SOLAR - COOLING FAÇADES:

AN INTEGRATED FAÇADE DESIGN WITH THERMOELECTRIC COOLING SYSTEMS FOR OFFICE BUILDINGS IN ATHENS

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4517563

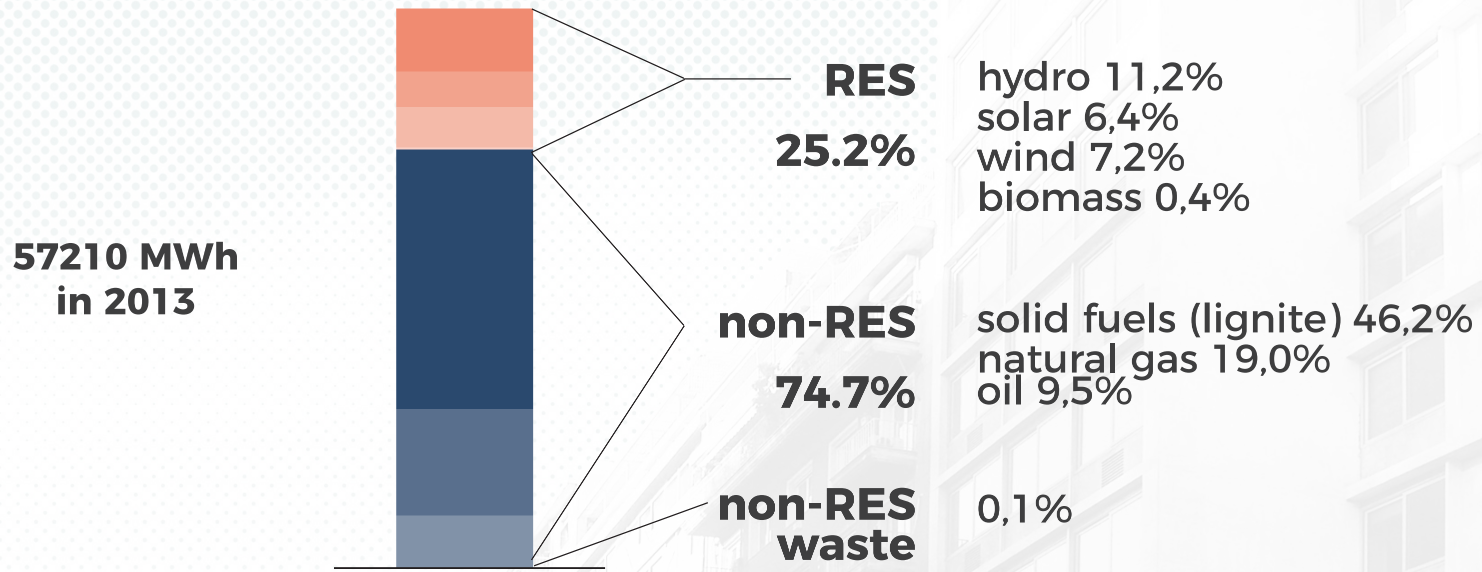
WHAT IS A SOLAR-COOLING FAÇADE?

SOLAR POWER: USED FOR COOLING THROUGH A SYSTEM OF DEVICES > INTEGRATED ON A FAÇADE

THERMOELECTRIC SOLAR-COOLING FAÇADE

PROBLEM DEFINITION

- **RENEWABLE ENERGY RESOURCES**
- **HIGH COOLING DEMAND IN ATHENS DURING SUMMER MONTHS**



Fractions of gross energy consumption for 2013 (MWh). Source: Gaglia et al.

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METHODOLOGY & RESEARCH REVIEW

RESEARCH QUESTIONS

Main research question

How can a façade regulate the indoor temperature in an office building located in Athens by using bioclimatic strategies and thermoelectric technology in order to reduce the amount of energy needed for cooling?

RESEARCH QUESTIONS

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How can a façade regulate the indoor temperature in an office building located in Athens by using bioclimatic strategies and thermoelectric technology in order to reduce the amount of energy needed for cooling?

Research sub-questions

- **What is the *state-of-the art* of PV and TE technology and what are the future potentials?**
- **Which are the most distinctive *climate characteristics* that need to be considered and which *passive design strategies* can be applied to an office façade in Athens?**
- **To what extend can these building physics strategies be adequate for the achievement of indoor thermal comfort? (*How far can we go* with passive strategies?)**
- **What is the *typical office building* in Athens?**

METHODOLOGY

LITERATURE REVIEW

- **STATE-OF-THE-ART (THERMOELECTRICS & PHOTOVOLTAICS)**
- **CLIMATE**
- **BUILDING PHYSICS / PASSIVE STRATEGIES**

FIELD RESEARCH

- **25 CASE STUDIES**
- **TYPICAL OFFICE**

CALCULATIONS

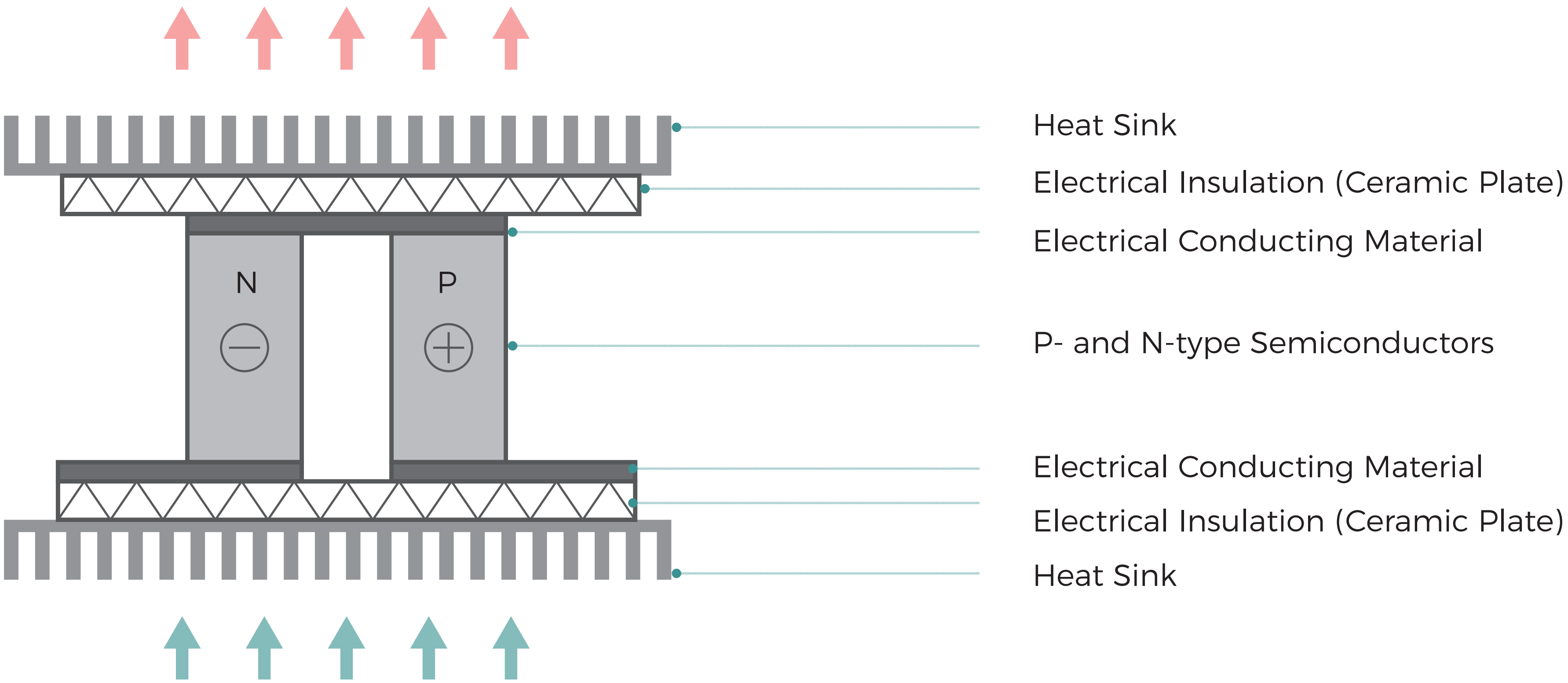
- **SIMULATIONS / DESIGN BUILDER**
- **HAND CALCULATIONS**
- **PASSIVE OPTIMIZATION**

DESIGN

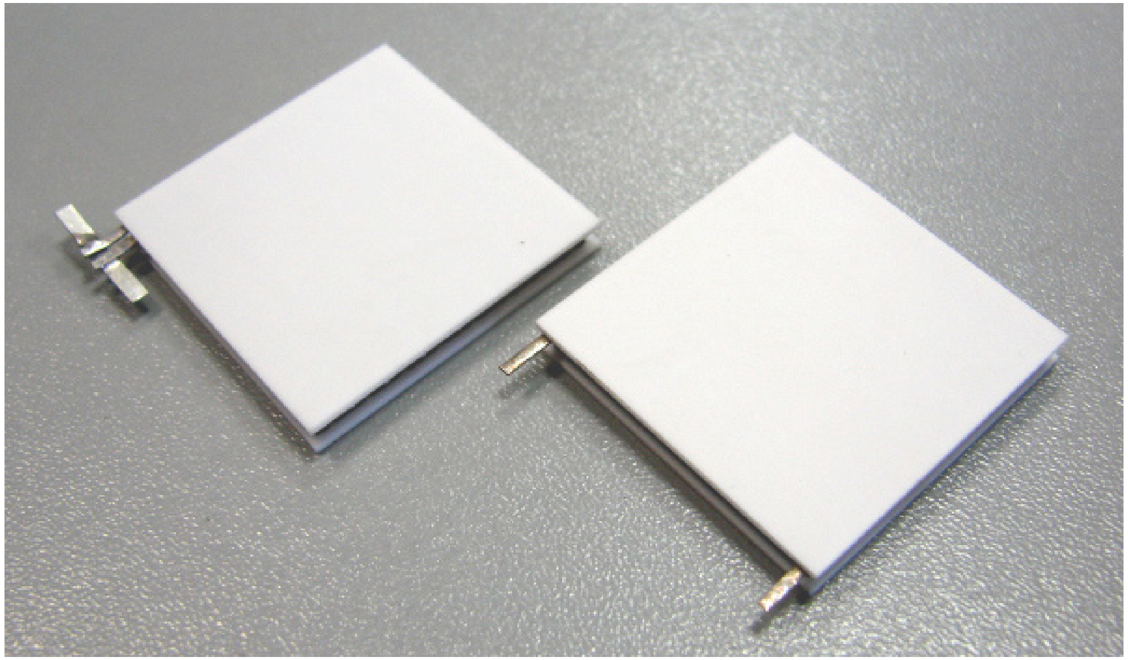
- **DESIGN APPLICATION**
- **ARCHITECTURAL POSSIBILITIES**

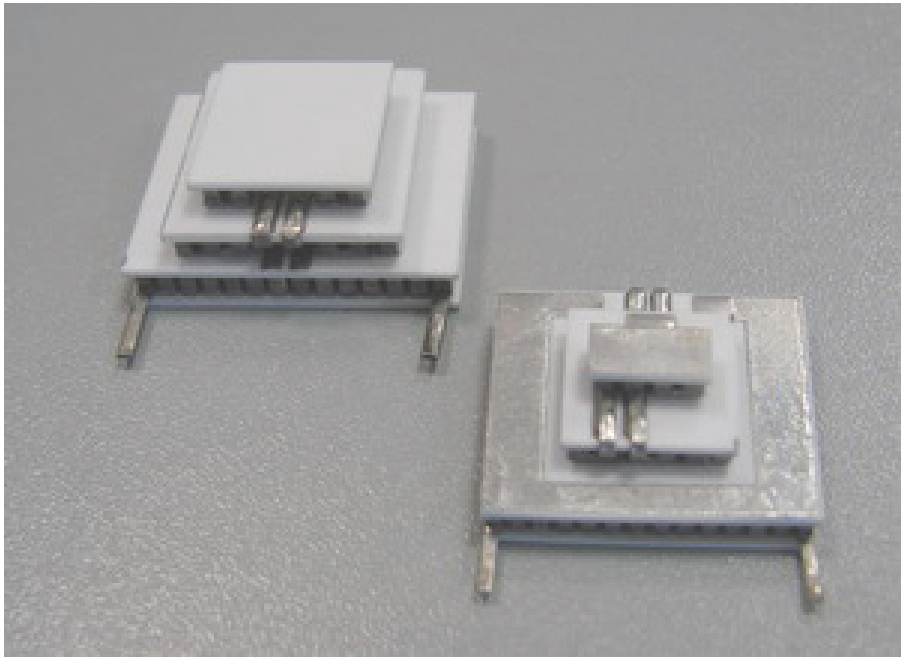
WHAT IS A THERMOELECTRIC MODULE? (PELTIER MODULE)

SOLID-STATE HEAT PUMP



WHAT IS A THERMOELECTRIC MODULE? (PELTIER MODULE)



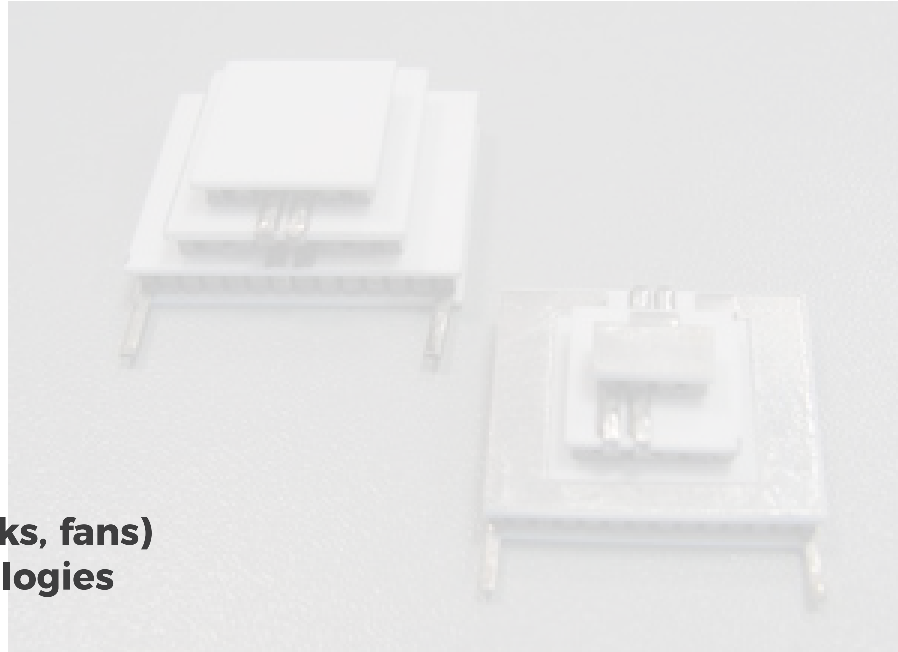


WHAT IS A THERMOELECTRIC MODULE? (PELTIER MODULE)

- **solid-state heat pump / Peltier effect**
- **DC current**
- **ΔT up to 70˚C**
- **small dimensions (40-60mm)**

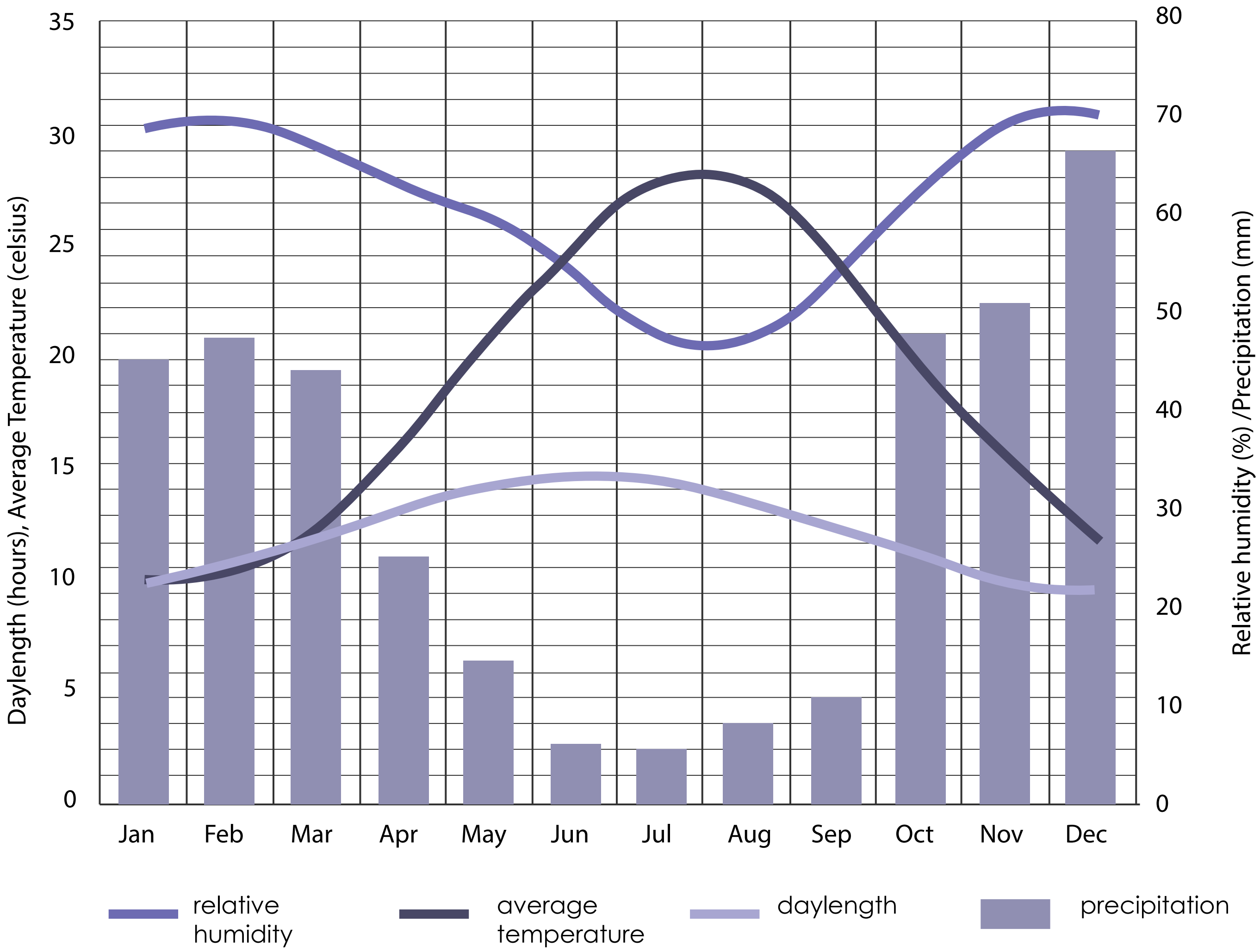
+ **emission free**
+ **low-maintenance**
+ **noise-free**

- **trade-off between CoP and energy output**
- **need for auxiliary equipment (batteries, heat sinks, fans)**
- **low efficiency compared to other cooling technologies**



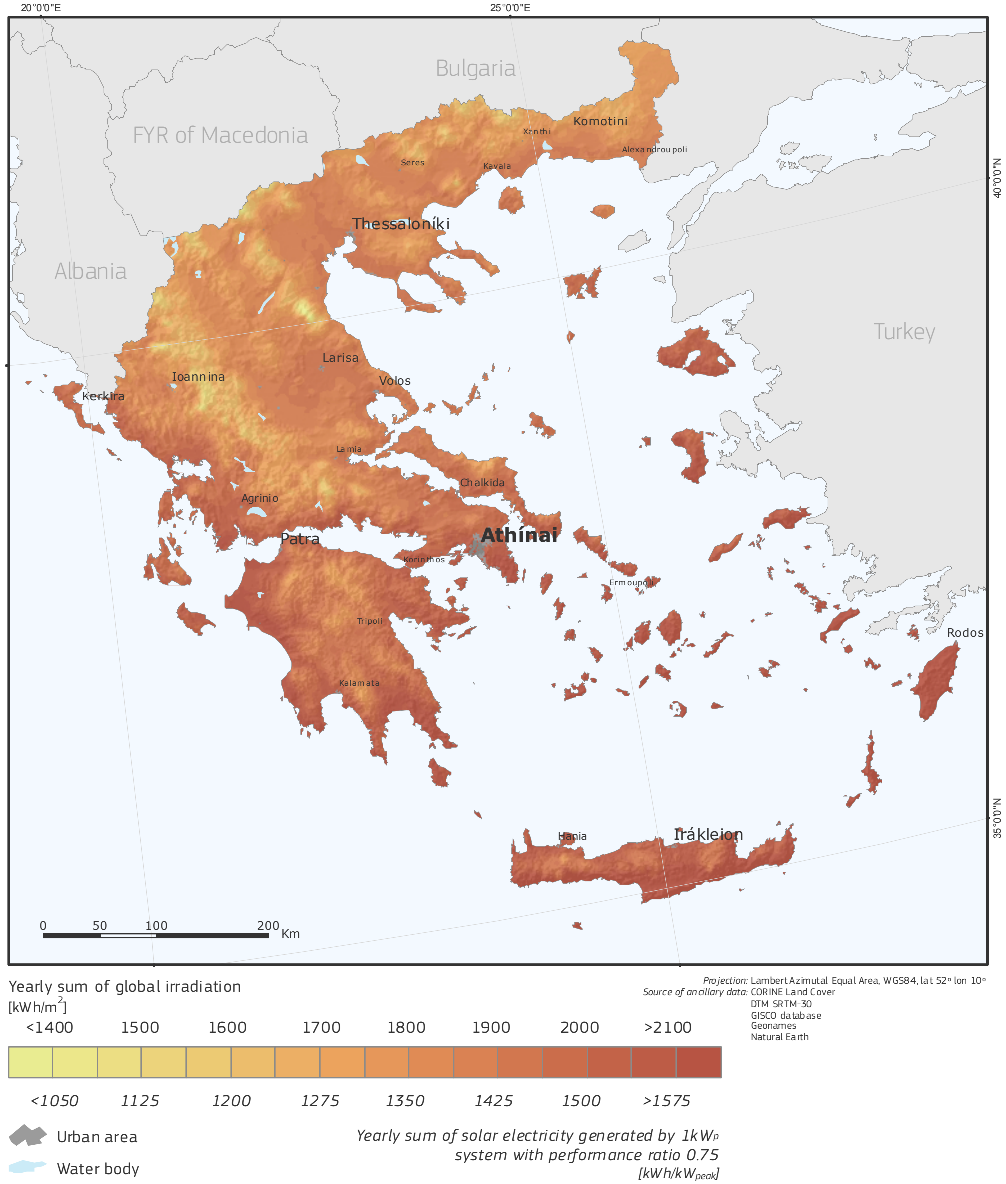
CLIMATE PROFILE OF ATHENS

mild mediterrannean (mild and rainy winters, relatively warm and dry summers)
Csa category, (Köppen-Geiger classification)

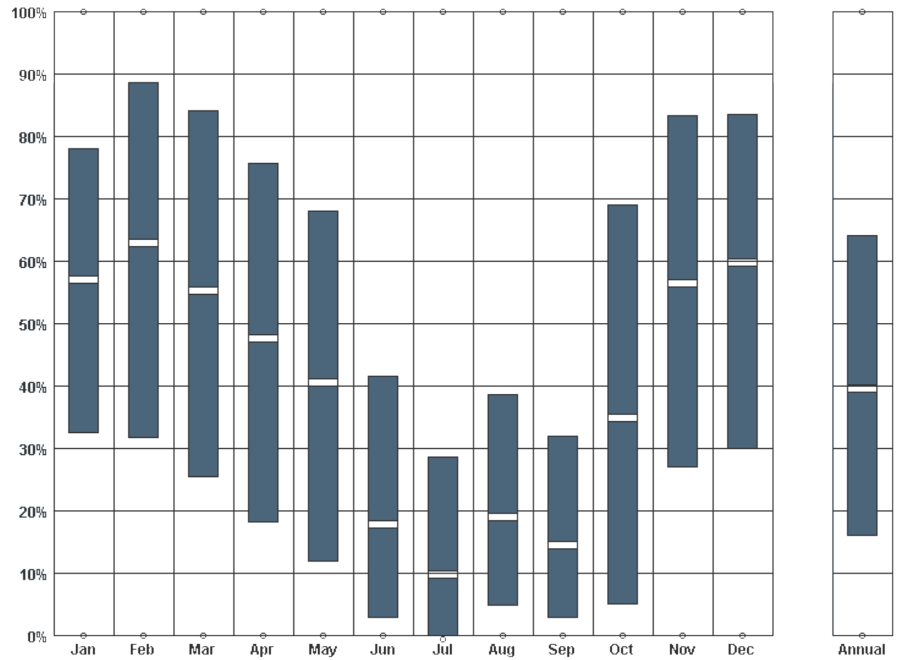


SOLAR ELECTRICITY POTENTIAL

GLOBAL IRRADIATION



SKY COVER RANGE



TYPICAL OFFICE IN ATHENS

FIELD RESEARCH

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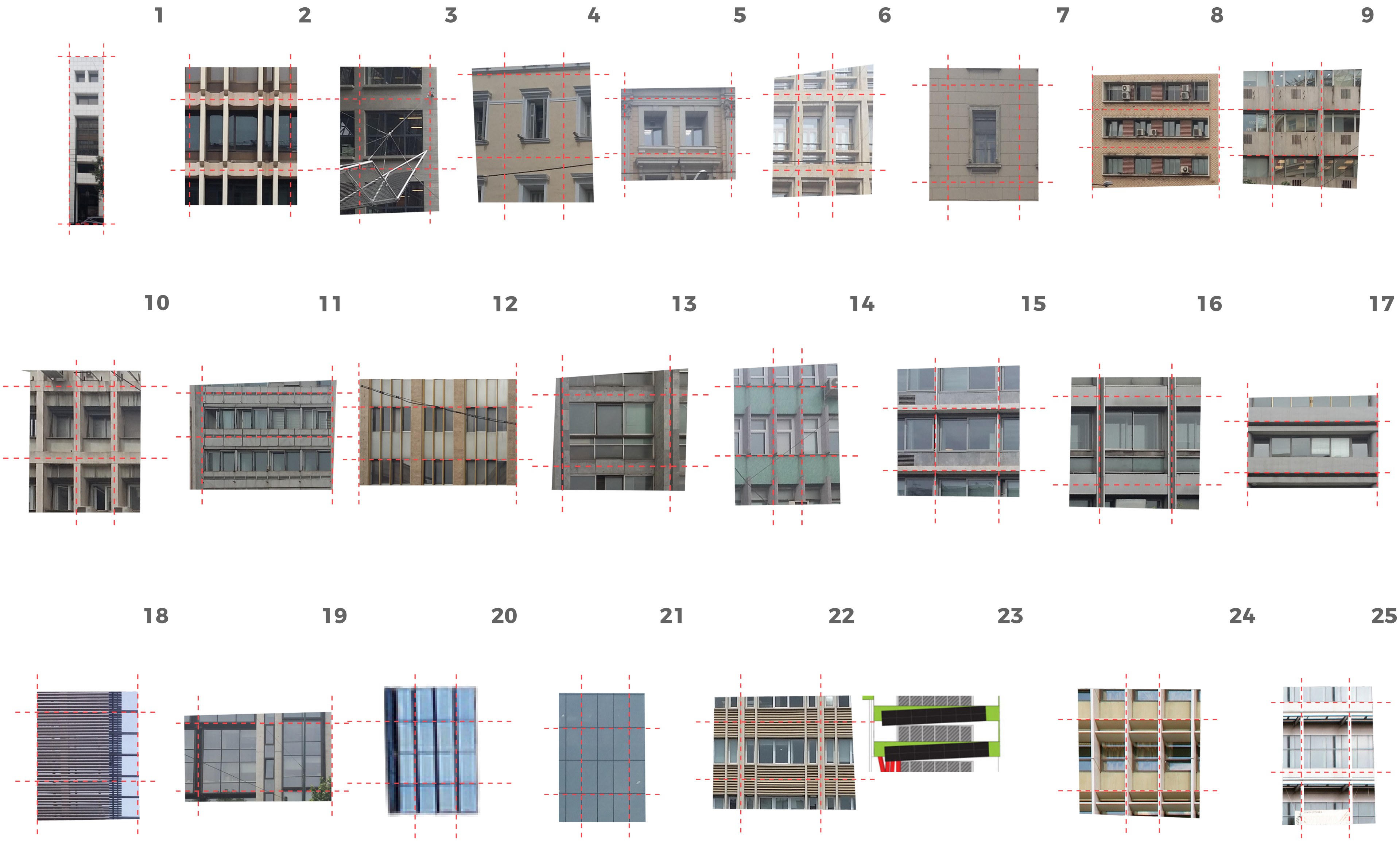
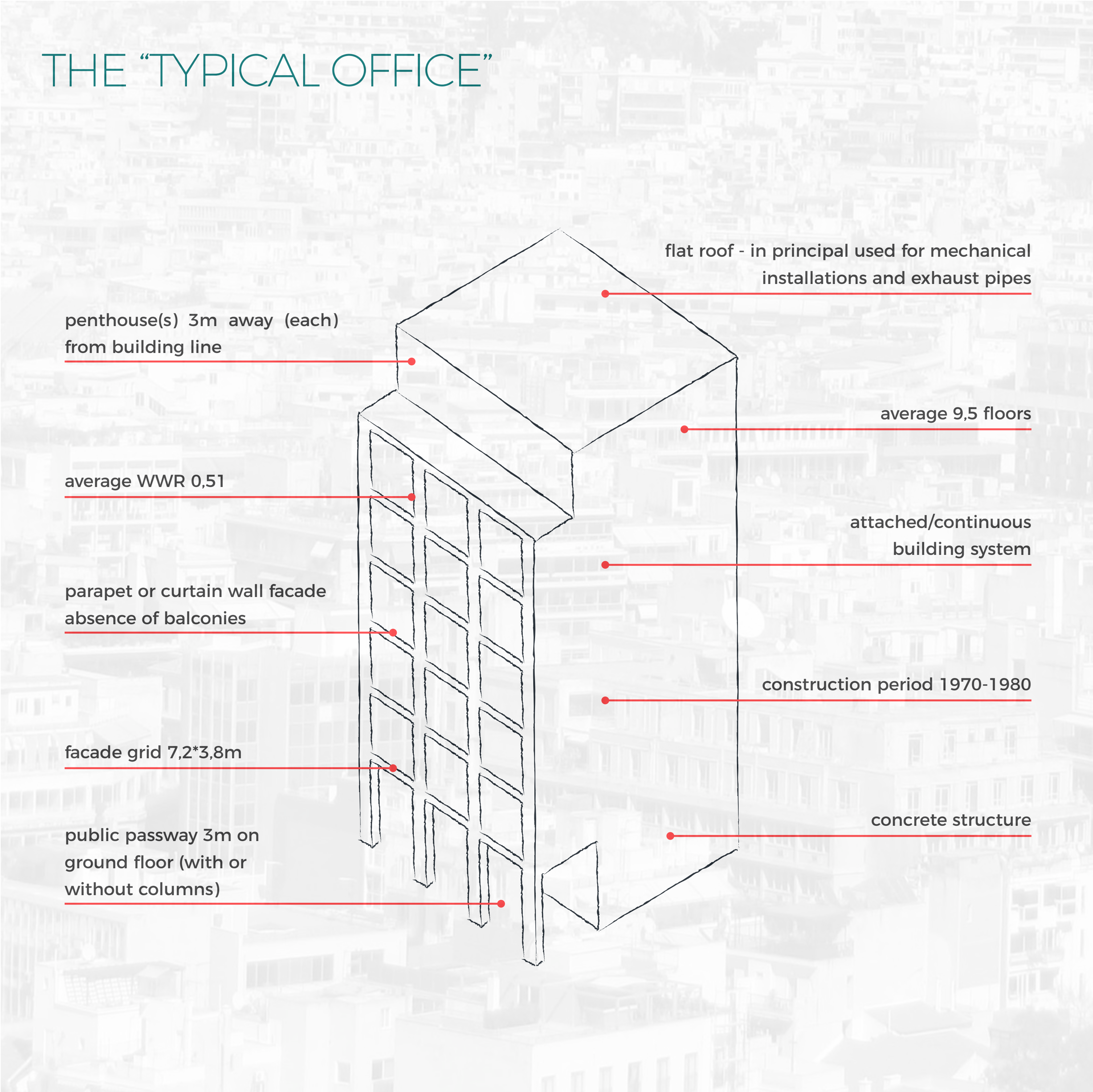
FIELD RESEARCH



THE "TYPICAL OFFICE"



CASE STUDY BUILDING

LOCATION	ATHENS, CENTER
FACADE	3.30M HEIGHT
	2.70M WIDTH
WWR	0.55
STRUCTURE	CONCRETE
TOTAL HEIGHT	33M
FLOORS	10
YEAR	~1975
MATERIALS	CONCRETE, MARBLE , GLASS

		Strategy	Cooling loads (kWh/m2)		Design Capacity (kW)	Cooling load
			ANNUAL SIMULATION	DESIGN SUMMER WEEK	DESIGN SUMMER DAY	ANNU SIMULAT
enario	0	No passive strategies	175,82	6,23	3,28	
enario	1.0	Glazing Type				
	1.1	dbl clear 6mm/6mm Air	163,42	5,61	2,80	
	1.2	dbl LoE Clr 6mm/6mm Air	113,03	4,53	2,20	
	1.3	dbl LoE Tint 6mm/6mm Air	94,05	4,17	2,09	
	1.4	dbl Ref Clr 6mm/6mm Air	71,06	3,80	1,97	
	1.5	dbl Ref Tint 6mm/6mm Air	74,92	3,97	2,09	
	1.6	dbl Clr 6mm/13mm Argon	171,03	5,67	2,78	
	1.7	dbl LoE Clr 6mm/13mm Argon	127,51	4,61	2,09	
	1.8	dbl Ref Clr 6mm/6mm Argon	110,90	4,52	2,23	
	1.9	dbl LoE Tint 6mm/13 Argon	96,84	4,02	1,85	
enario	2.0	Night Ventilation				
	2.1	schedule a: n=5/hour	111,81	5,76	3,27	
	2.2	schedule a: n=6/hour	111,48	5,74	3,27	
	2.3	schedule a: n=7/hour	111,22	5,73	3,27	
enario	3.0	Shading				
	3.1	external - slats - solar	67,74	4,00	1,94	
	3.2	internal - slats - solar	100,18	4,74	2,40	
	3.3	external - slats - always on	62,66	3,79	1,94	
	3.4	internal -slats - always on	98,14	4,65	2,39	
	3.5	ext - roll med opaque - solar	64,88	3,97	1,87	
	3.6	el/chromic - refl - switchable	93,88	4,70	2,57	
enario	4.0	WWR				
	4.1	WWR = 15%	80,43	3,94	1,71	
	4.2	WWR = 25%	106,89	4,63	2,14	
	4.3	WWR = 30%	120,94	4,97	2,37	
	4.4	WWR = 40%	148,80	5,61	2,83	
	4.5	WWR = 50% (scenario 0)	175,82	6,23	3,28	
	4.6	WWR = 60%	201,59	6,81	3,73	
	4.7	WWR = 70%	226,83	7,36	4,17	
	4.8	WWR = 80%	243,98	7,73	4,48	

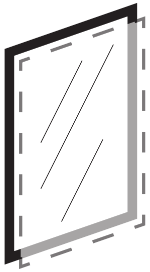
PASSIVE OPTIMIZATION

METHOD DESCRIPTION

- **TYPICAL BUILDING**
- **STRATEGIES COMMONLY USED FOR COOLING (GREEK CONTEXT)**
- **MODEL IN DESIGN BUILDER**
- **VARIOUS SCENARIOS ACCORDING TO STRATEGIES**
- **TRIAL & ERROR > BEST SCENARIO COMBINATION**
- **OPTIMAL SCENARIO**

METHOD DESCRIPTION

STRATEGIES

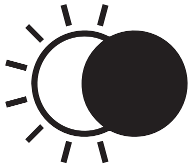


1- GLAZING TYPE

- dbl clr air
- dbl LoE clr air
- dbl LoE tint air
- dbl refl clr air
- dbl refl tint air
- dbl clr argon
- dbl LoE clr argon
- dbl refl clr argon
- dbl LoE tint argon

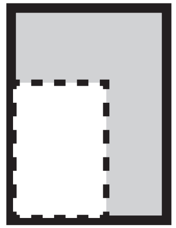
2- NIGHT VENTILATION

- 5 per hour
- 6 per hour
- 7 per hour



3- SUN SHADING

- ext slats solar
- int slats solar
- ext slats on
- int slats on
- ext roll solar
- electrochromic

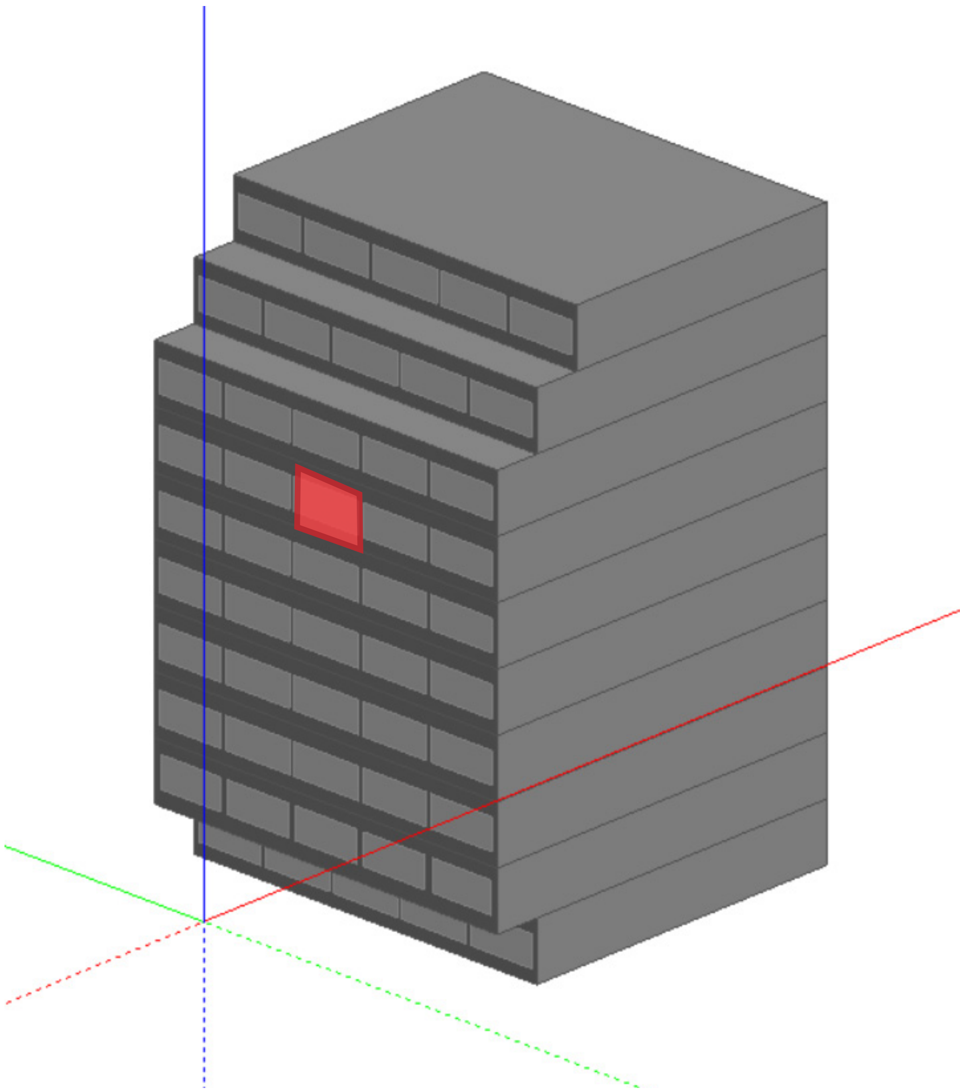


4- WWR

- 15%
- 25%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%

DESIGN BUILDER

MODEL & CRITERIA



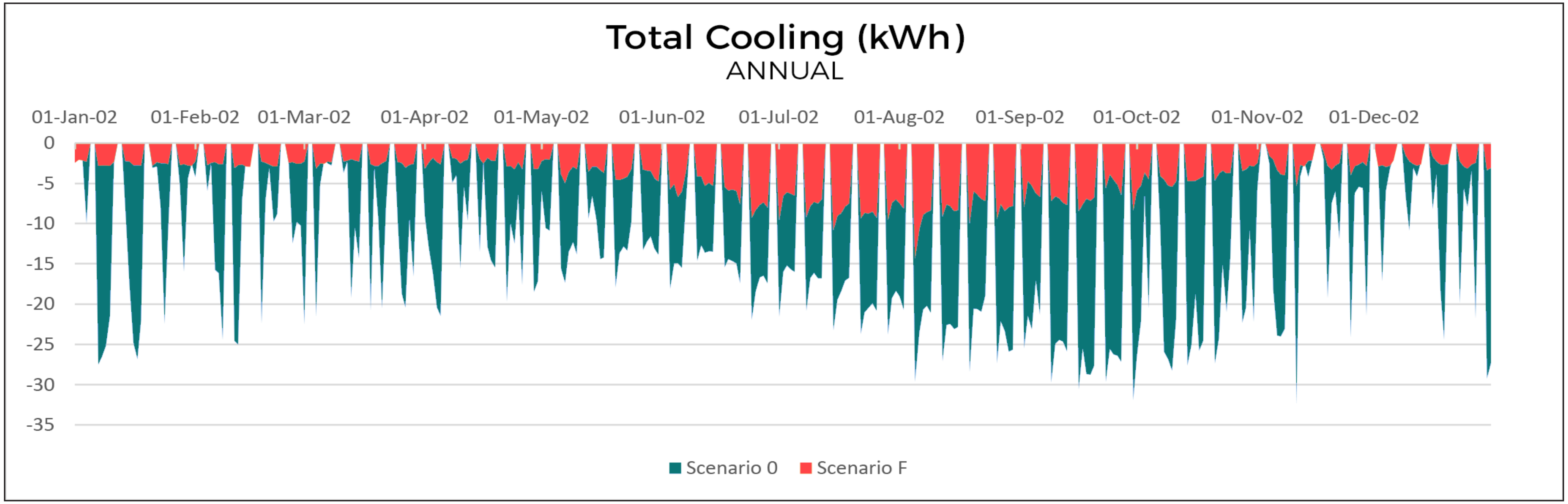
- COOLING LOADS (ANNUAL)
- COOLING LOADS (SUMMER DESIGN WEEK)
- DESIGN CAPACITY
- LIGHTING LOADS (ANNUAL)
- ALL ORIENTATIONS

HOW FAR CAN WE GO WITH PASSIVE STRATEGIES?

OPTIMUM SCENARIO

Glazing:	double Low-E Clear 6mm/6mm Air
Night ventilation:	n=5per hour
Shading:	external slats solar
WWR:	40%

ANNUAL



HOW FAR CAN WE GO WITH PASSIVE STRATEGIES?

OPTIMUM SCENARIO

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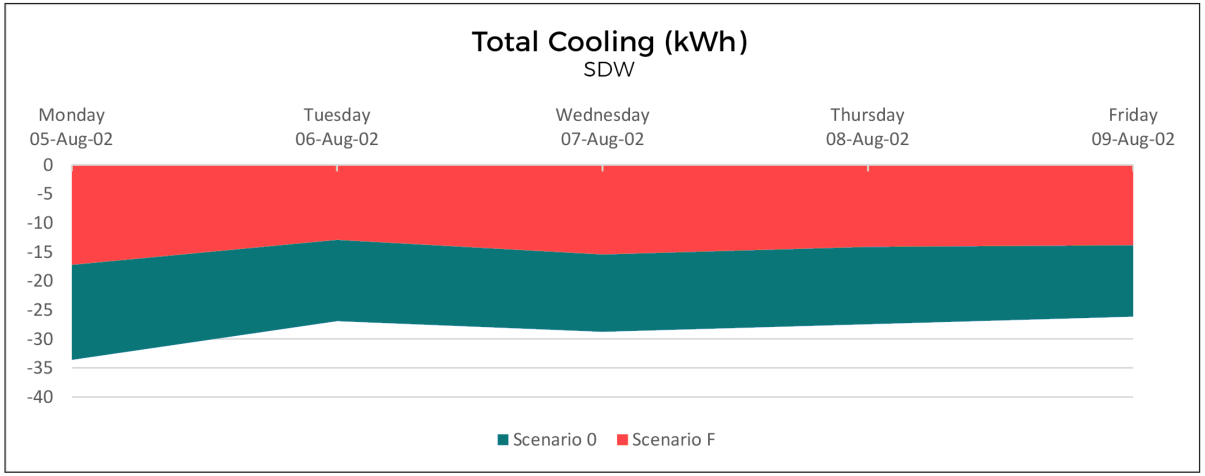
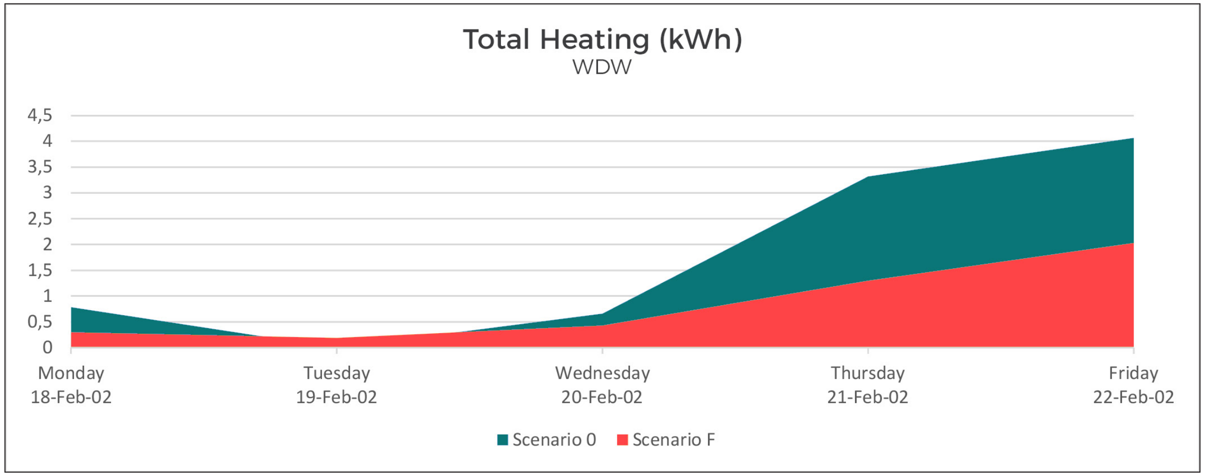
SUMMER

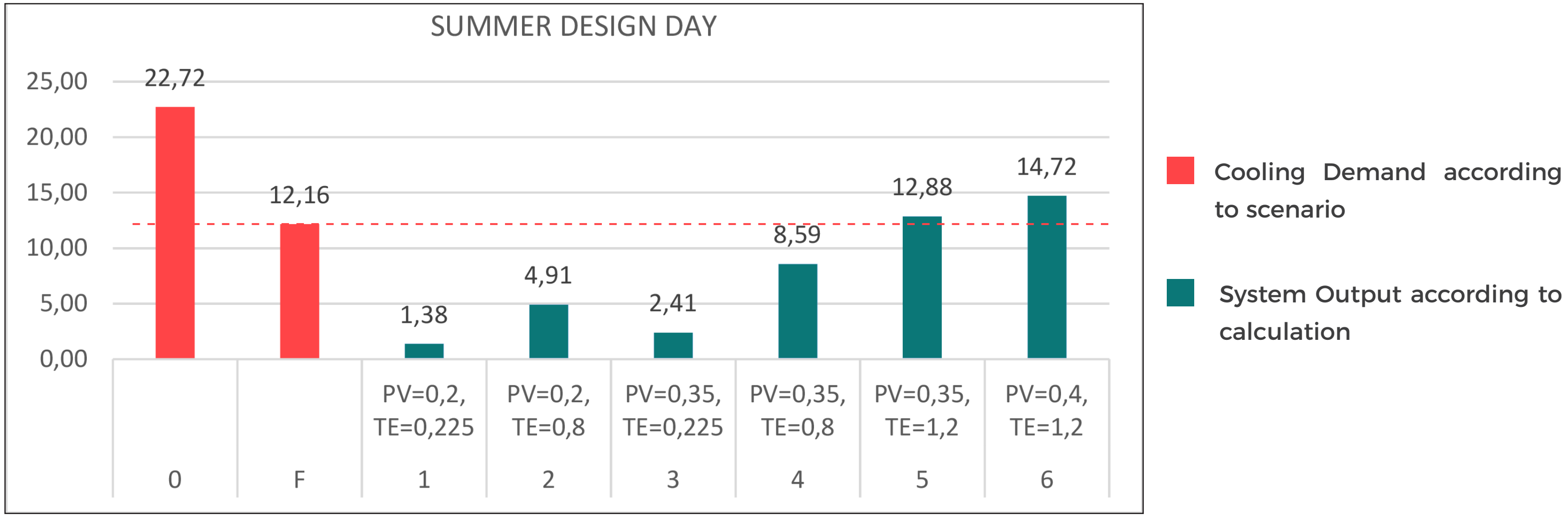


WINTER

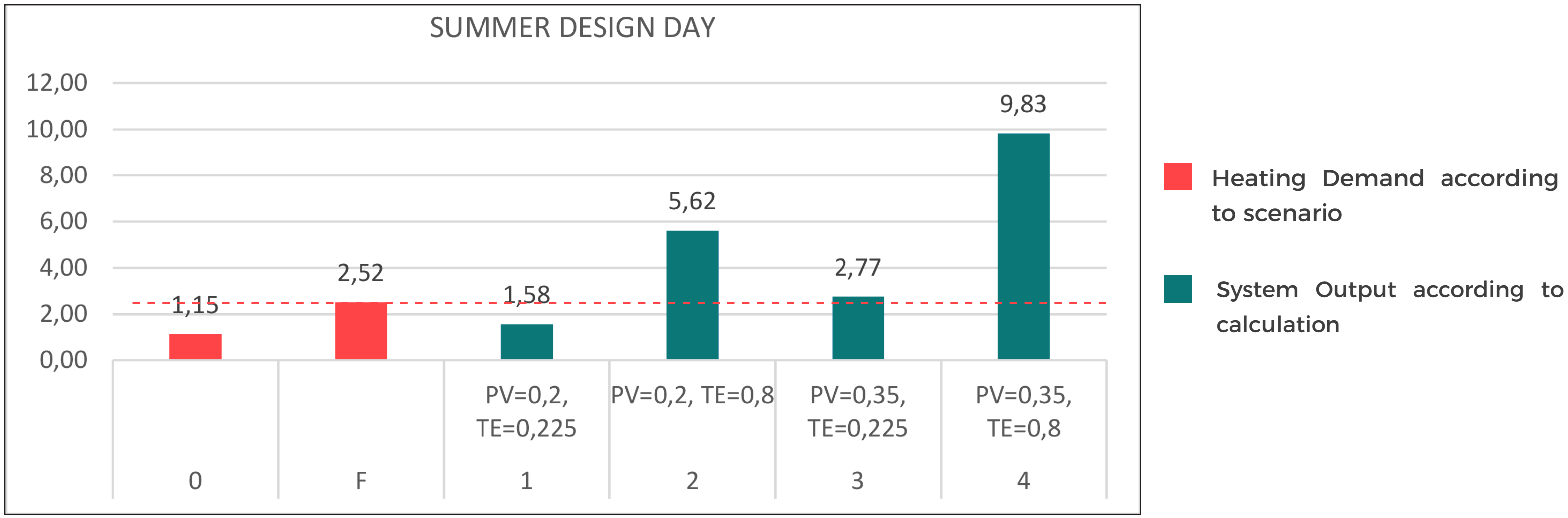


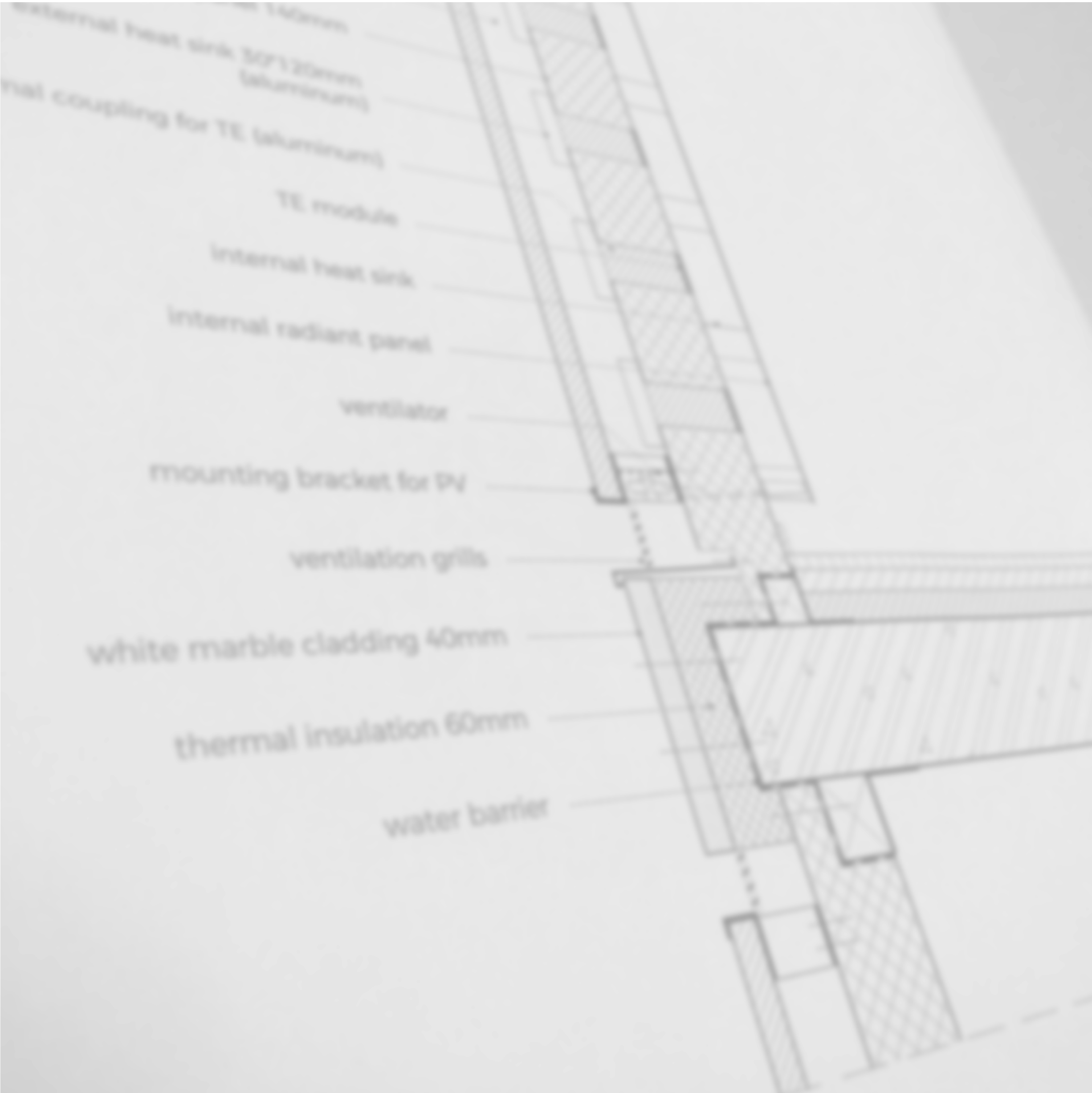
HOW MUCH DELTA CAN WE COVER WITH THE TE/PV SYSTEM?

COOLING LOADS (kWh)



HEATING LOADS (kWh)

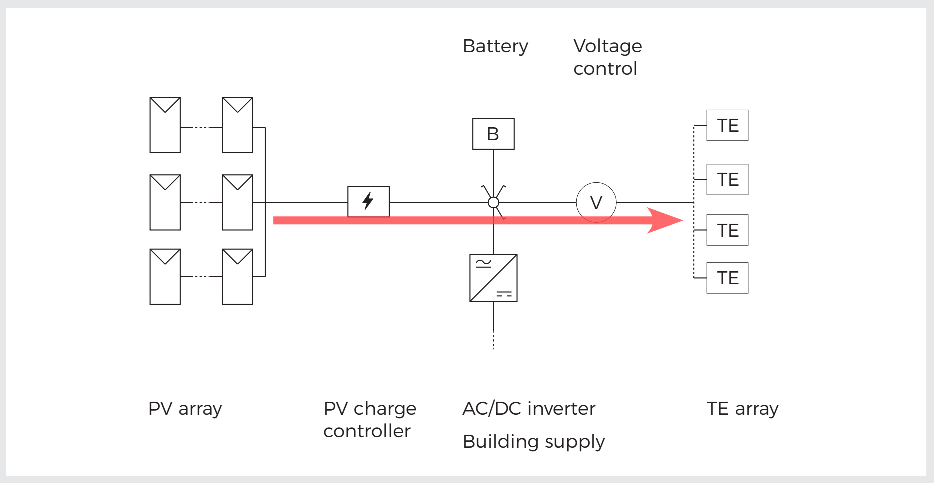



TE module
internal heat sink
internal radiant panel
ventilator
mounting bracket for PV
ventilation grills
white marble cladding 40mm
thermal insulation 60mm
water barrier

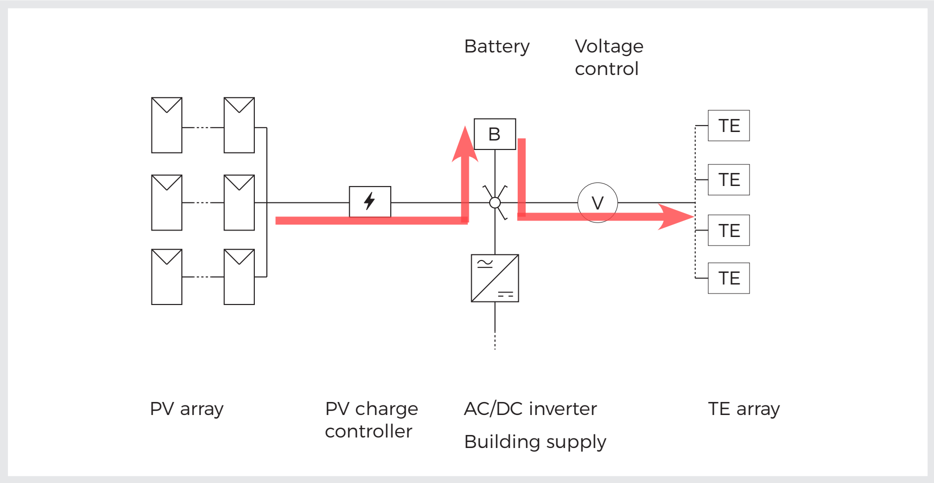
DESIGN

SYSTEM DESIGN - FUNCTIONS

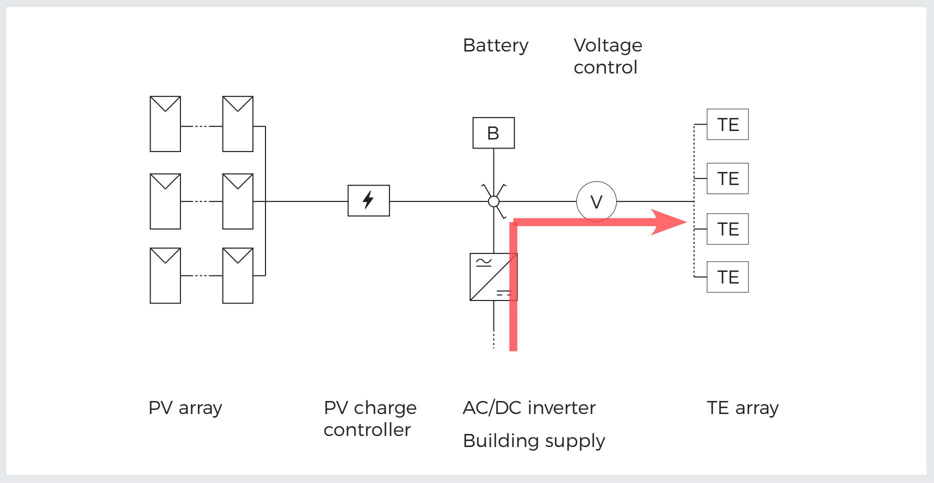
PRIMARY



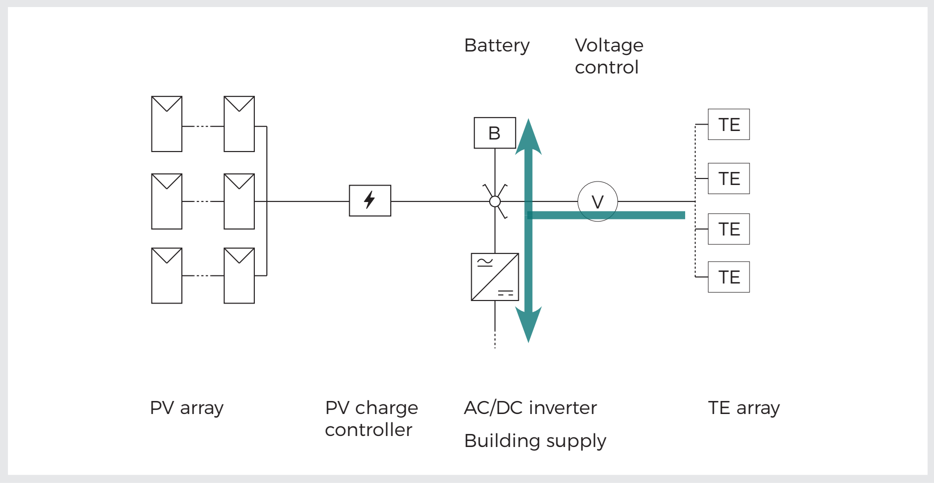
SECONDARY



AUXILIARY

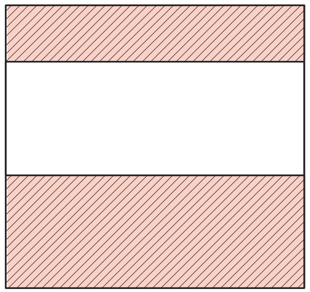


REVERSE

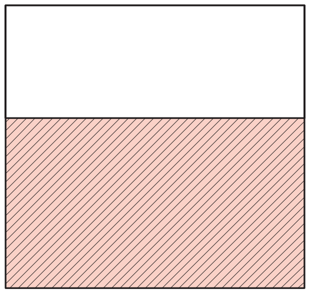


ARCHITECTURAL POSSIBILITIES

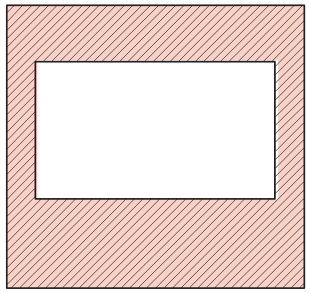
MORPHOLOGY



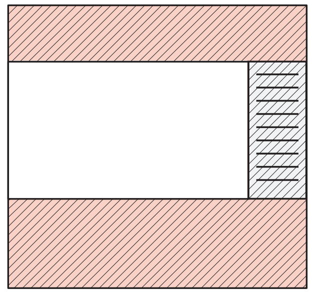
a. Horizontal stripe, middle position



b. Horizontal stripe, upper position



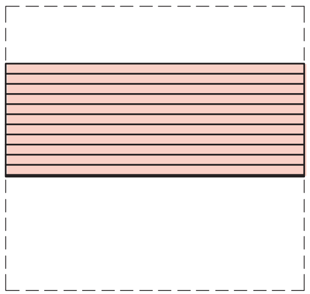
c. Rectangular, middle



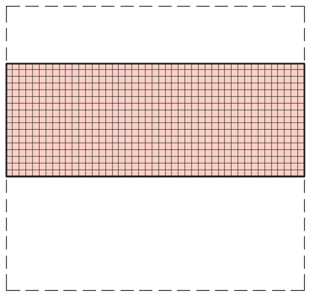
d. Rectangular, w ventilation grills

ARCHITECTURAL POSSIBILITIES

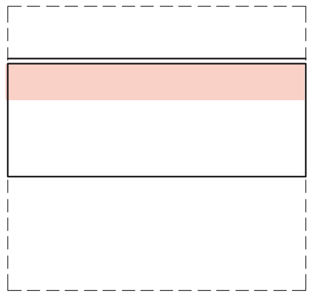
TYPE OF SUN-SHADING



a. Louvres diffusing



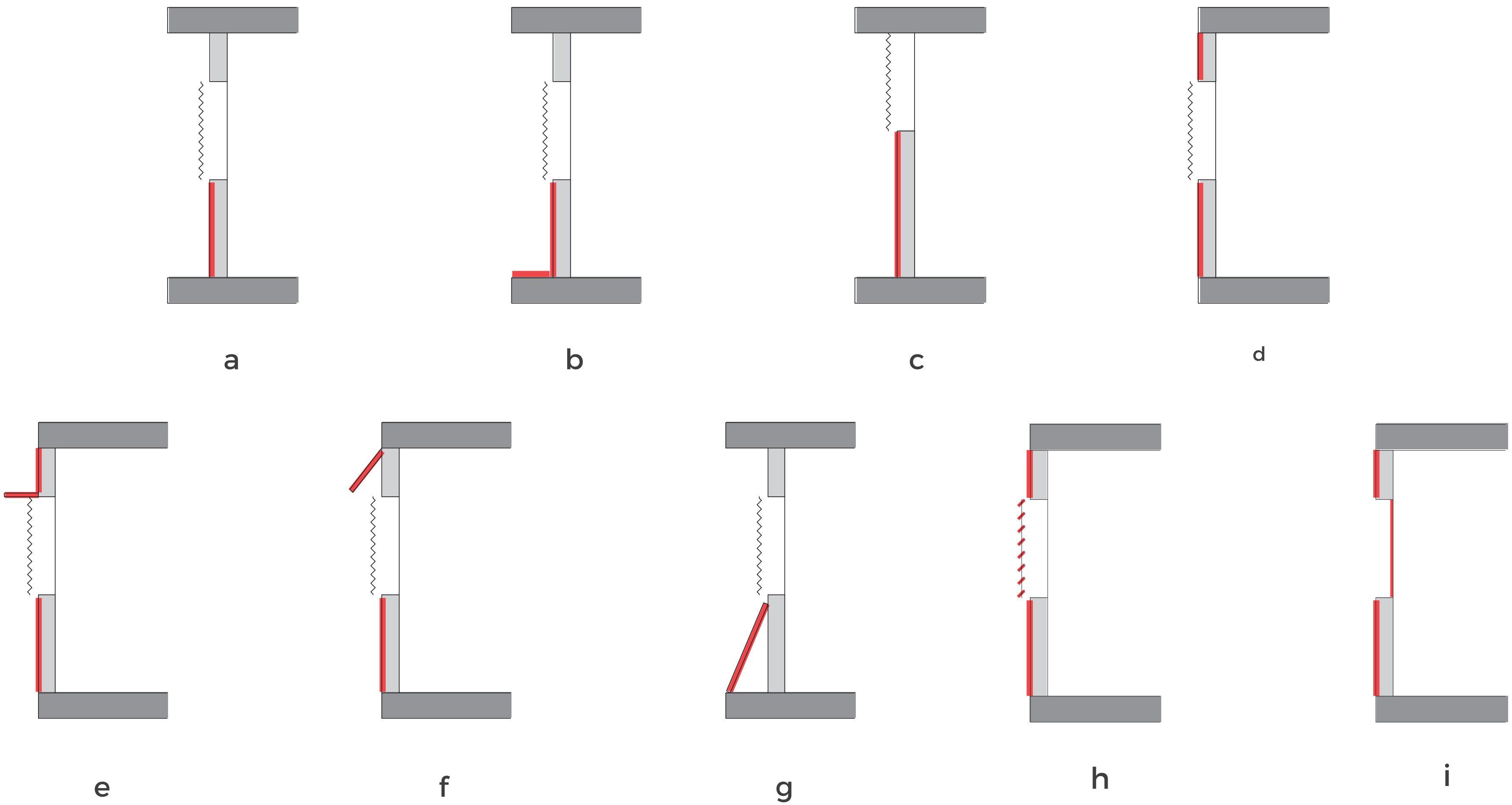
b. Roll diffusing



c. Horizontal overhang

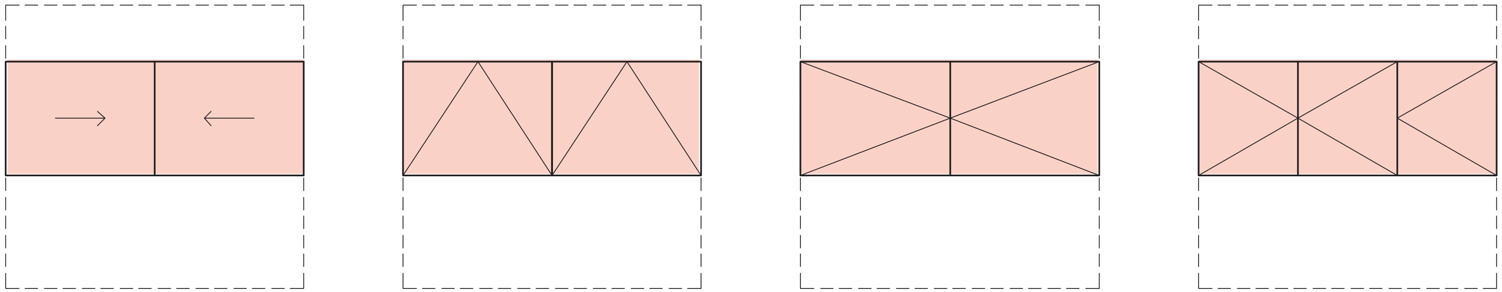
ARCHITECTURAL POSSIBILITIES

SECTION - OFFSET FROM BUILDING LINE & PV PLACEMENT



ARCHITECTURAL POSSIBILITIES

TYPE OF OPENING



a. Sliding

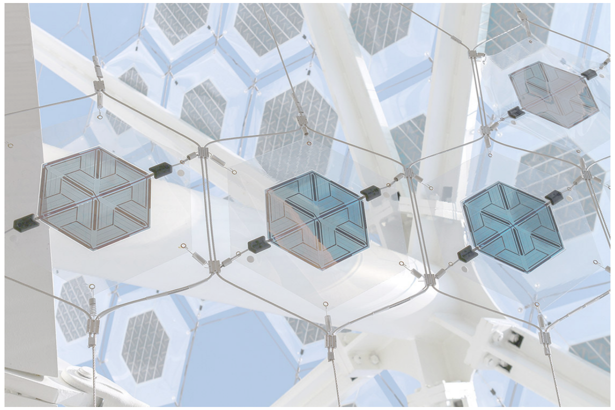
b. Swing vertical

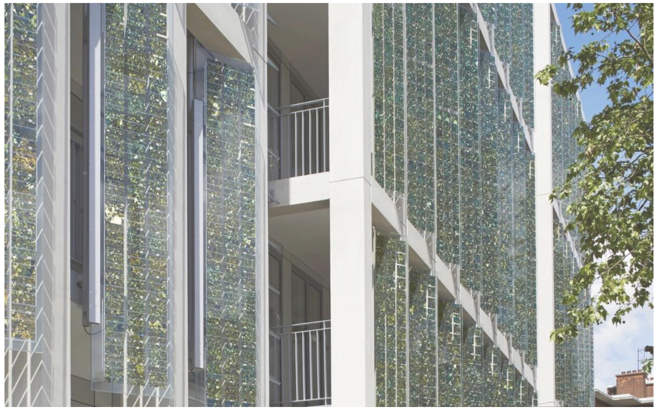
c. Swing horizontal (2)

d. Swing horizontal (3 or multiple)

ARCHITECTURAL POSSIBILITIES

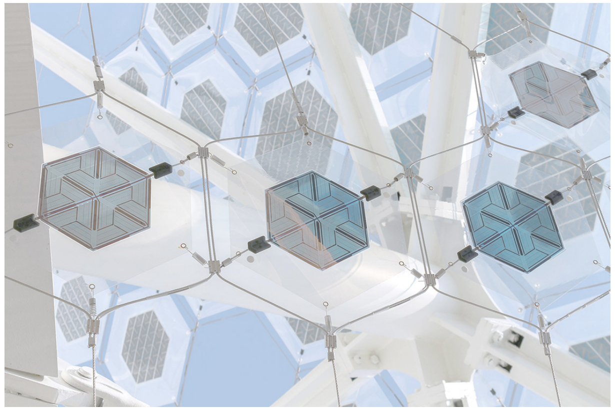
PHOTOVOLTAICS

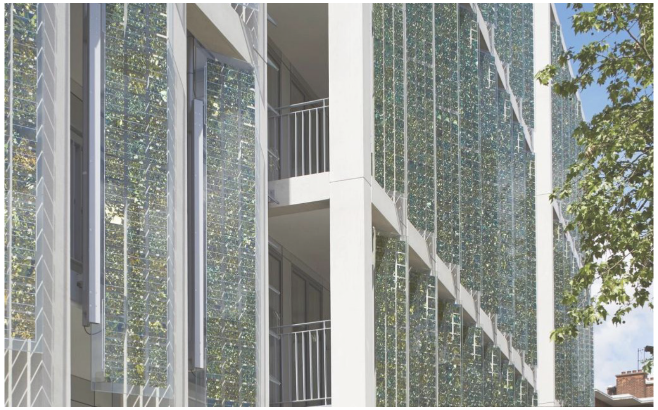




ARCHITECTURAL POSSIBILITIES

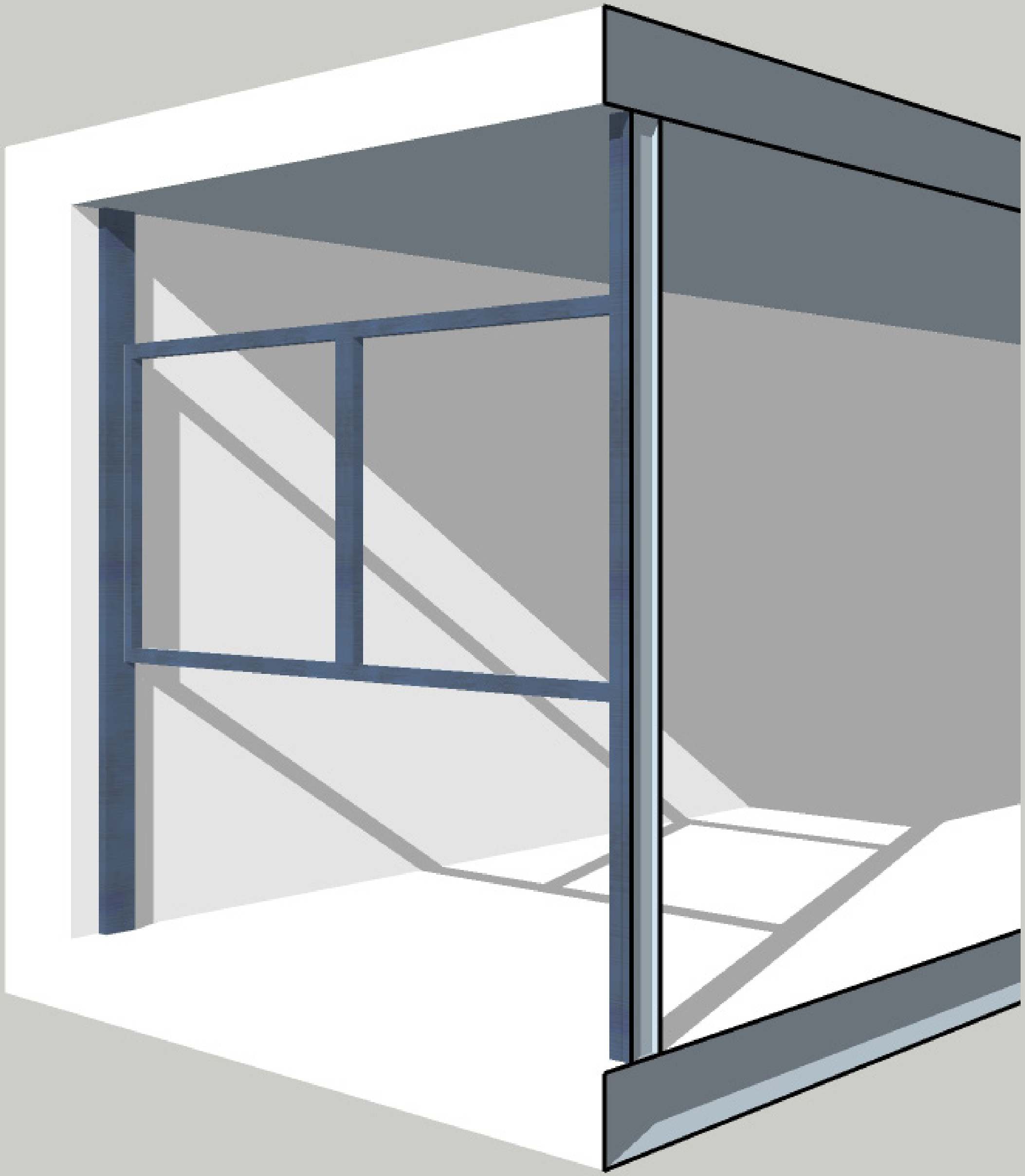
PHOTOVOLTAICS

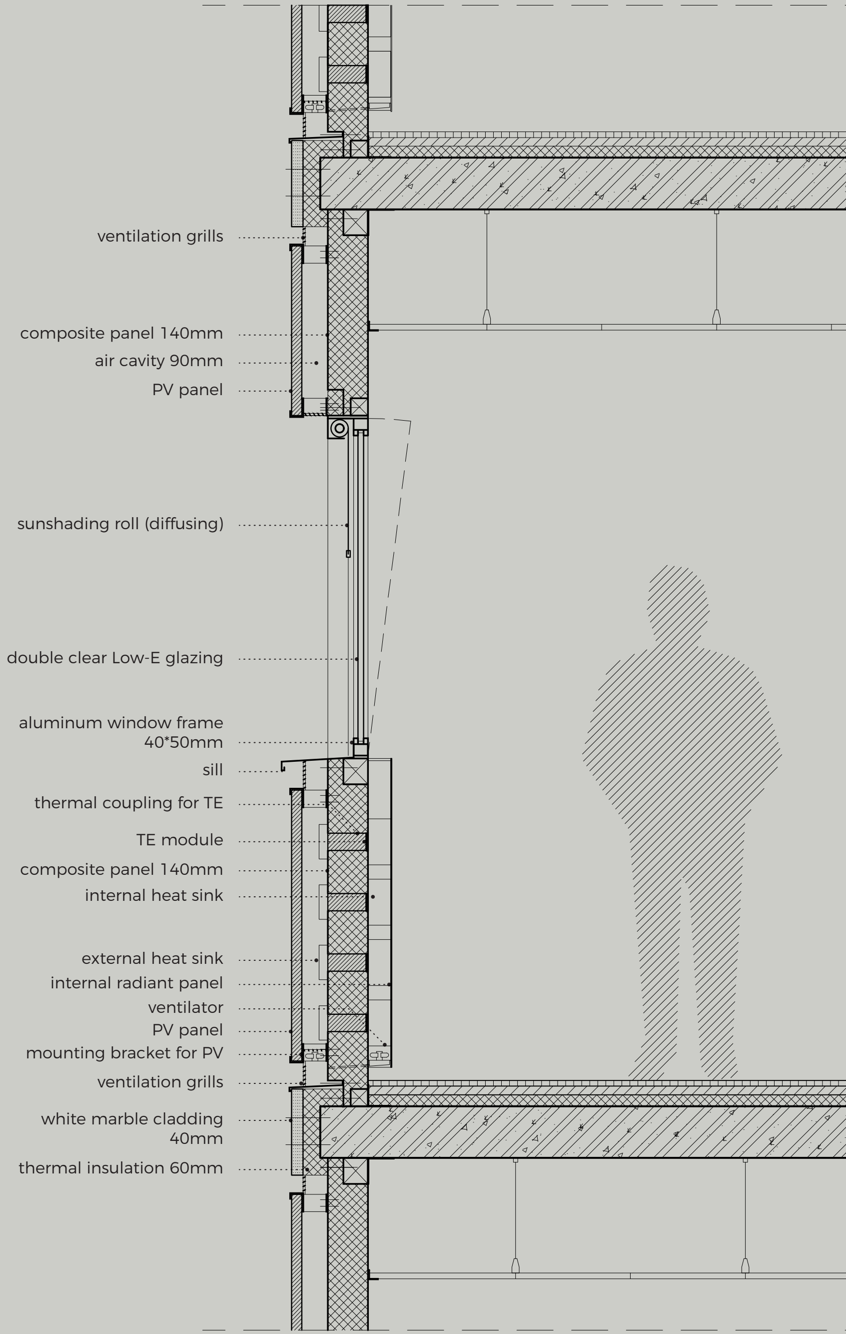




SUN-SHADING DEVICE

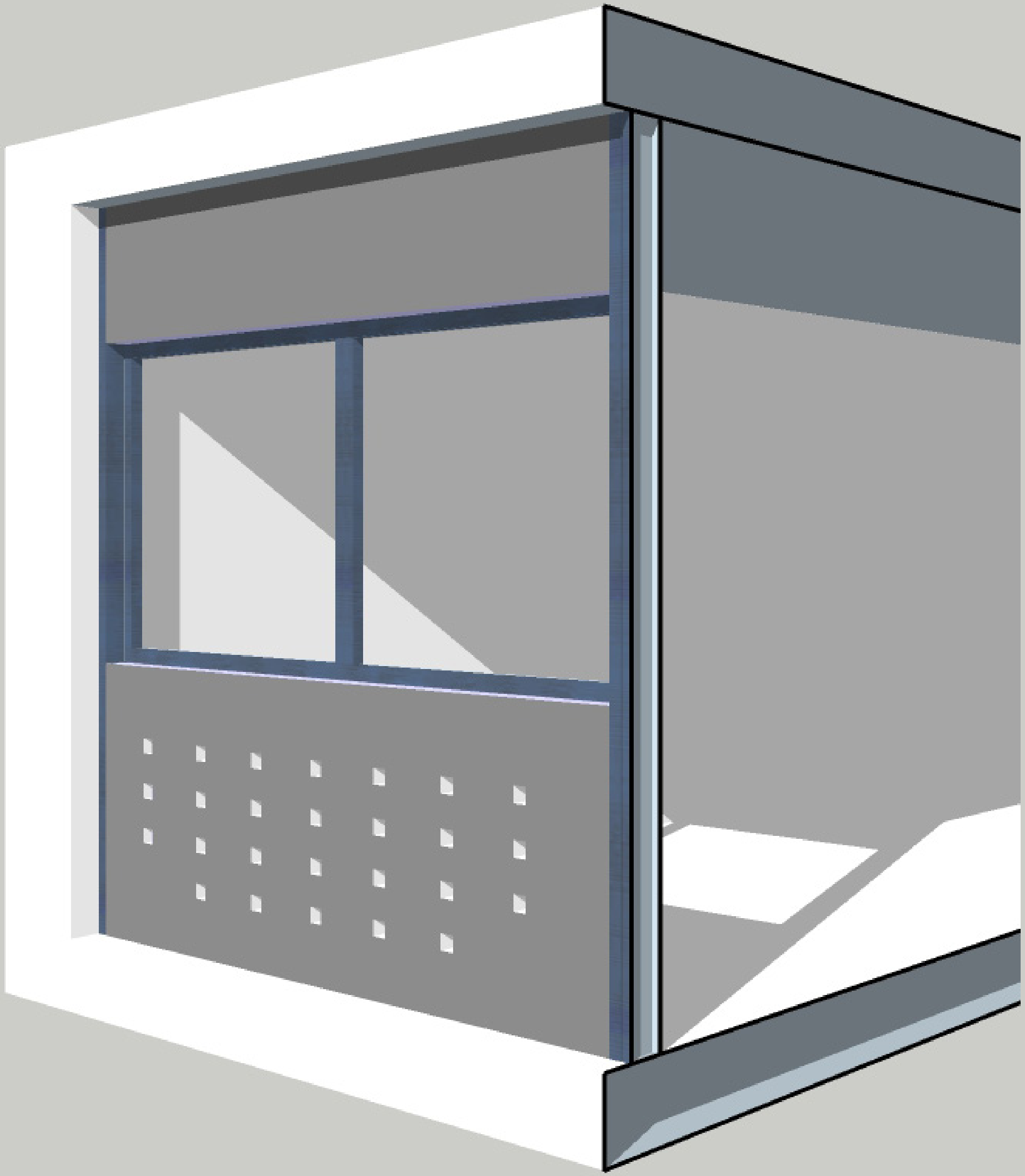
COMPONENTS & CONSTRUCTION

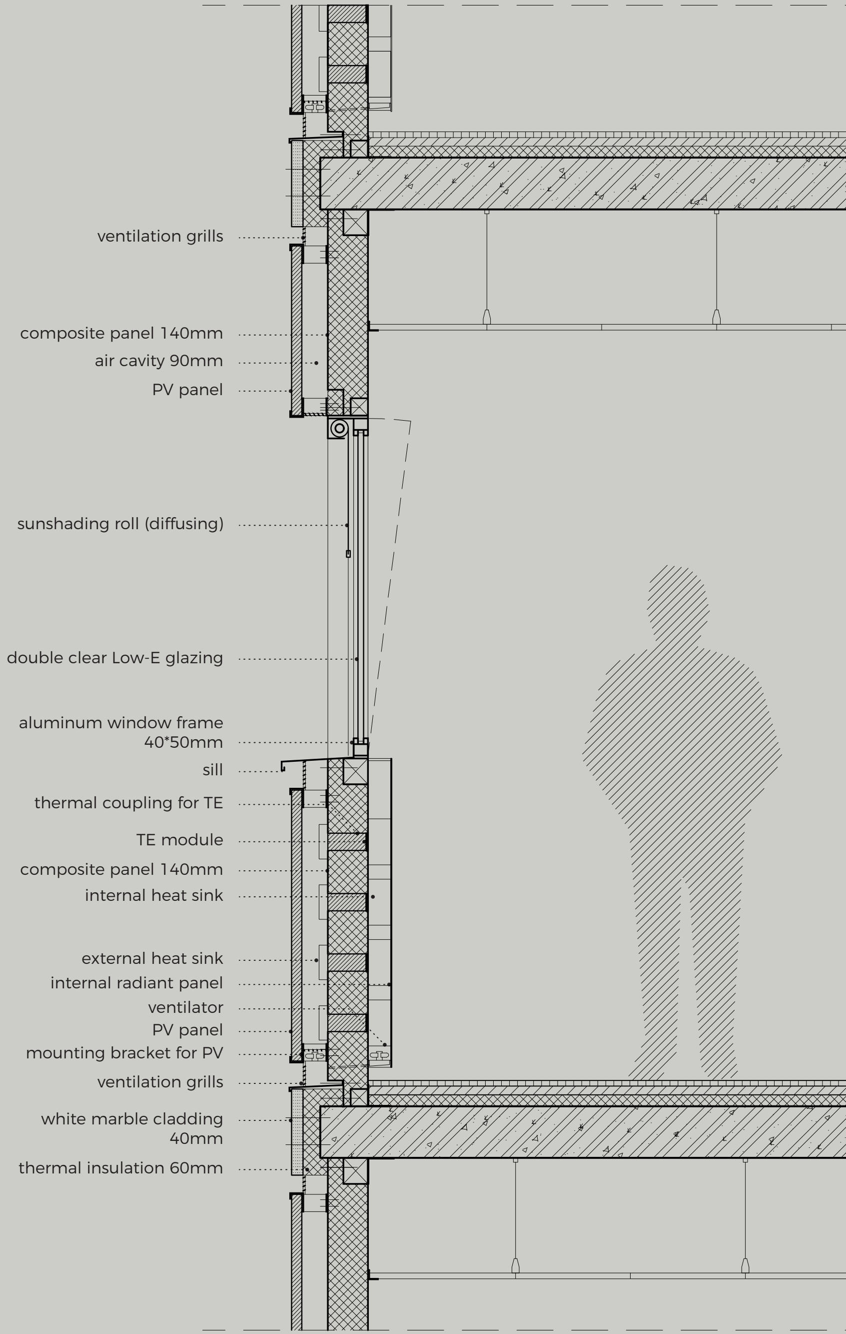




01- Frame structure

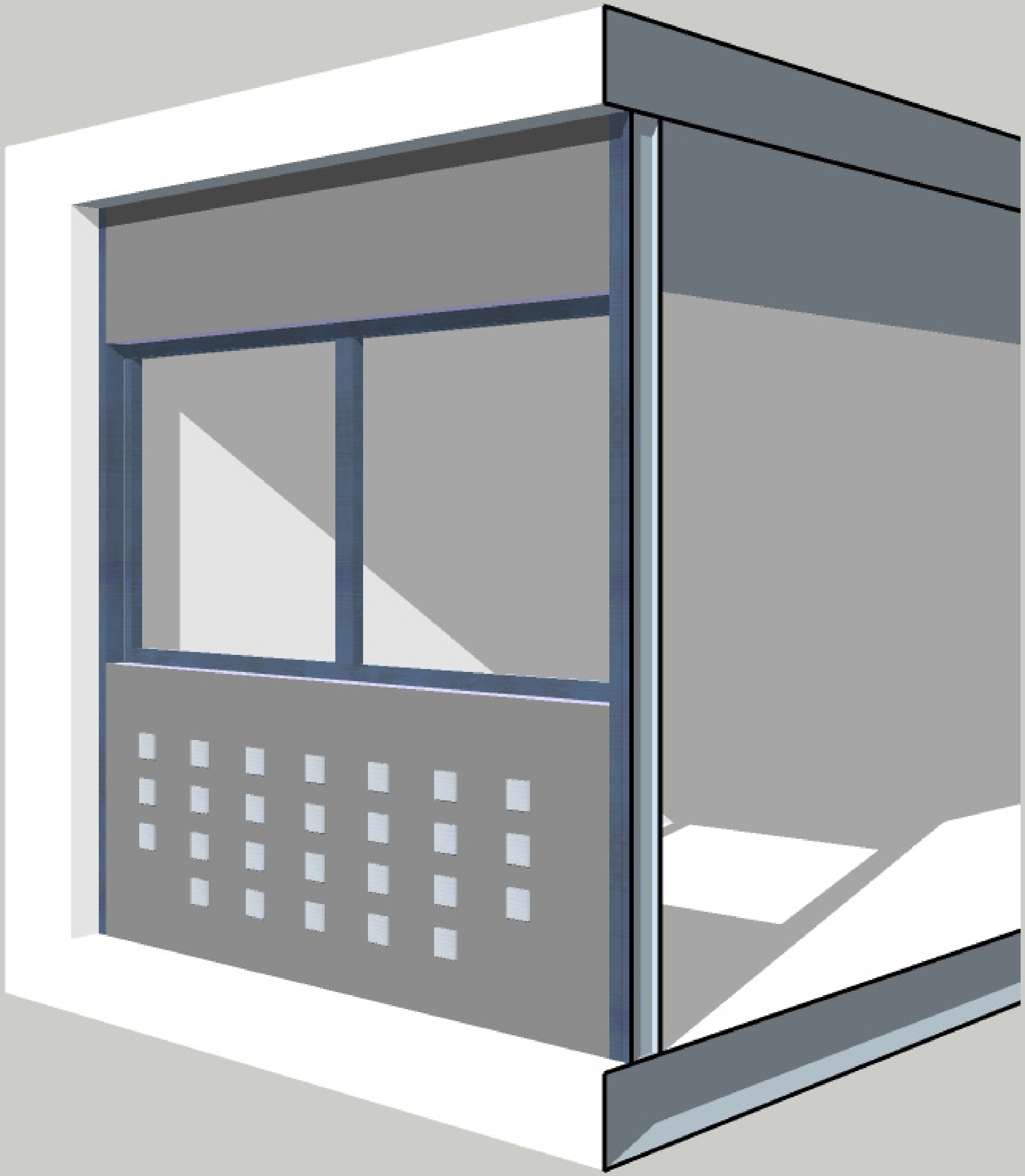
COMPONENTS & CONSTRUCTION

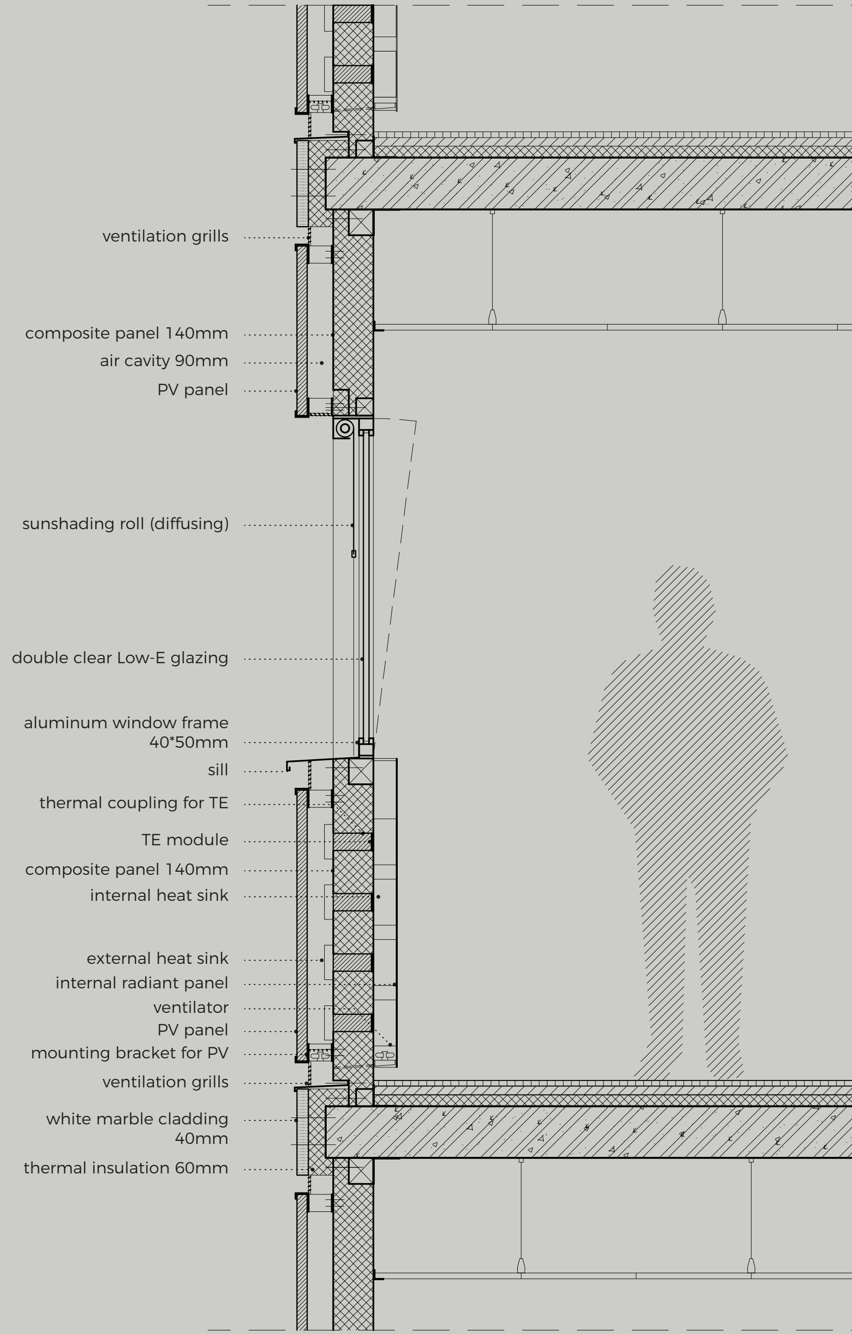




02- Composite panel perforated

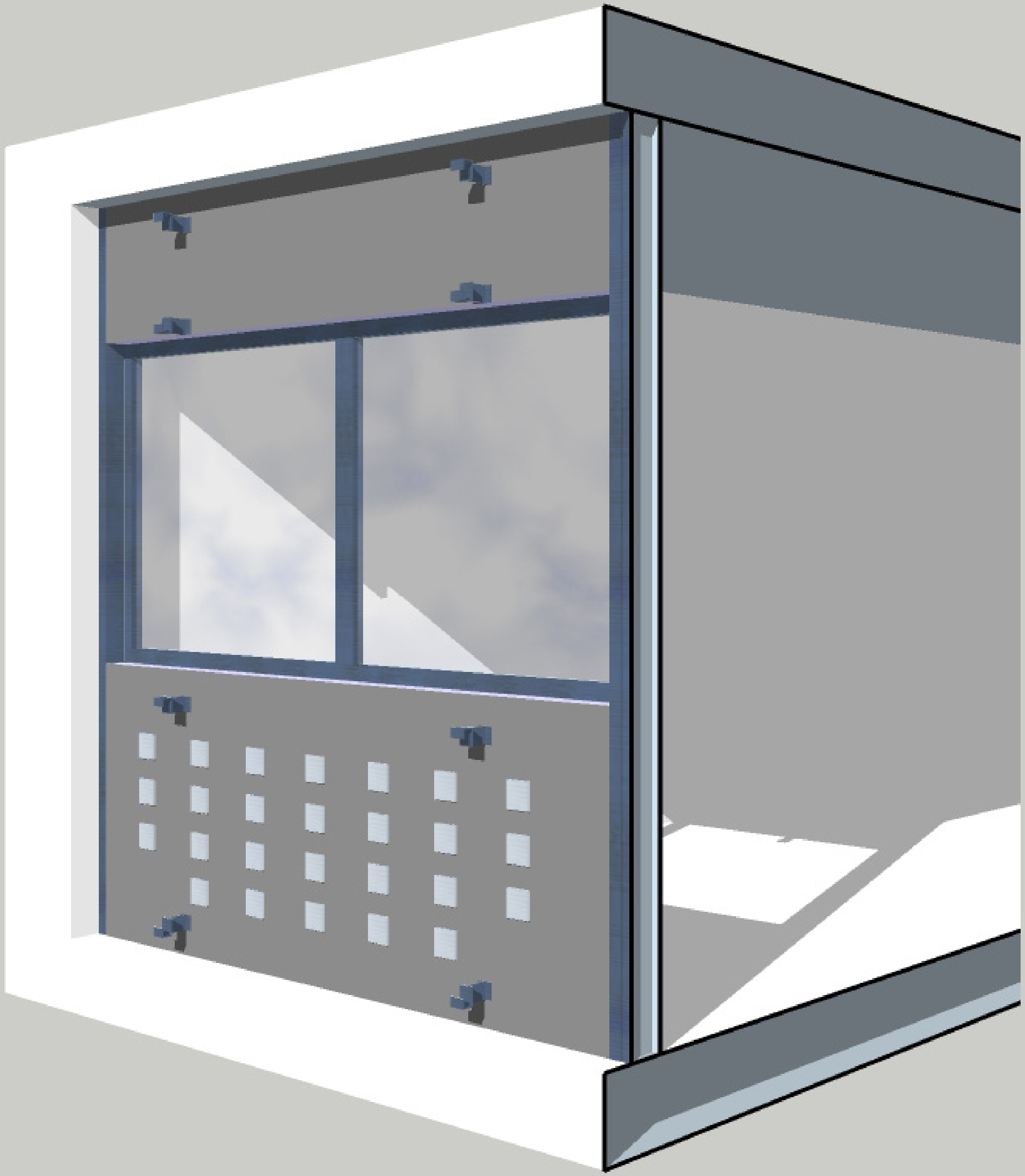
COMPONENTS & CONSTRUCTION

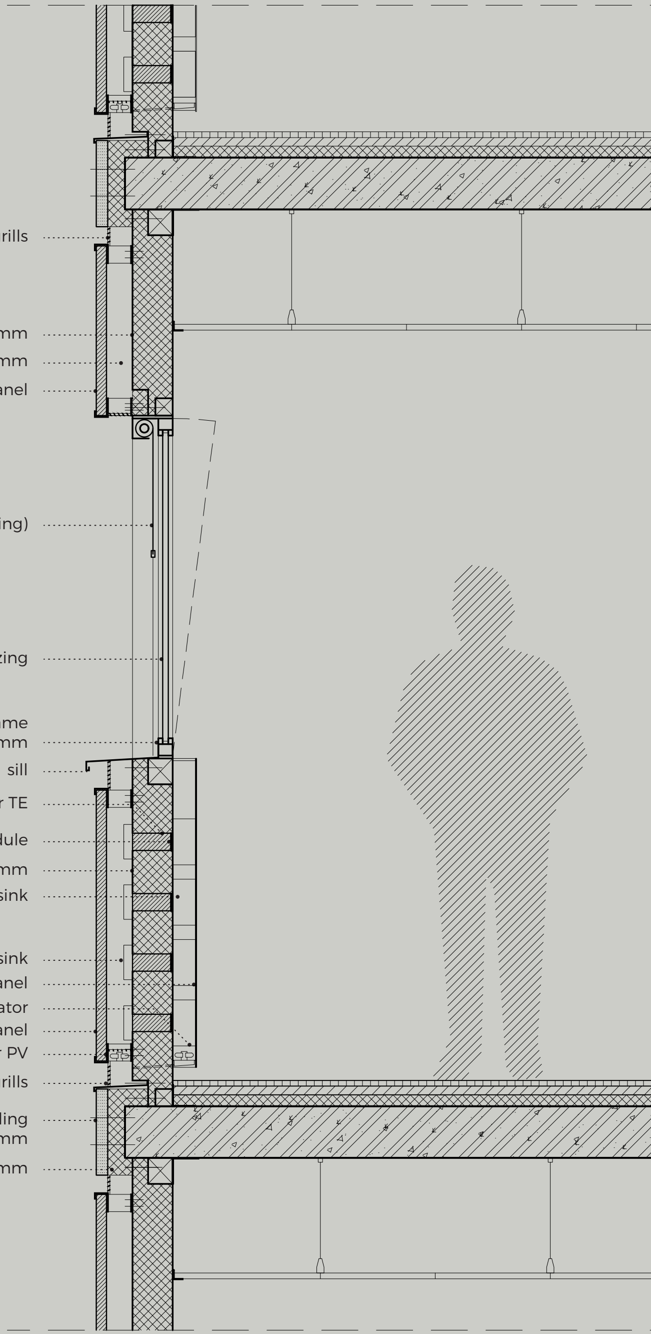




03- TEMs & heat sinks & radiant panel

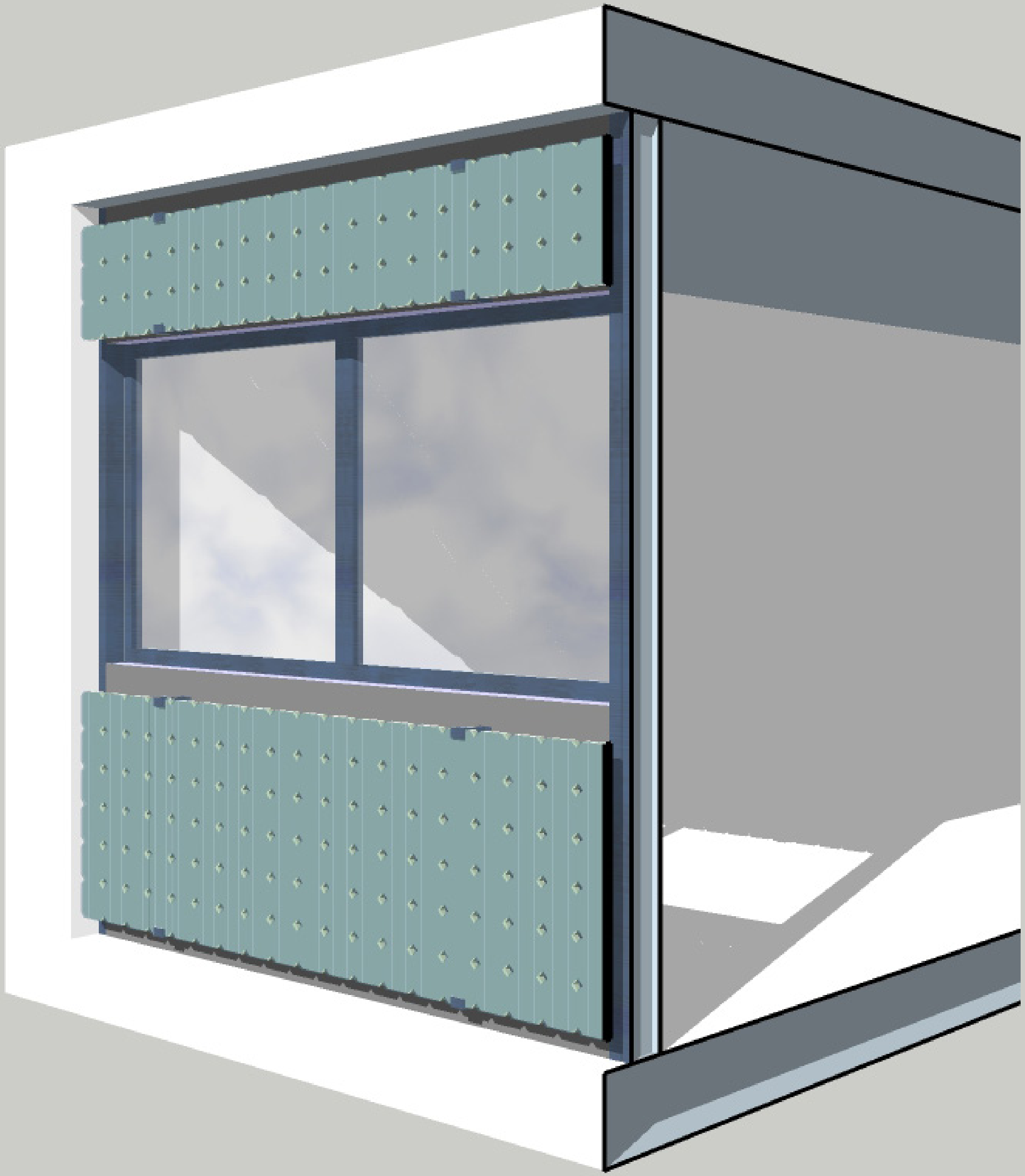
COMPONENTS & CONSTRUCTION

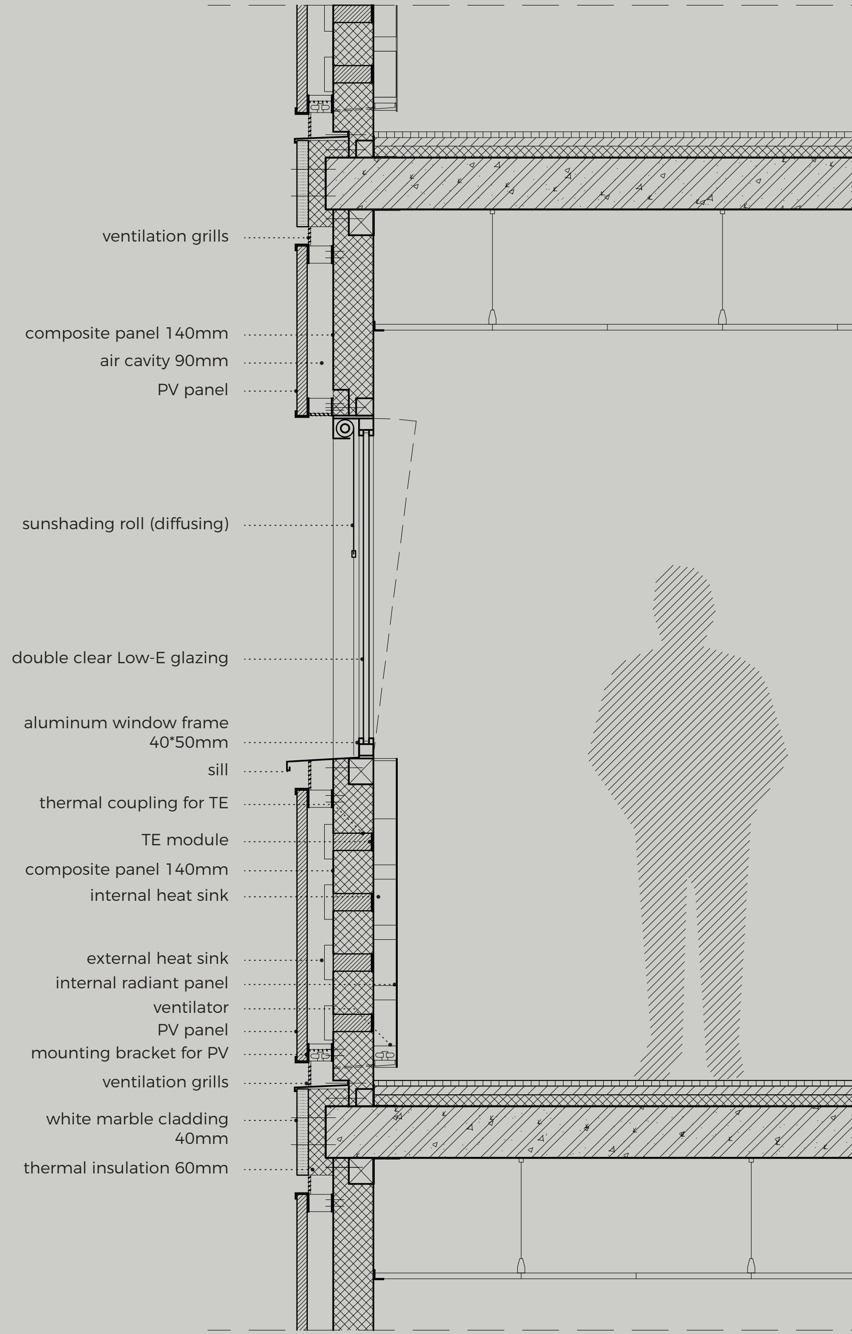




04- Mounting brackets for PVs

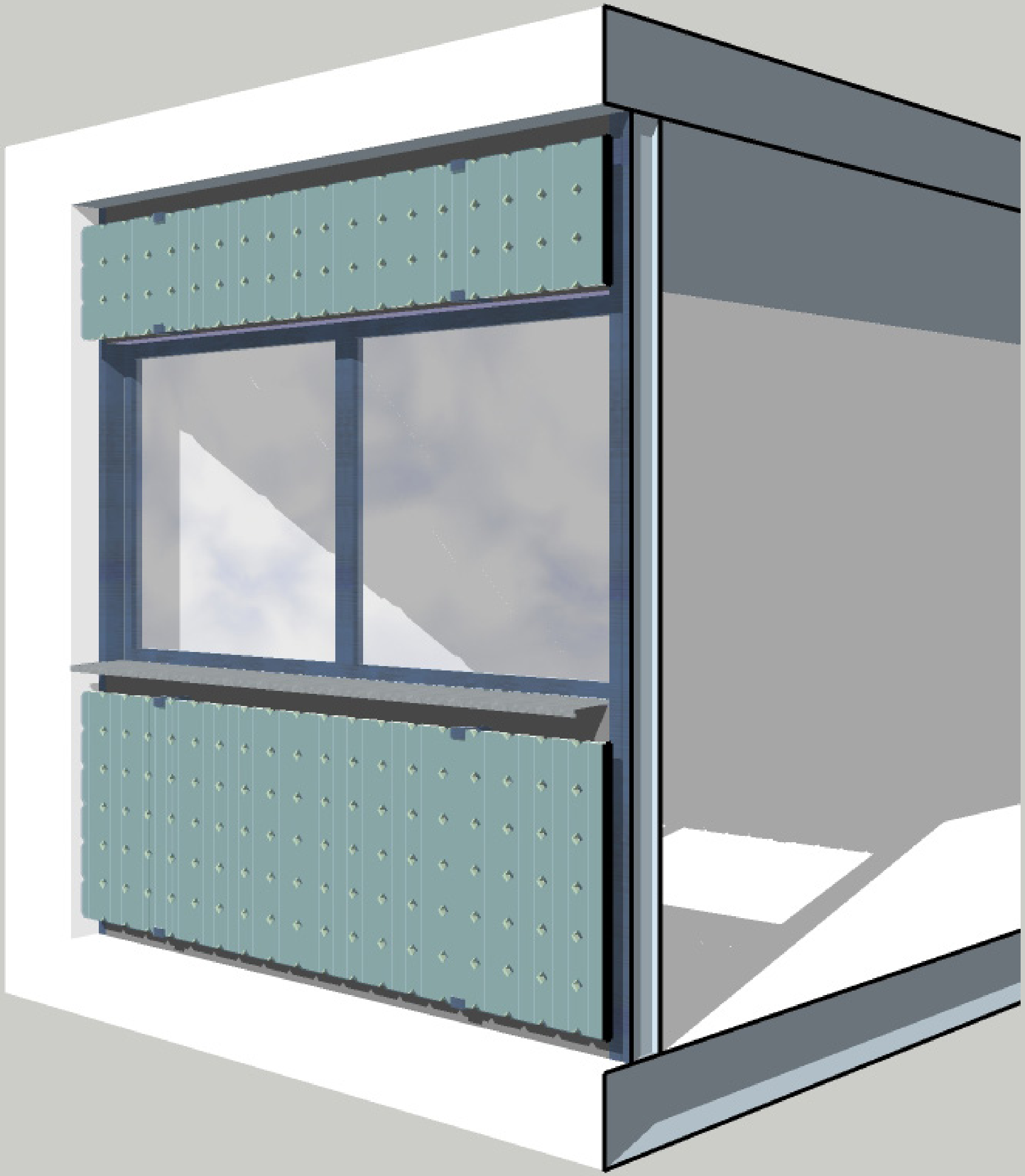
COMPONENTS & CONSTRUCTION

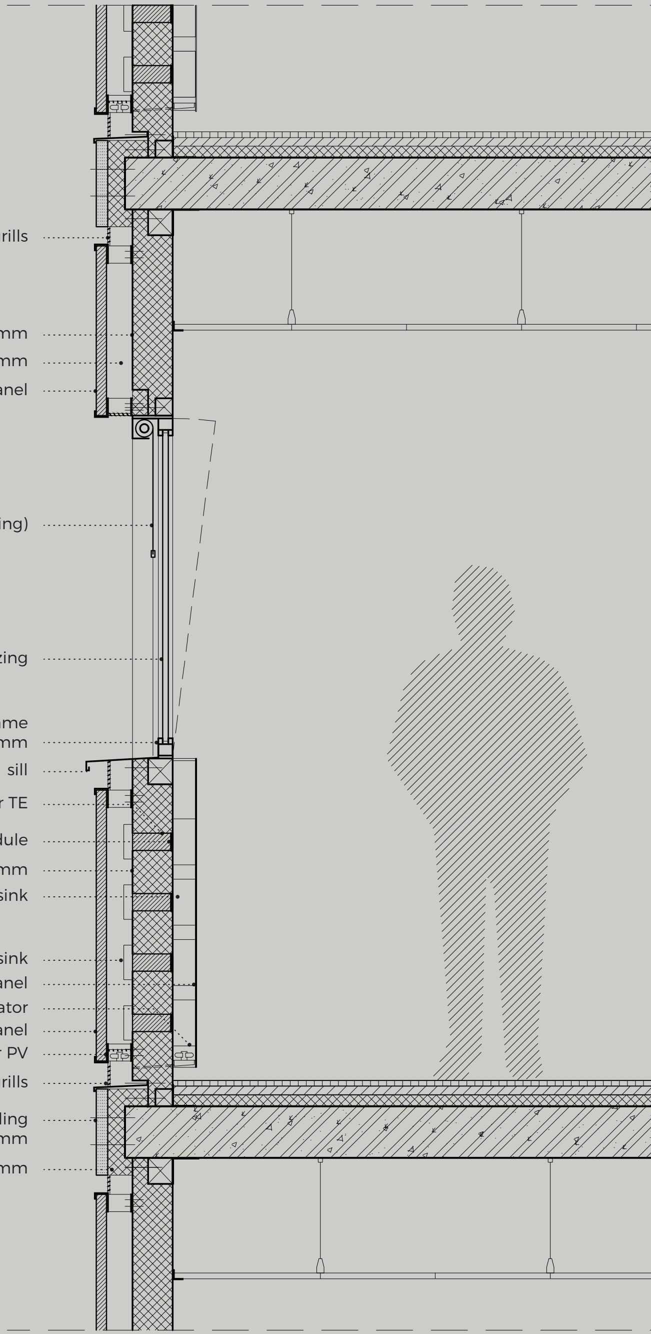




05- PV panels

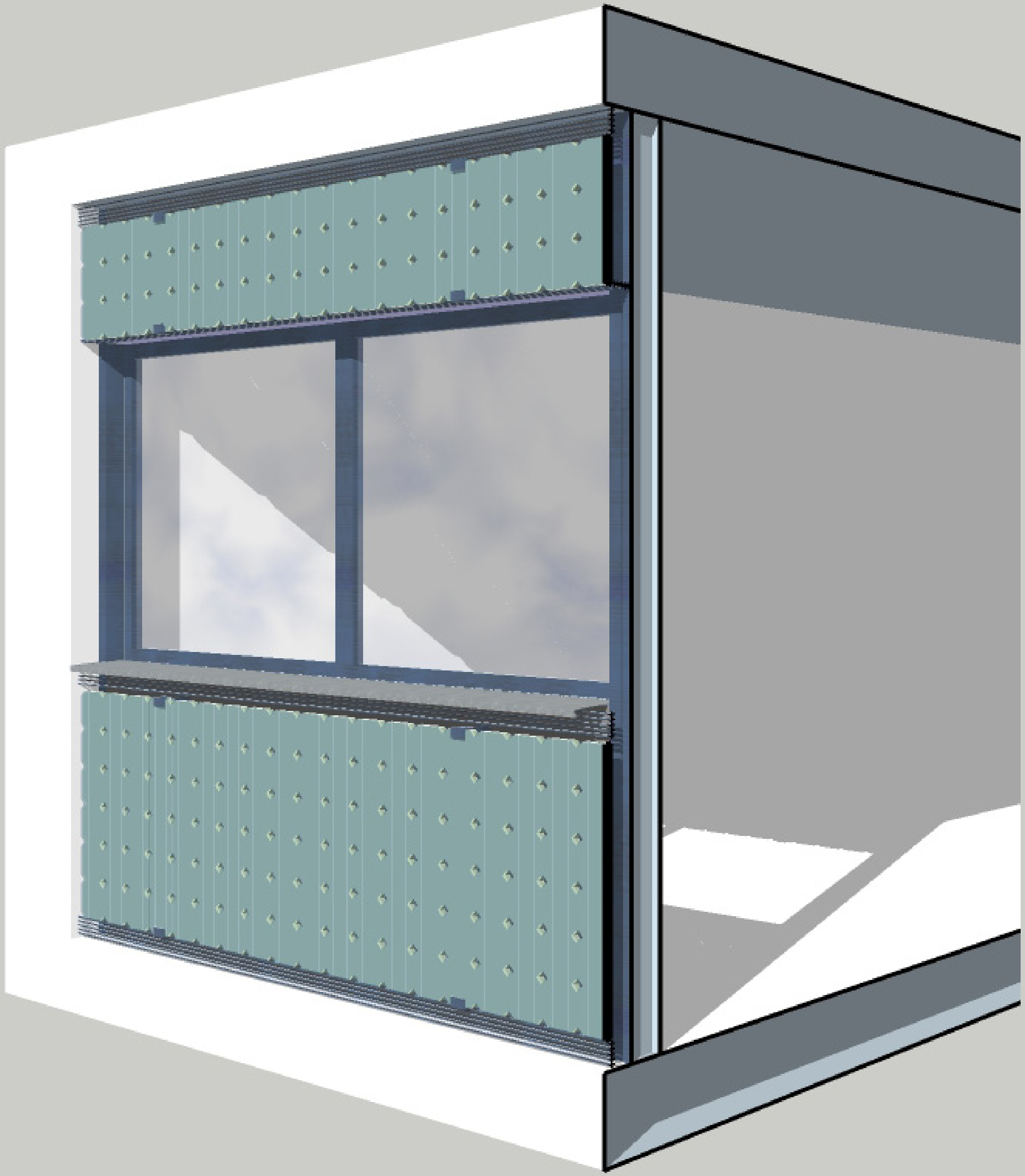
COMPONENTS & CONSTRUCTION

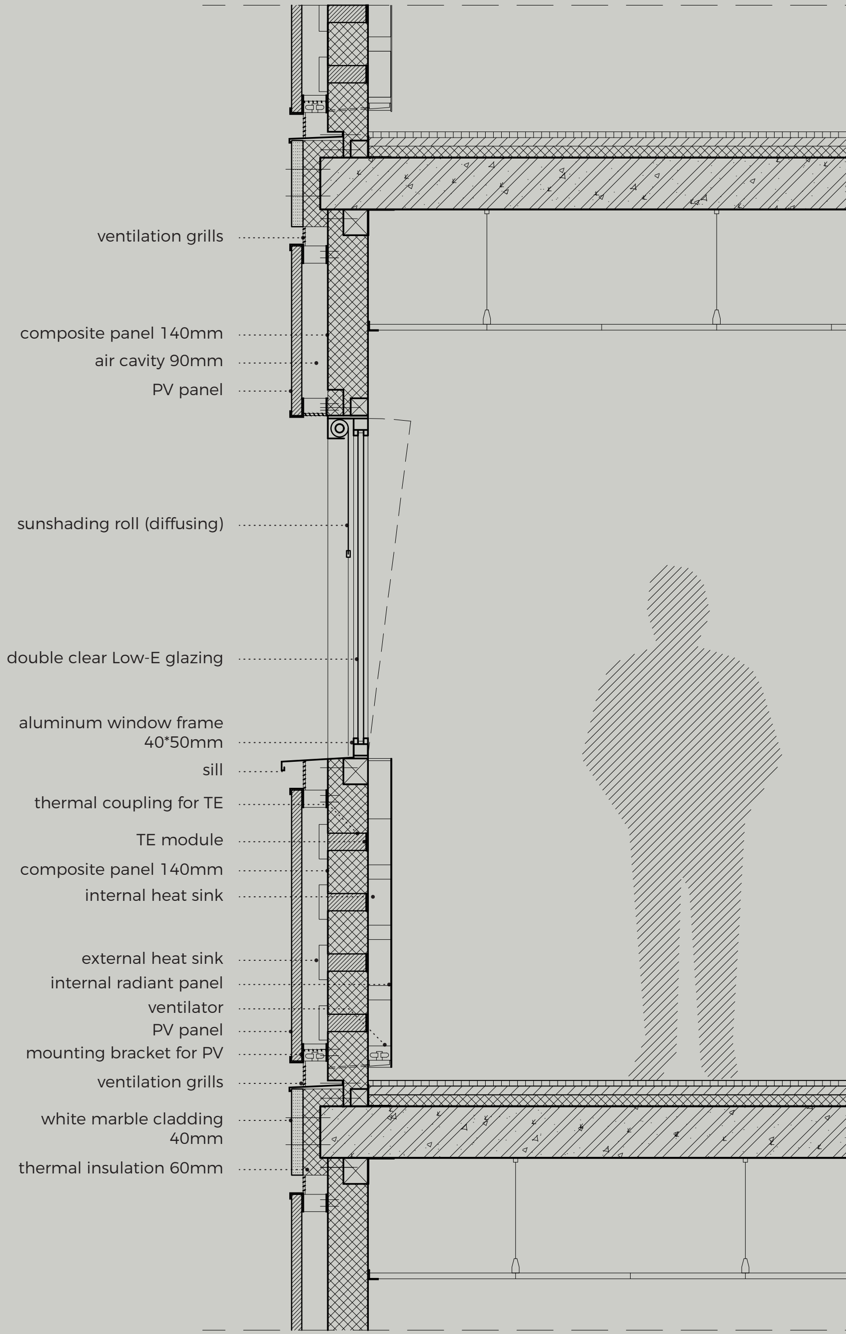




06- Window sill

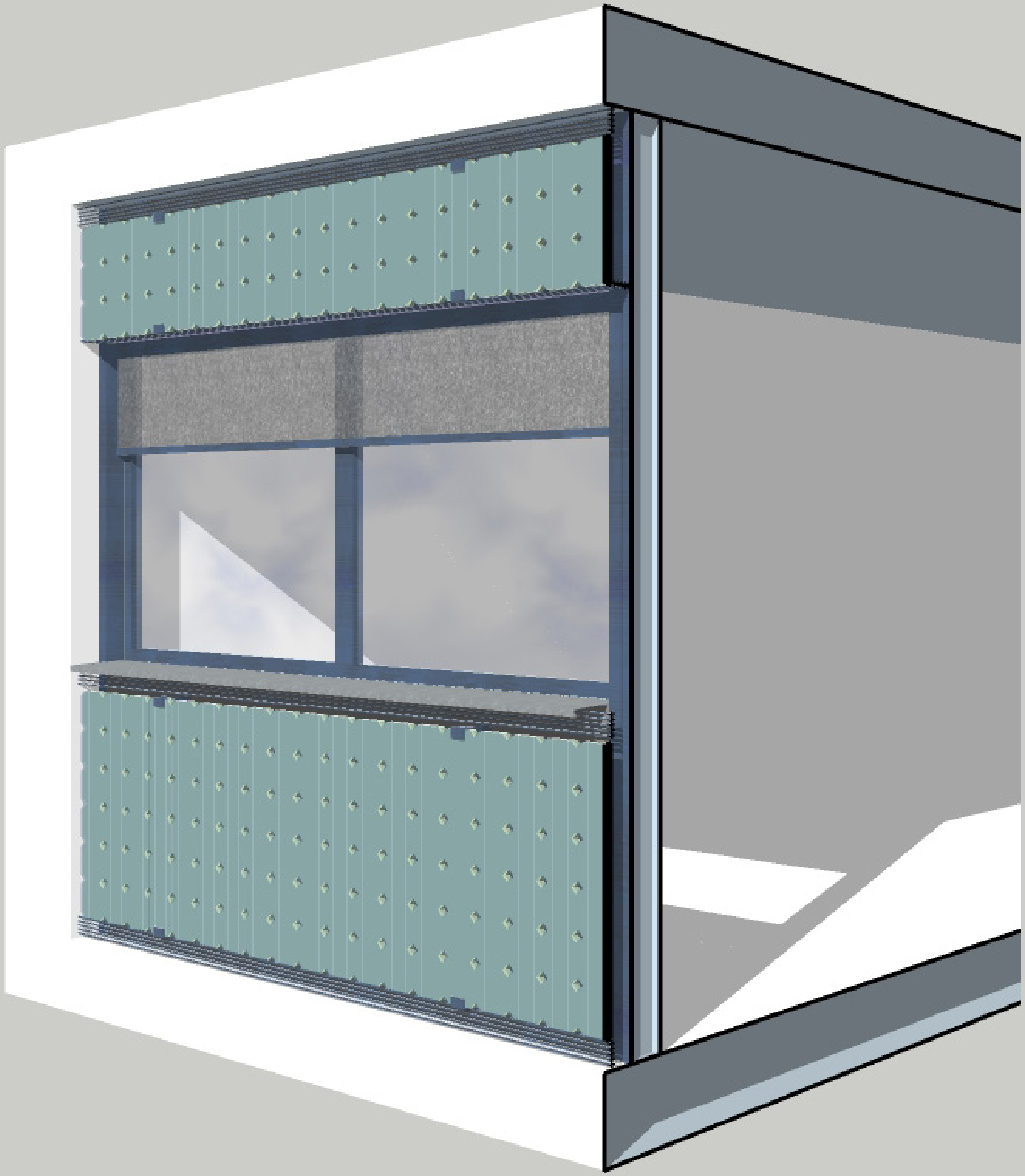
COMPONENTS & CONSTRUCTION

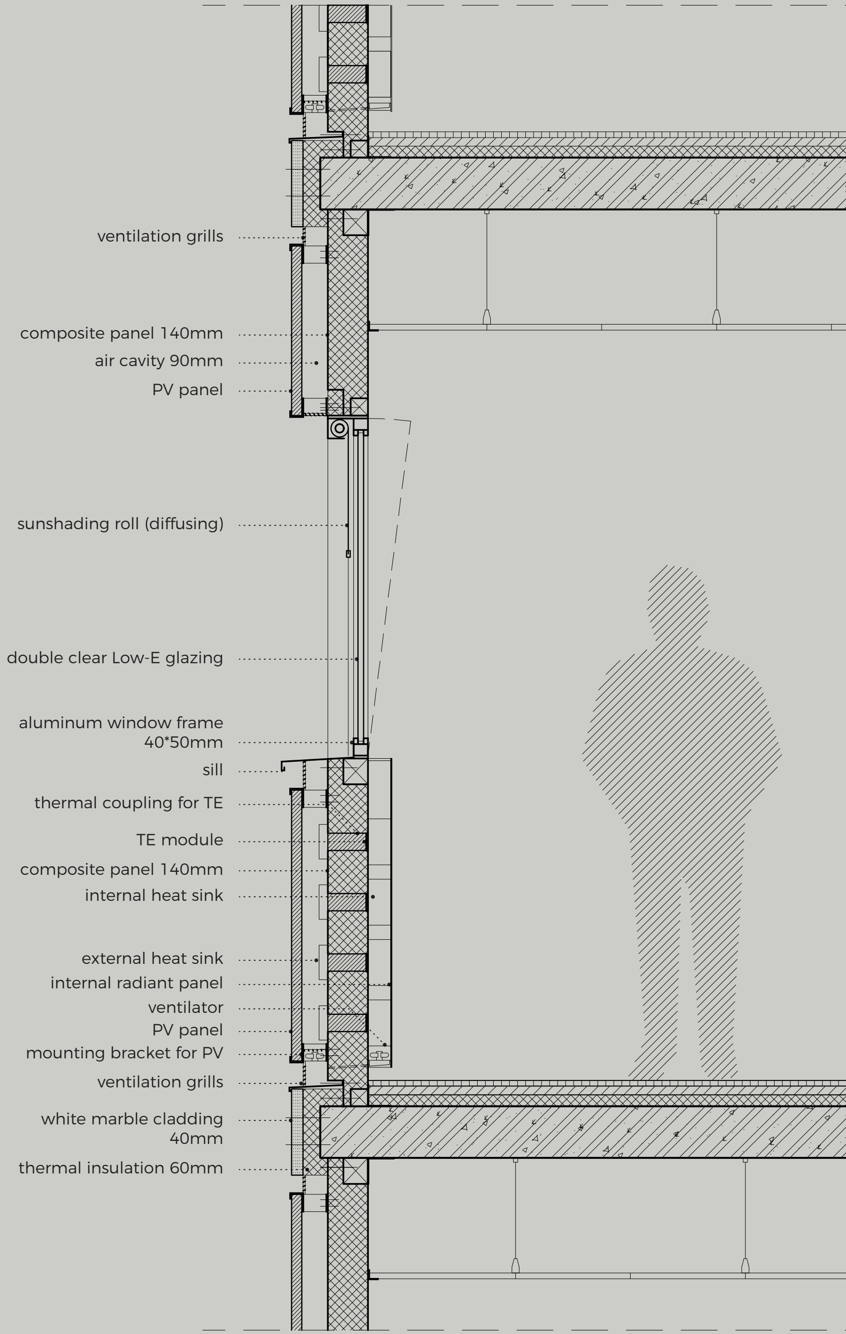




07- Ventilation grills

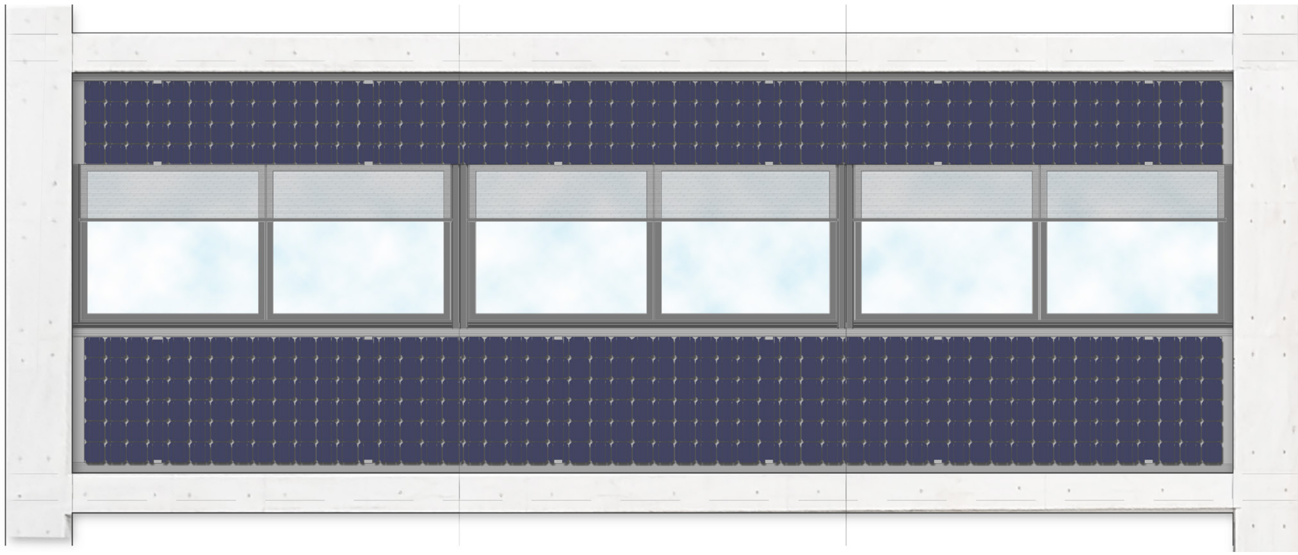
COMPONENTS & CONSTRUCTION





08- Sunshading roll

OLD & NEW



STREET VIEW

INTERIORS

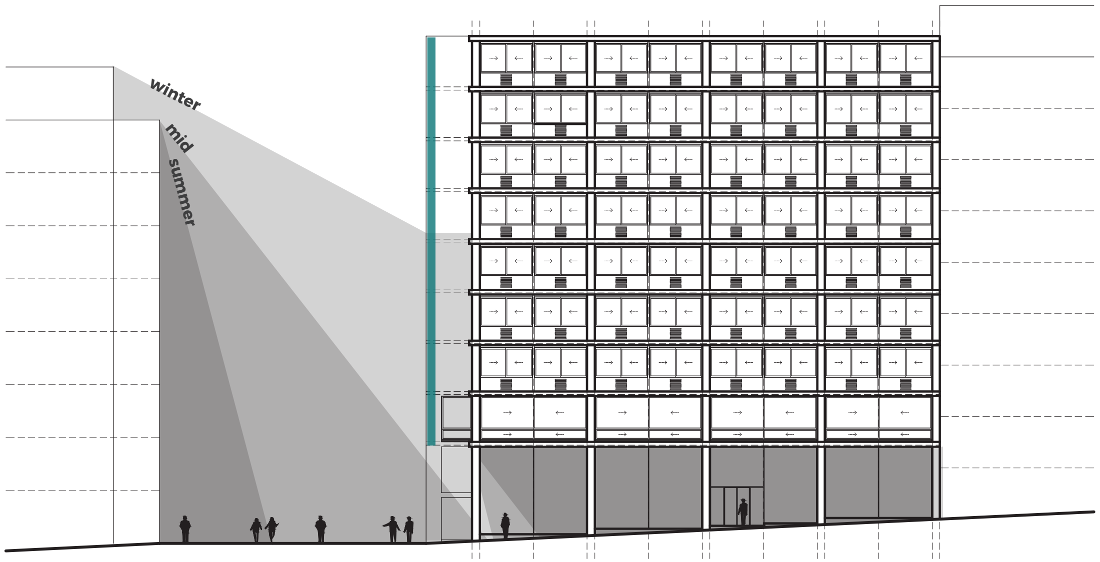
CONCLUSIONS

OVERALL ASSESSMENT - EVALUATION OF RESULT

INNOVATION
- **Thermoelectric application on HVAC**

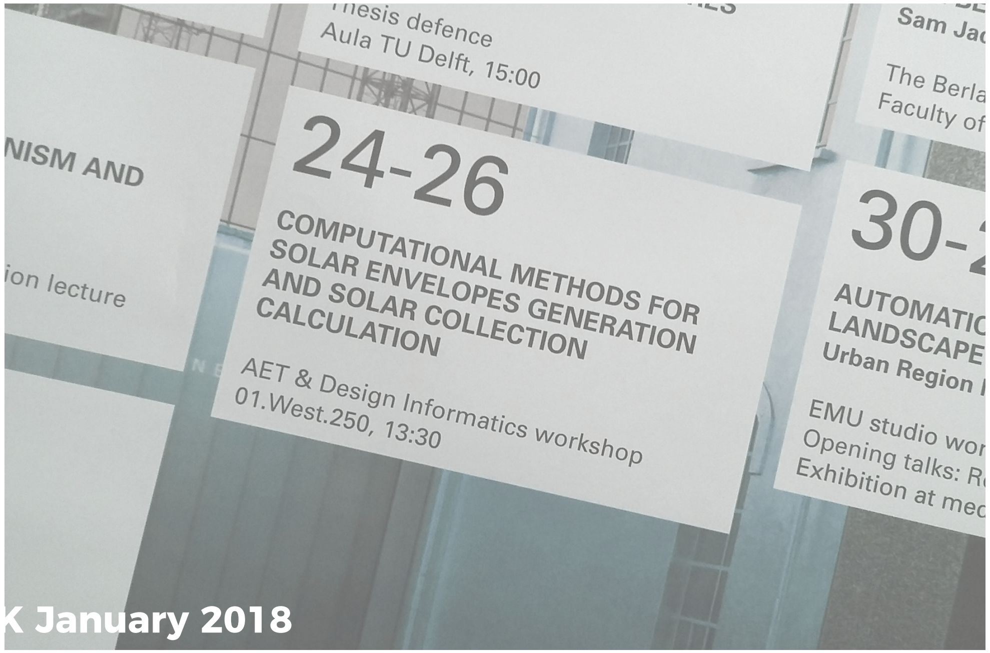
PERFORMANCE
- **Coverage 40% of peak demand in summer design day (with current state of the art)**

WEAKNESSES
- **System dependent on solar incidence > limited performance on cloudy days, particular hours/day**
- **System itself is not sufficient to cover the peak cooling demand > powered from grid**
- **Very low temperature on cold plate of TE > condensation occurs > ventilation and drainage**



OVERALL ASSESSMENT - EVALUATION OF METHOD

- Calculations for system sizing > complex (multiple factors)
- Method for solar collection calculations > computational / parametric




THANK YOU!