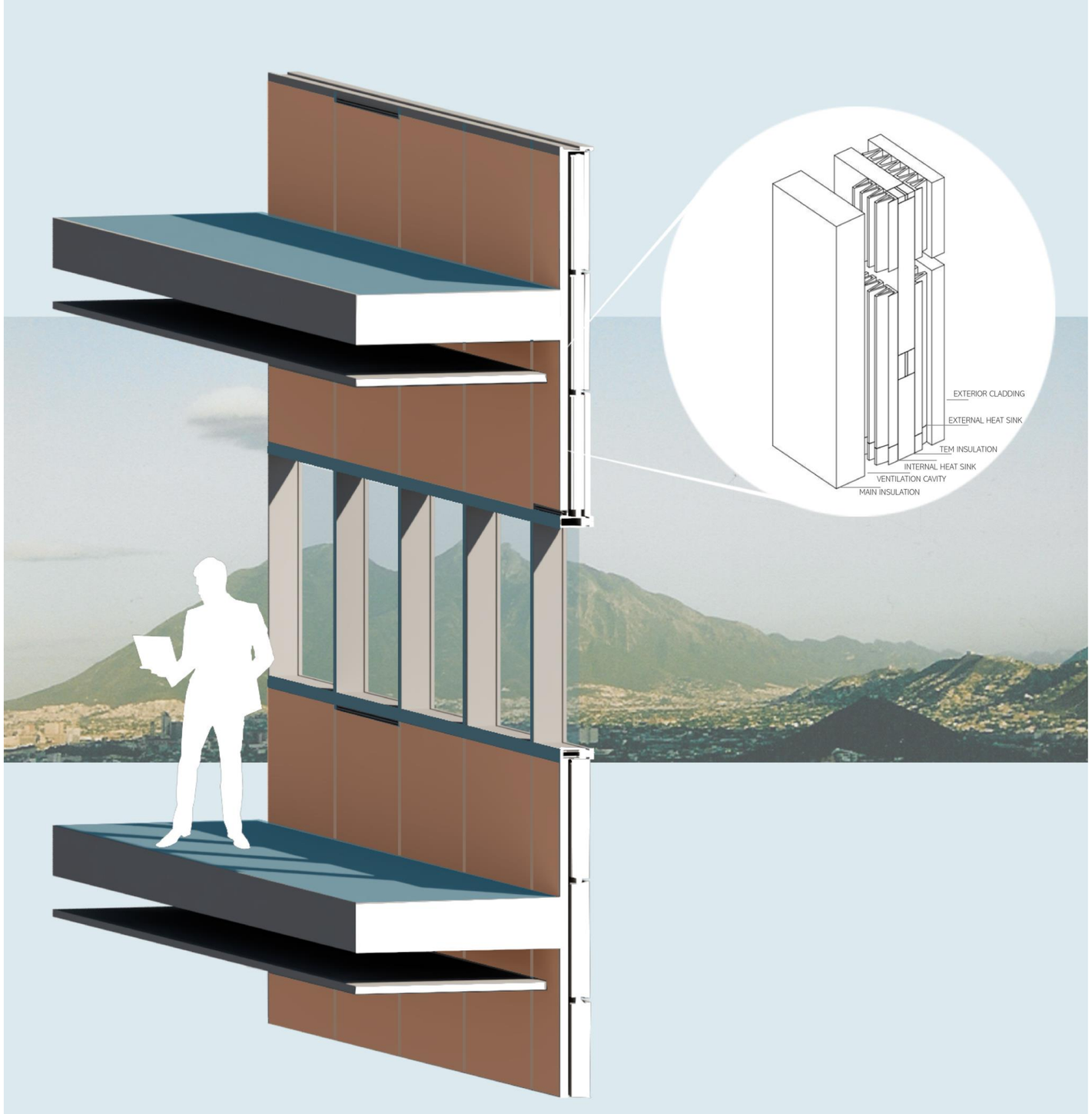


+FACADE TYPES

06-09
COMPLETE SYSTEM




Air Extraction
4000 mm
223 mm
Air Inlet FS 2.1
(to cool down)
External Heat Sink ventilation
Air Supply (Recirculation/cooled down)


EXTERIOR CLADDING
EXTERNAL HEAT SINK
TEM INSULATION
INTERNAL HEAT SINK
VENTILATION CAVITY
MAIN INSULATION

04 DESIGN

+CONCEPT

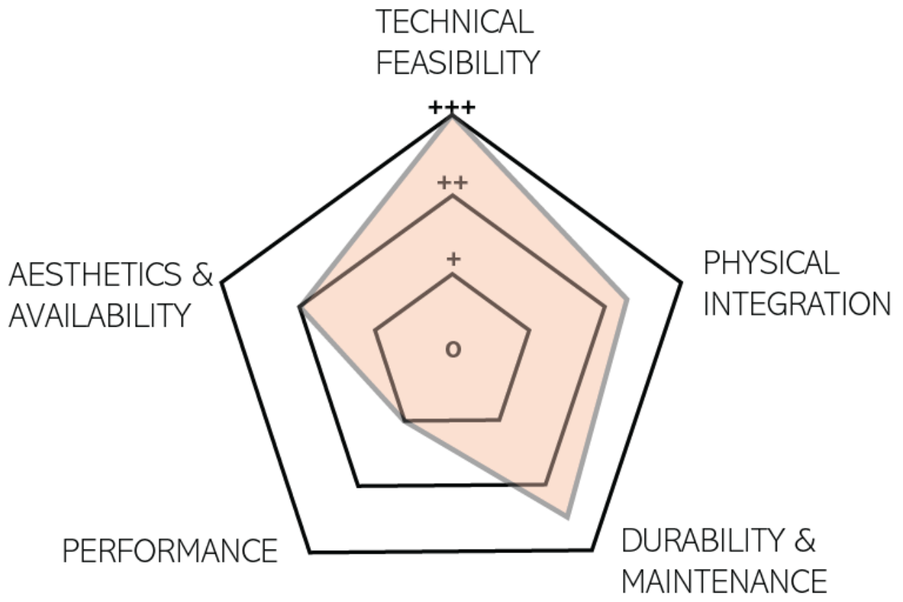
+GUIDELINES

+FAÇADE DEVELOPMENT

+FAÇADE TYPES

+EVALUATION

+EVALUATION



*Based on assessment method by Prieto et al. (2019)

05 CONCLUSION

+ CONCLUSION

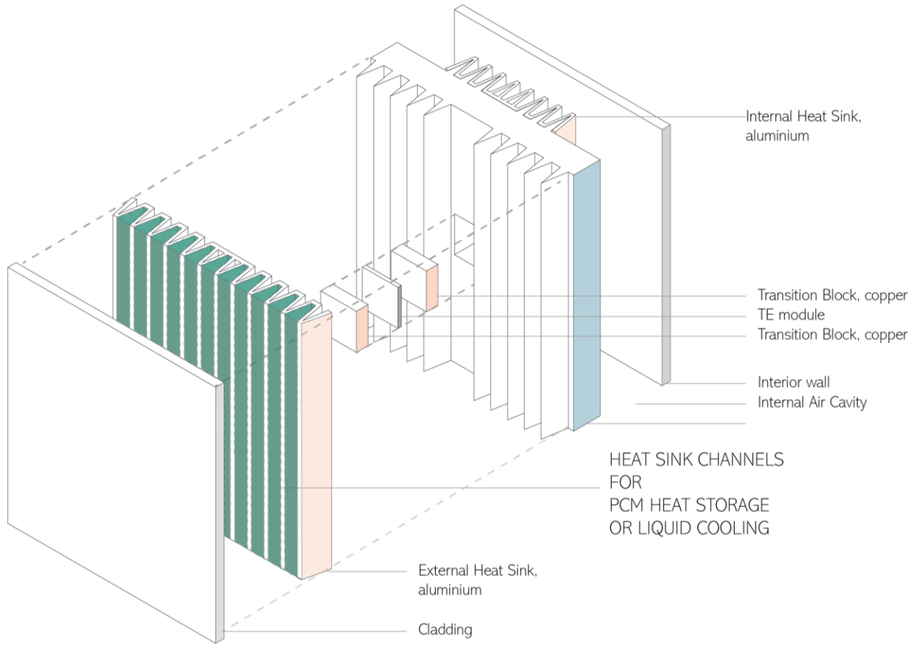
+OTHER POSSIBLITIES

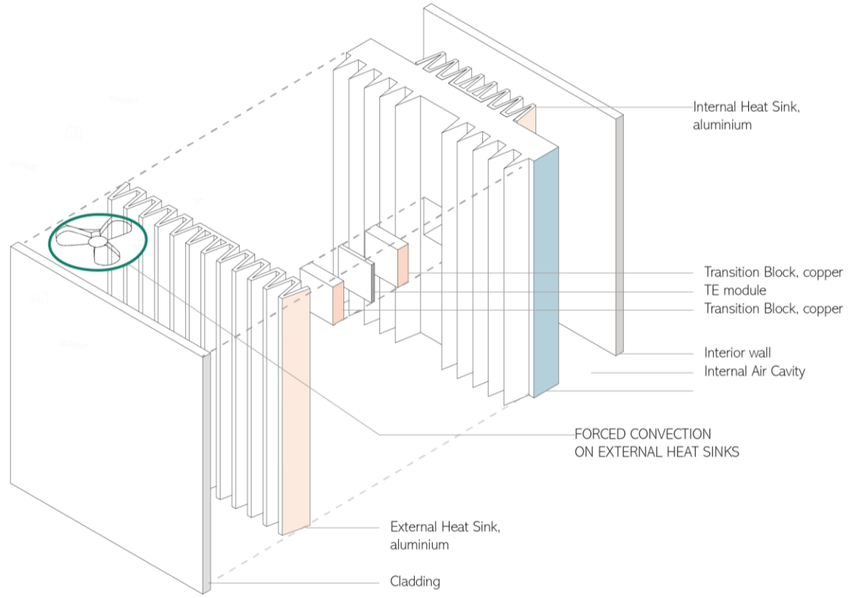
+ FUTURE WORK

+CONCLUSIONS

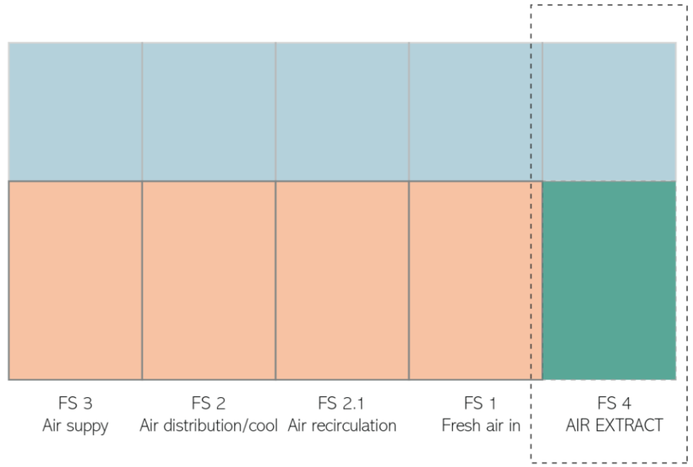
TEM low capacity requires high quantity of modules
Performance improved but it requires all the façade panels having TEMs
Much material usage (heat sinks)
Difference in temperature is small (component level)
Geometry affects thermal performance
Identified trends (both scales)
Potential!

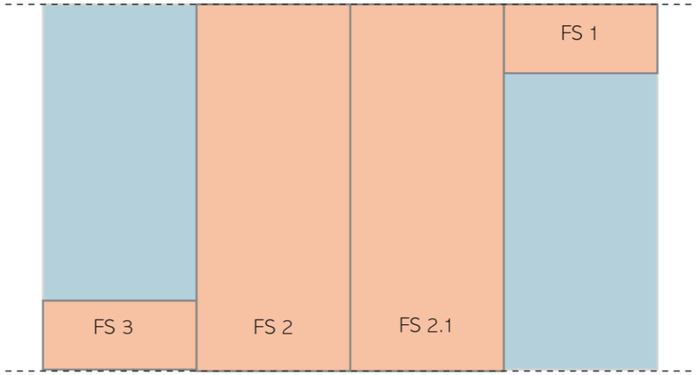
+OTHER POSSIBILITIES

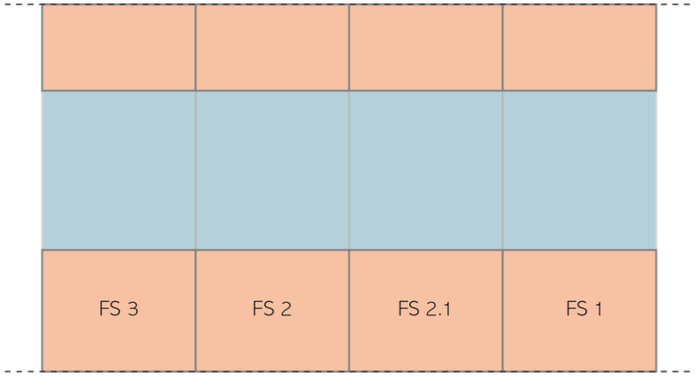


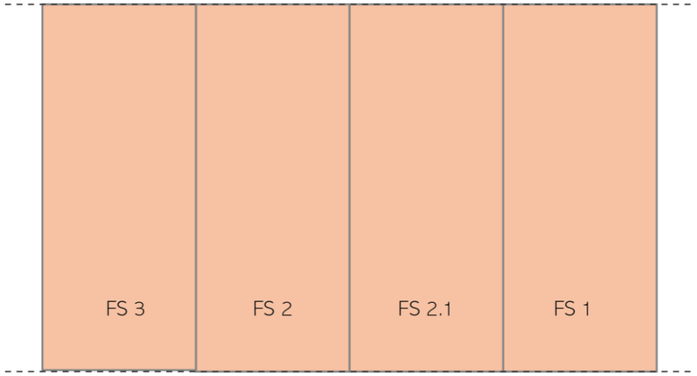


+OTHER POSSIBILITIES









+FUTURE WORK

Exploration on the TE material
Design possibilities (too many)
Parametrization for the heat sink shape
Material
Other climatic conditions
Other typologies

THANK YOU

MENTORS:

Dr. Alejandro Prieto

Ir. Eric van den Ham

Lei Qu

TU Delft