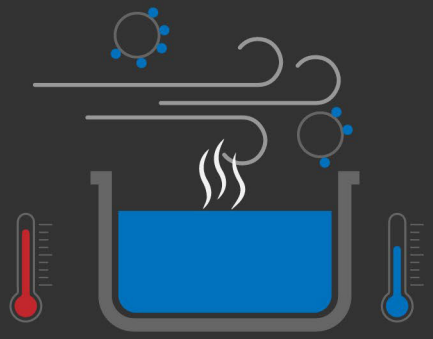


de-VAP

Decentralized Desiccant Enhanced Evaporative cooling integrated facade

PRETHVI RAJ // 4738659

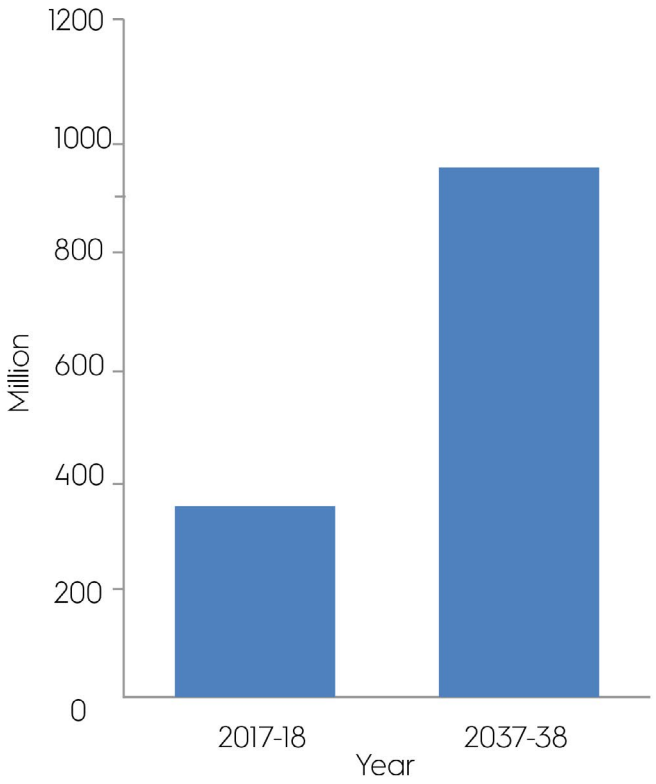
Sustainable Design Graduation Studio

1st Mentor Façade Design : Dr. Alejandro Prieto

2nd Mentor Climate Design : Dr. WH Van der spoel

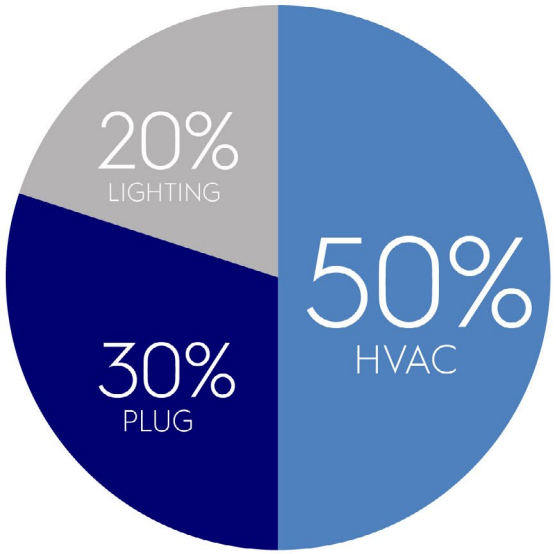
July 2019

Decentralized Desiccant Enhanced Evaporative Cooling Integrated Facade



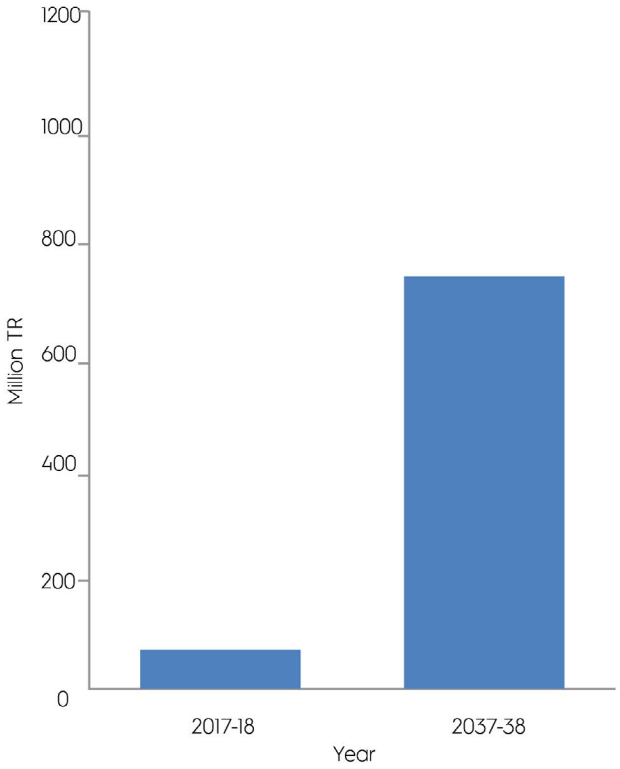
2/3rd

Office stock is yet to be built in India



50%

Energy consumption in
Indian Offices is HVAC

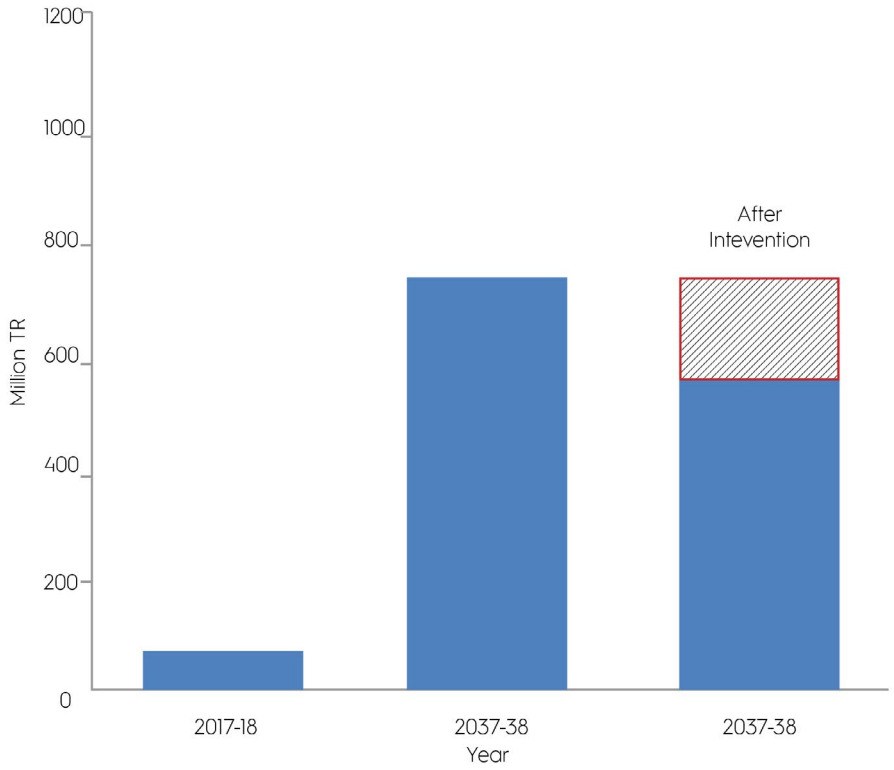


8x

Space Cooling
Demand in India

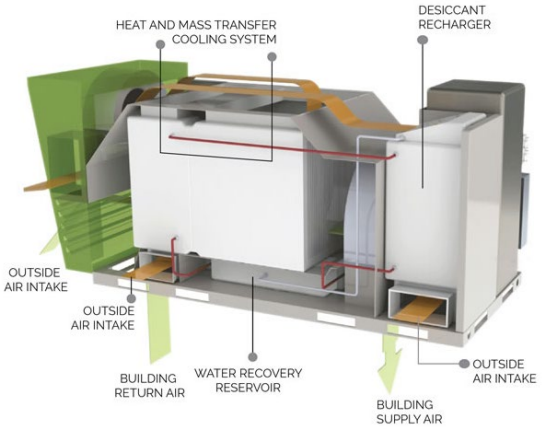
3x

Electricity consumption
of the national figure
of 90 kWh

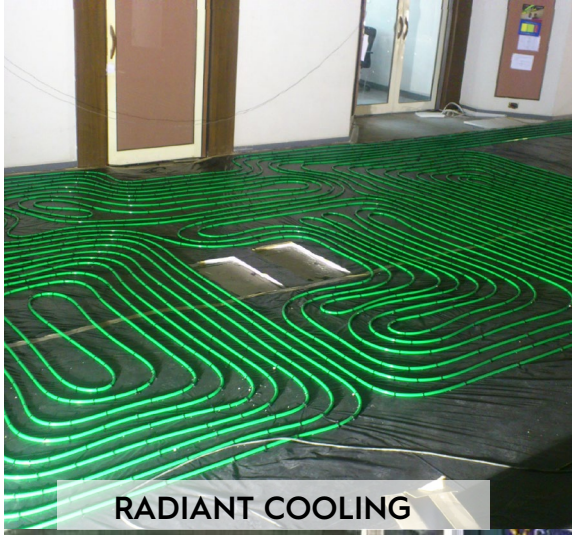


25%

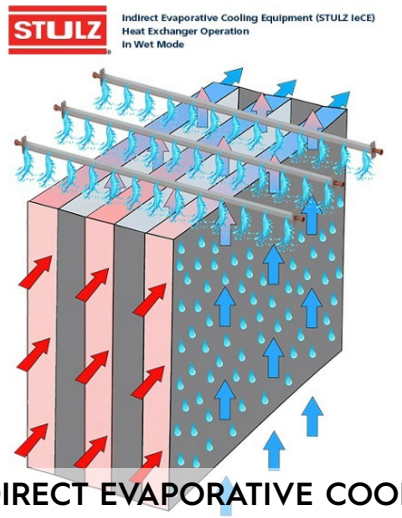
Reduction of
Cooling Demand after
Intervention by Indian
Govt.



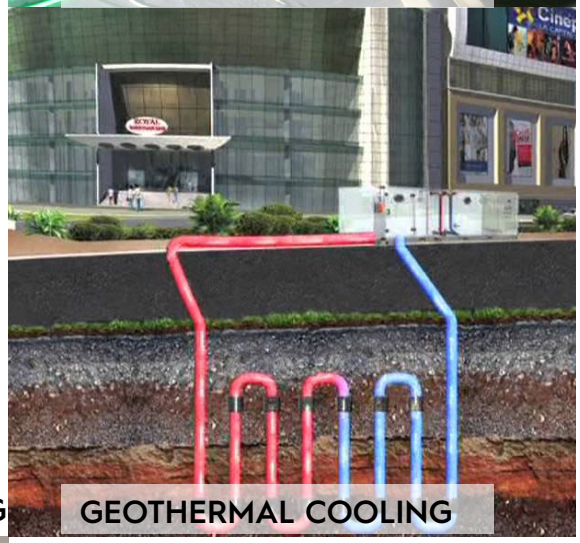
DESICCANT COOLING



RADIANT COOLING

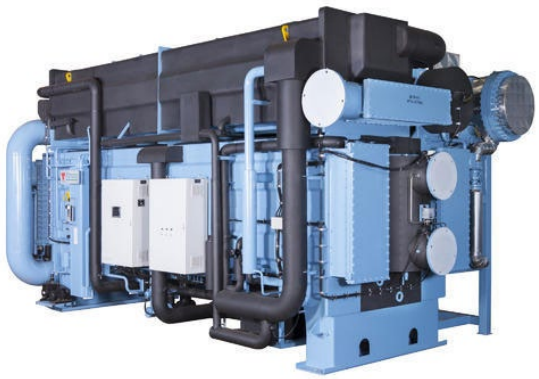


INDIRECT EVAPORATIVE COOLING



GEOTHERMAL COOLING

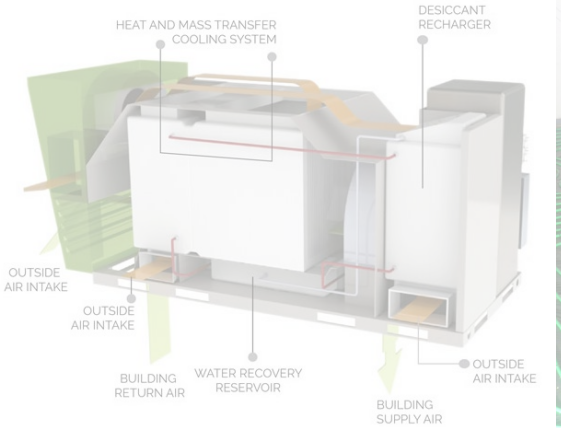
STRUCTURE COOLING



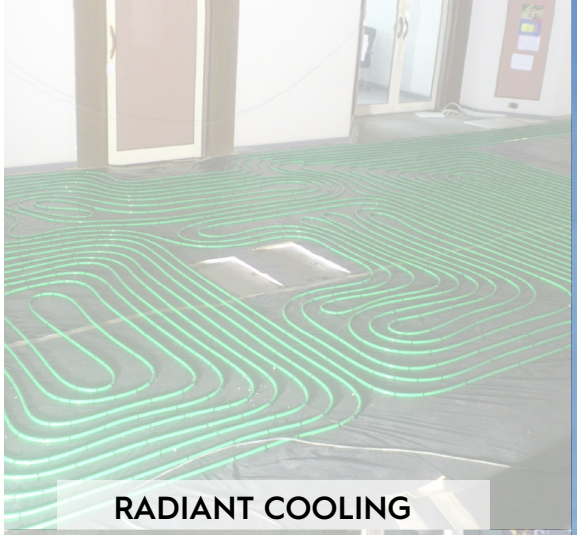
VAPOUR ABSORPTION

Not in Kind

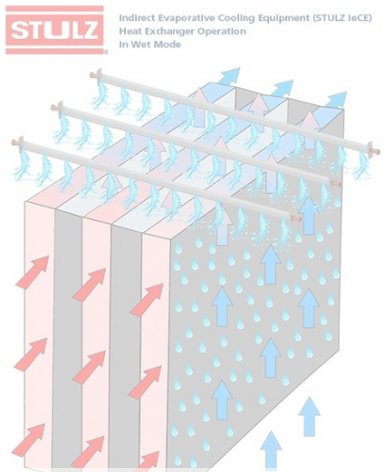
Cooling Upcoming Technologies - Low Energy Consumption - Cooling Systems



DESICCANT COOLING



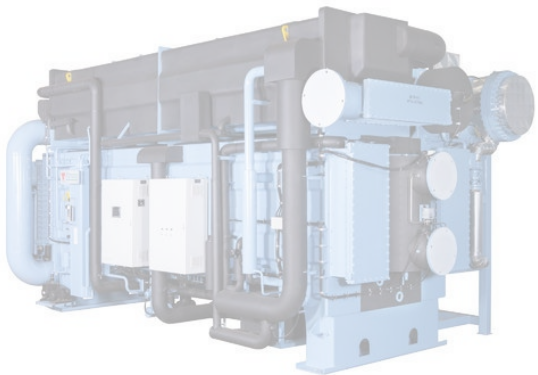
RADIANT COOLING



INDIRECT EVAPORATIVE COOLING

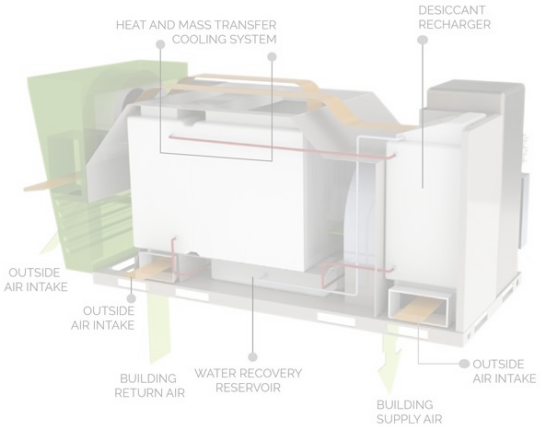
GEOTHERMAL COOLING

STRUCTURE COOLING

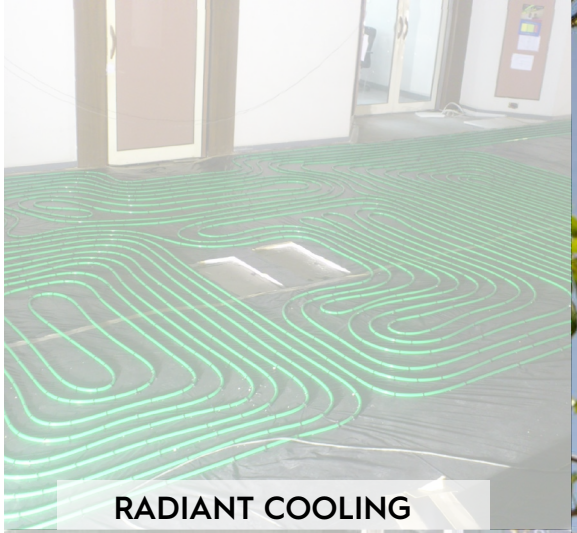


VAPOUR ABSORPTION

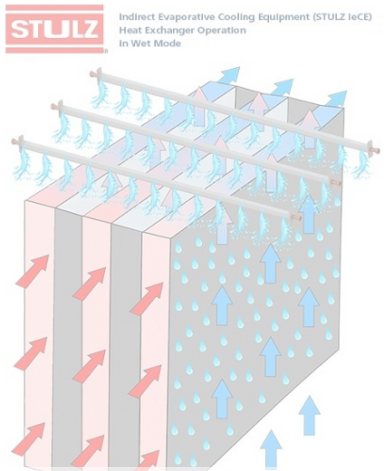
HOSPITAL GENERAL DR. MANUEL GEA GONZÁLEZ, MEXICO



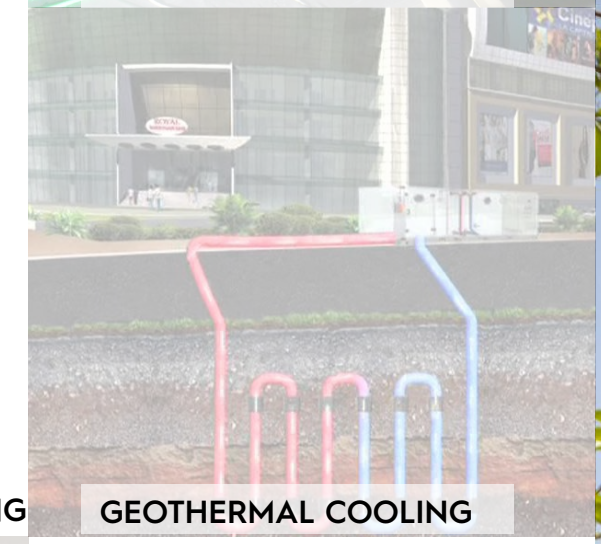
DESICCANT COOLING



RADIANT COOLING

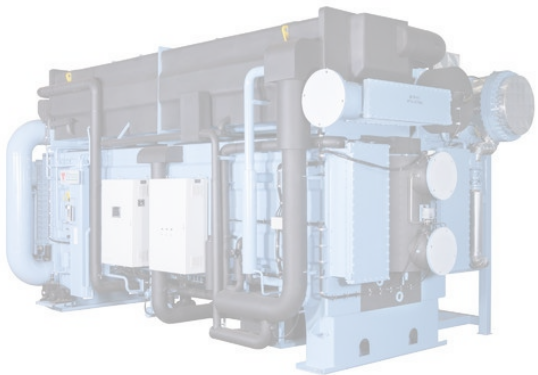


INDIRECT EVAPORATIVE COOLING



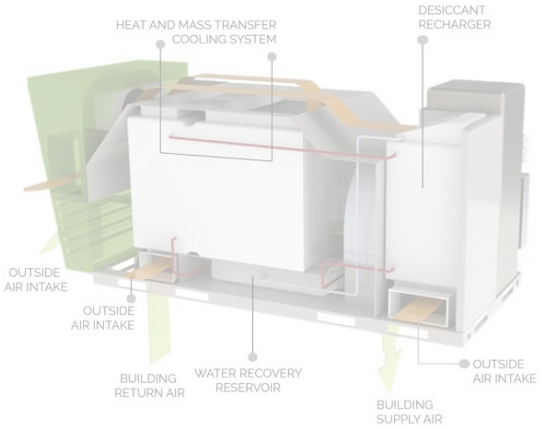
GEOTHERMAL COOLING

STRUCTURE COOLING

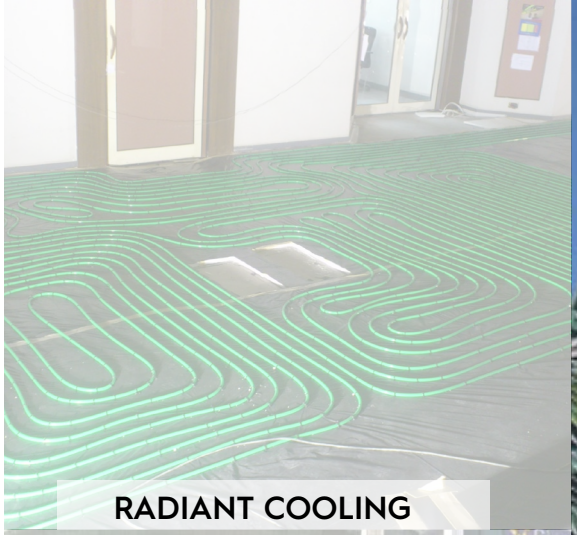


VAPOUR ABSORPTION

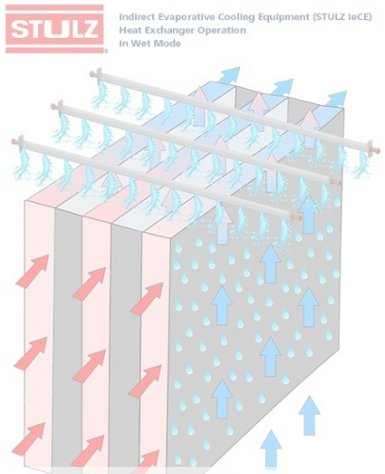
AL BAHR TOWERS, ABU DHABI



DESICCANT COOLING



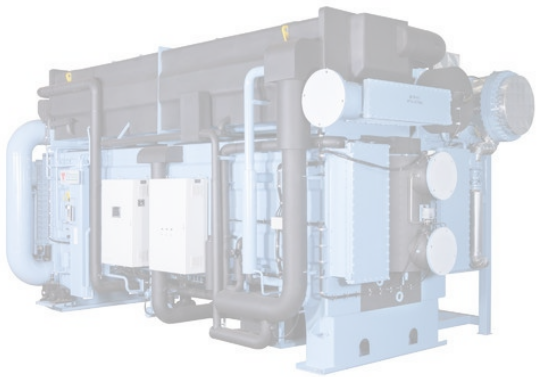
RADIANT COOLING



INDIRECT EVAPORATIVE COOLING

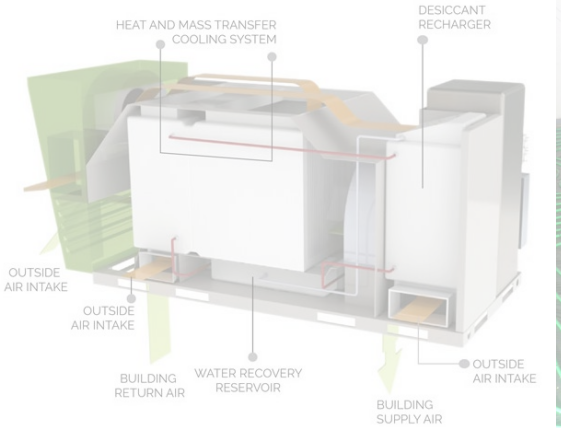
GEOTHERMAL COOLING

STRUCTURE COOLING

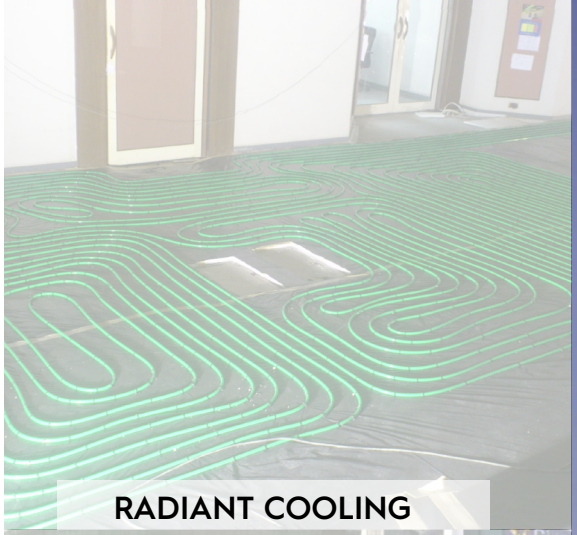


VAPOUR ABSORPTION

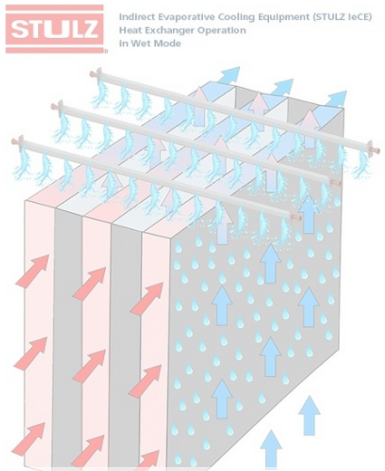
EAT ME WALL



DESICCANT COOLING



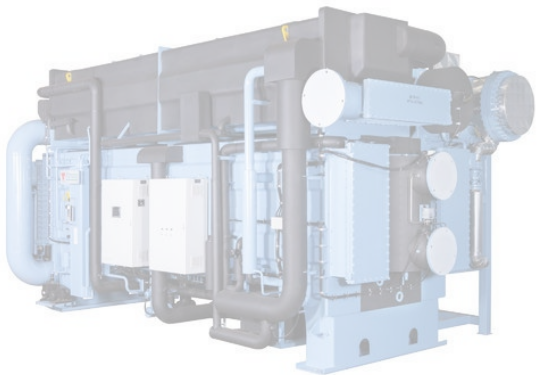
RADIANT COOLING



INDIRECT EVAPORATIVE COOLING

GEOTHERMAL COOLING

STRUCTURE COOLING

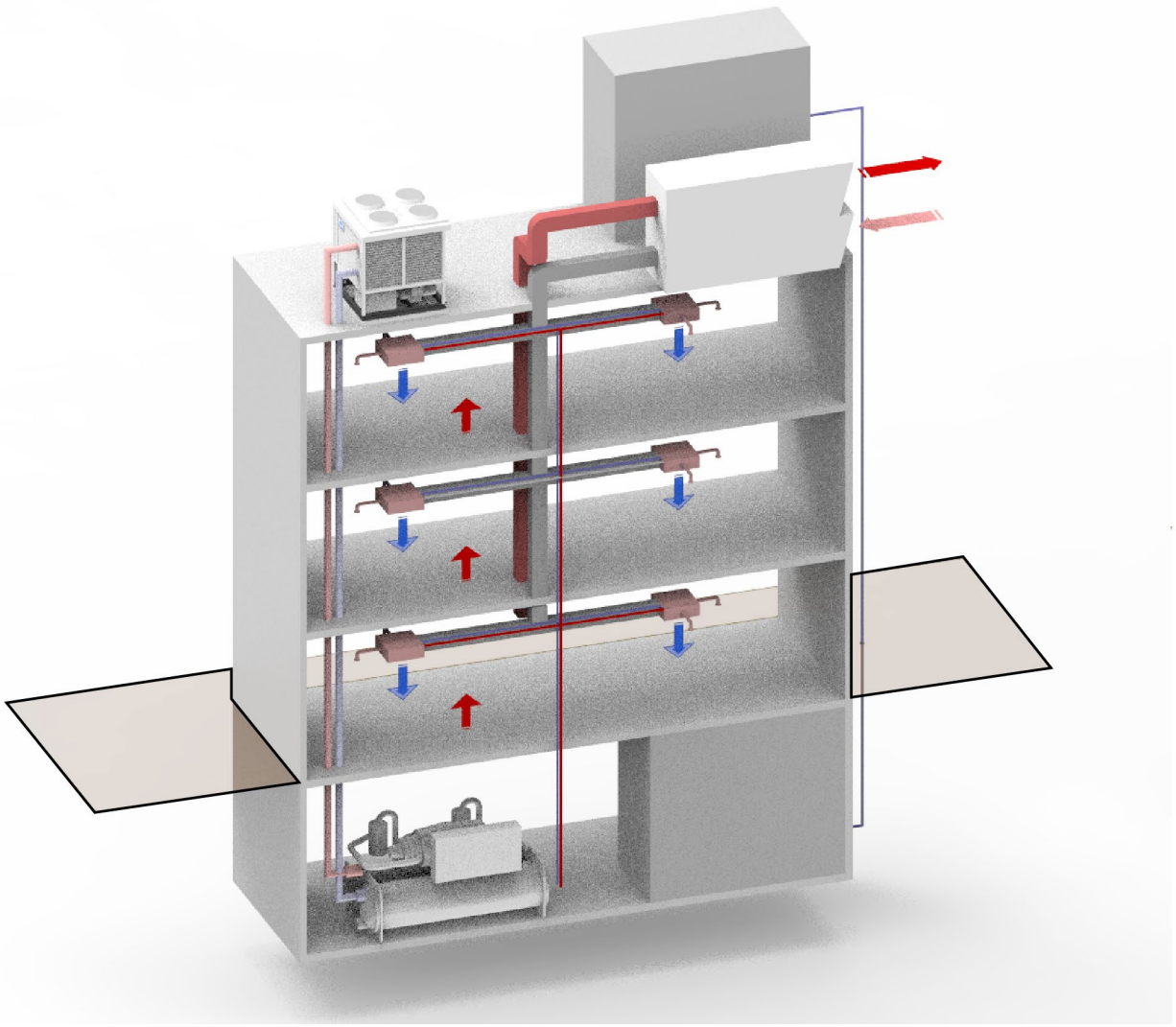


VAPOUR ABSORPTION

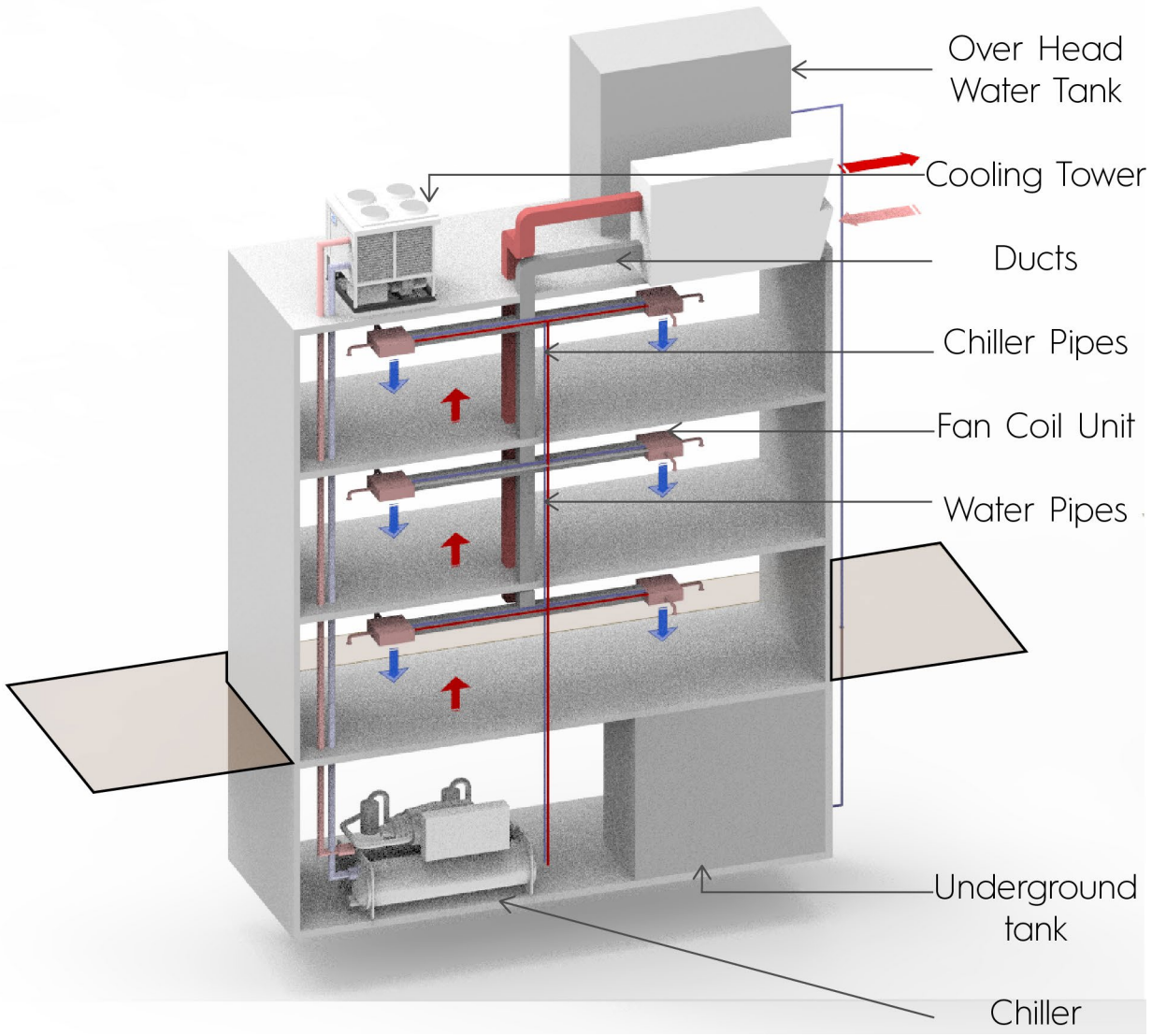
POST TOWERS,BONN

Decentralized

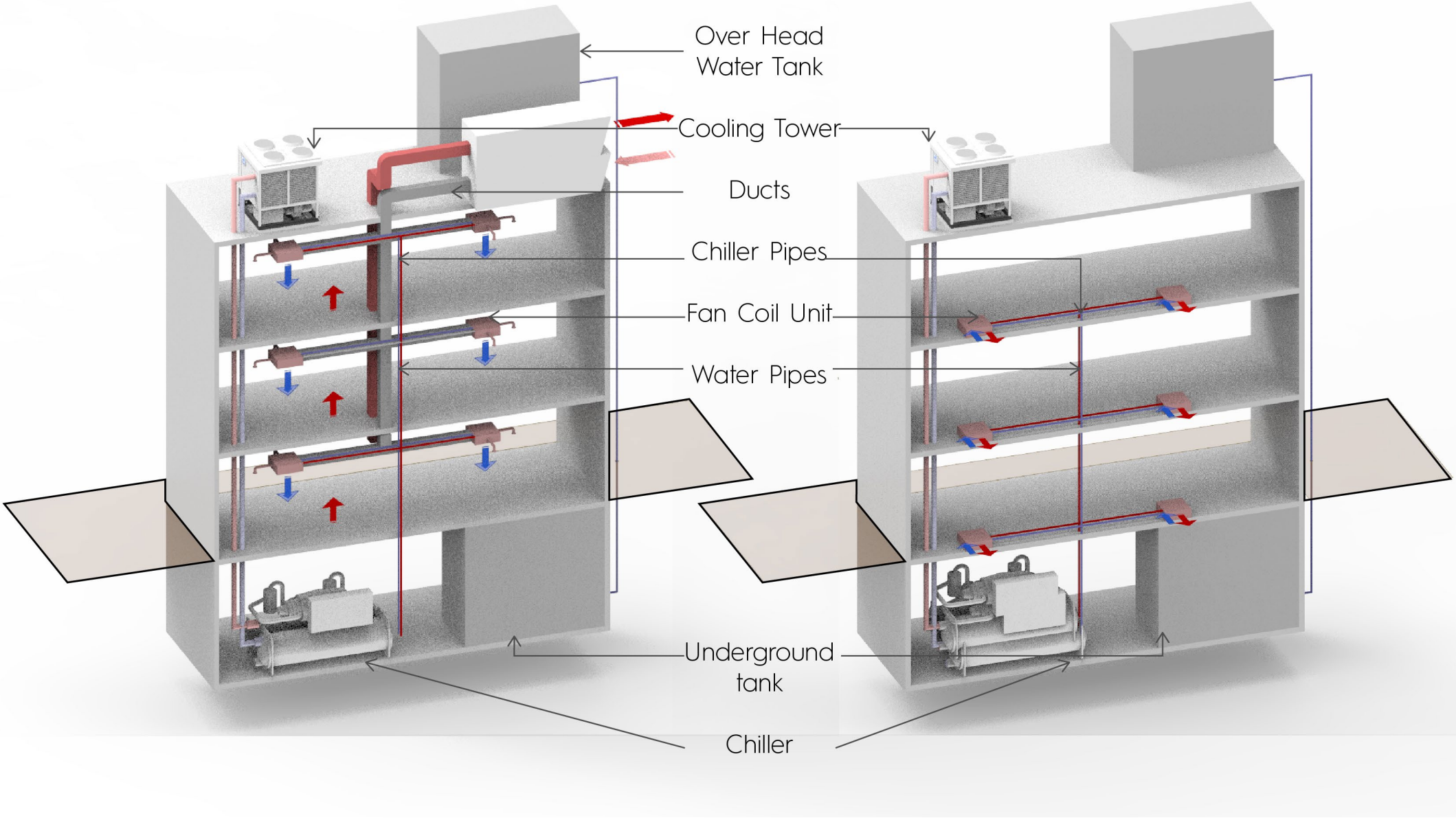
Ventilation



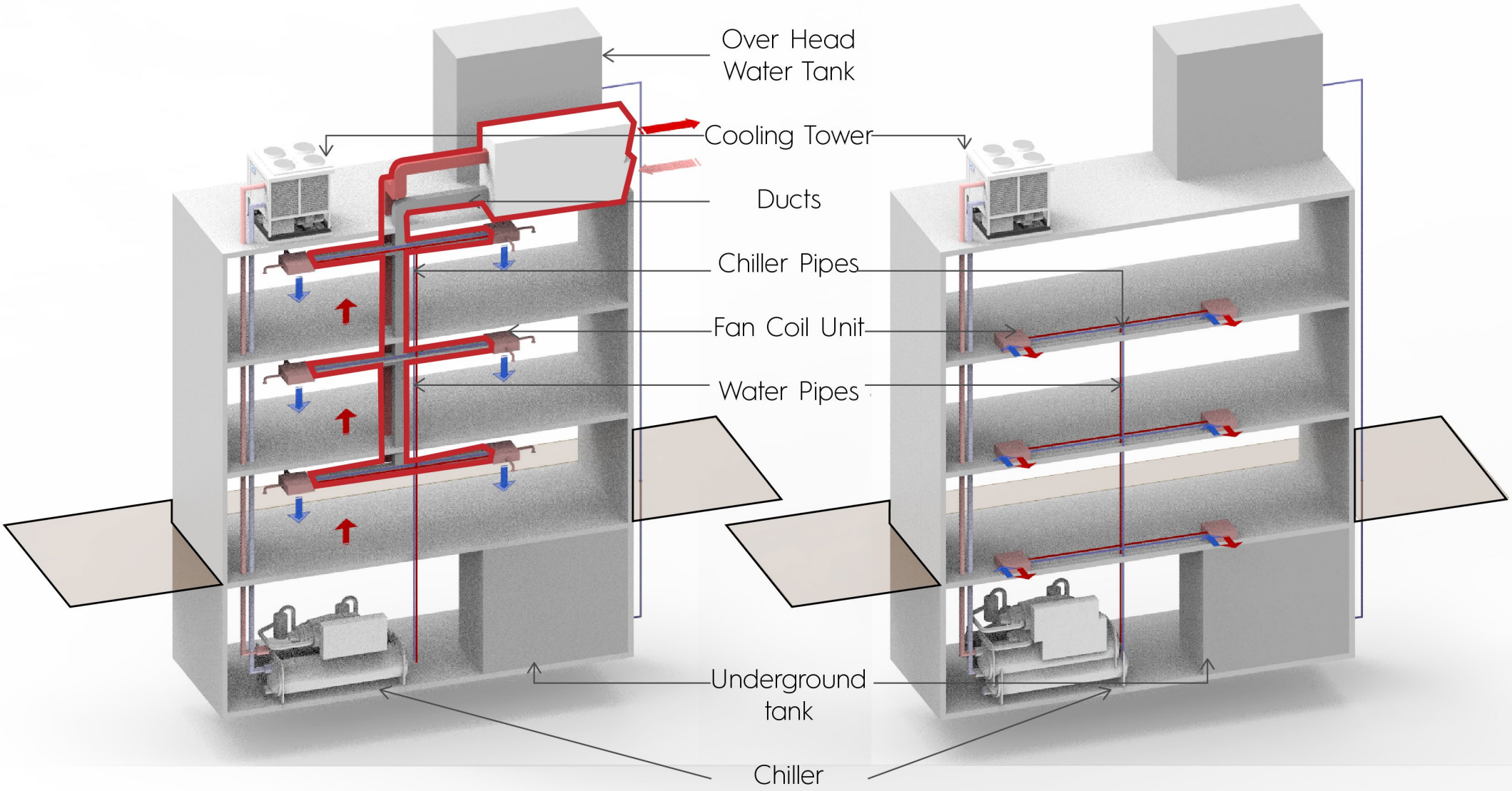
Centralized Systems



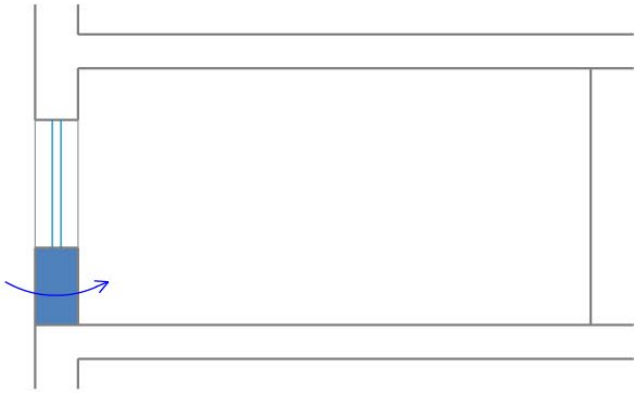
Centralized Systems



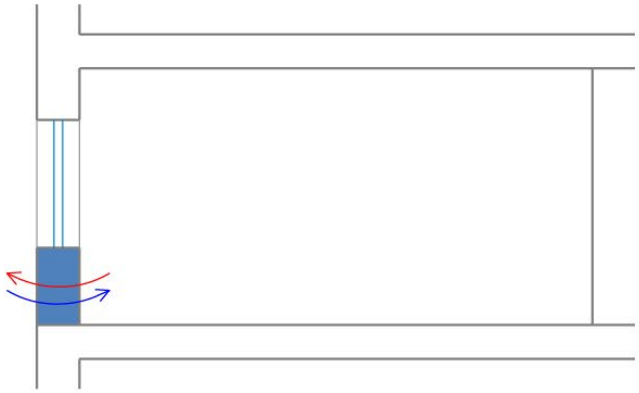
Centralized / Decentralized system



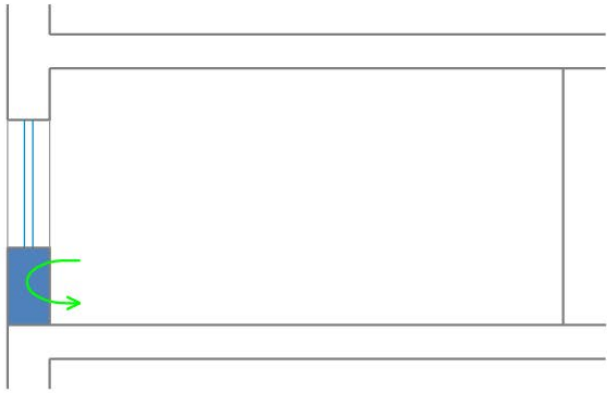
Decentralized system - No Ducts



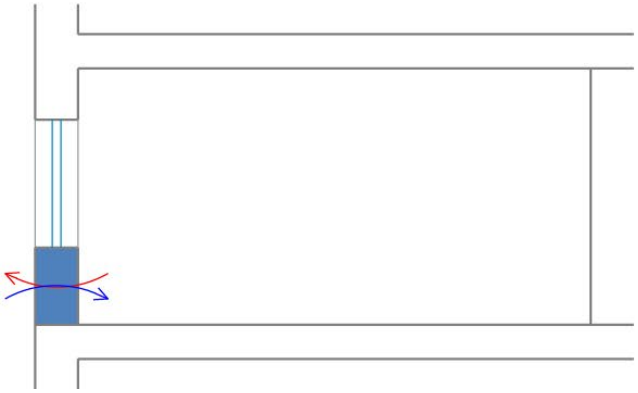
Supply Air



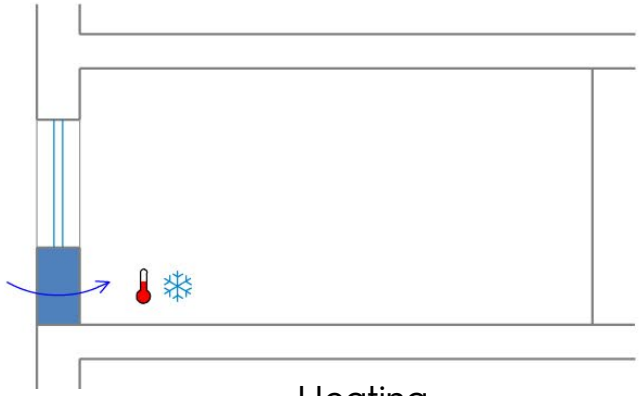
Supply Air
Return Air



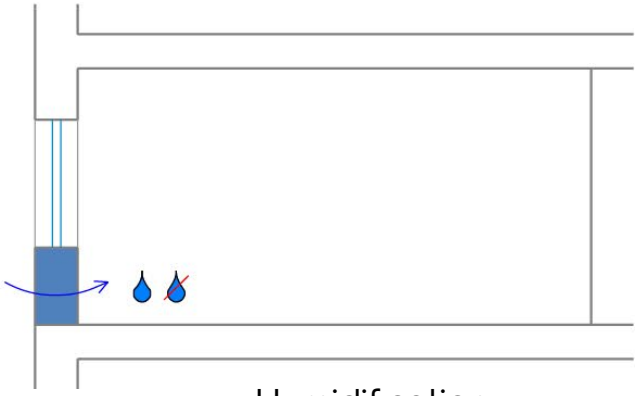
Recirculation



Heat Recovery



Heating
Cooling

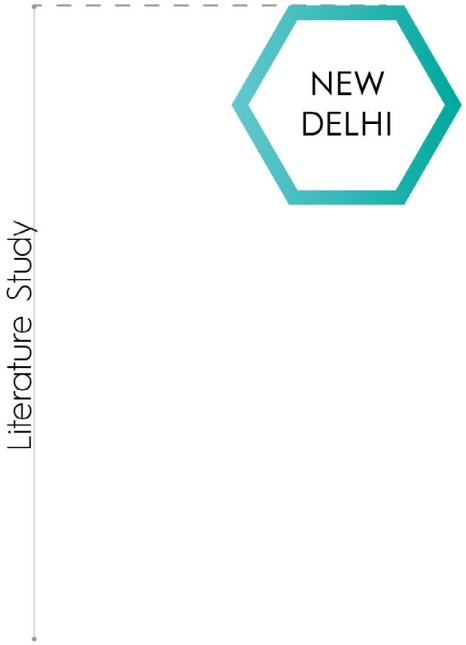


Humidification
Dehumidification

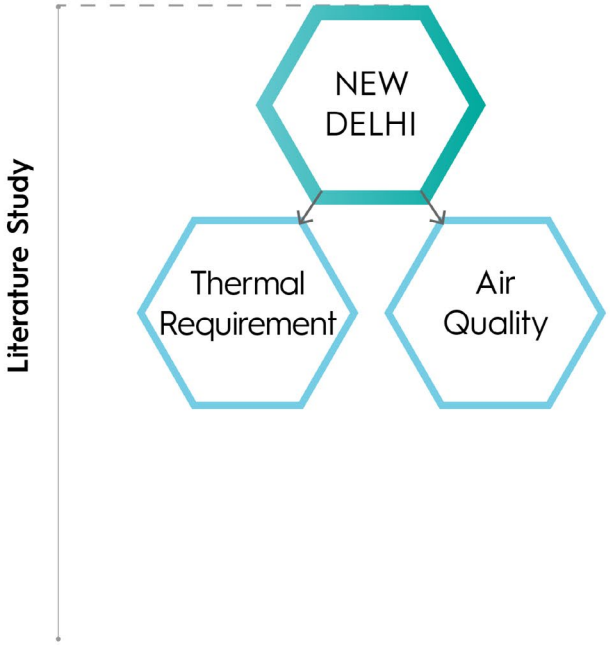
Decentralized systems are smart

" To what extent a ***decentralized evaporative cooling*** *system can be integrated on a façade to reduce the cooling demand of offices in Delhi (composite climate)* ? *"*

Centralized / Decentralized system



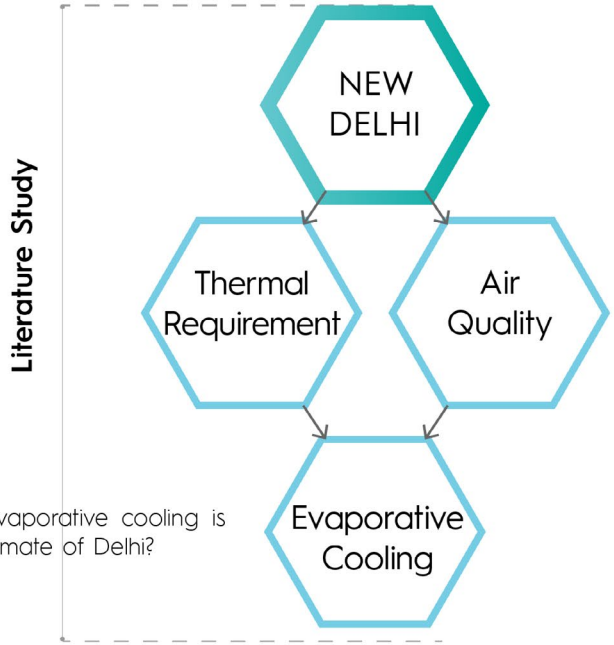
Sub - Research questions



Context:

1. What are the desired passive strategies that need to be integrated in a Composite climate (Delhi) for thermal comfort and air quality requirements for Delhi?

Sub - Research questions



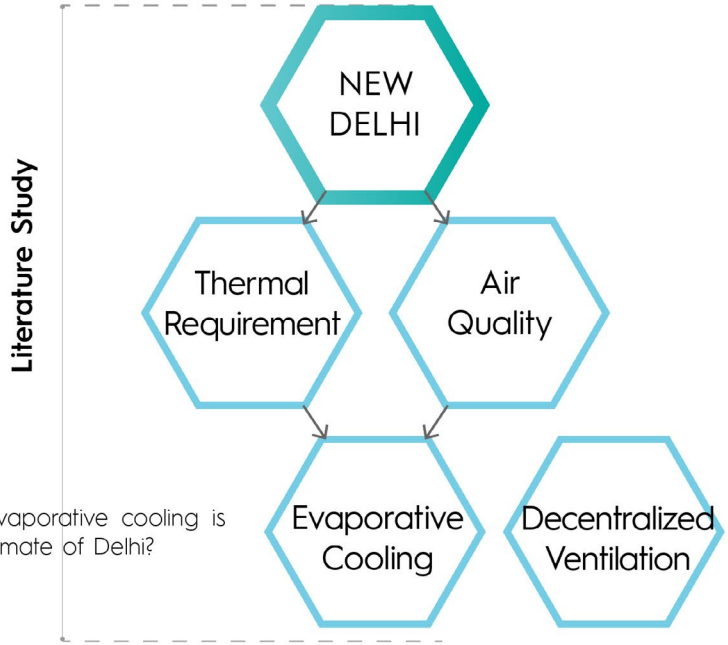
Context:

1. What are the desired passive strategies that need to be integrated in a Composite climate (Delhi) for thermal comfort and air quality requirements for Delhi?

Context:

2. Which type of evaporative cooling is more suitable for the climate of Delhi?

Sub - Research questions



Context:

1. What are the desired passive strategies that need to be integrated in a Composite climate (Delhi) for thermal comfort and air quality requirements for Delhi?

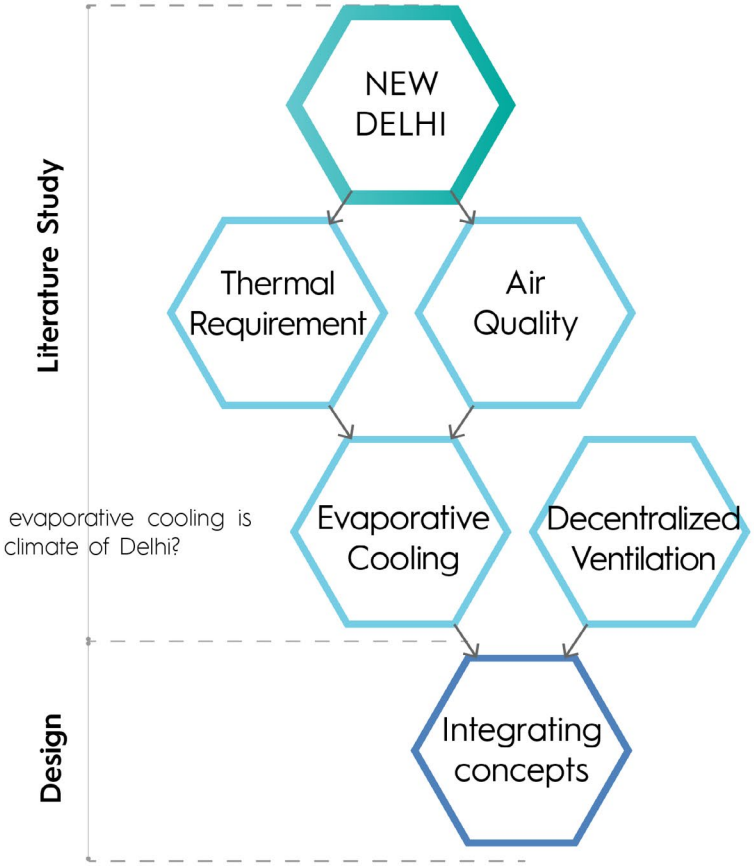
System:

3. What are the advantages and limitations of de-centralized system over centralized and what are the state of the art Façade Integrated ventilation systems in the market?

Context:

2. Which type of evaporative cooling is more suitable for the climate of Delhi?

Sub - Research questions



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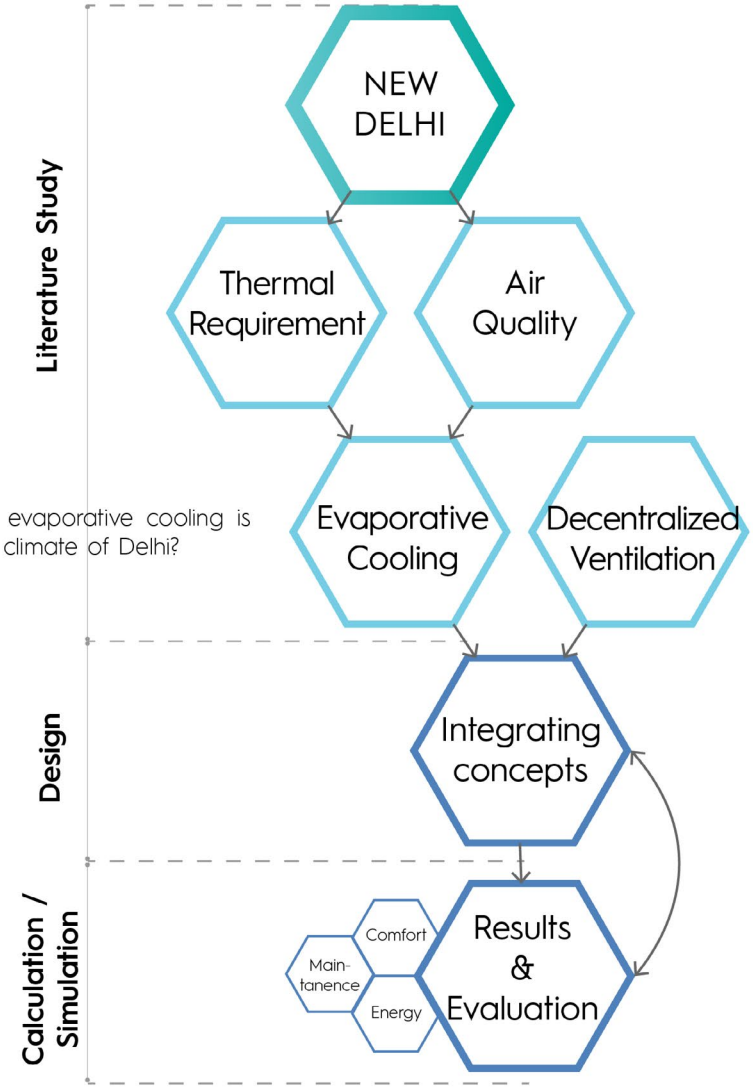
3. What are the advantages and limitations of de-centralized system over centralized and what are the state of the art Façade Integrated ventilation systems in the market?

4. What are the components and the layout of the system that are required to supply desired air flow and temperature?

5. How this system can be designed in form of a facade that can be integrated over the built structure?

Sub - Research questions



Context:

2. Which type of evaporative cooling is more suitable for the climate of Delhi?

Context:

1. What are the desired passive strategies that need to be integrated in a Composite climate (Delhi) for thermal comfort and air quality requirements for Delhi?

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3. What are the advantages and disadvantages of centralized and de-centralized system and how to retain the benefits from both?

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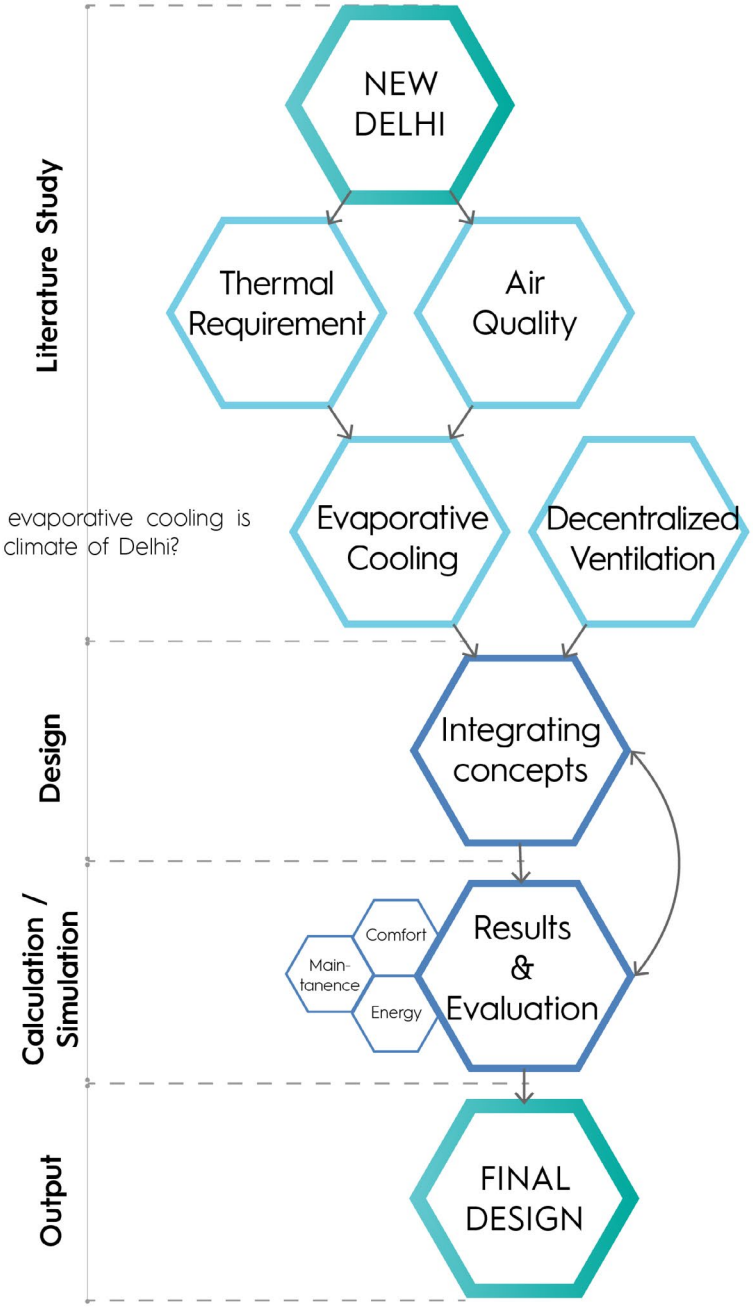
5. How this system can be designed in form of a facade that can be integrated over the built structure?

Evaluation:

6. To what extent the solar energy can be used to produce heat and energy for the sustainable operation of the evaporative facade?

7. What is the saving potential in the cooling load by this façade system compared to a conventional centralized system?

Sub - Research questions



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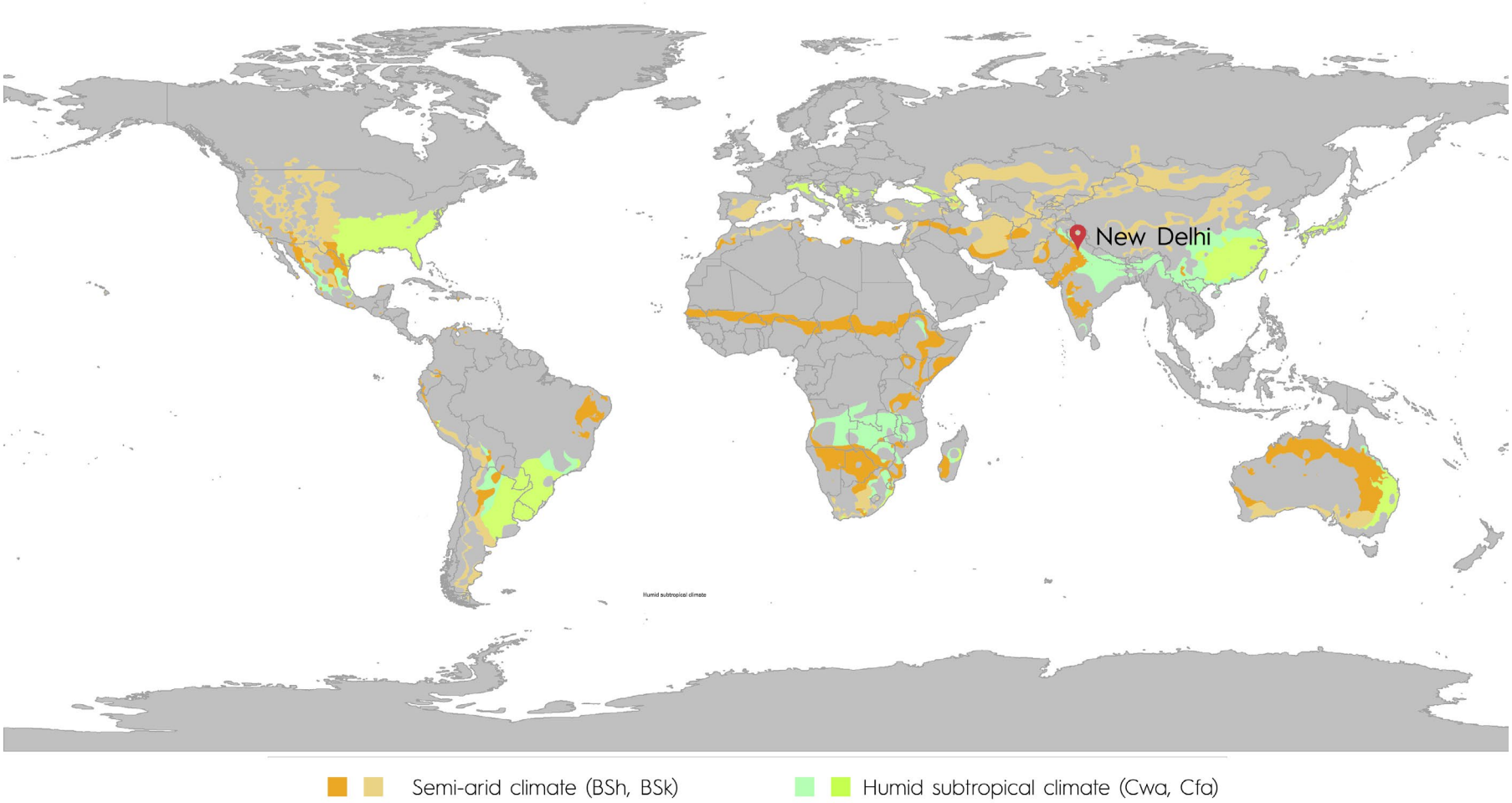
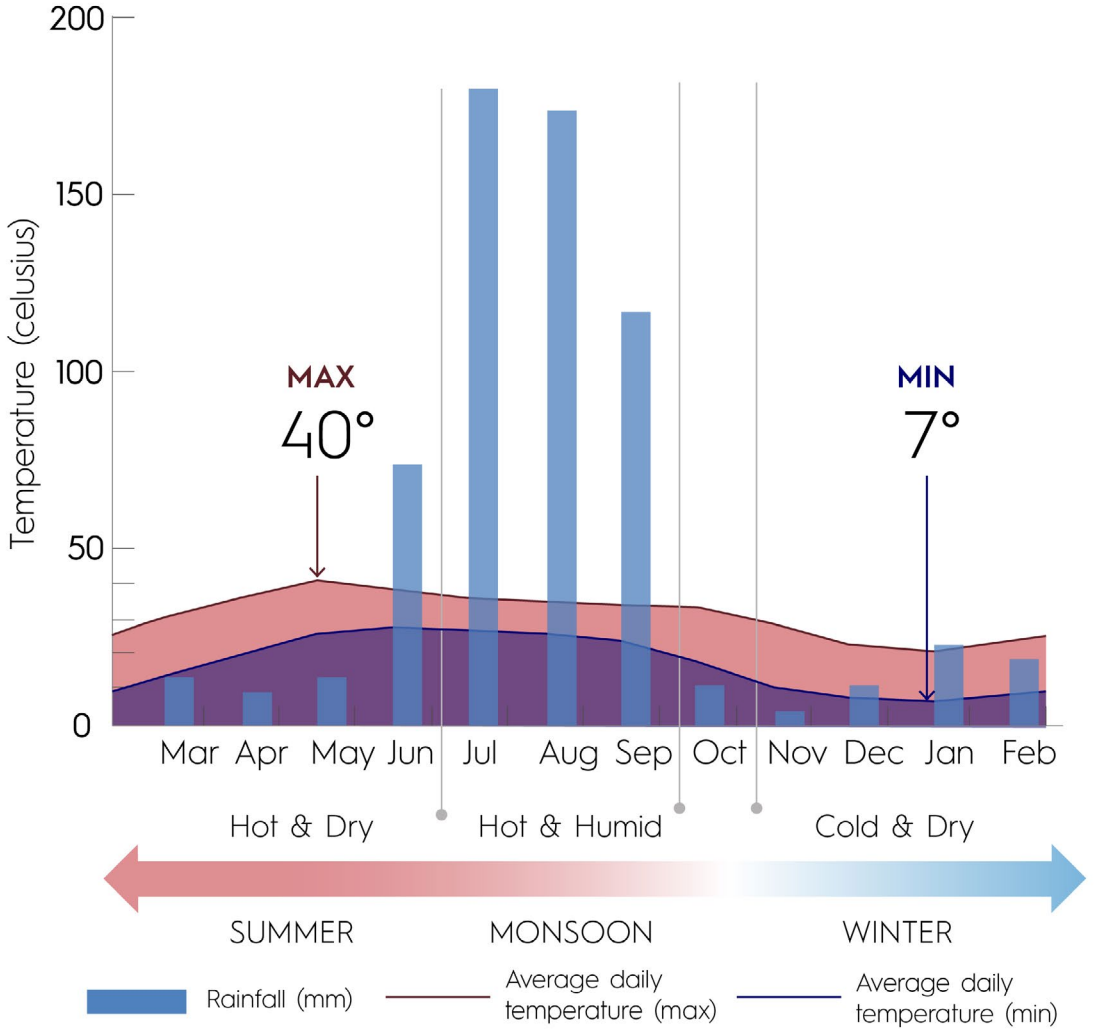
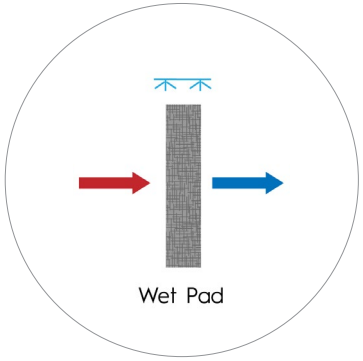


Koppen Climate Classification

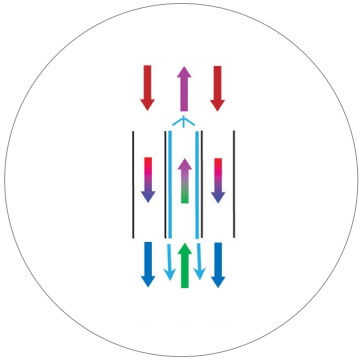


Climate Of Delhi

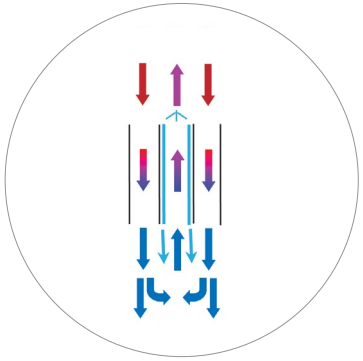
Evaporative Cooling



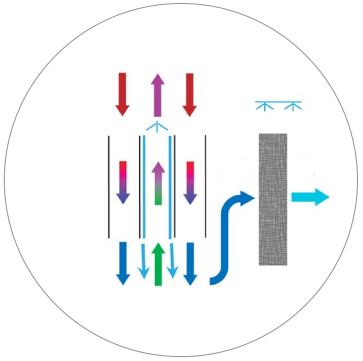
Direct



Indirect

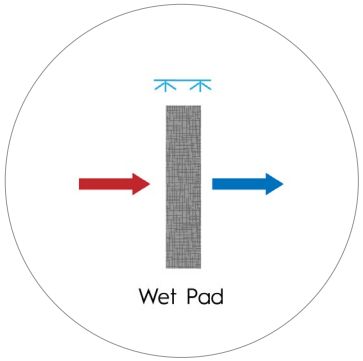


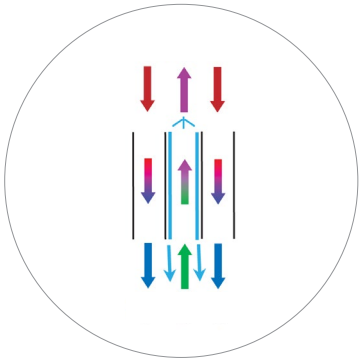
Dew-Point

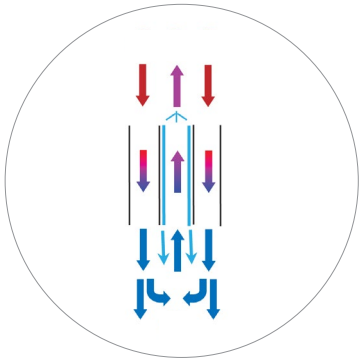


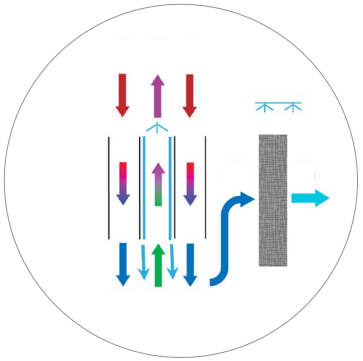
Combined

Types









Direct

HUMIDITY
Increases

WB
Effectiveness
70% - 85%

Indirect

HUMIDITY
Neutral

WB
Effectiveness
40% - 60%

Dew-Point

HUMIDITY
Neutral

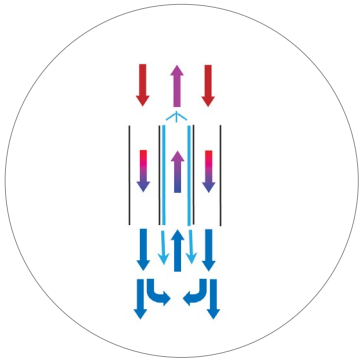
WB
Effectiveness
92% - 114%

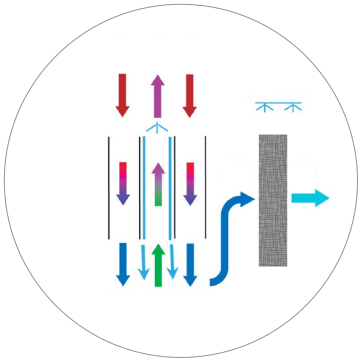
Combined

HUMIDITY
Increases

WB
Effectiveness
109% - 116%

Types





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Combined

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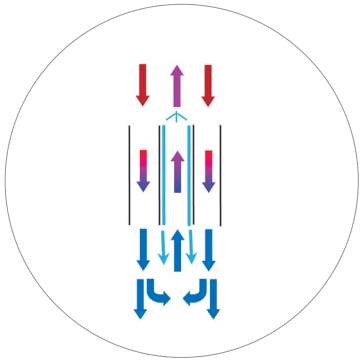
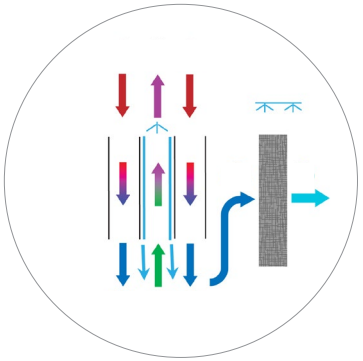
Types





Direct

HUMIDITY
Increases

WB
Effectiveness
70% - 85%

Indirect

HUMIDITY
Neutral

WB
Effectiveness
40% - 60%

Dew-Point

Complex Air flow

Less Primary air

Combined

Size

55% more water consumption

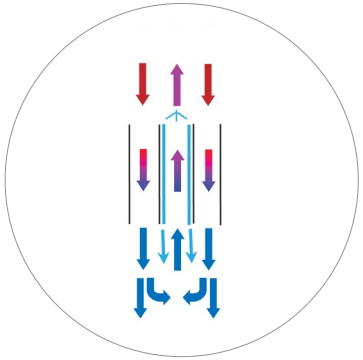
More components

Cost

Types

Direct

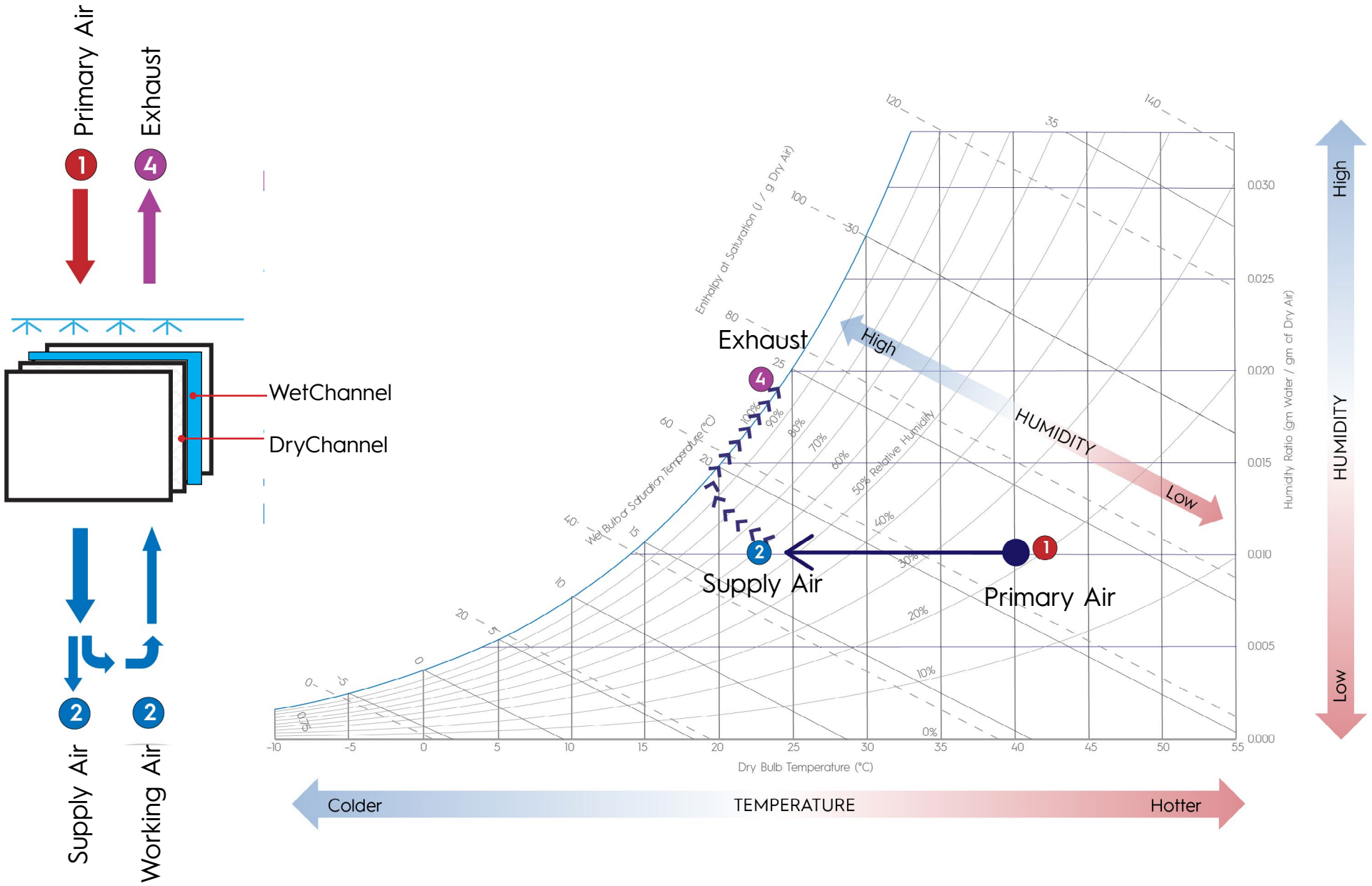
Indirect



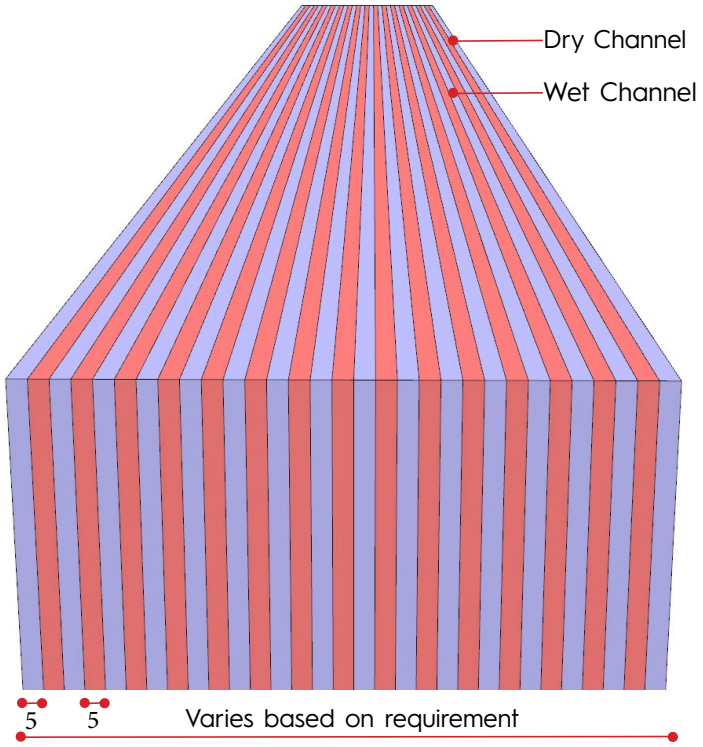
Dew-Point Indirect Evaporative Cooling

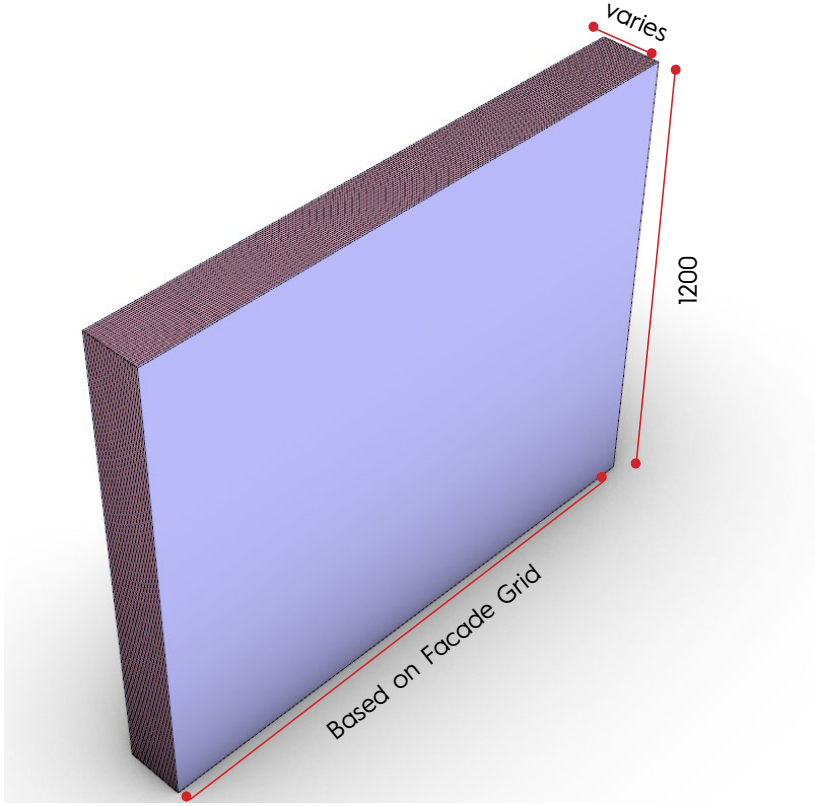
Combined

Types



Dewpoint Indirect Evaporative Cooling





5mm
Channel Gap

> 1m
Channel Length

122%
WB Efficiency

Cooler Size

Sizing?

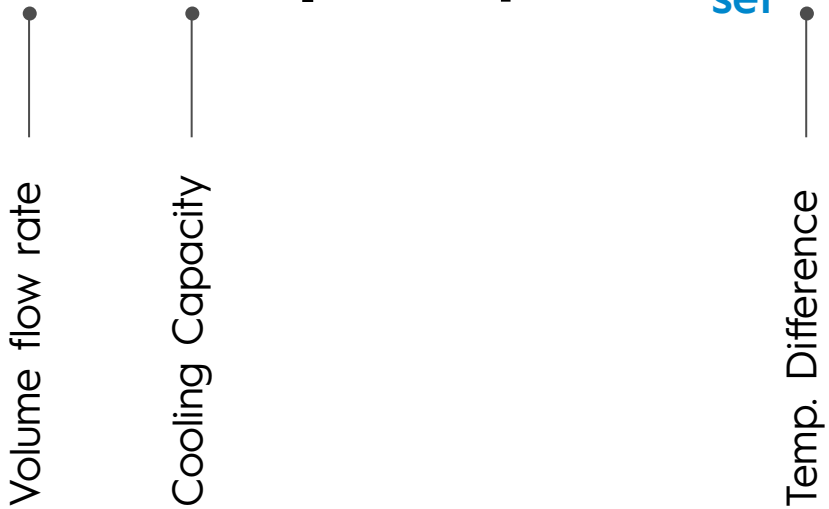
$$Q = M * Cp * \Delta T$$

$$V = Q / \rho * Cp * (T_{set} - T_{sup})$$

Cooling Capacity

$$Q = M * Cp * \Delta T$$

$$V = Q / \rho * Cp * (T_{set} - T_{sup})$$



Cooling Capacity

$$Q = M * Cp * \Delta T$$
$$V = Q / \rho * Cp * (T_{set} - T_{sup})$$

Cooling Capacity (Q)

(Building)

Diff. in Temp (ΔT)

(Set Temp. - Supply Temp.)

Size of the Systems

Cooling Capacity

Cooling Capacity (Q)

(Building)

Diff. in Temp (ΔT)

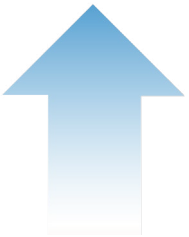
(Set Temp. - Supply Temp.)

Size
of the
Systems

Sizing The System

Cooling Capacity (Q)

(Building)



Diff. in Temp (ΔT)

(Set Temp. - Supply Temp.)

Size
of the
Systems

Sizing The System

Cooling Capacity (Q)

(Building)

Diff. in Temp (ΔT)

(Set Temp. - Supply Temp.)

Size
of the
Systems

Sizing The System

Cooling Capacity (Q)

(Building)

Diff. in Temp (ΔT)

(Set Temp. - Supply Temp.)

Size of the Systems

Sizing The System

				
Name	Wipro	VECH	IPB	SkyView
Year	2005	2012	2014	2015
WWR%	33	80	20	55
Glazing	1.8	2.1	1.8	1.8
Solid	0.6	1.1	0.5	1.1
Shading	Horizontal louvers	Louvers	Recessed	No Shading
LPD	5.4	4	5	9.5
Cooing	Central	HVAC underfloor	Geothermal	Central
EPI **179 kWh/m2/year**	**85**	**96**	**45.25**	**112**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EPI **179 kWh/m2/year**	85	96	**45.25**	112

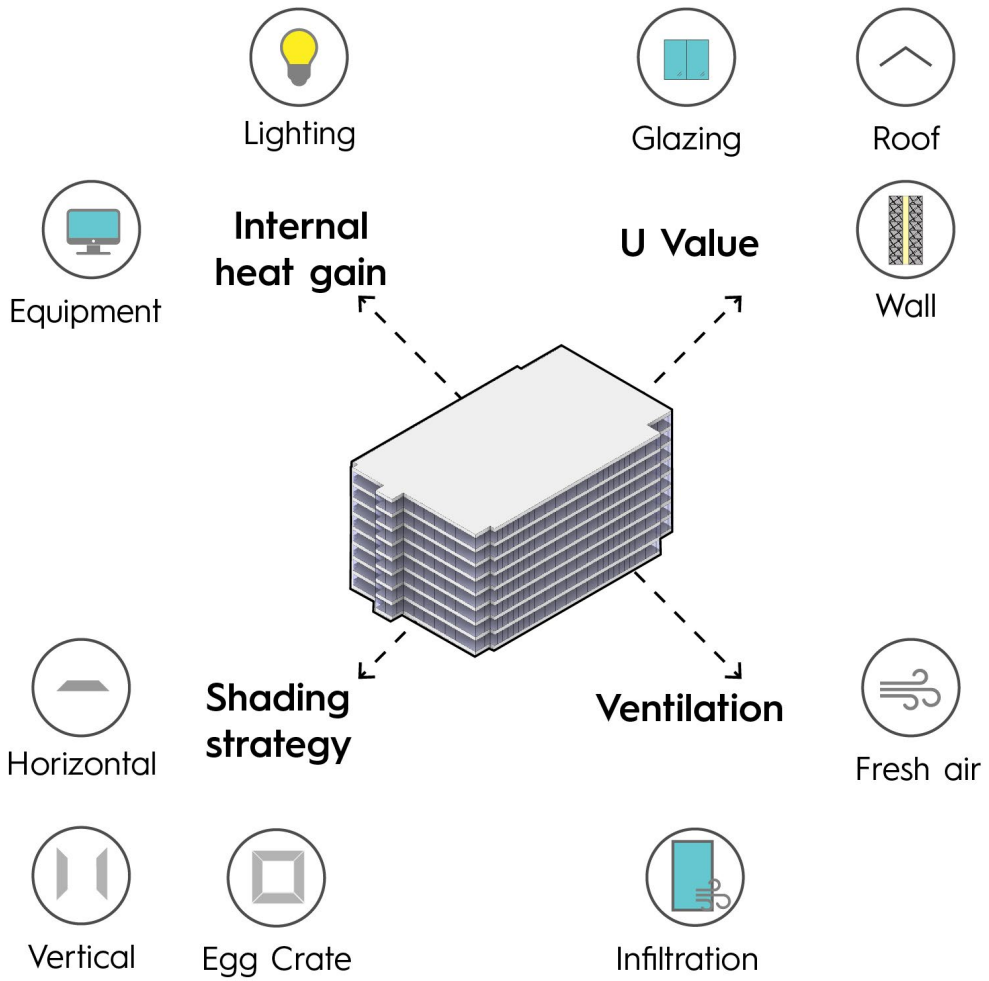
DLF Cyber City, Gurgaon

GLAZING IS COMING

DLF Cyber City, Gurgaon

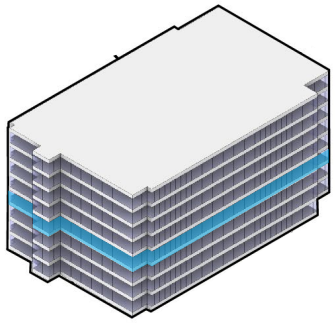
Sky View, Gurgaon

Sky View, Gurgaon



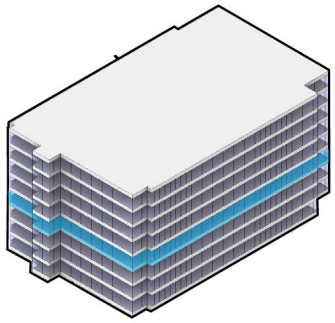
Passive Strategies

WWR	**Location**	**Floor Area**	**Orientation**	Energy Performance Index kWh/m²/year	Cooling Capacity kW	Cooling load per m2 kW/m2
60%	New Delhi	1792m2	Longer axis N-S			



WWR	Location	Floor Area	Orientation
60%	New Delhi	1792m2	Longer axis N-S

	Energy Performance Index kWh/m²/year	Cooling Capacity kW	Cooling load per m2 W/m2
Base Case	343.2	190.72	109.6



WWR	Location	Floor Area	Orientation
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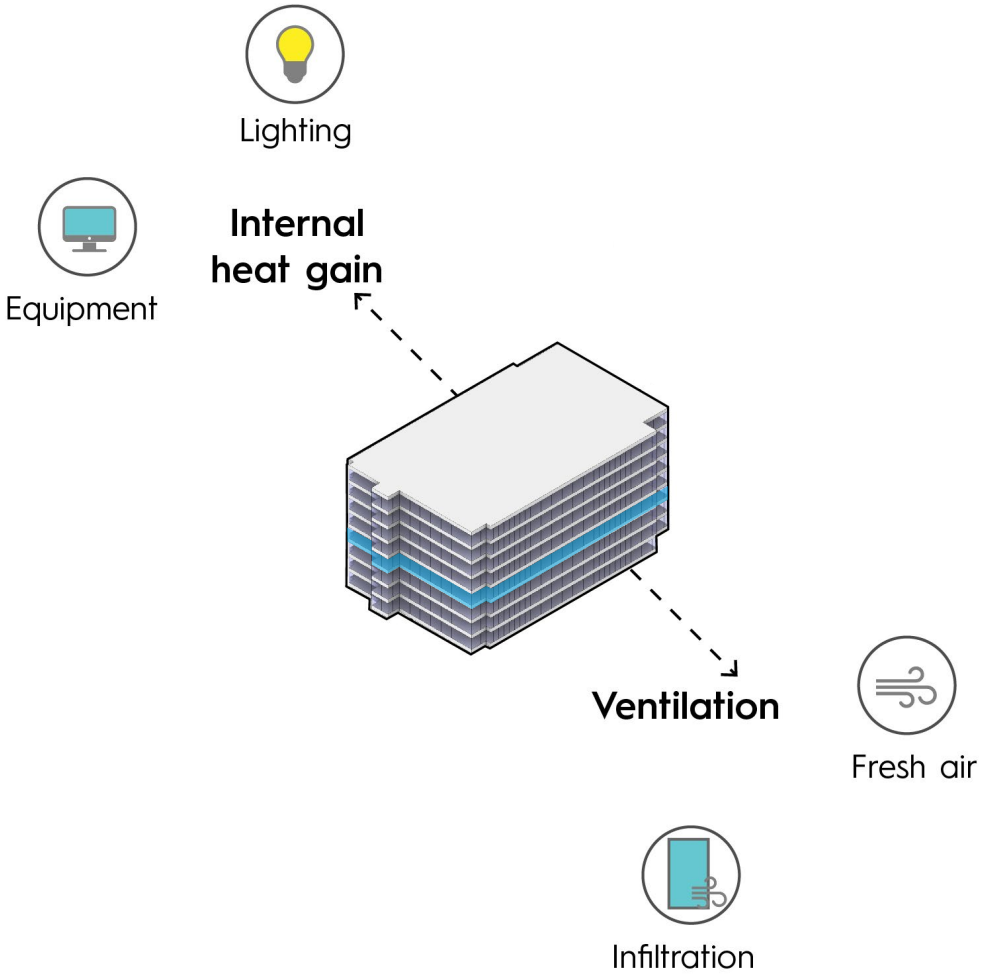
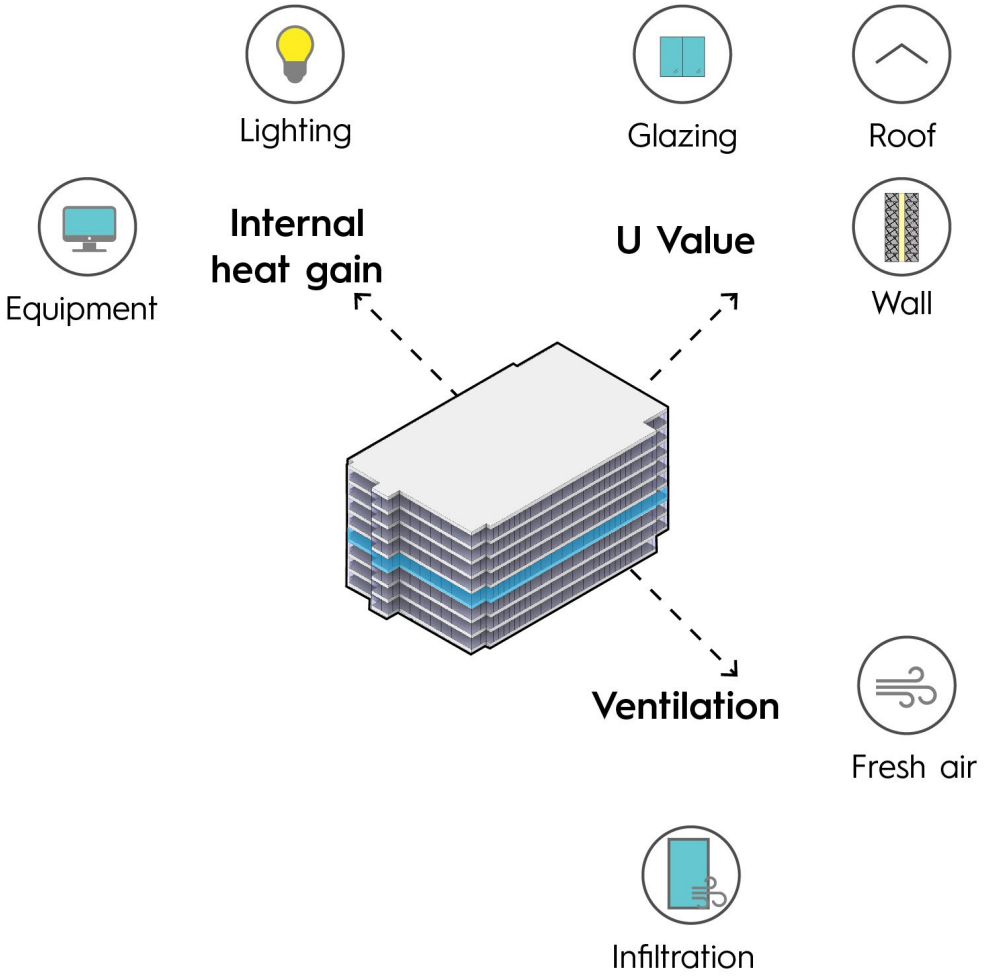


	Energy Performance Index kWh/m²/year	Cooling Capacity kW	Cooling load per m2 W/m2
Base Case	343.2	190.72	109.6
Ventilation / Internal heat gains	183.4	145.6	83.4

25%

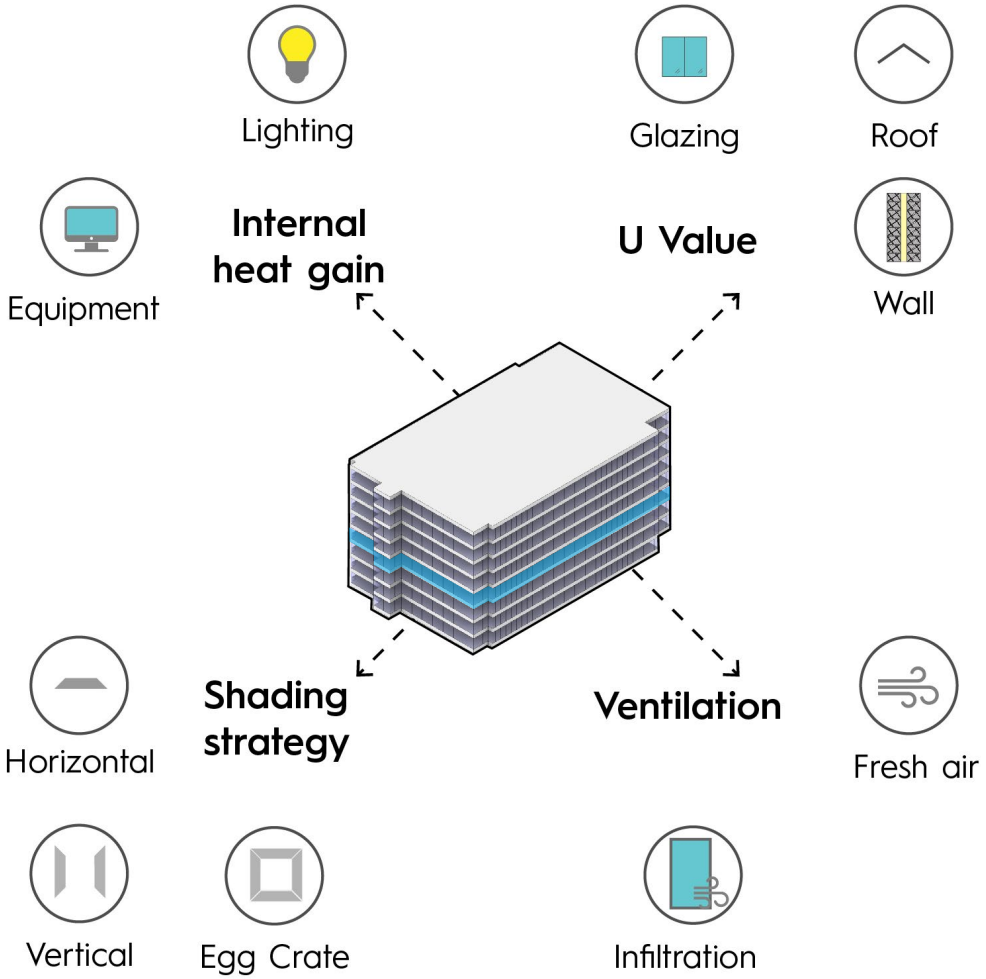
WWR	Location	Floor Area	Orientation
60%	New Delhi	1792m2	Longer axis N-S



	Energy Performance Index kWh/m²/year	Cooling Capacity kW	Cooling load per m2 W/m2
Base Case	343.2	190.72	109.6
Ventilation / Internal heat gains	183.4	145.6	83.4
U-Value	168.54	100.3	57.2

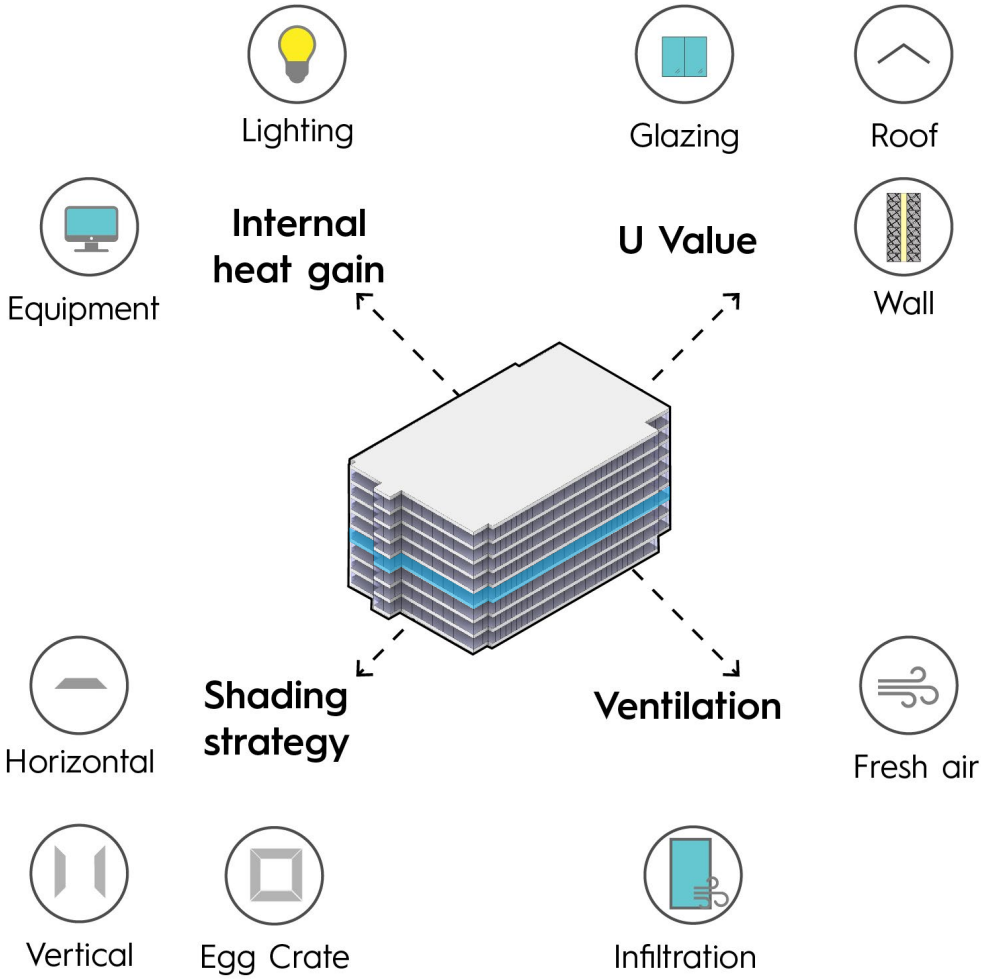
30%

WWR	Location	Floor Area	Orientation
60%	New Delhi	1792m2	Longer axis N-S



	Energy Performance Index kWh/m²/year	Cooling Capacity kW	Cooling load per m2 W/m2
Base Case	343.2	190.72	109.6
Ventilation / Internal heat gains	183.4	145.6	83.4
U-Value	168.54	100.3	57.2
			13%
Shading Strategy	151.35	89.3	51.3
	157.45	95.4	54.4
	146.41	87.65	50

WWR	Location	Floor Area	Orientation
60%	New Delhi	1792m2	Longer axis N-S



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Base Case	343.2	190.72	109.6
Ventilation / Internal heat gains	183.4	145.6	83.4
U-Value	168.54	100.3	57.2
Shading Strategy	151.35	89.3	51.3
	157.45	95.4	54.4
	146.41	87.65	50

50%

Cooling Capacity (Q)

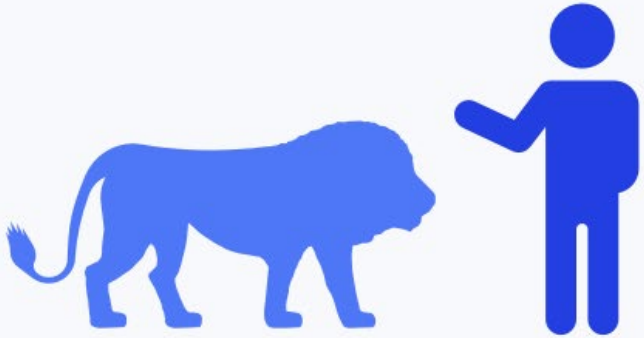
(Building)

Diff. in Temp (ΔT)

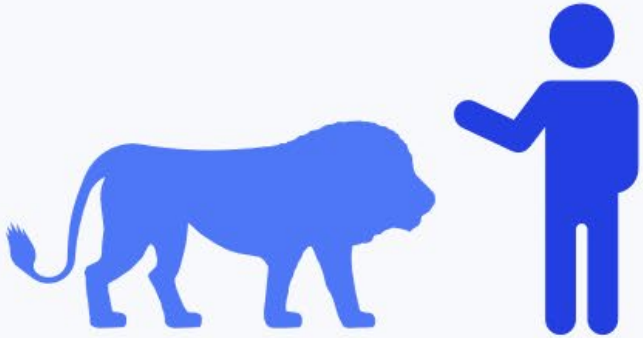
(Set Temp. - Supply Temp.)

Size
of the
Systems

Sizing The System



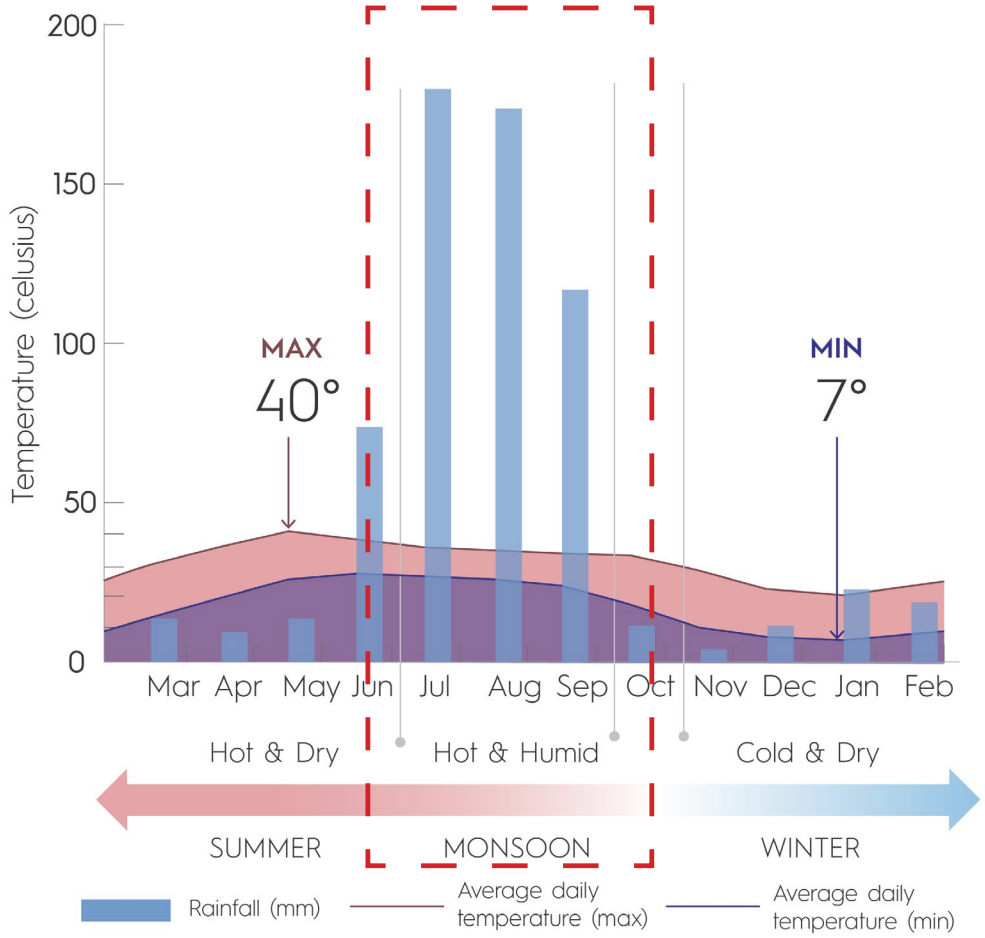
Design
Expectation



Design
Expectation

vs

Design
Reality



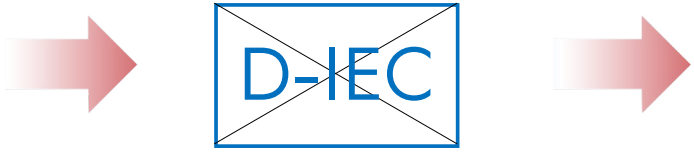
Moisture In The Air - Evaporative coolers WORST Enemy

Climate Of Delhi

AUGUST - DELHI

30°C
Drybulb temperature

27°C
Wetbulb temperature



122%
WB Efficiency

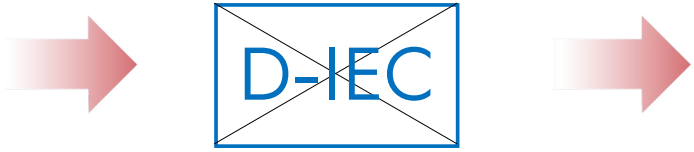
26.3°C
Supply temperature

High Humidity

AUGUST - DELHI

30°C
Drybulb temperature

27°C
Wetbulb temperature



122%
WB Efficiency

26.3°C
Supply temperature

25°C
Setpoint temperature

<

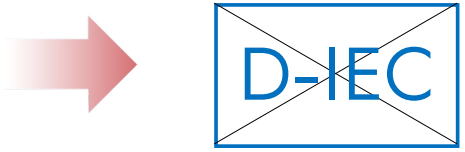
26.3°C
Supply temperature

High Humidity

AUGUST - DELHI

30°C
Drybulb temperature

27°C
Wetbulb temperature



122%
WB Efficiency

26.3°C
Supply temperature

25°C
Setpoint temperature

<

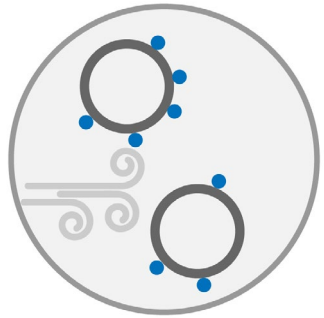
26.3°C
Supply temperature

NO EFFECTIVE COOLING

High Humidity

Dehumidification

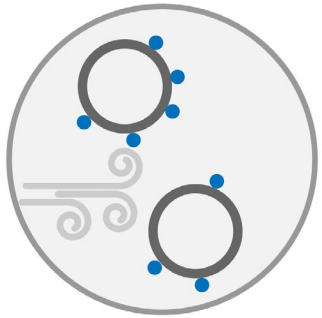
Cooling Coil



Desiccant System

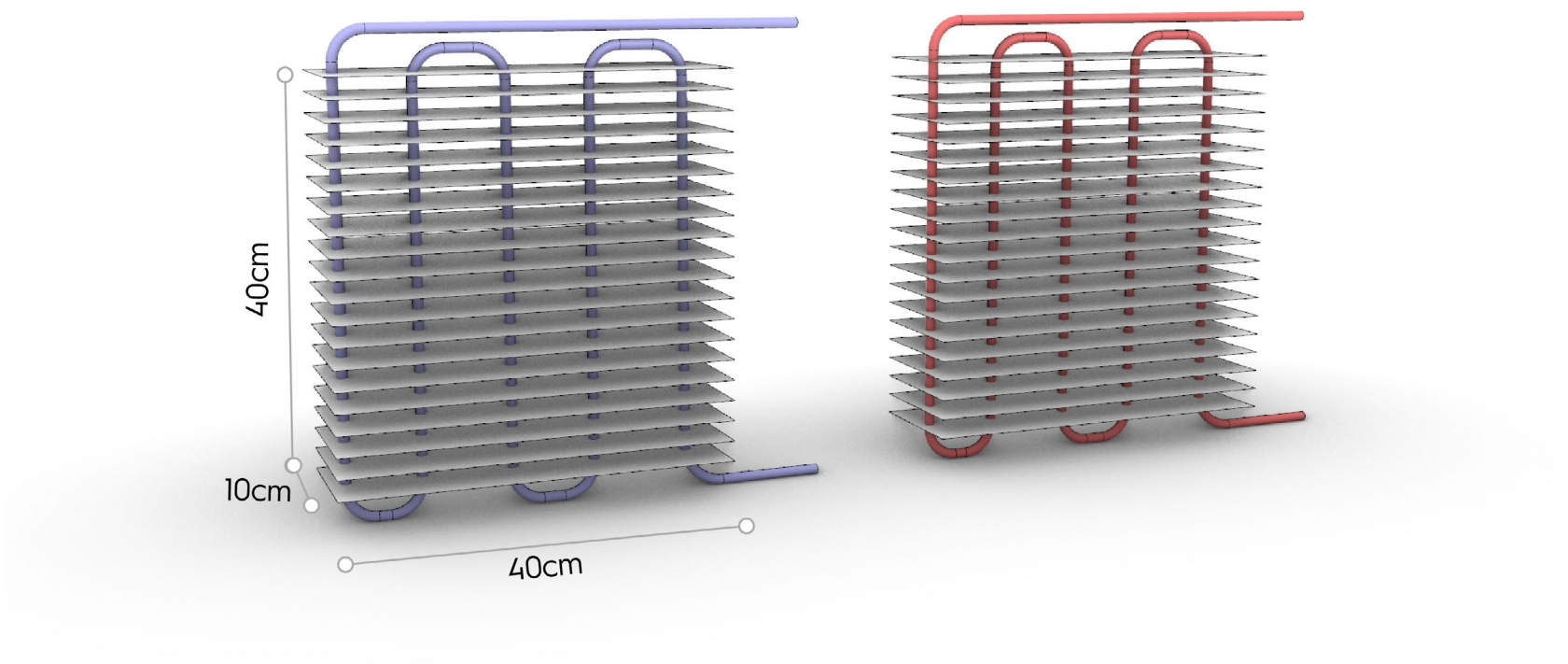
Dehumidification Strategies

Cooling Coil



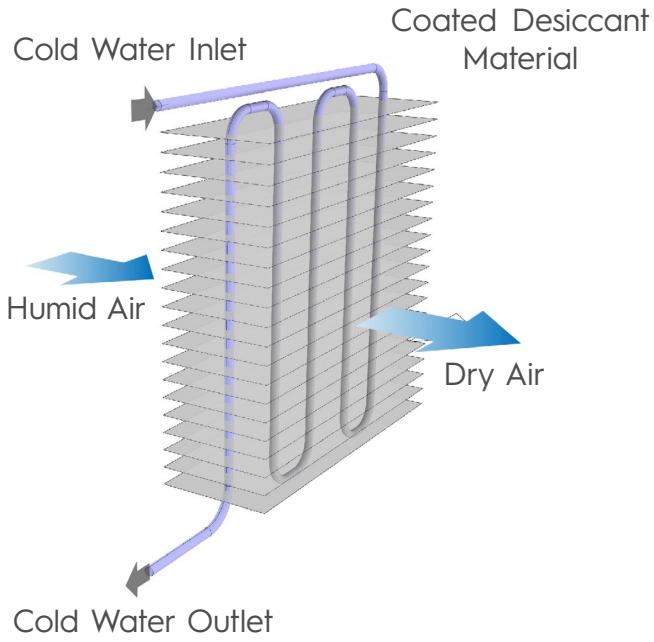
Desiccant System

Dehumidification Strategies

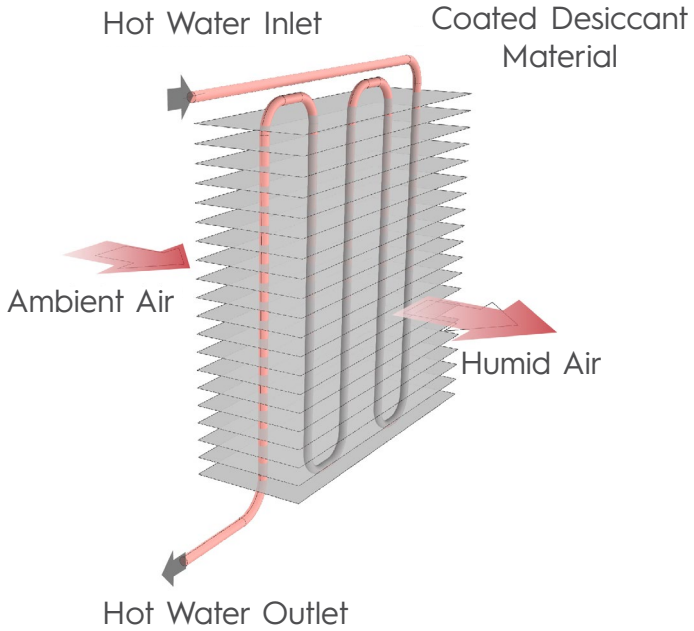


Desiccant Coated Heat Exchanger

De-humidification



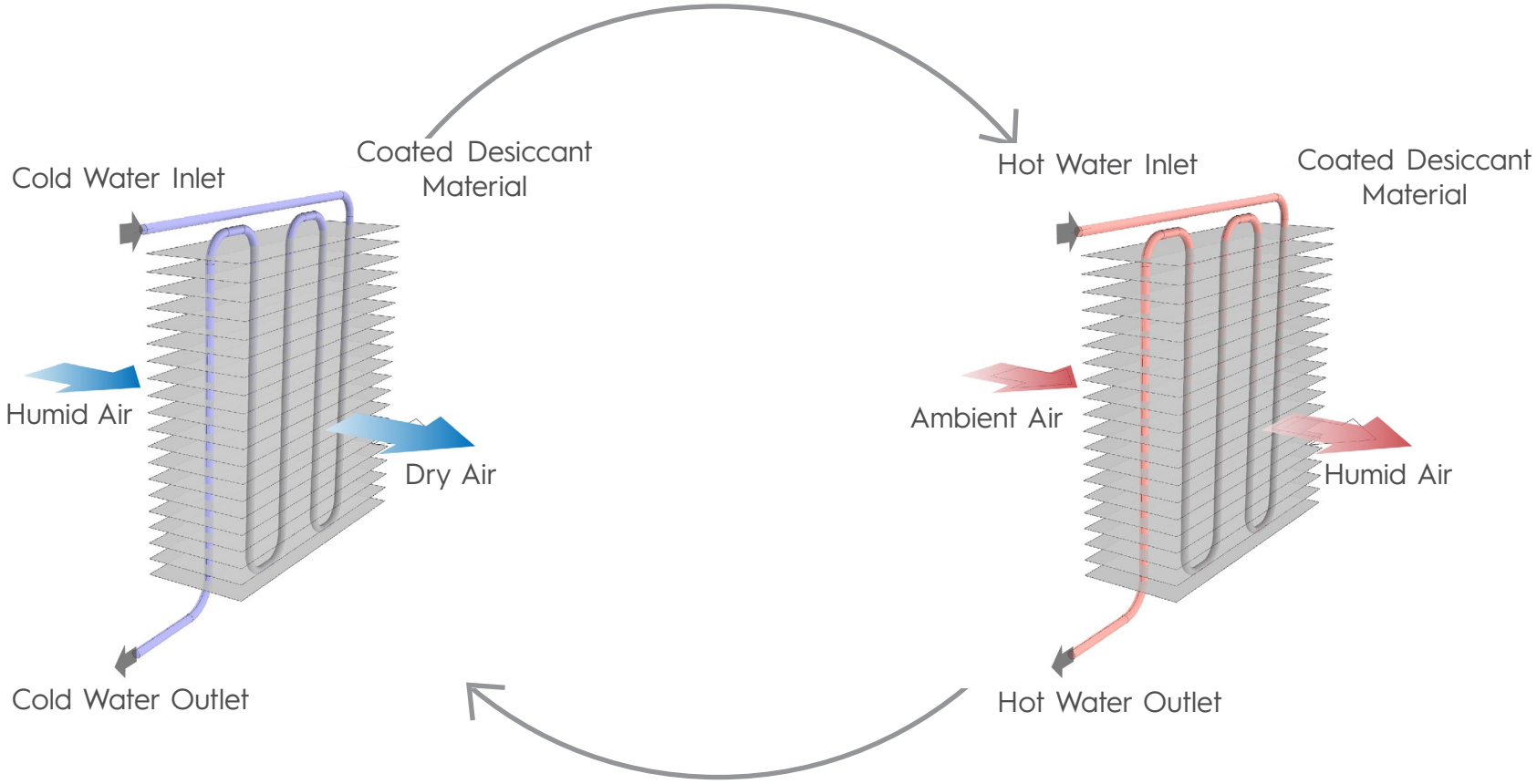
Regeneration



DCHE - Cycle

De-humidification

Regeneration



DCHE - Cycle

Before

30°C
Drybulb temperature

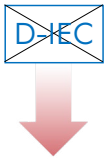
25°C
Setpoint temperature

122%
WB Efficiency

After

0.014 kg/kg
Humidity Ratio

Desiccant Coated Heat Exchanger



26.3°C
Supply temperature

After Dehumidification

Before

30°C
Drybulb temperature

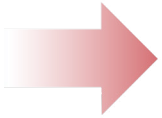
25°C
Setpoint temperature

122%
WB Efficiency

After

0.014 kg/kg
Humidity Ratio

26.3°C
Supply temperature



Desiccant Coated Heat Exchanger

After Dehumidification

Before

30°C
Drybulb temperature

25°C
Setpoint temperature

122%
WB Efficiency

After

0.014 kg/kg
Humidity Ratio

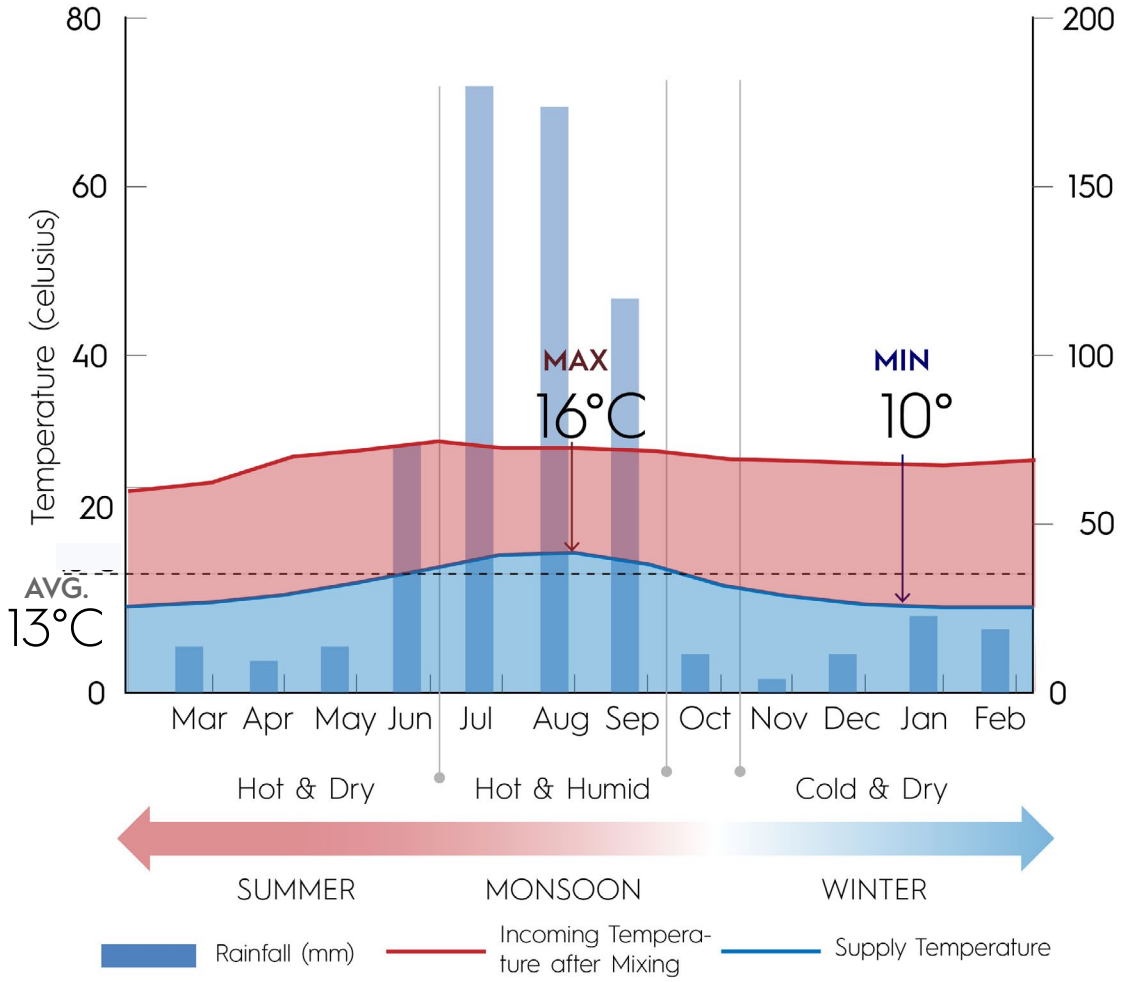
26.3°C
Supply temperature

Desiccant Coated Heat Exchanger

0.009 kg/kg
Humidity Ratio

16°C
Supply temperature

After Dehumidification



Yearly Supply Temperature

$$Q = M * Cp * \Delta T$$
$$V = Q / \rho * Cp * (T_{set} - T_{sup})$$

Cooling Capacity (Q)

(Building)

87.65 kW

Diff. in Temp (ΔT)

(Set Temp. - Supply Temp.)

9°C

Size of the Systems

8.19 m^3/s

Volume Flow rate

Sizing The System

Area of Opening = Volume flow rate / Velocity

8.19 m^3/s

Volume Flow rate

1.5 m/s

Velocity

Opening Size

Area of Opening = Volume flow rate / Velocity

8.19 m^3/s

Volume Flow rate

1.5 m/s

Velocity

5.46 m^2

Opening Required

Opening Size

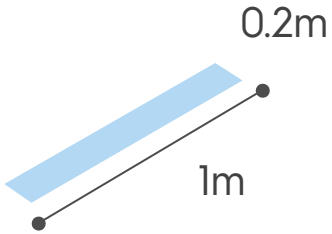
Area of Opening = Volume flow rate / Velocity

8.19 m^3/s

Volume Flow rate

1.5 m/s

Velocity



5.46 m^2

Opening Required

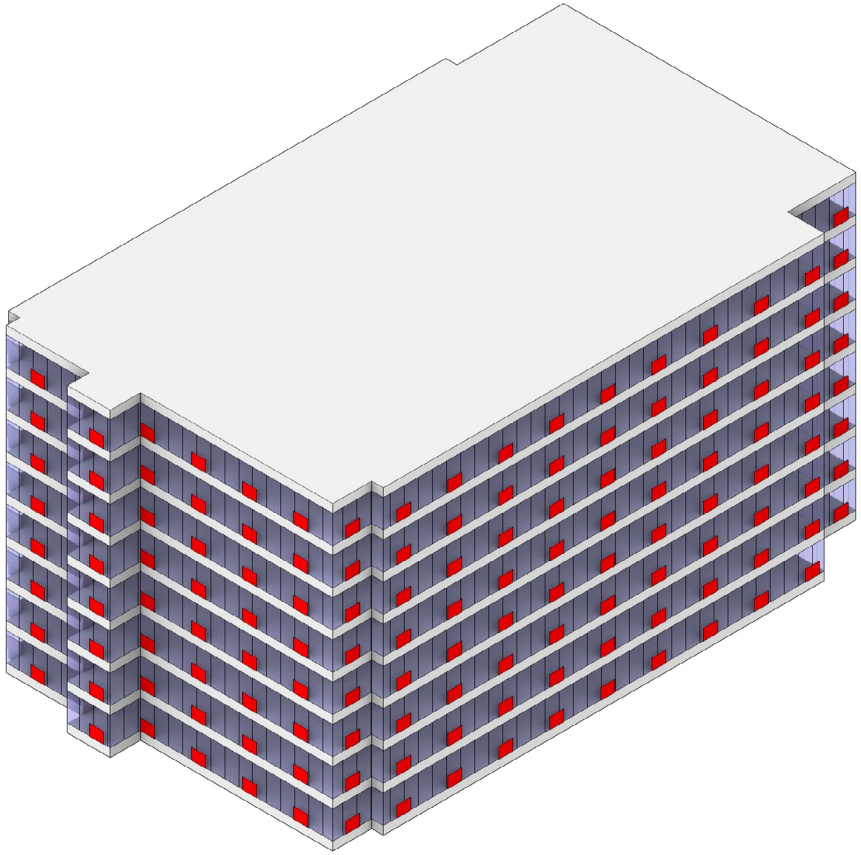
0.15 m^2

Opening of cooler

Opening Size

36

Devices
per floor



36

Devices
per floor

Design

Climate

Facade

Cooler Design

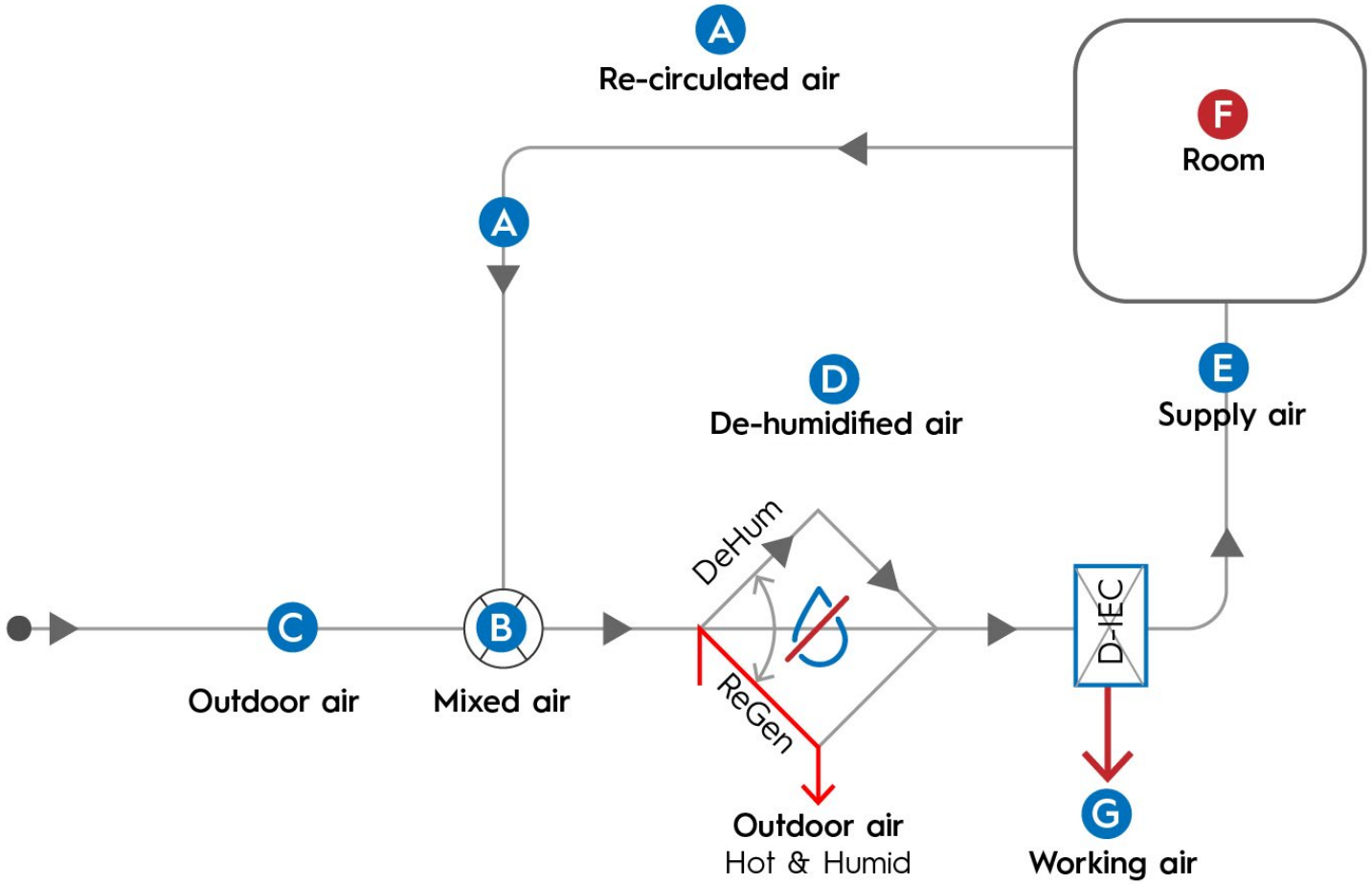
Ventilation Strategy

Integrating Concepts

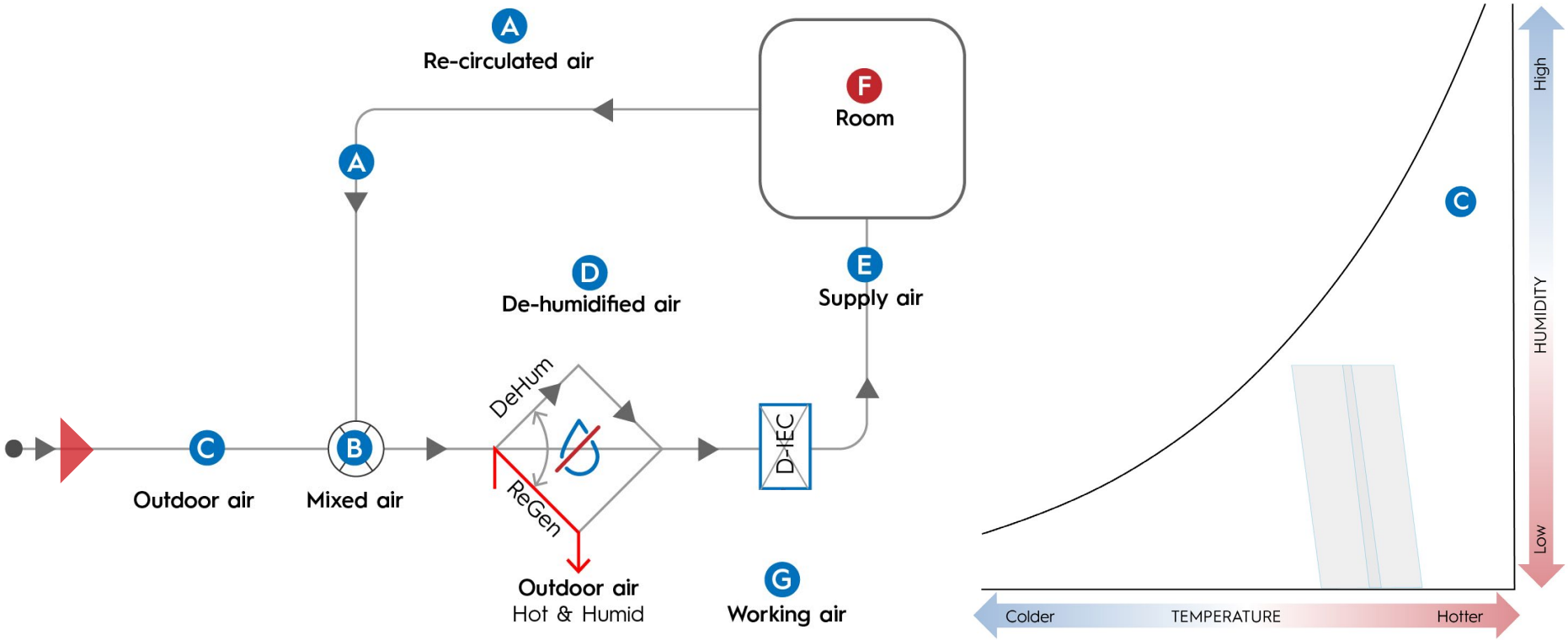
Thermal Resistance

Final Design

Cooler Design

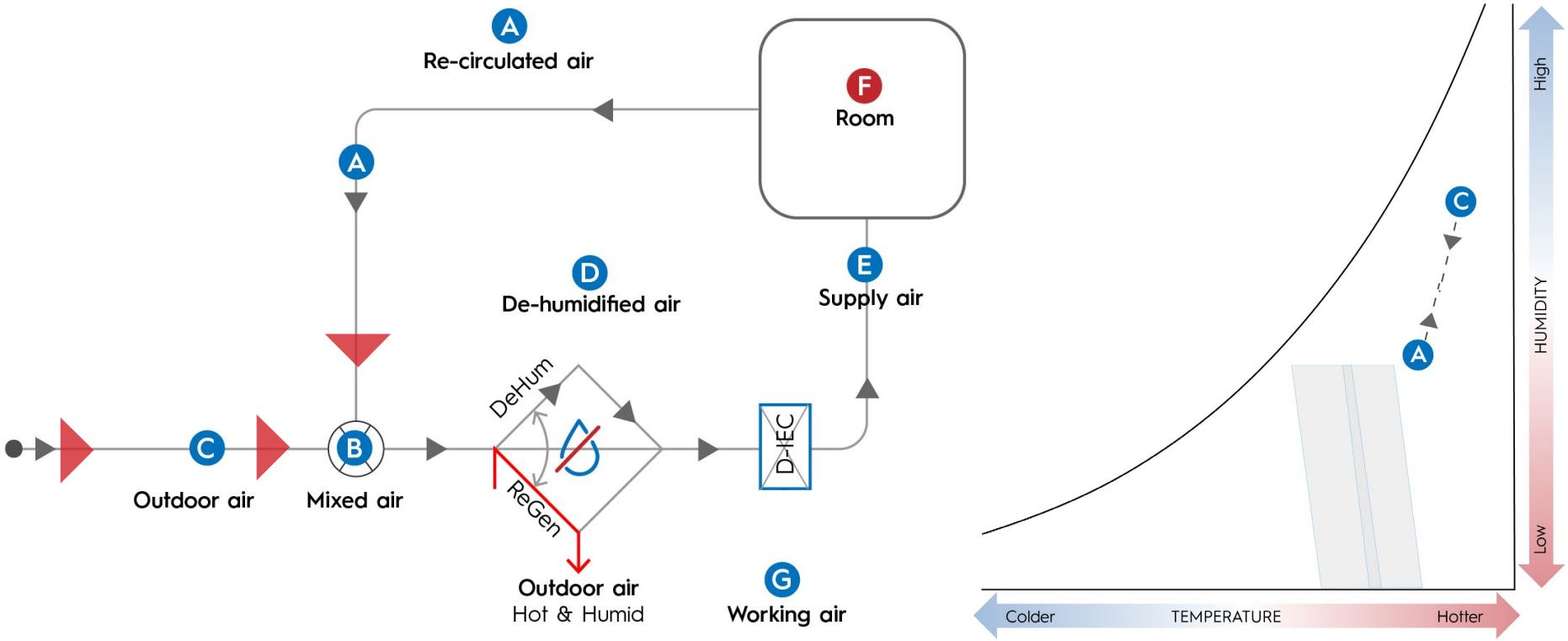


System Design



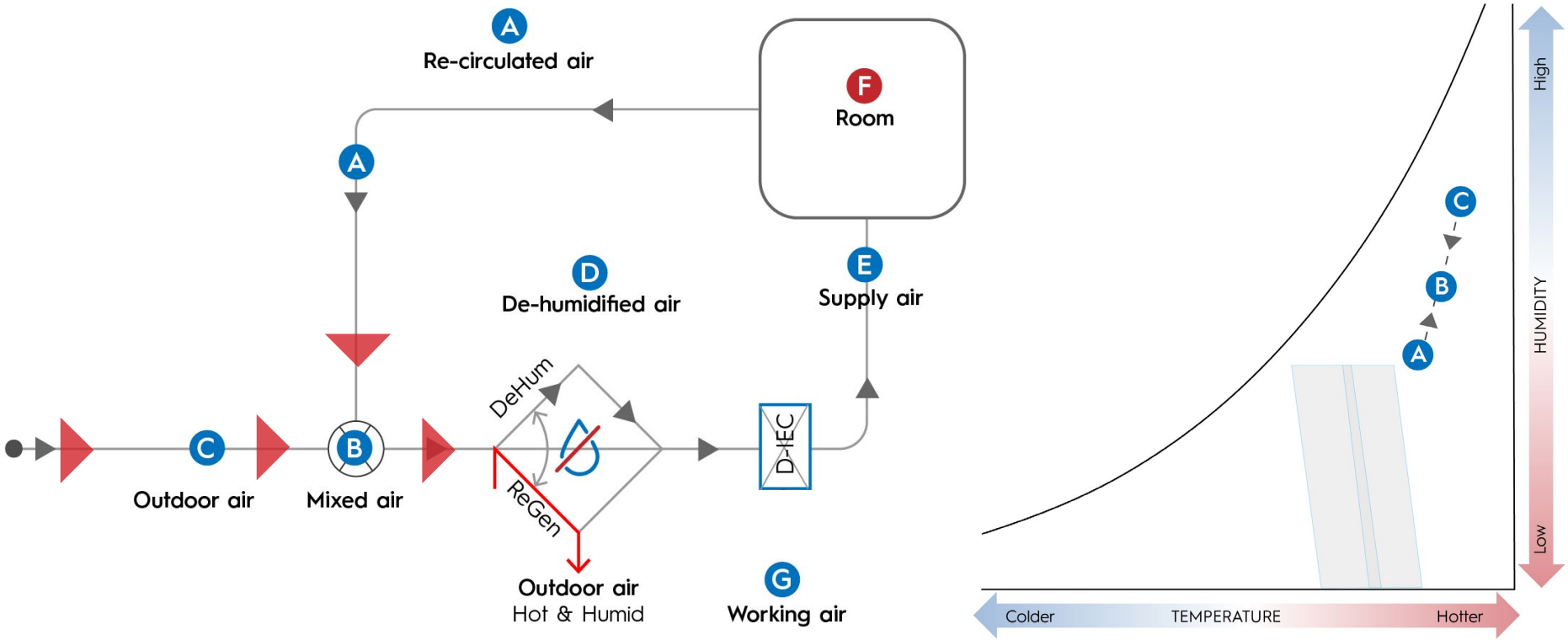
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Process



A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Process



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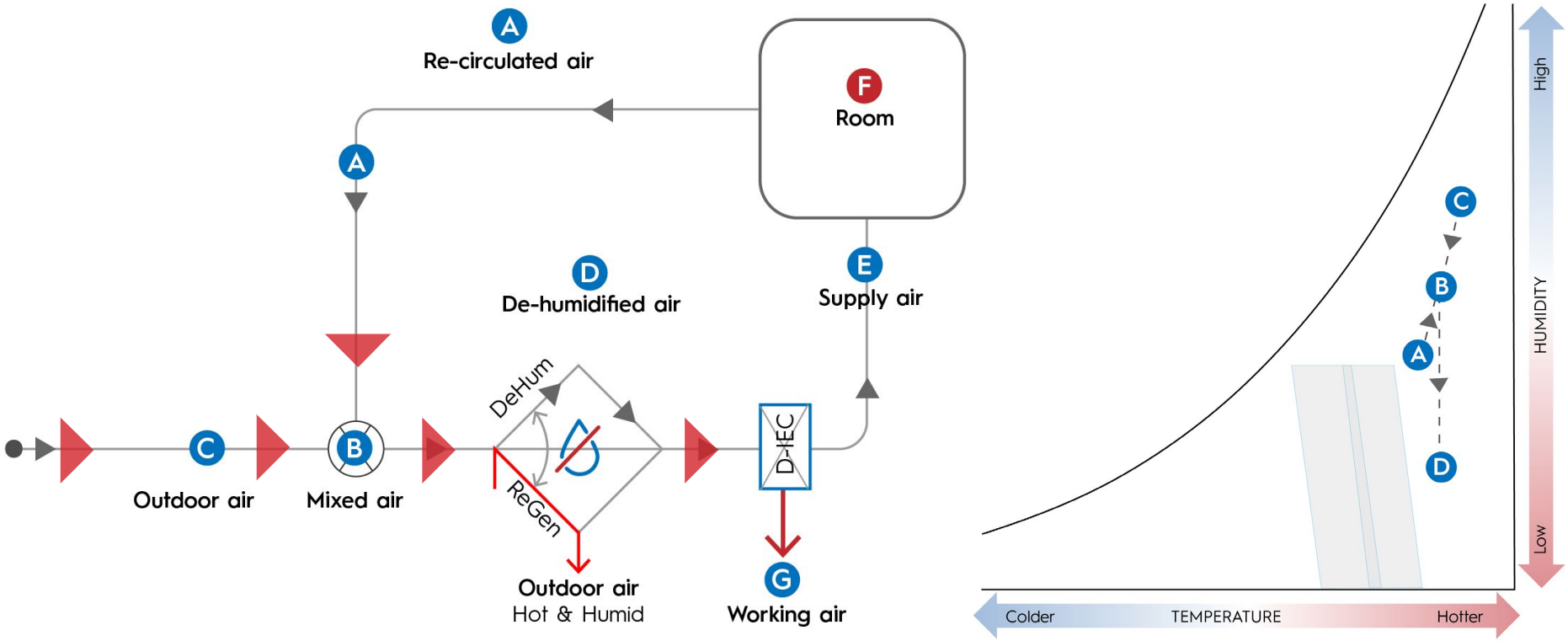
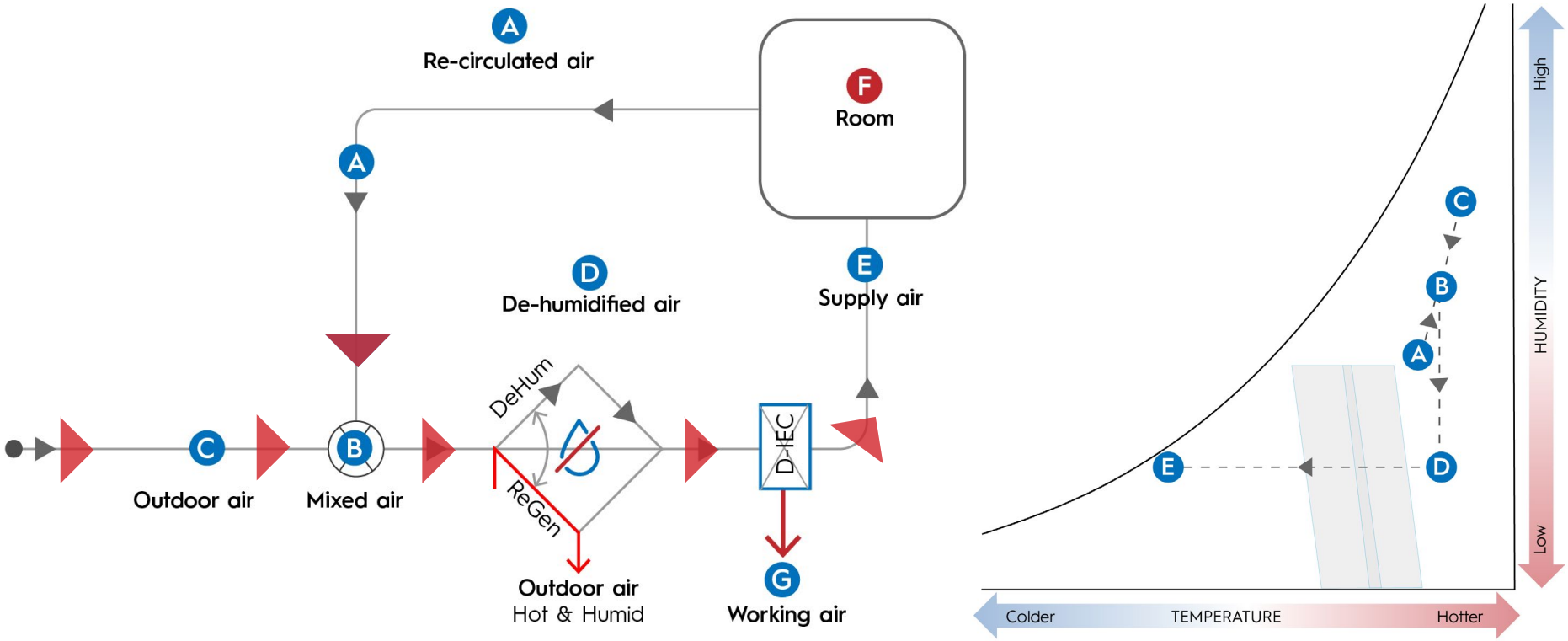
Process



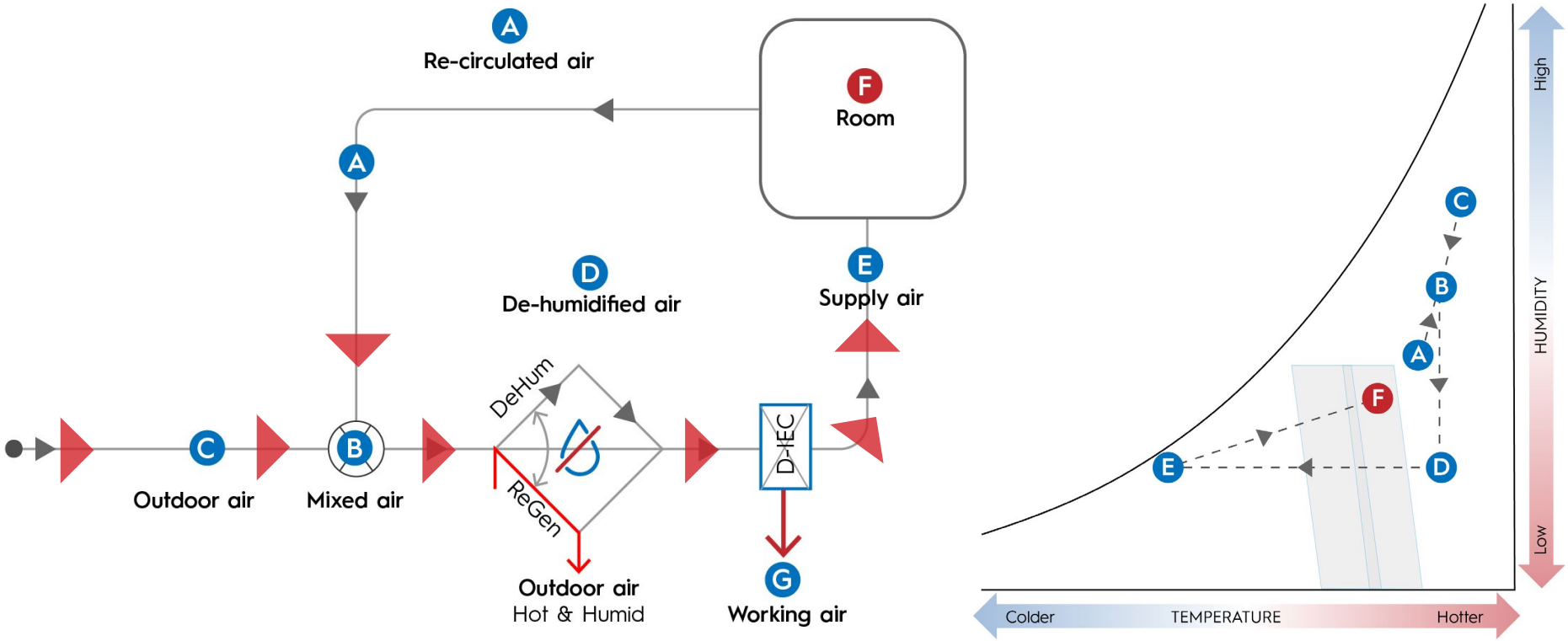
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Process



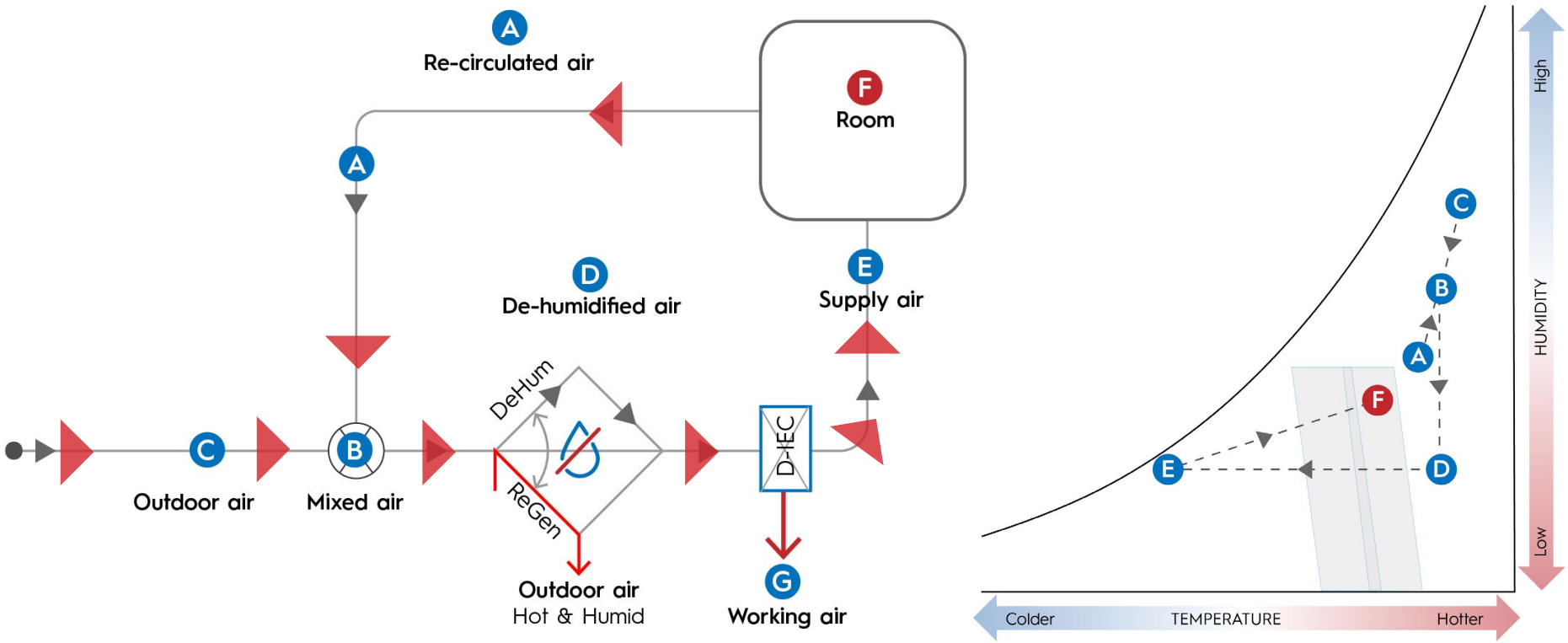
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Process



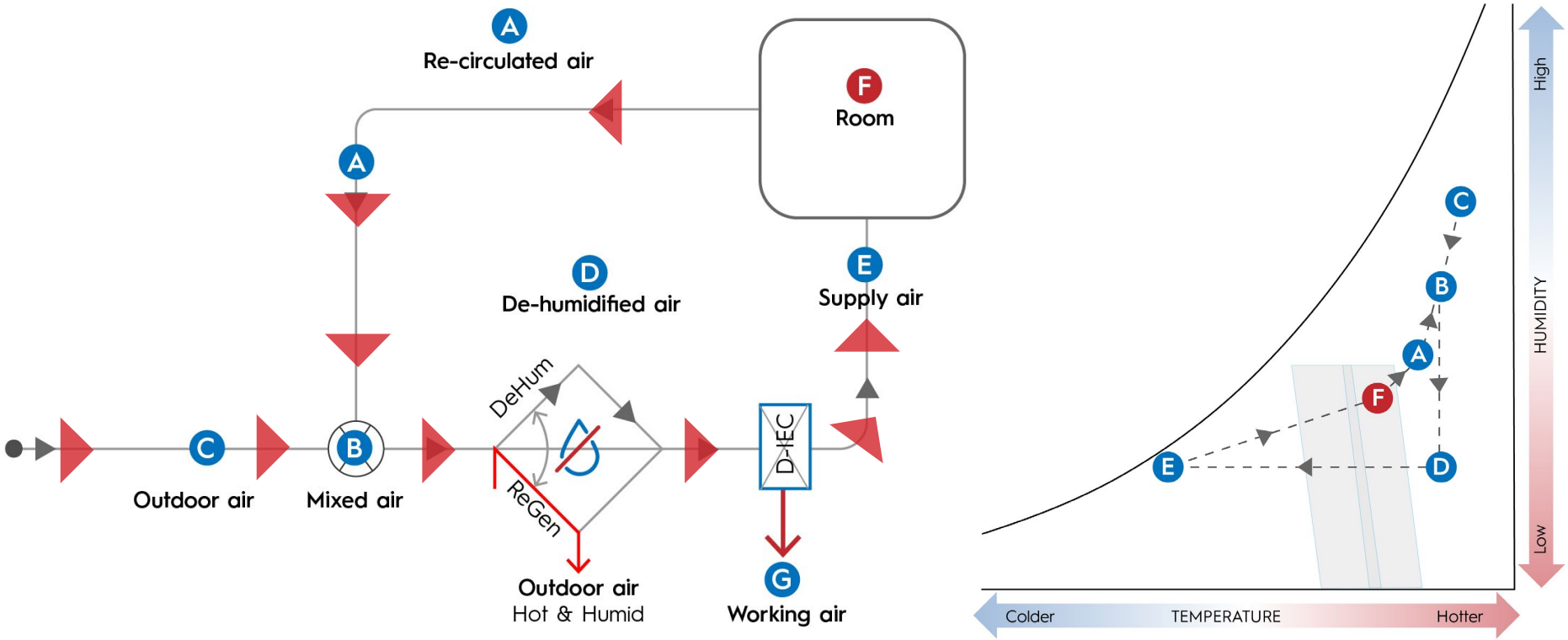
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Process



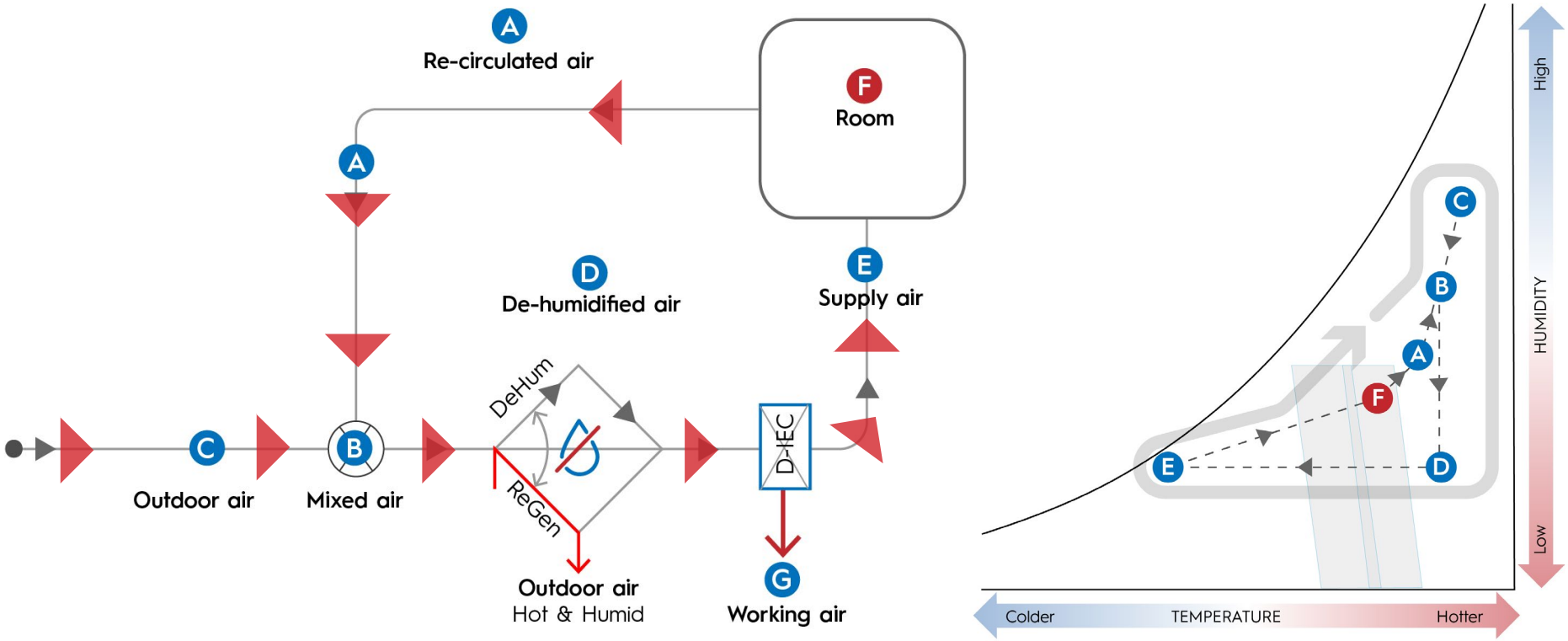
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Process



A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

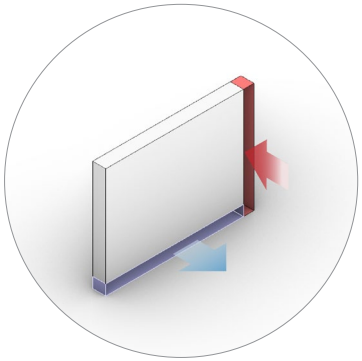
Process



A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

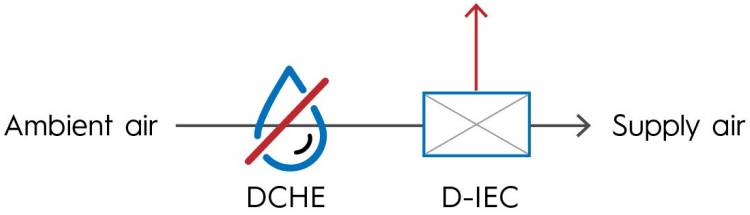
Process

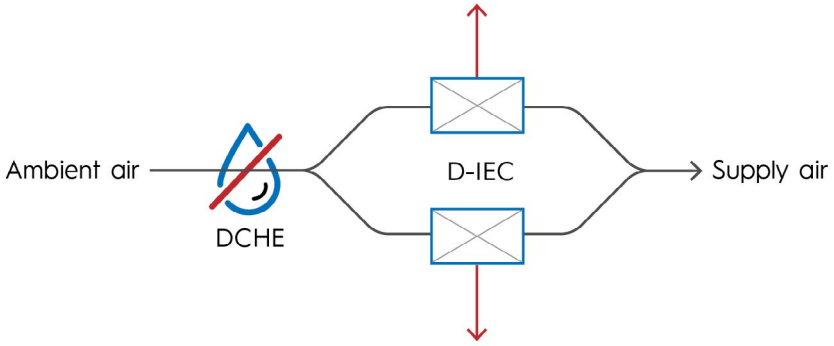
Facade Concepts



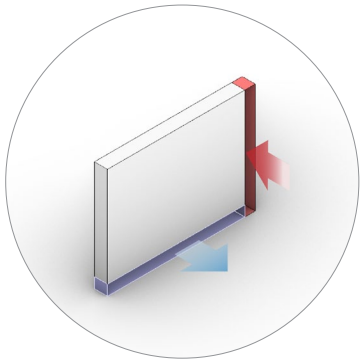
Sill Integrated

Wall Integrated





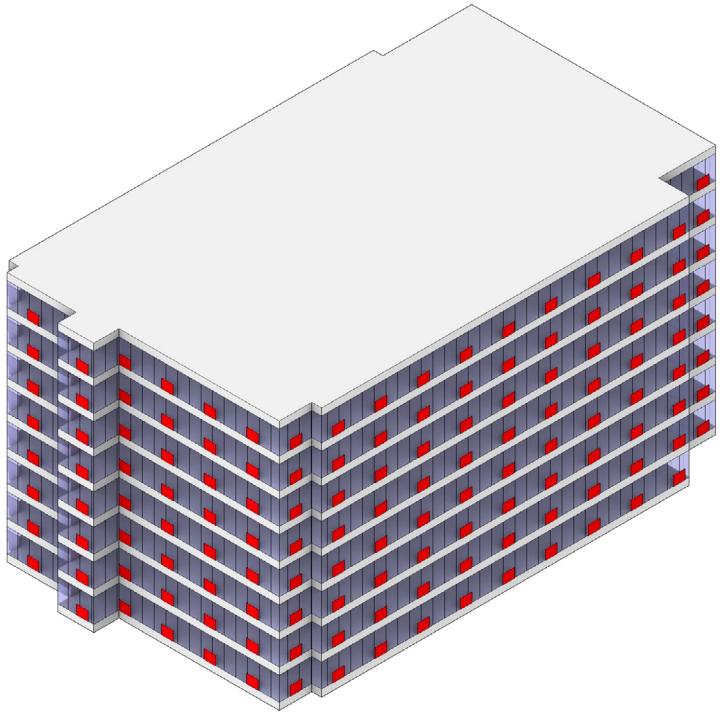
Initial Concepts



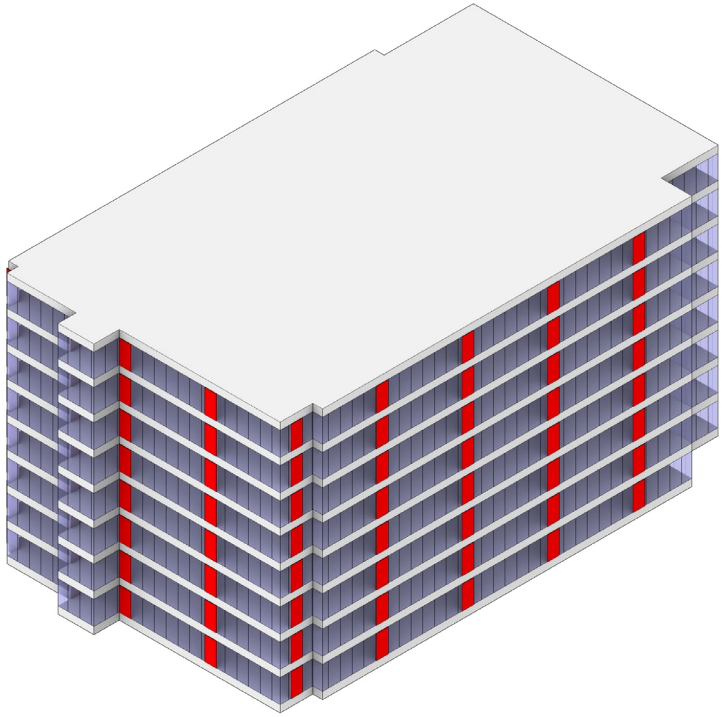
36
No. of Devices
/ per floor

18
No. of Devices
/ per floor

Sill Integrated



Wall Integrated



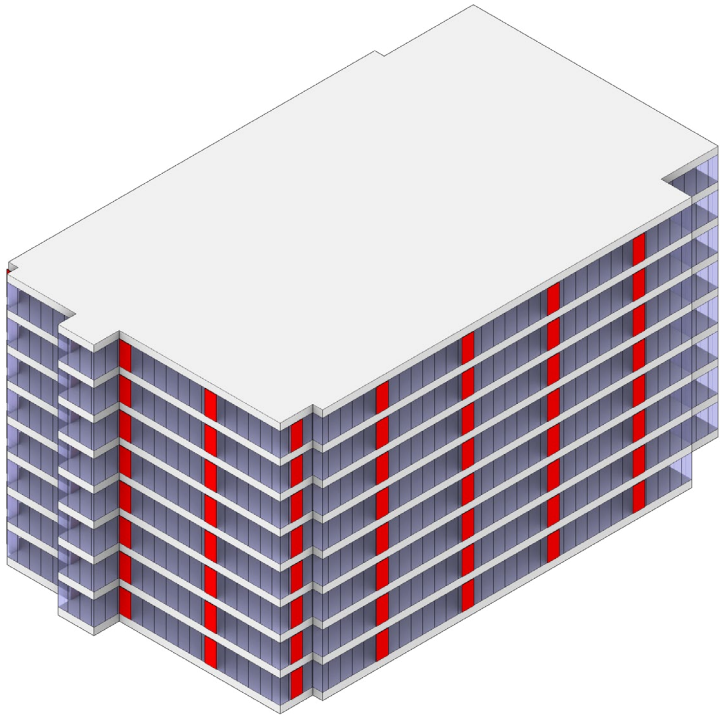
Initial Concepts

36
No. of Devices
/ per floor

18
No. of Devices
/ per floor

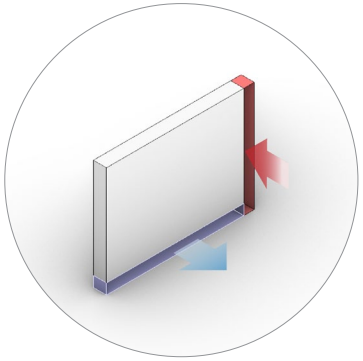
Sill Integrated

Wall Integrated

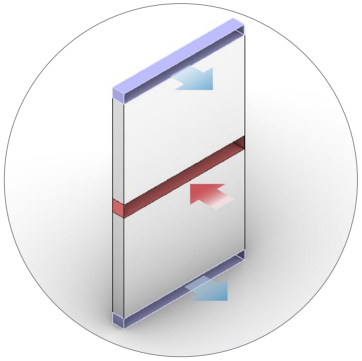


Initial Concepts

Outlet Design



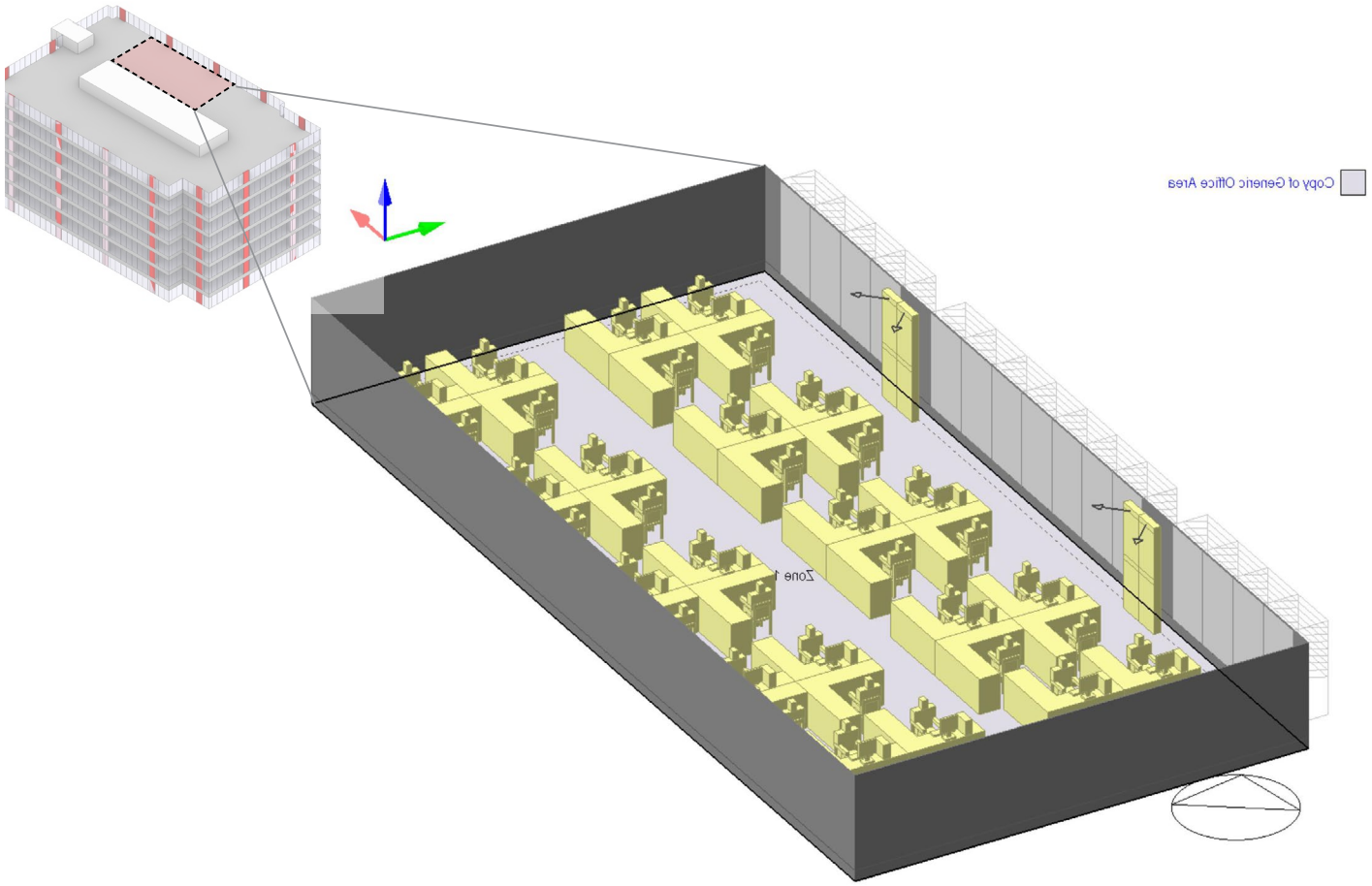
Displacement
Ventilation



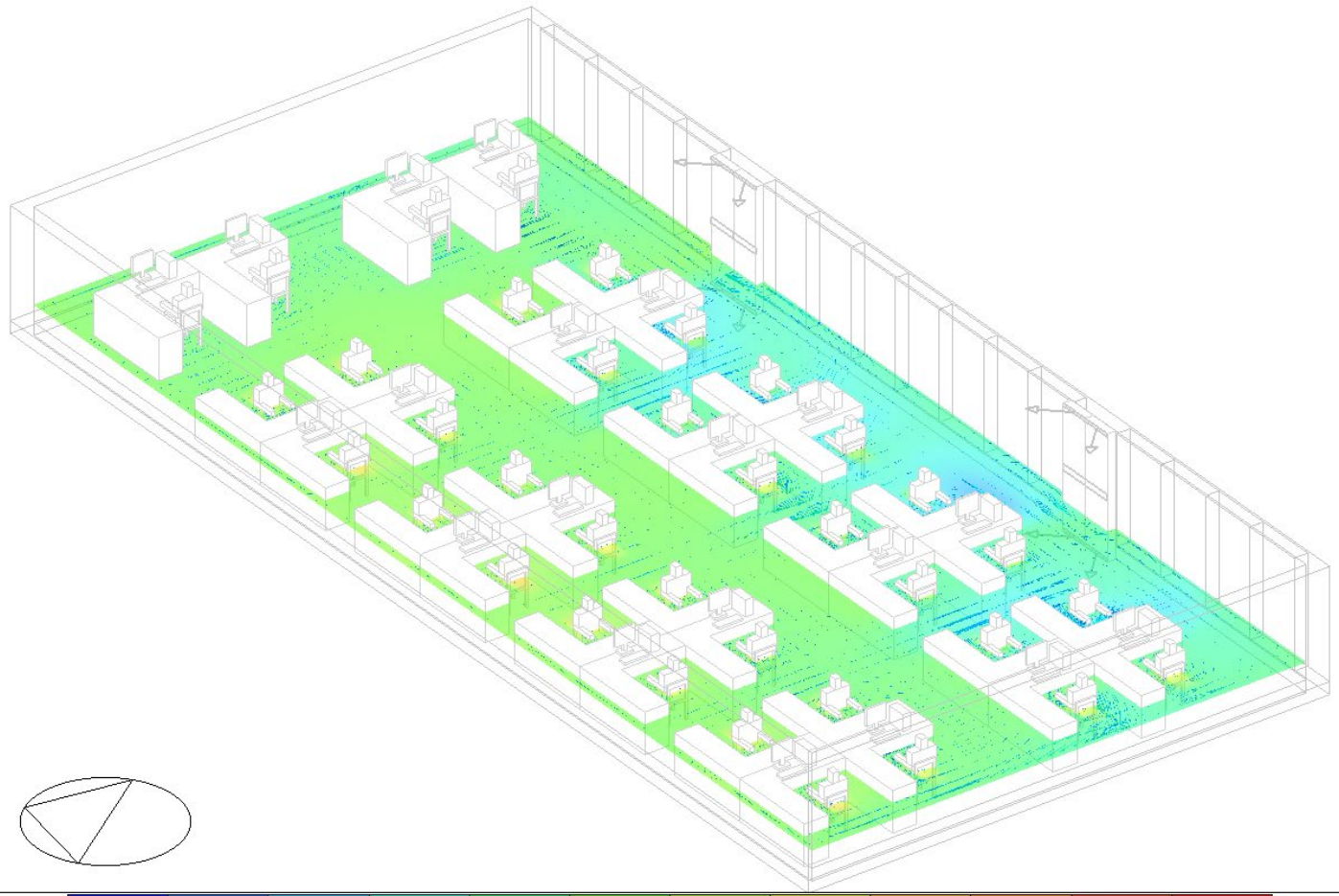
Mixed/Displacement
Ventilation

Mixed
Ventilation

Ventilation Strategy



Ventilation Strategy



@ 0.4 m

@ 1.1 m

@ 1.8 m

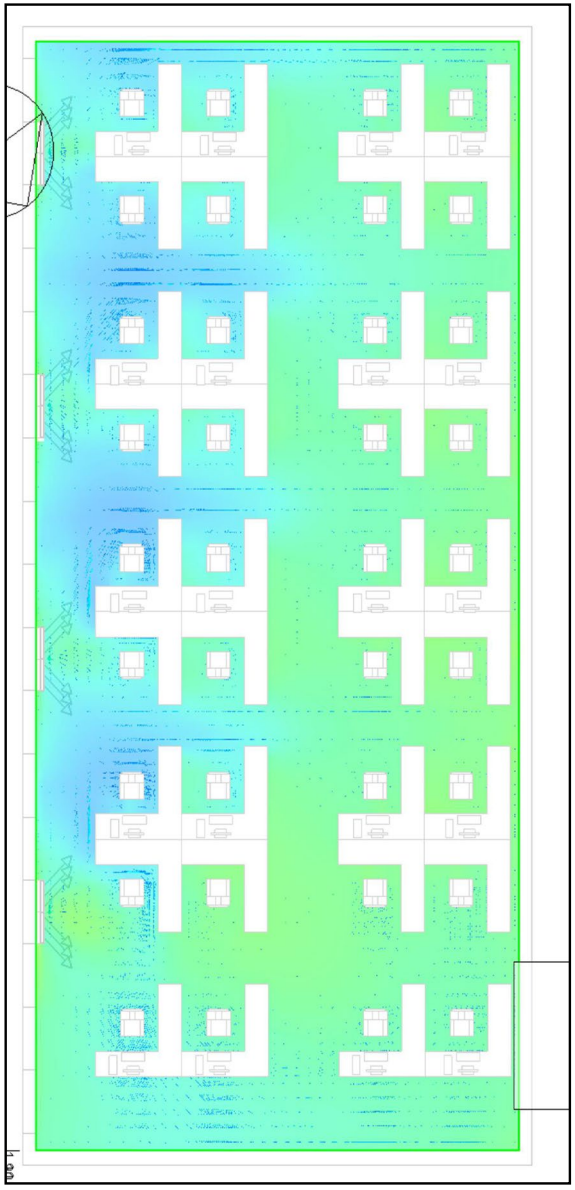
Results

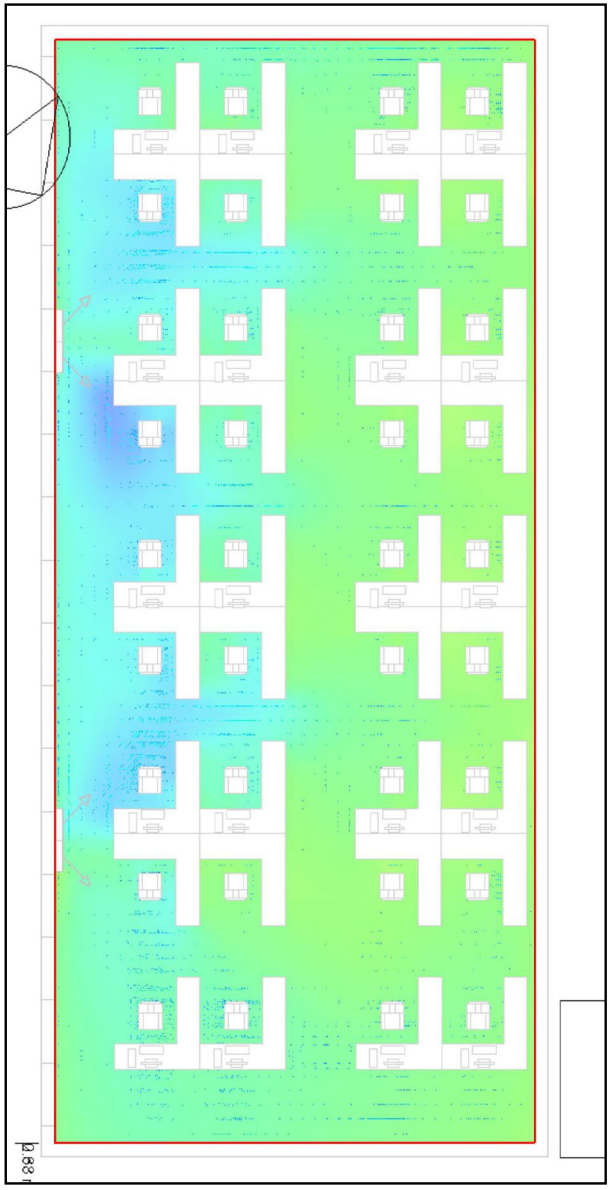
Displacement

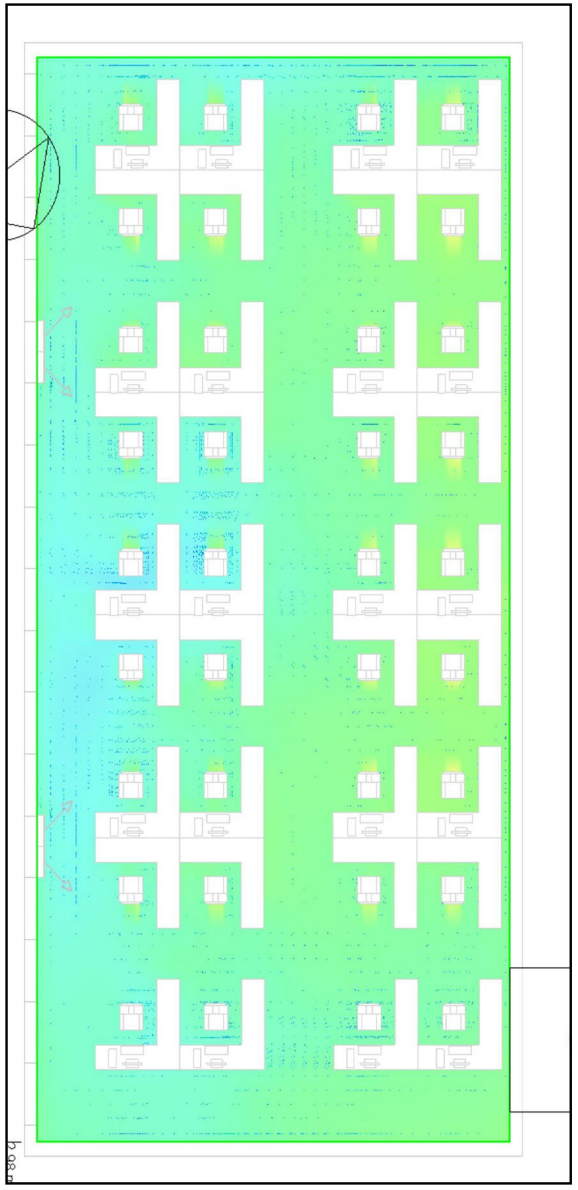
Mixed+Displacement

Mixed

@ 0.4 m







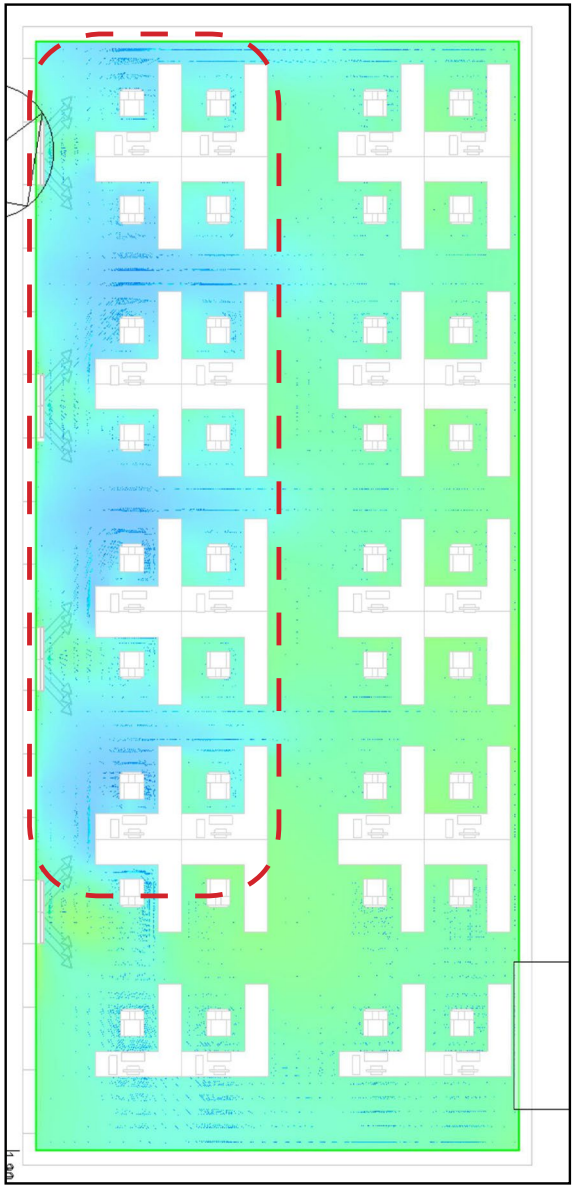
Temperature Distribution @ 0.4m

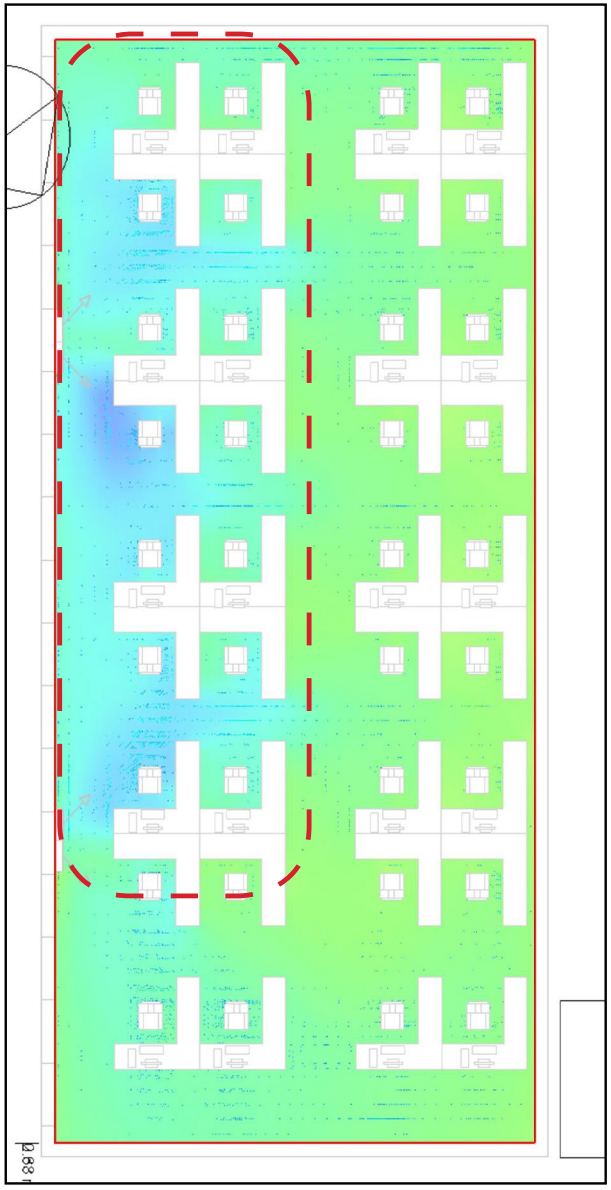
Displacement

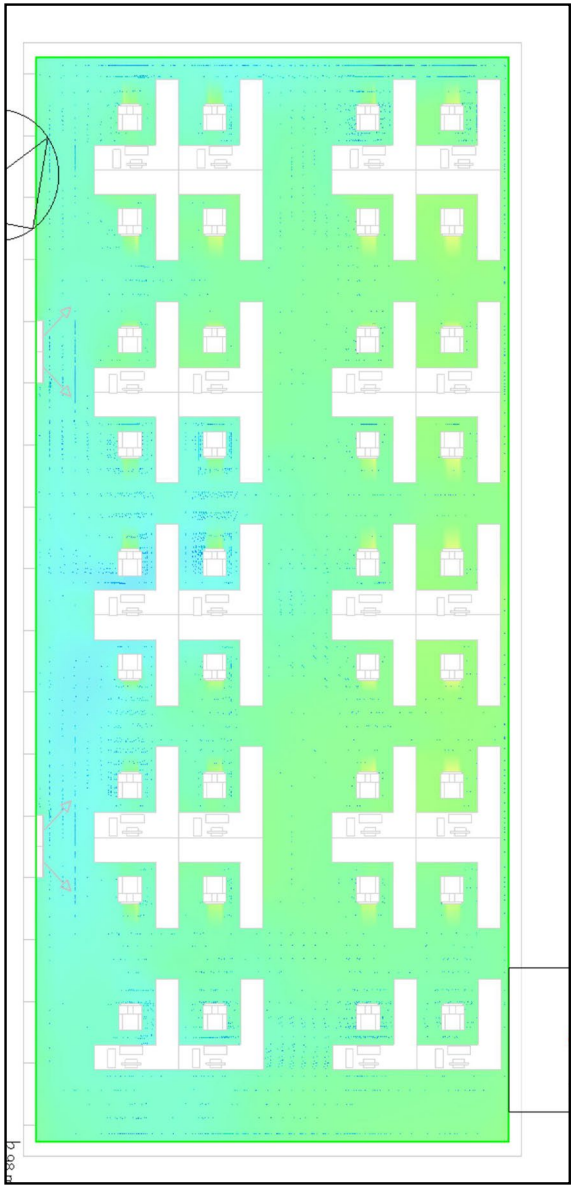
Mixed+Displacement

Mixed

@ 0.4 m







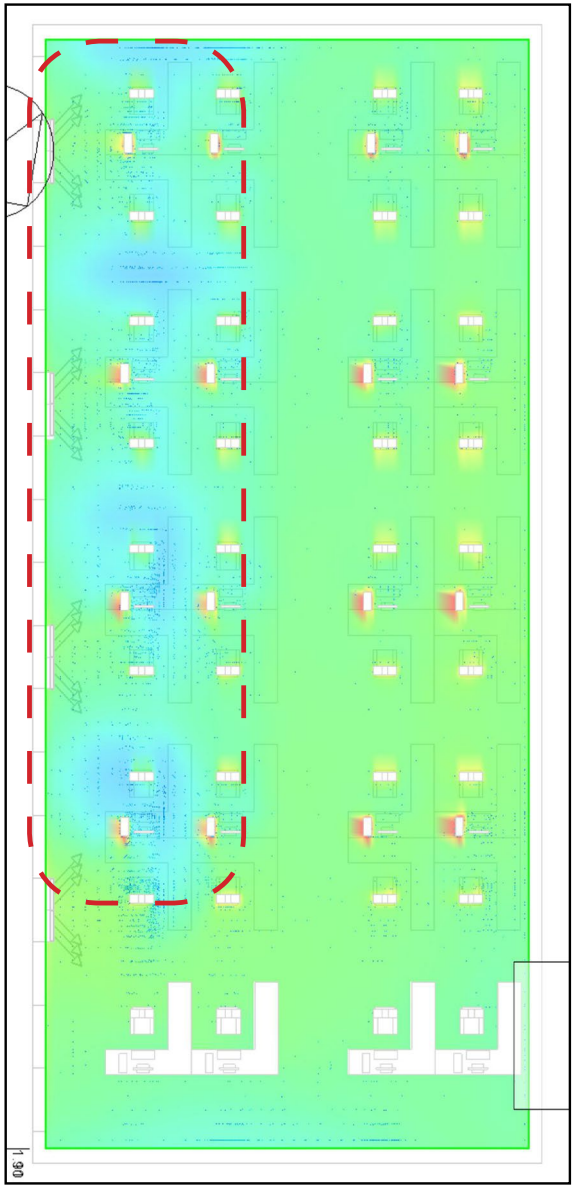
Temperature Distribution @ 0.4m

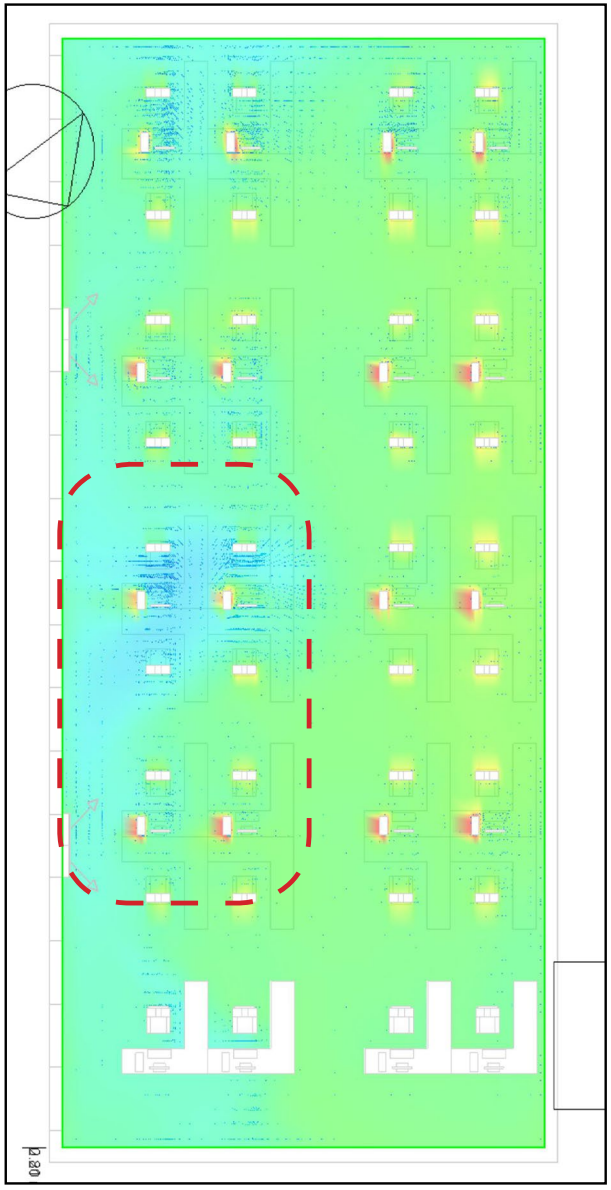
Displacement

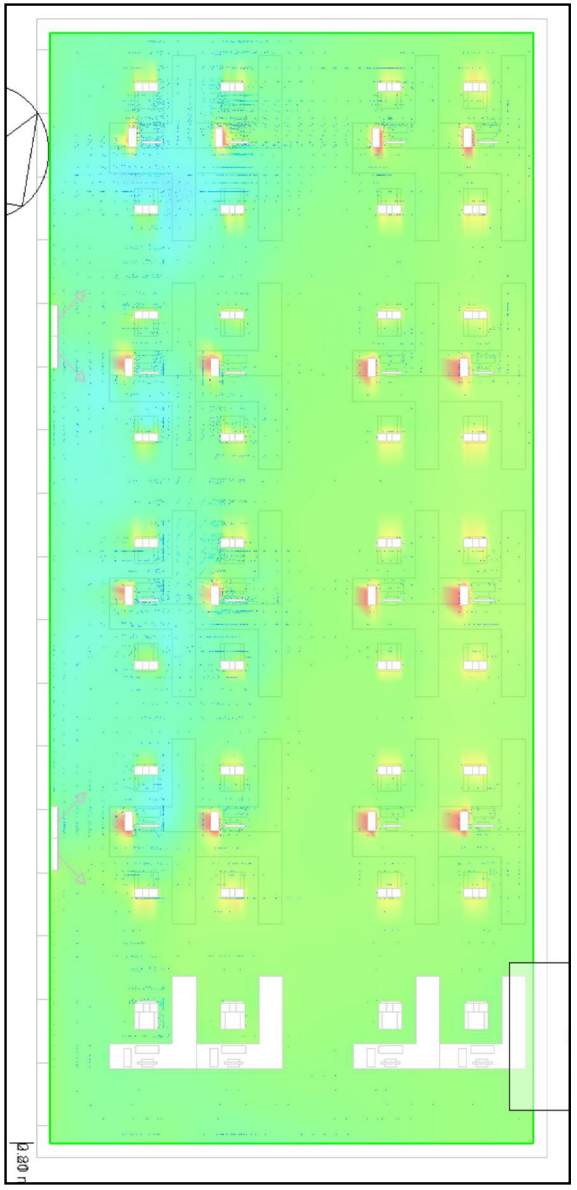
Mixed+Displacement

Mixed

@ 1.1 m







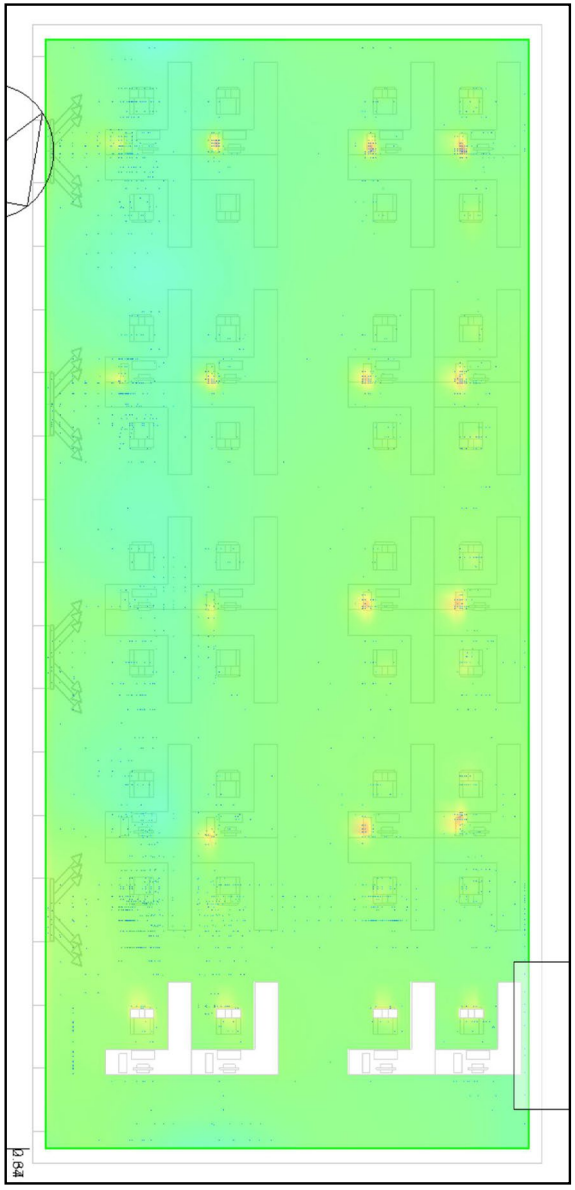
Temperature Distribution @ 1.1m

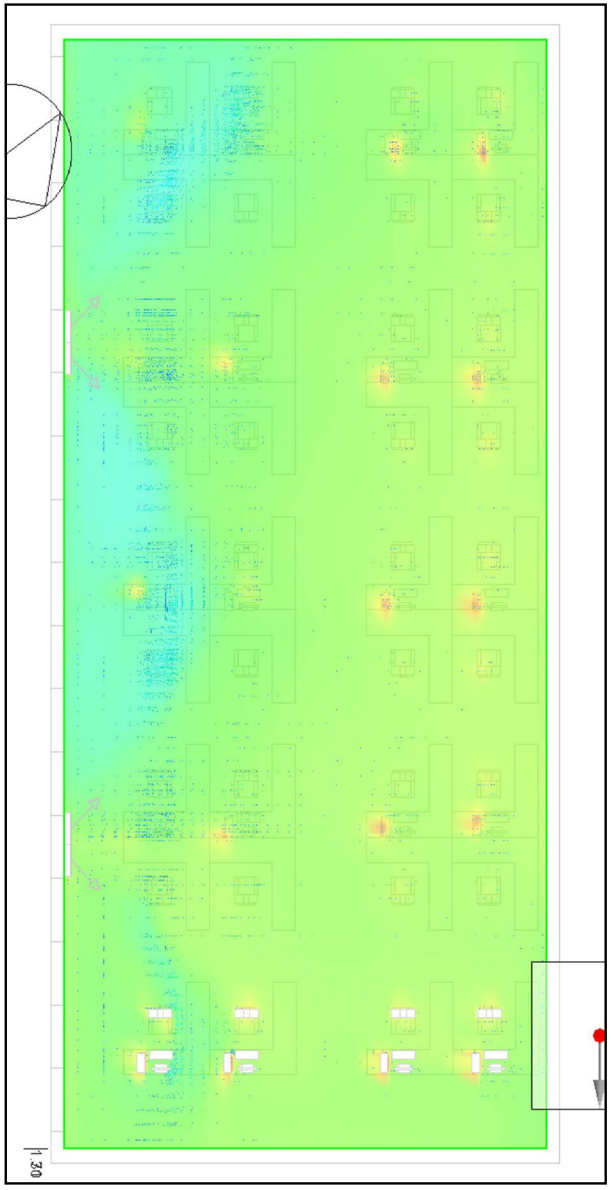
Displacement

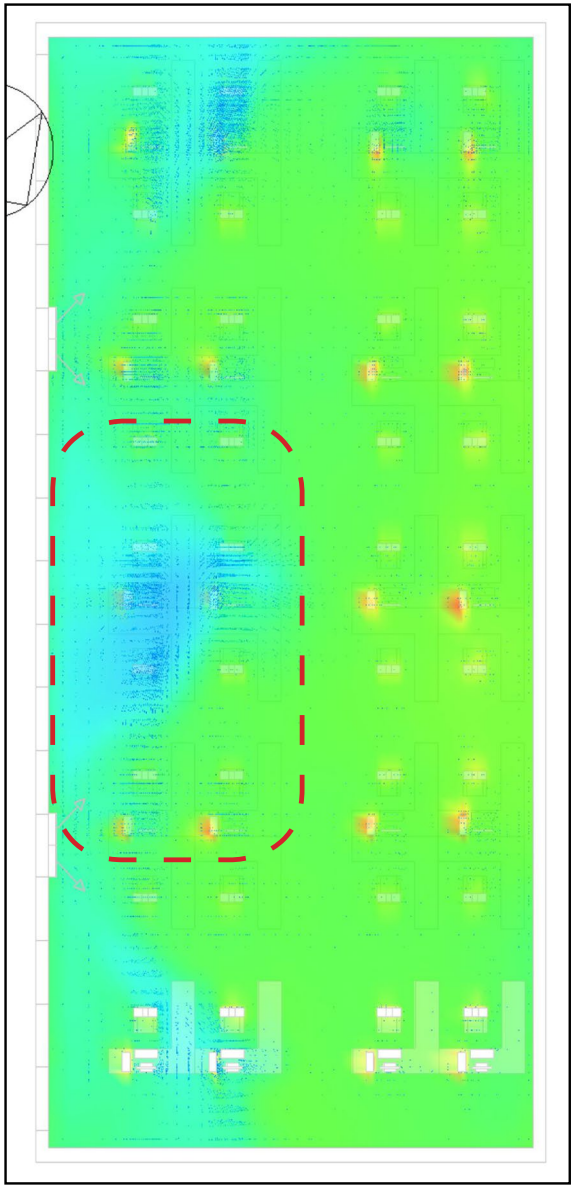
Mixed+Displacement

Mixed

@ 1.8 m







Temperature Distribution @ 1.8m

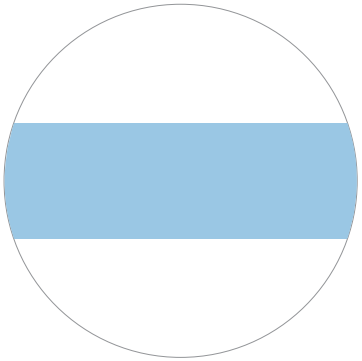
Displacement
Ventilation

Mixed/Displacement
Ventilation

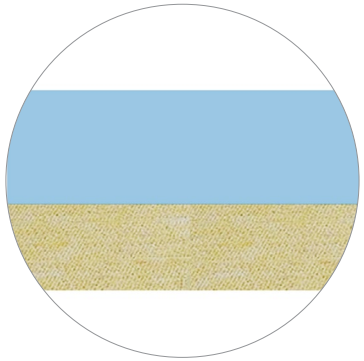
Mixed
Ventilation

Ventilation Strategy

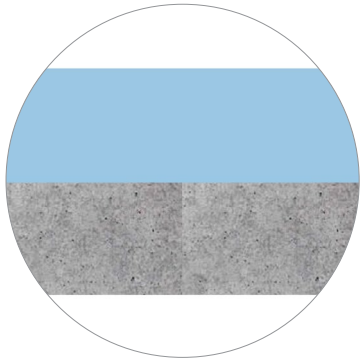
Thermal Resistance



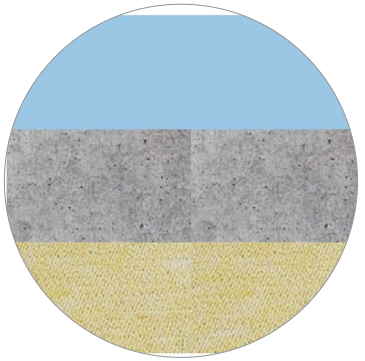
Standalone System



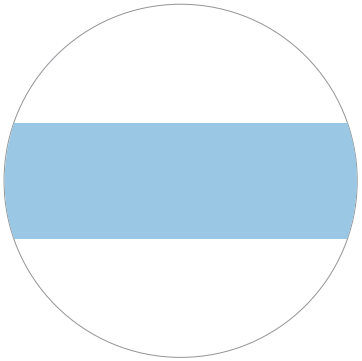
100mm XPS



150mm Concrete

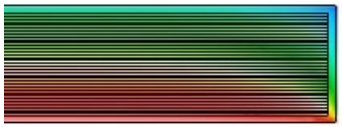


150mm Concrete + 100mmXPS

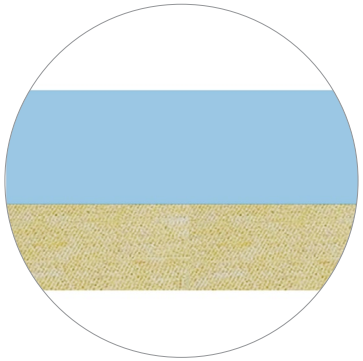


Standalone System

Inside

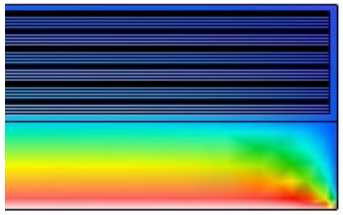


Outside

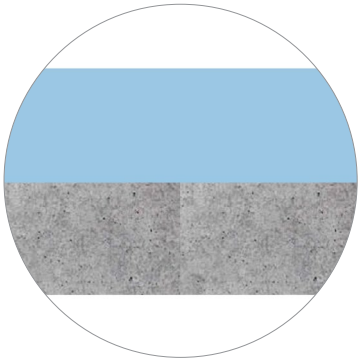


100mm XPS

Inside

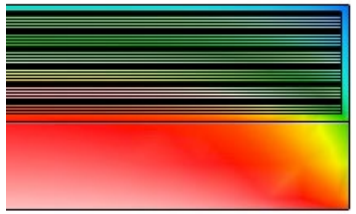


Outside

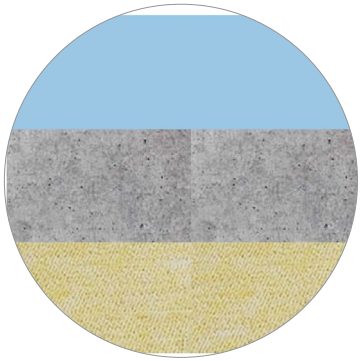


150mm Concrete

Inside

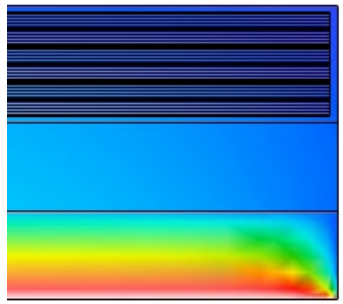


Outside

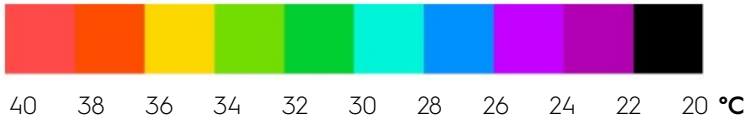


150mm Concrete + 100mmXPS

Inside



Outside

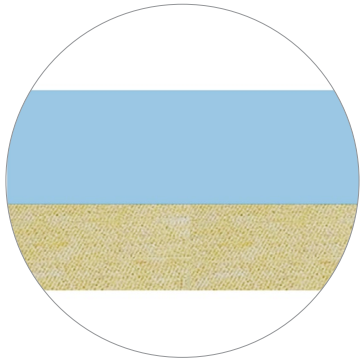


Thermal Performance

Standalone System

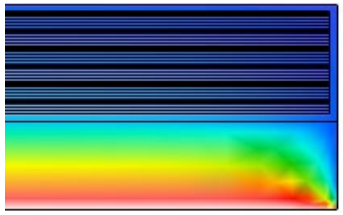
Inside

Outside



100mm XPS

Inside



Outside

150mm Concrete

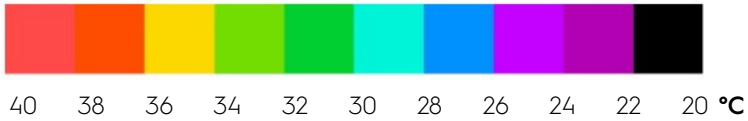
Inside

Outside

150mm Concrete + 100mmXPS

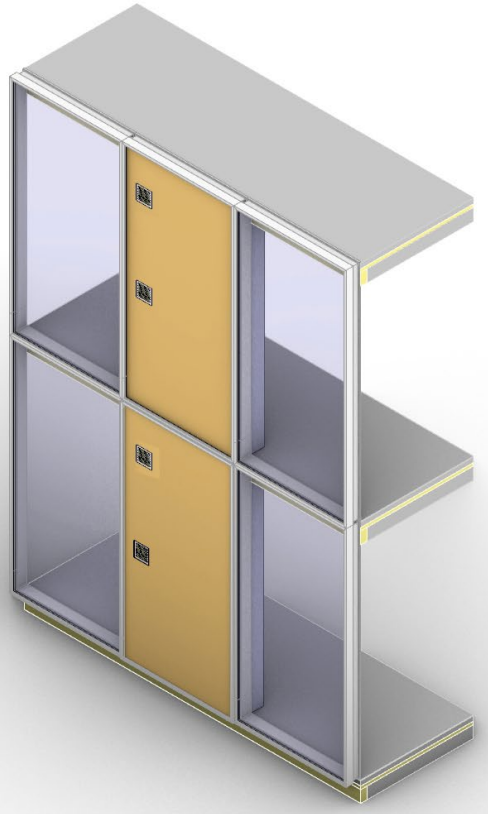
Inside

Outside

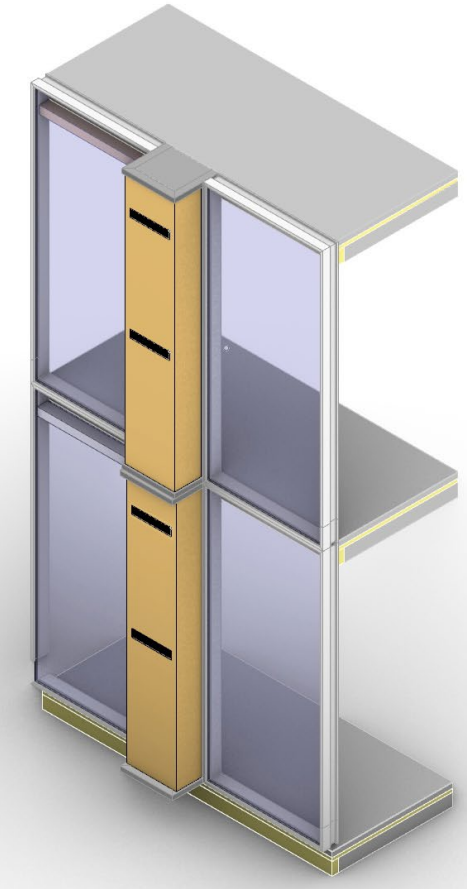


Thermal Performance

Final Design

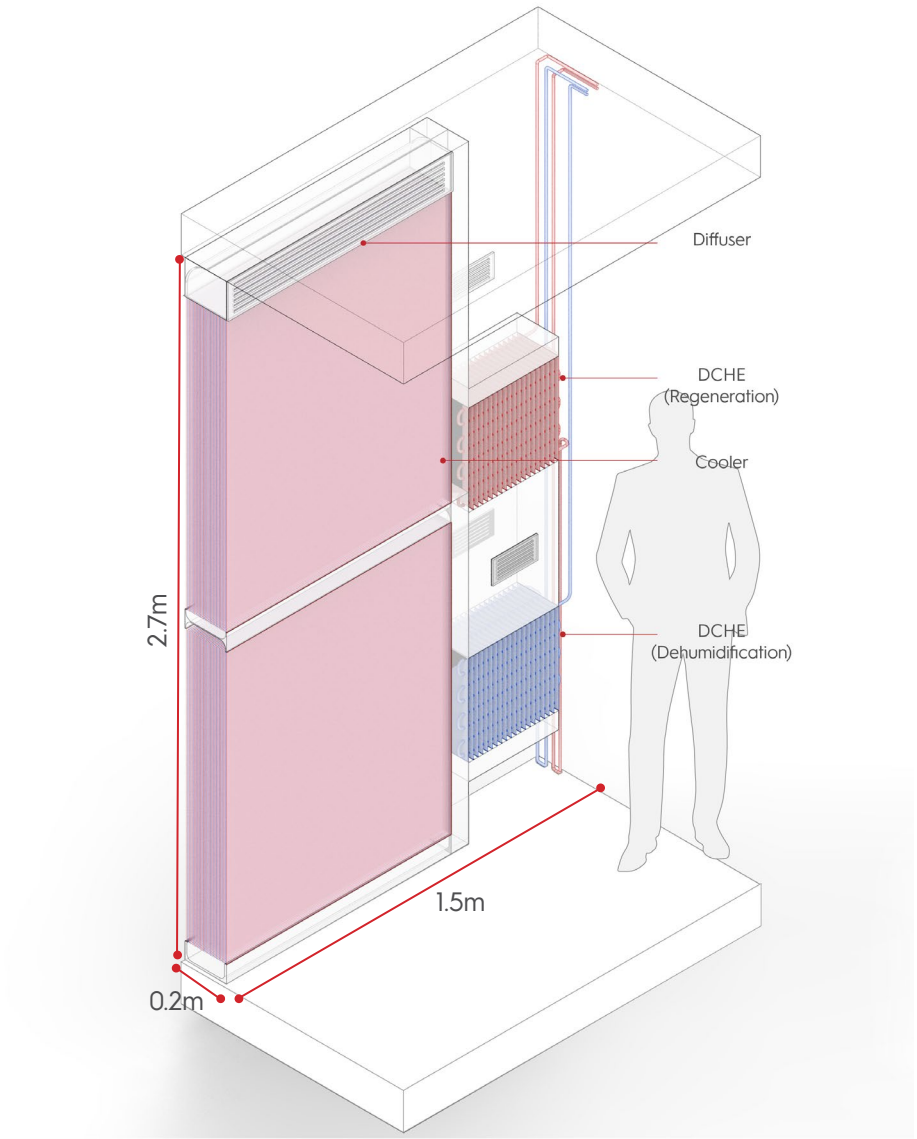


Wall Integrated System
2.7m high



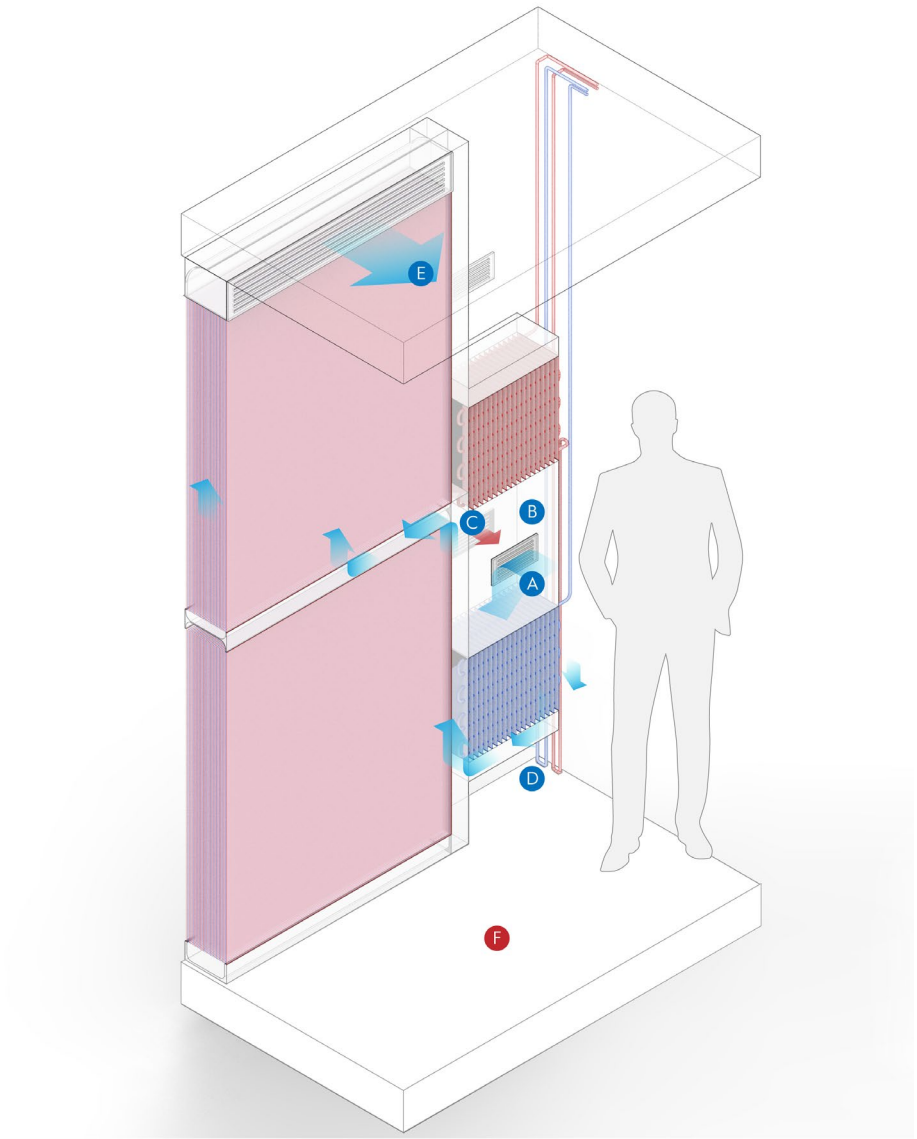
Shade Integrated System
3.0m high

Final Designs



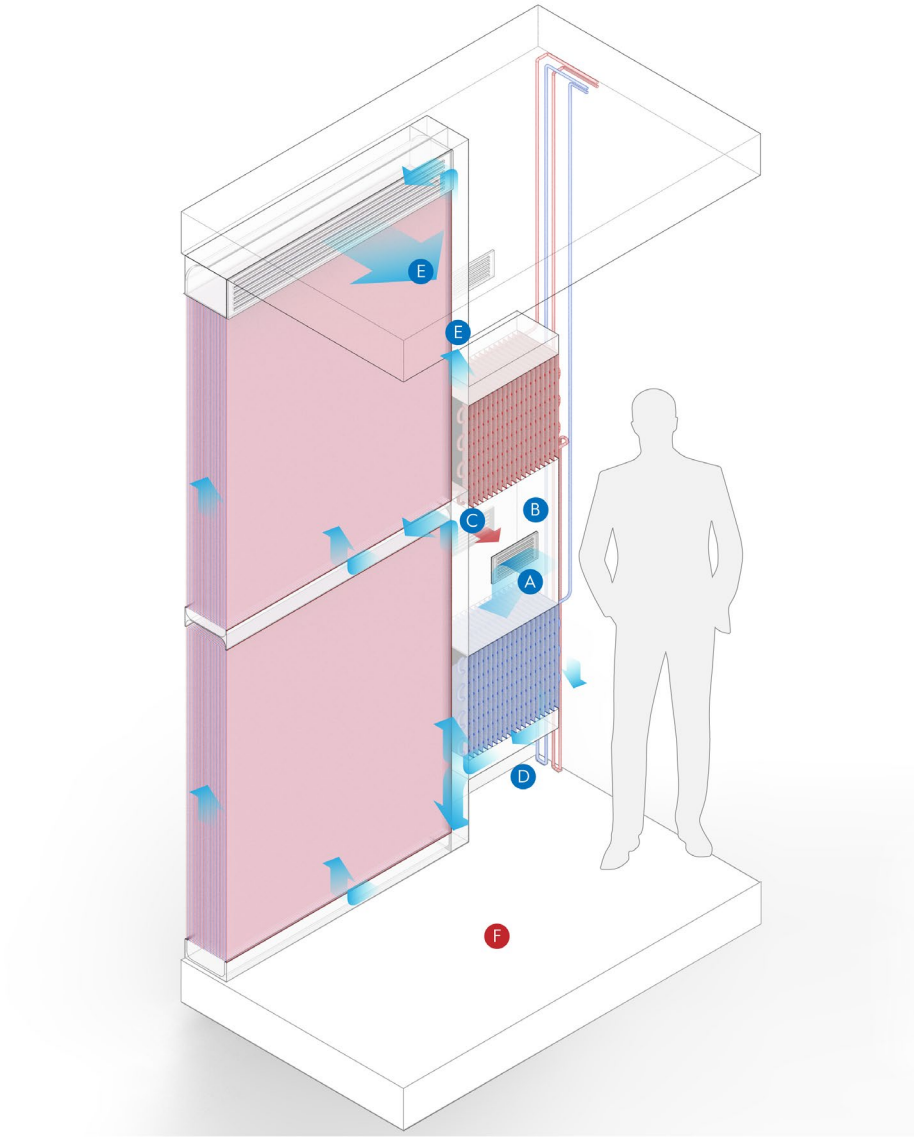
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Variation 01 - Wall System



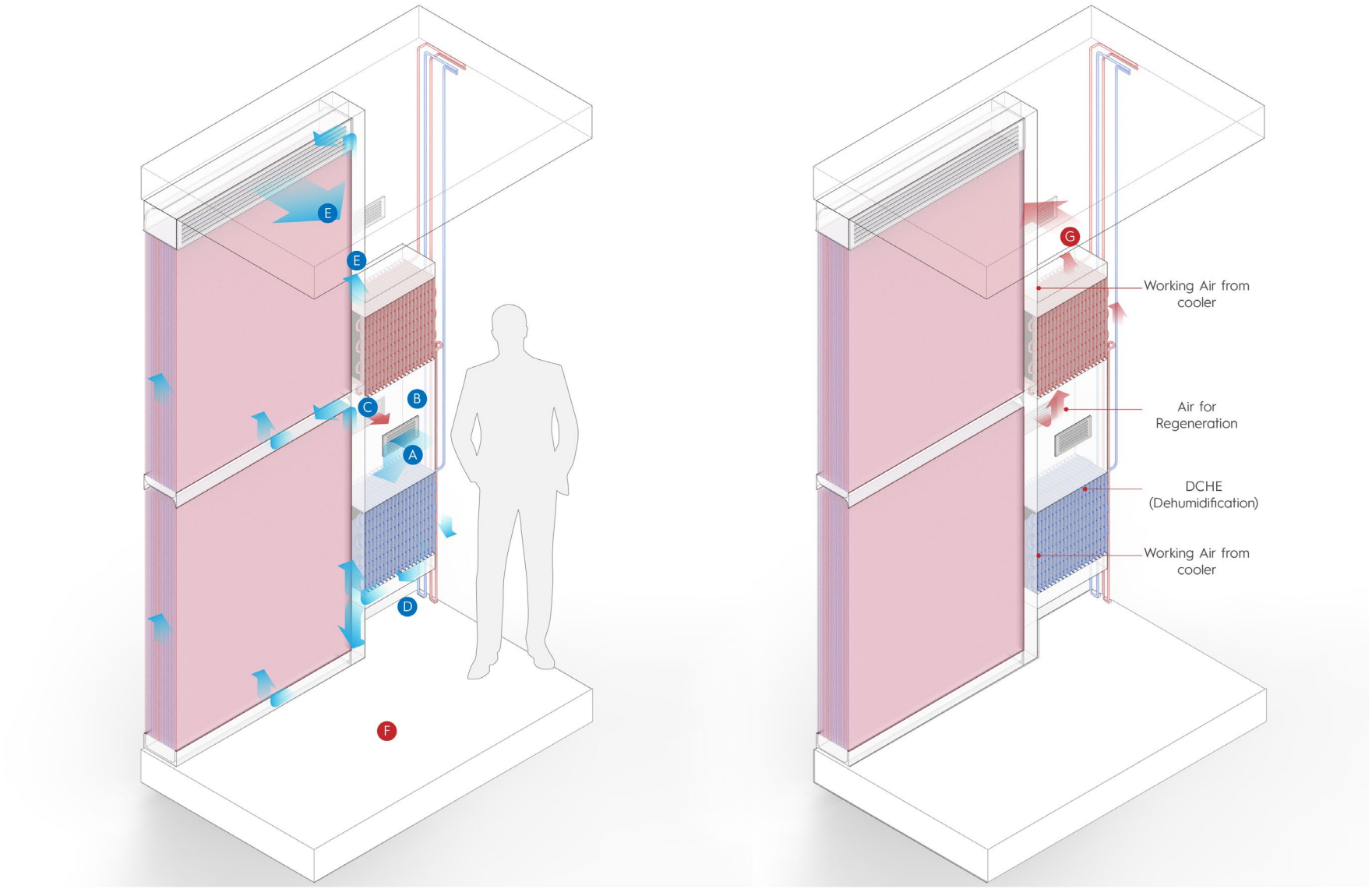
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Variation 01 - Wall System



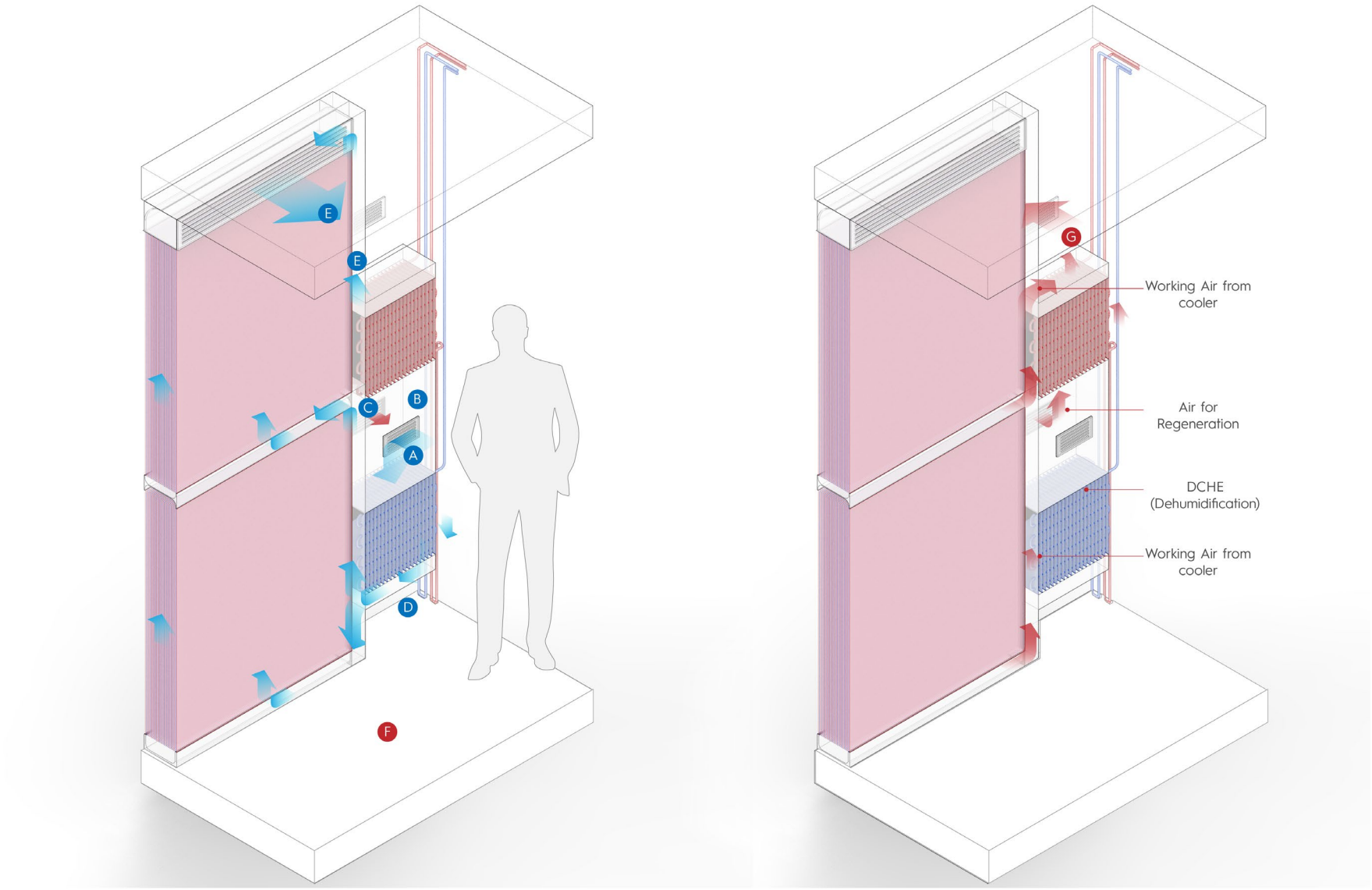
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Variation 01 - Wall System



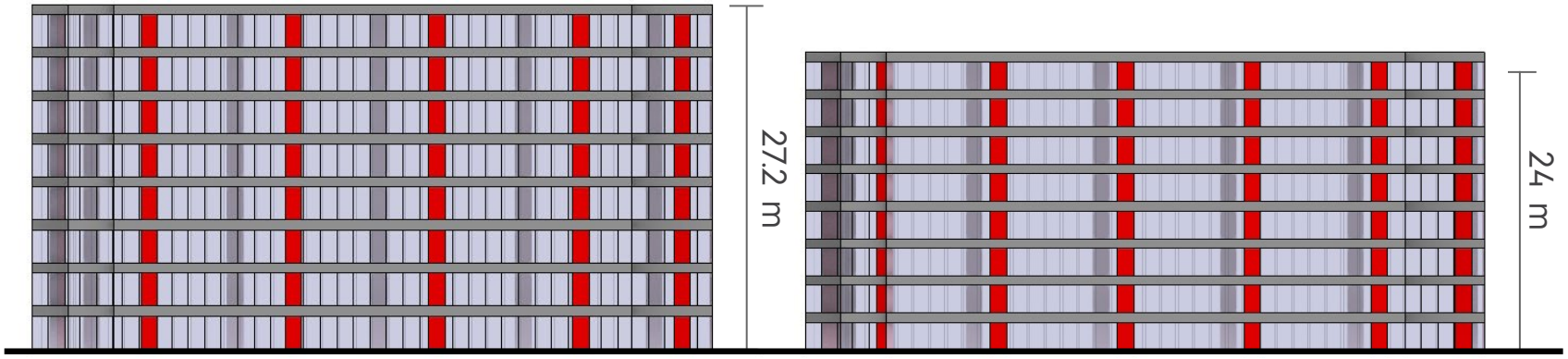
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Variation 01 - Wall System

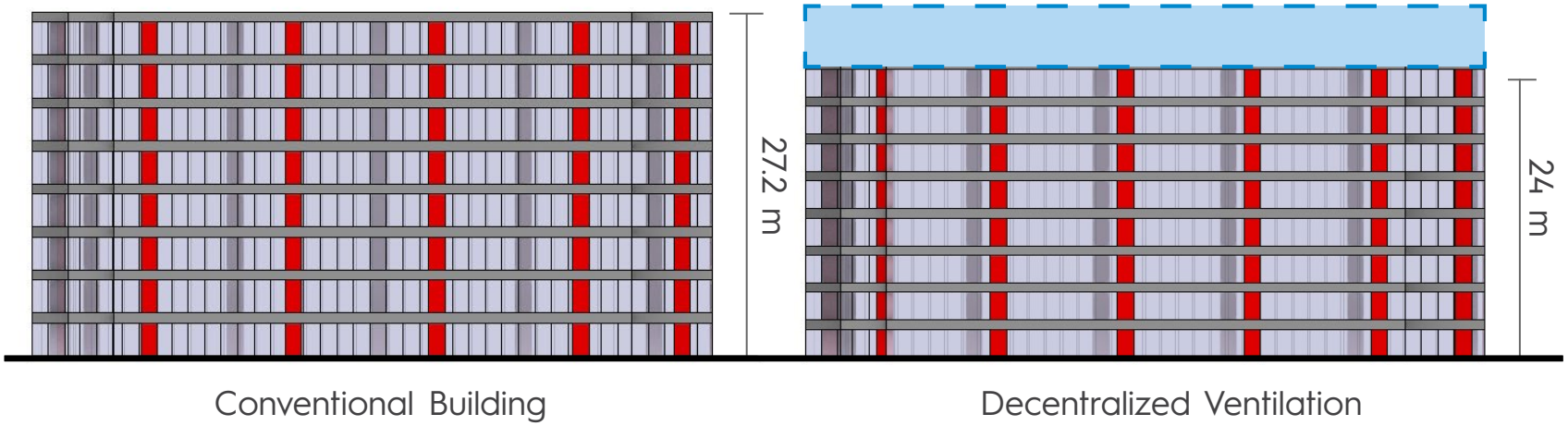


A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Variation 01 - Wall System

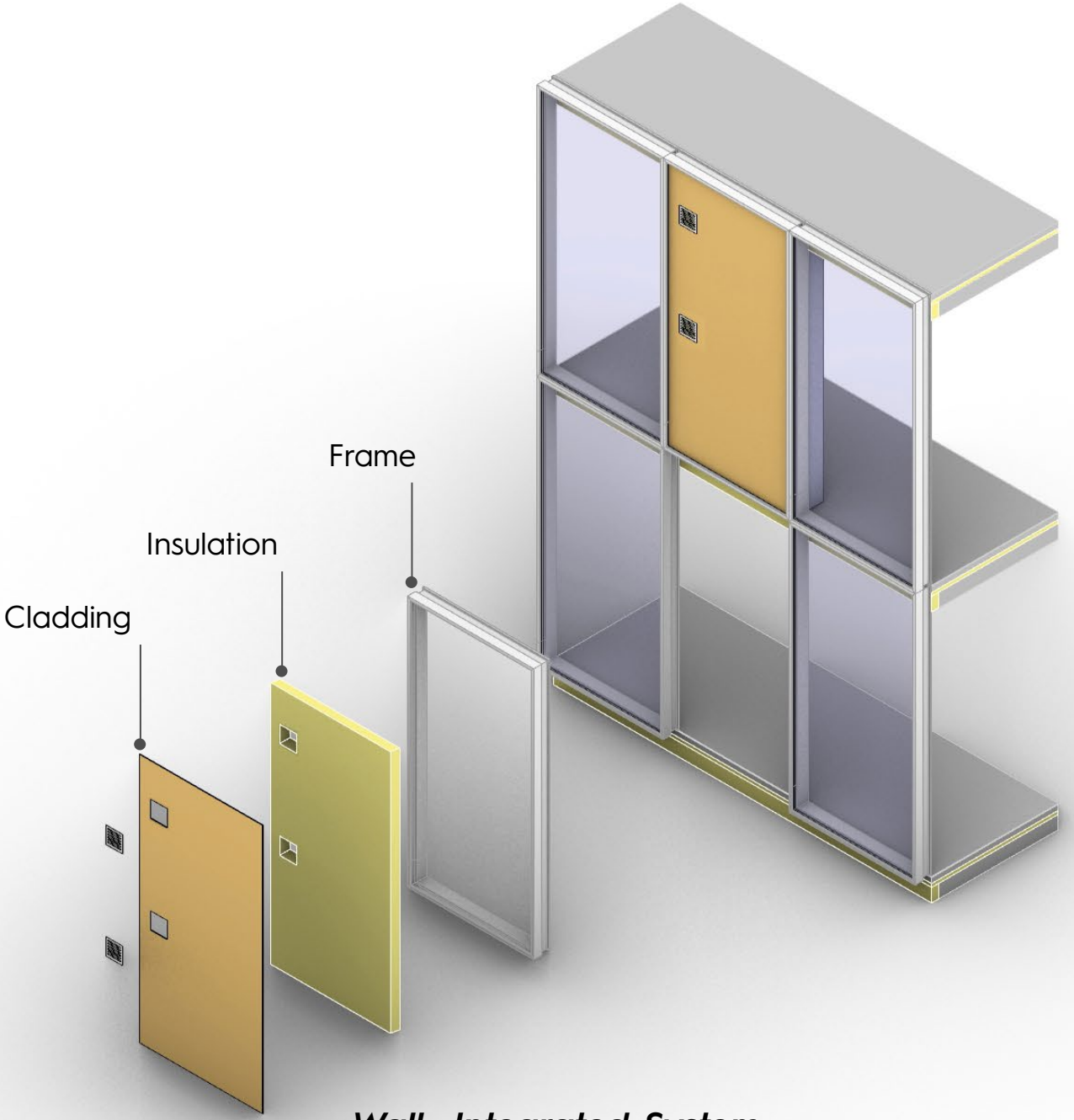

27.2 m
24 m
Conventional Building
Decentralized Ventilation

Advantages

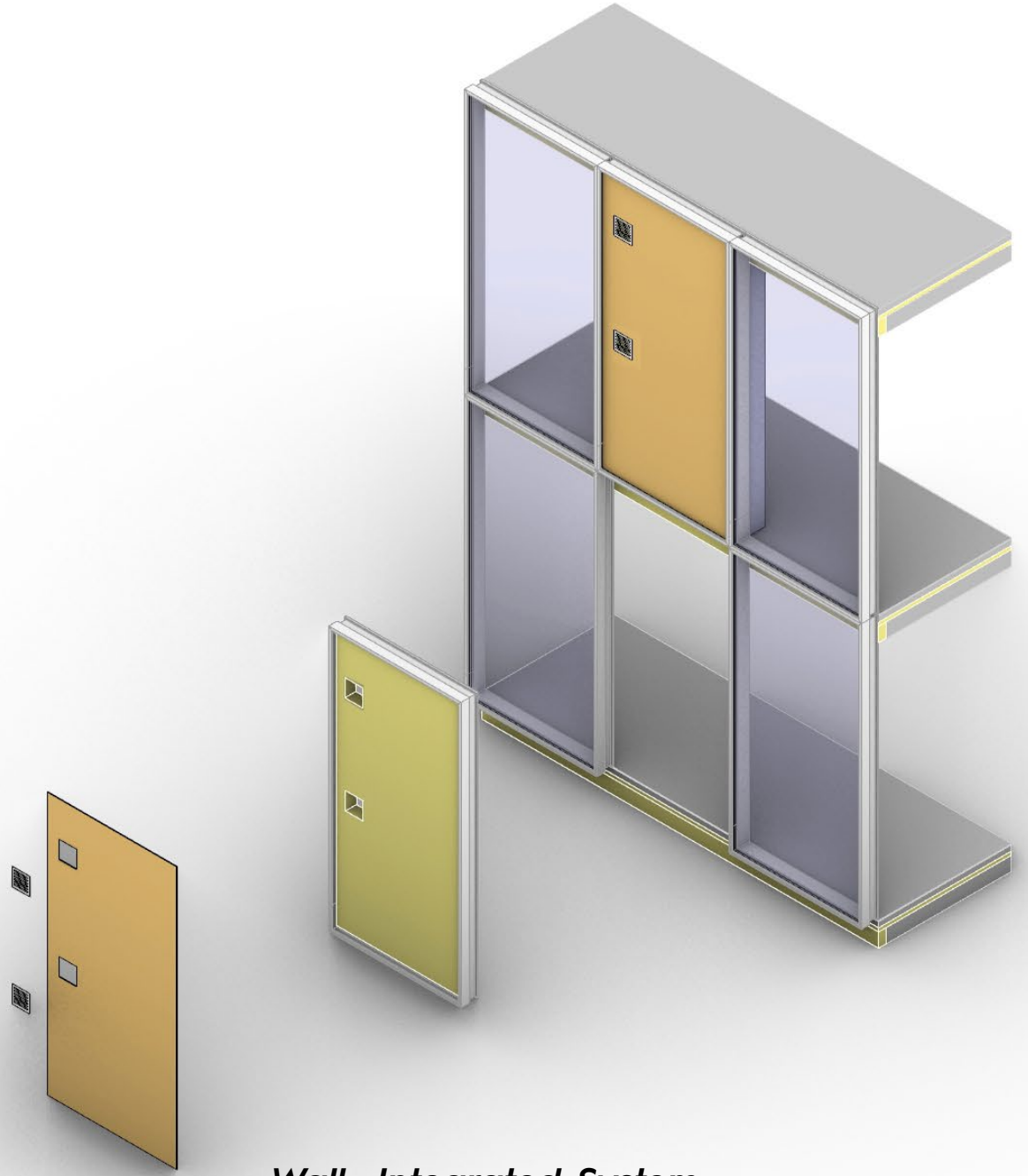


Advantages - Height Reduction

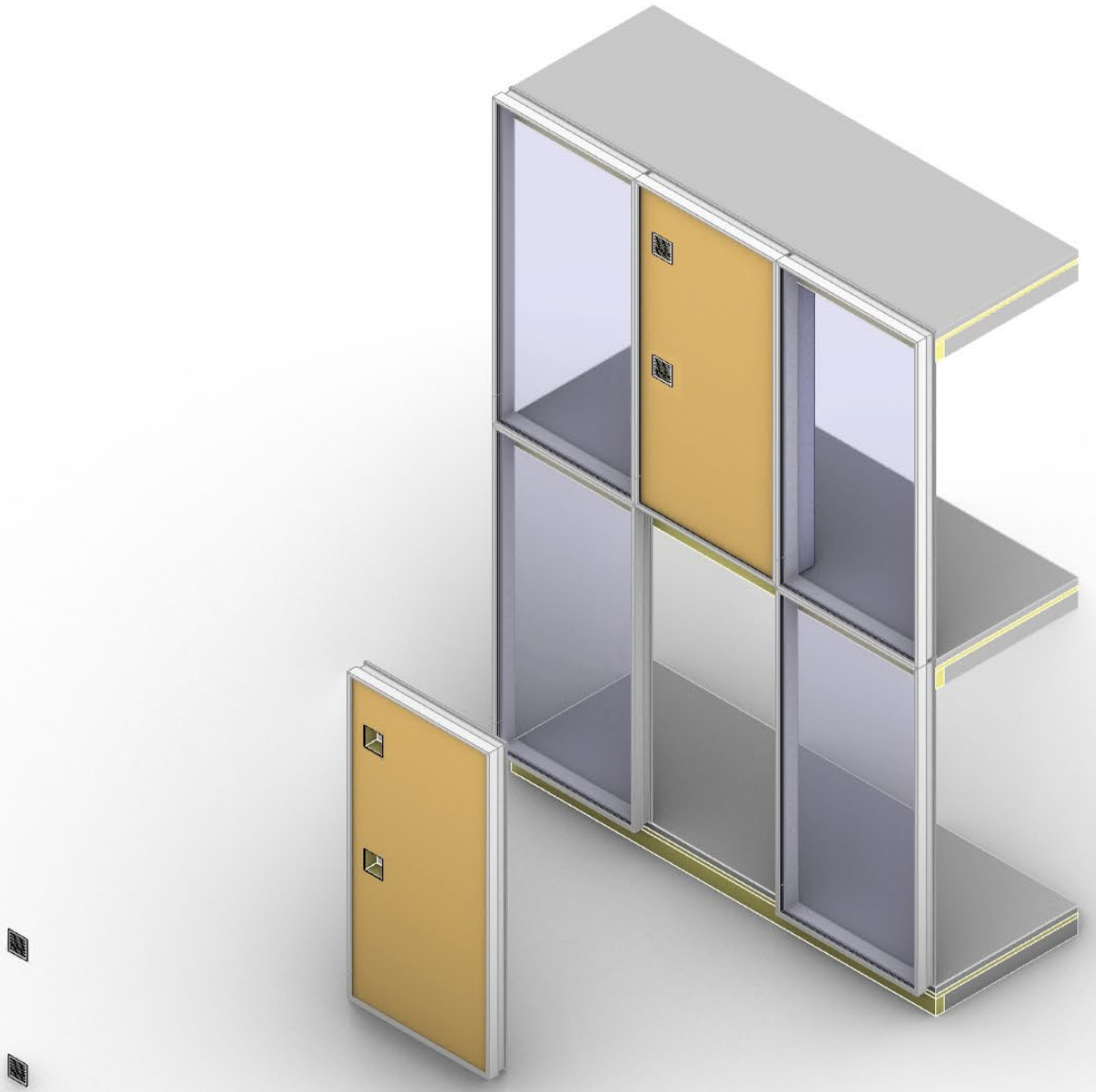
Wall Integrated System



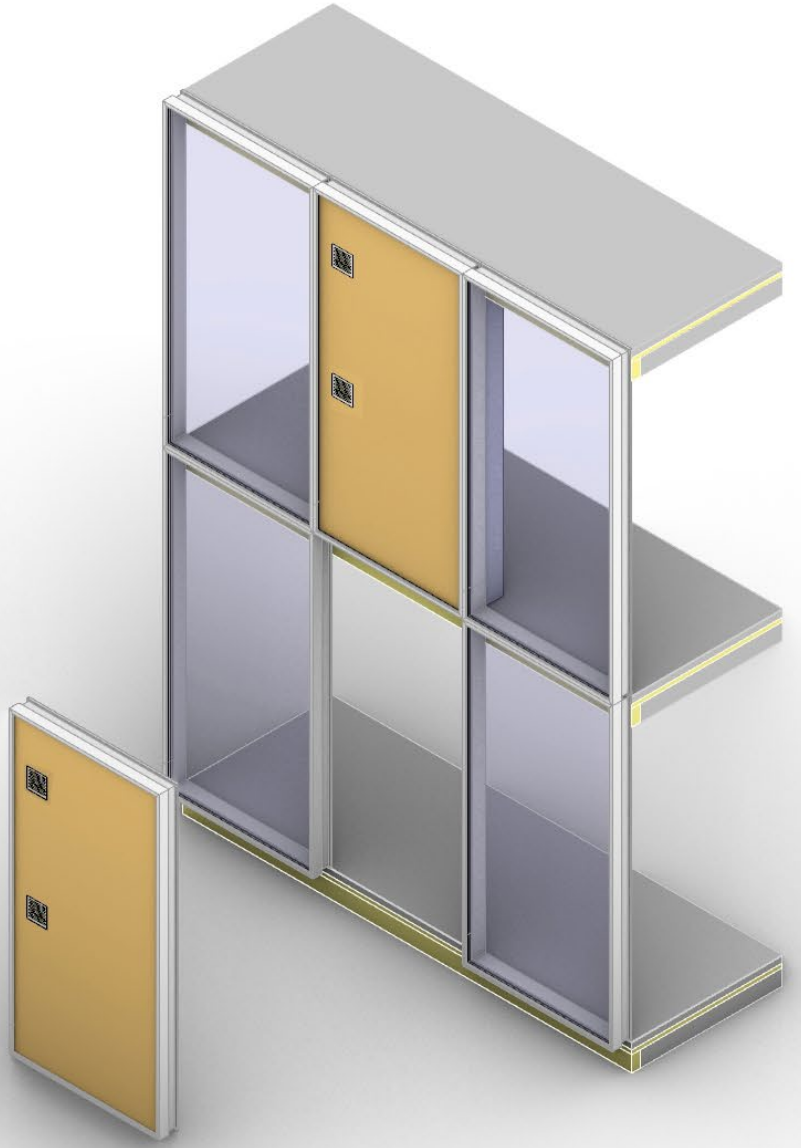
Wall Integrated System



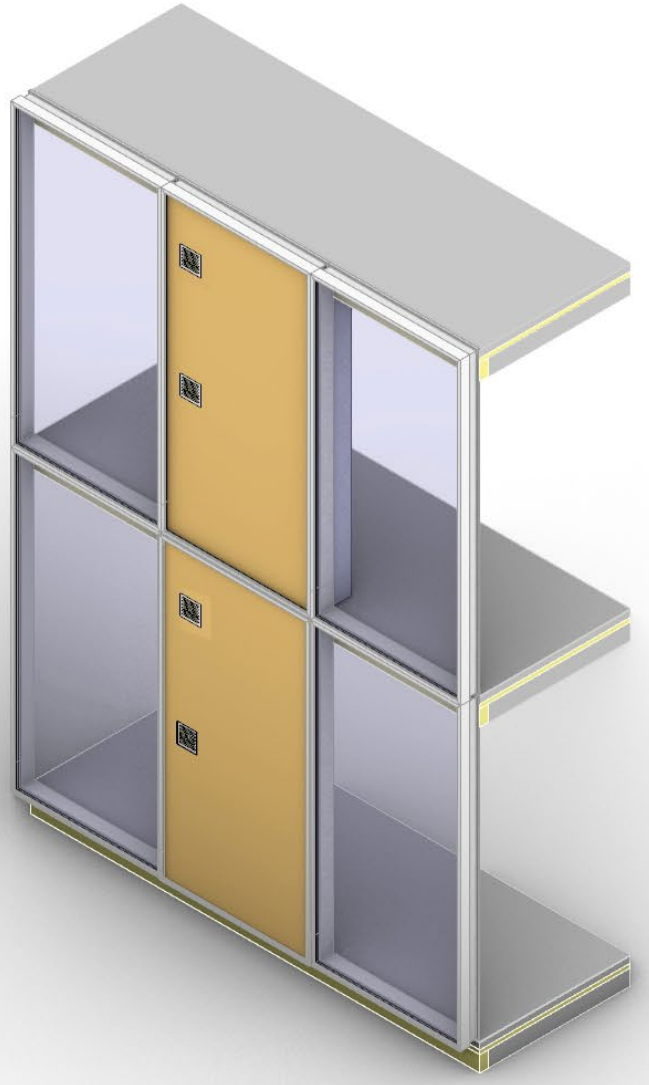
Wall Integrated System



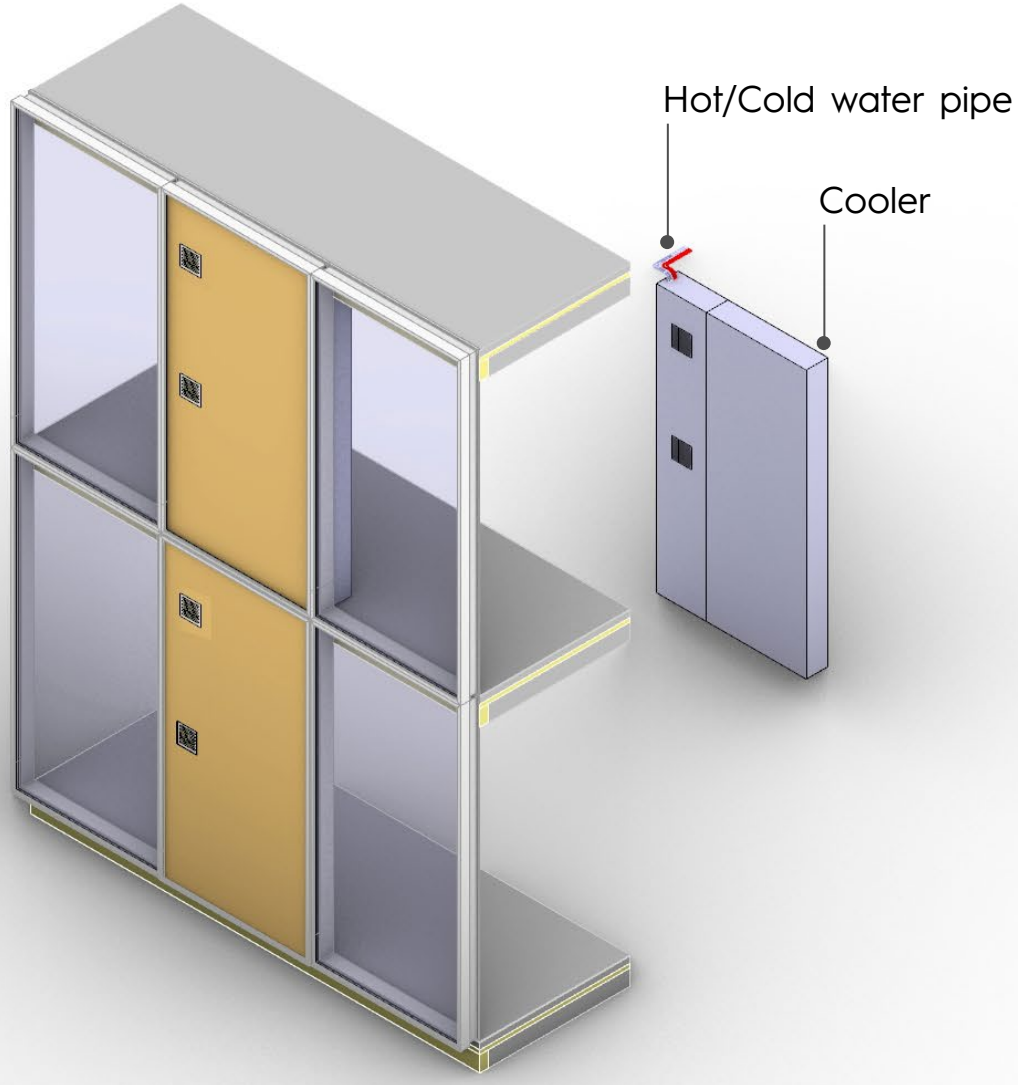
Wall Integrated System



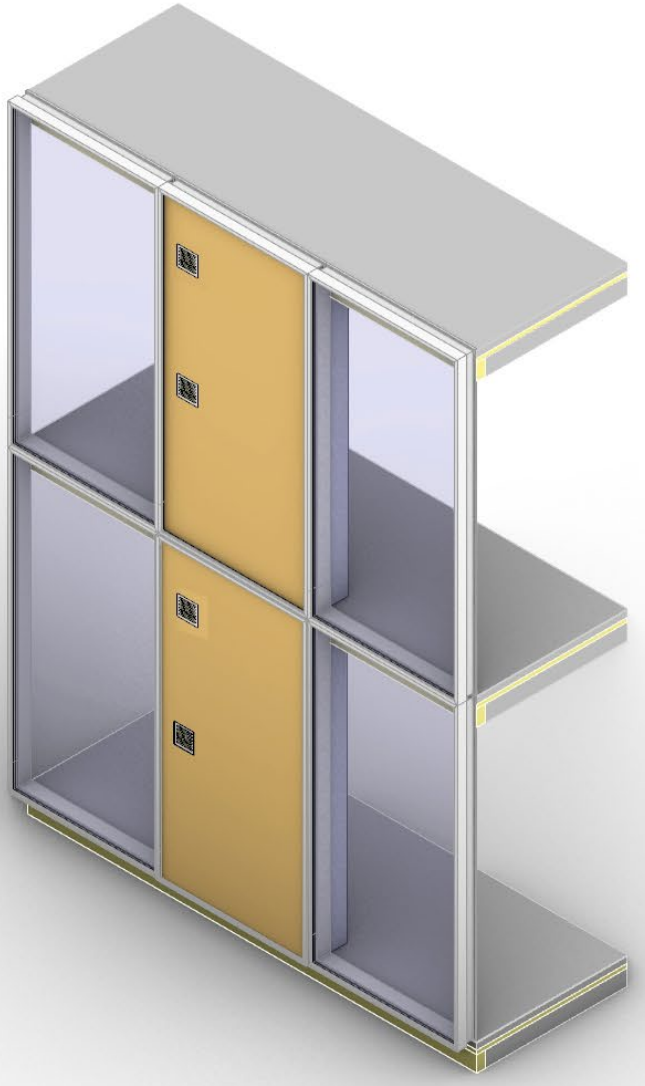
Wall Integrated System



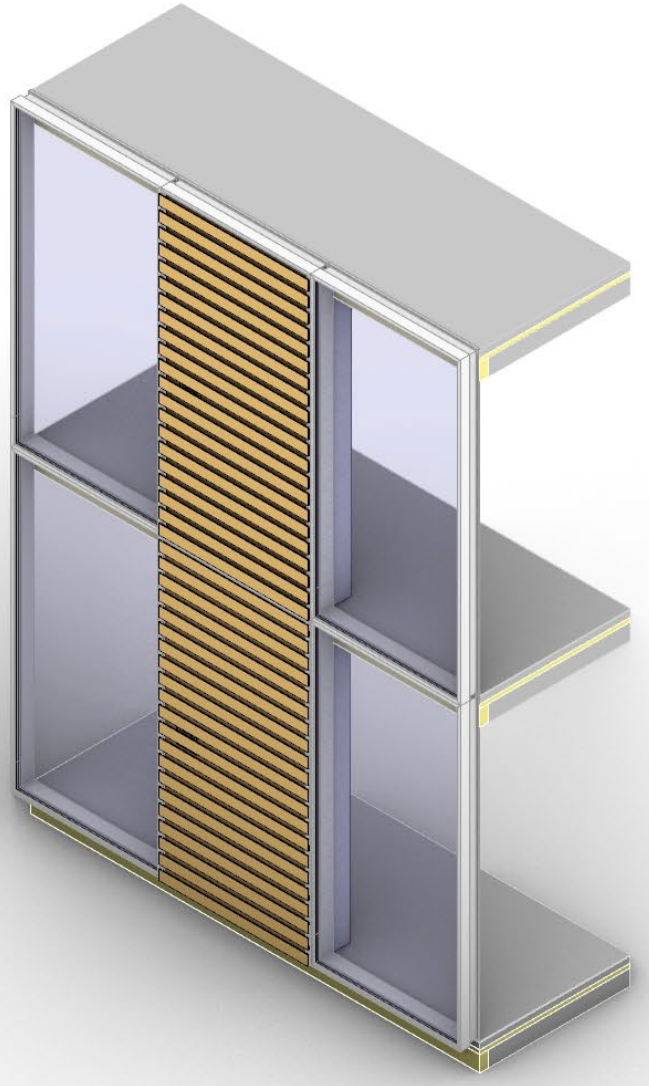
Wall Integrated System



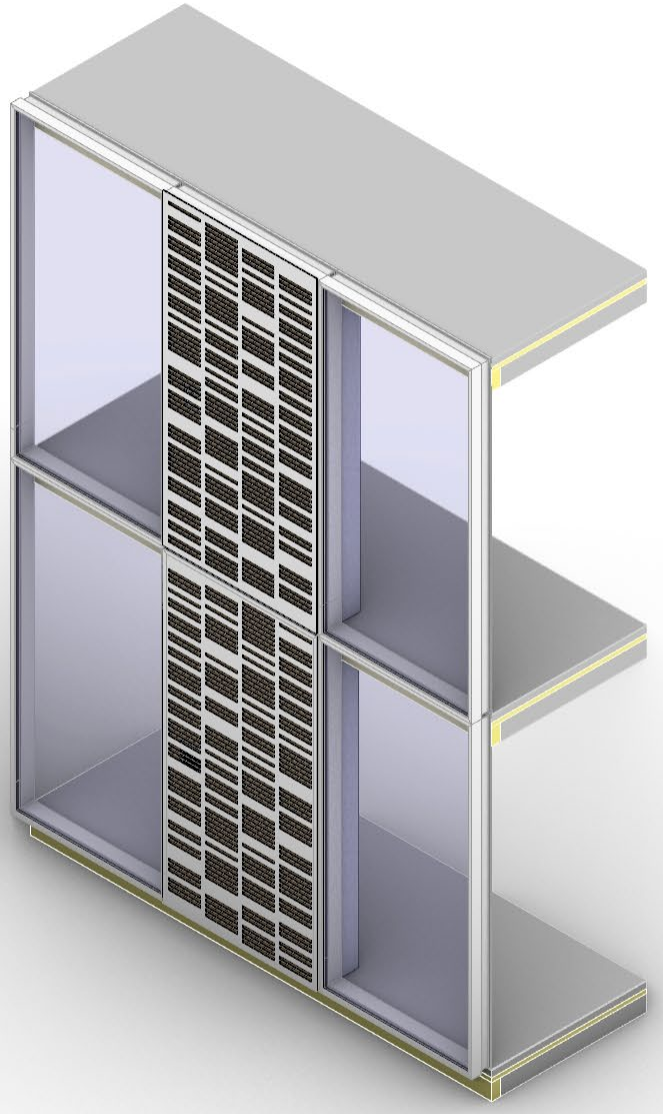
Wall Integrated System



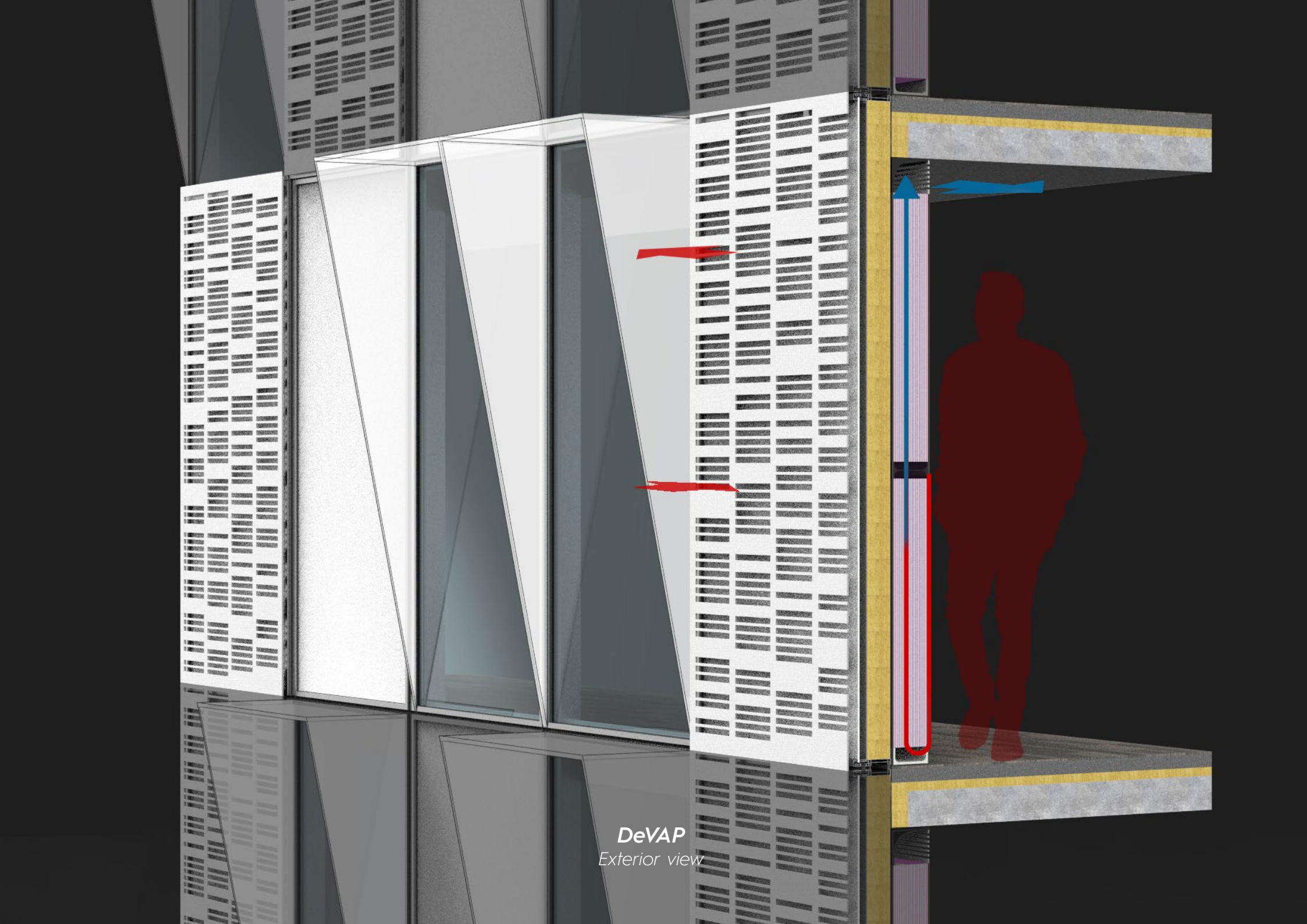
Wall Integrated System



Design Variations

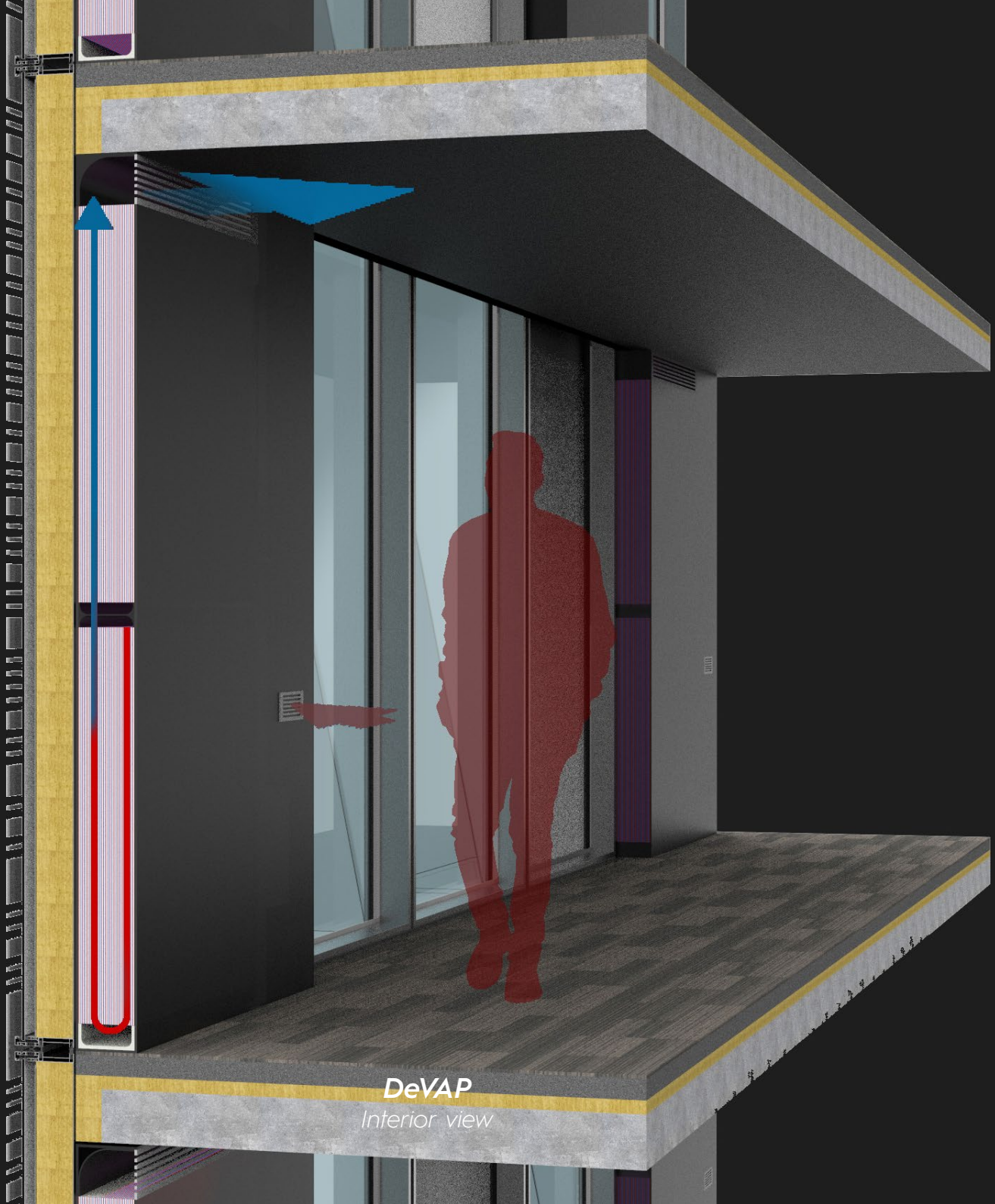


Design Variations



DeVAP

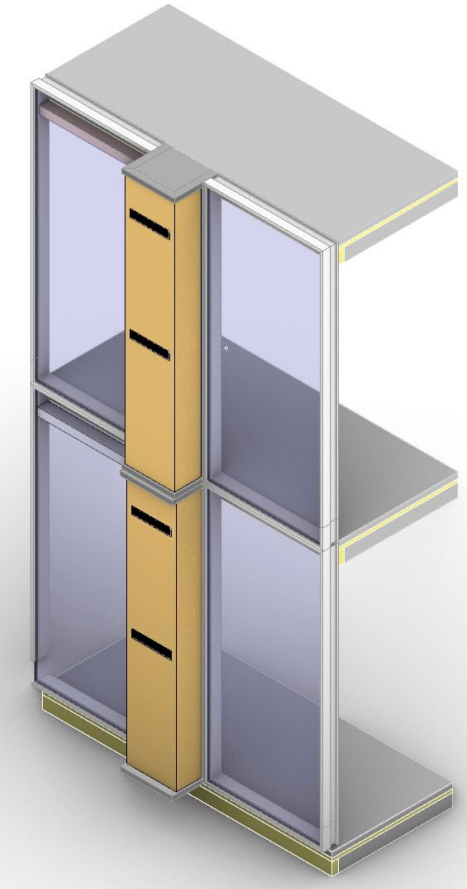
Exterior view



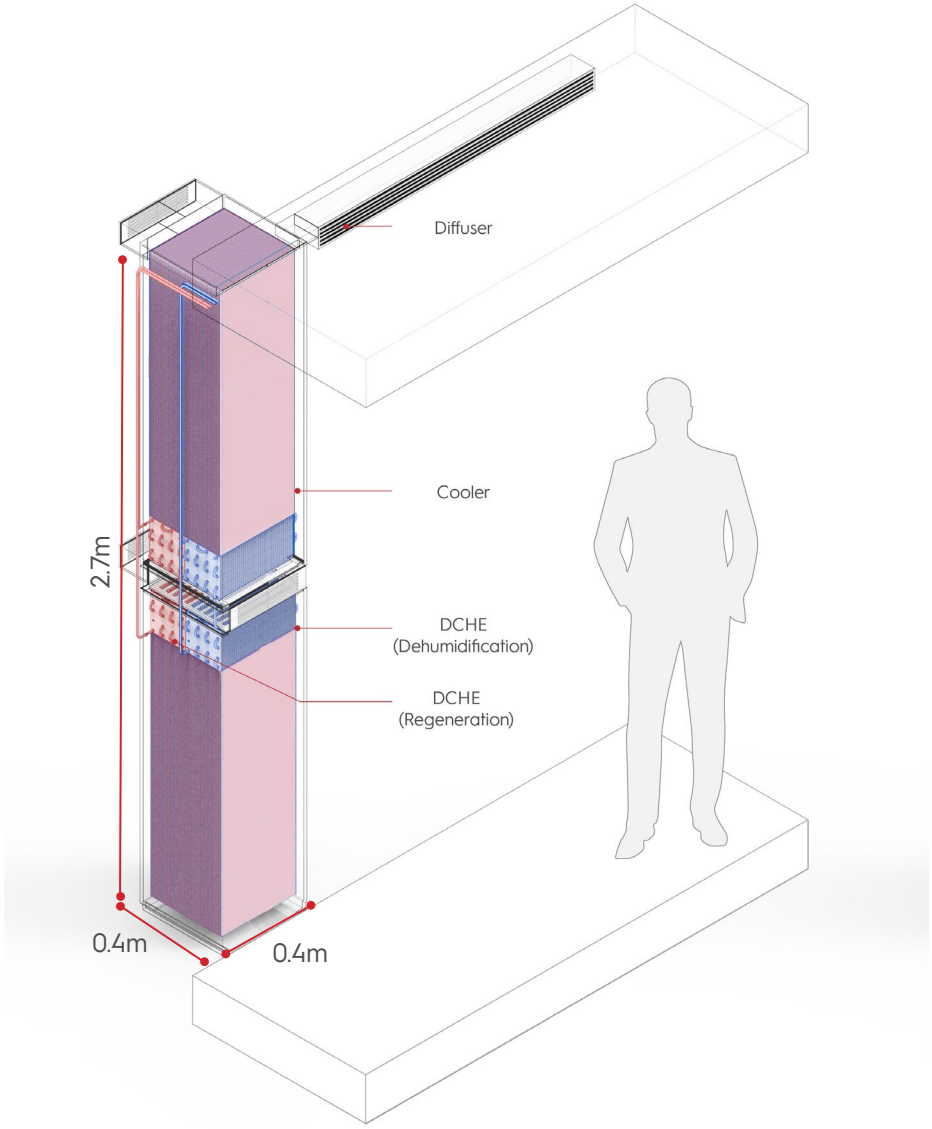
DeVAP

Interior view

Wall Integrated System
2.7m high

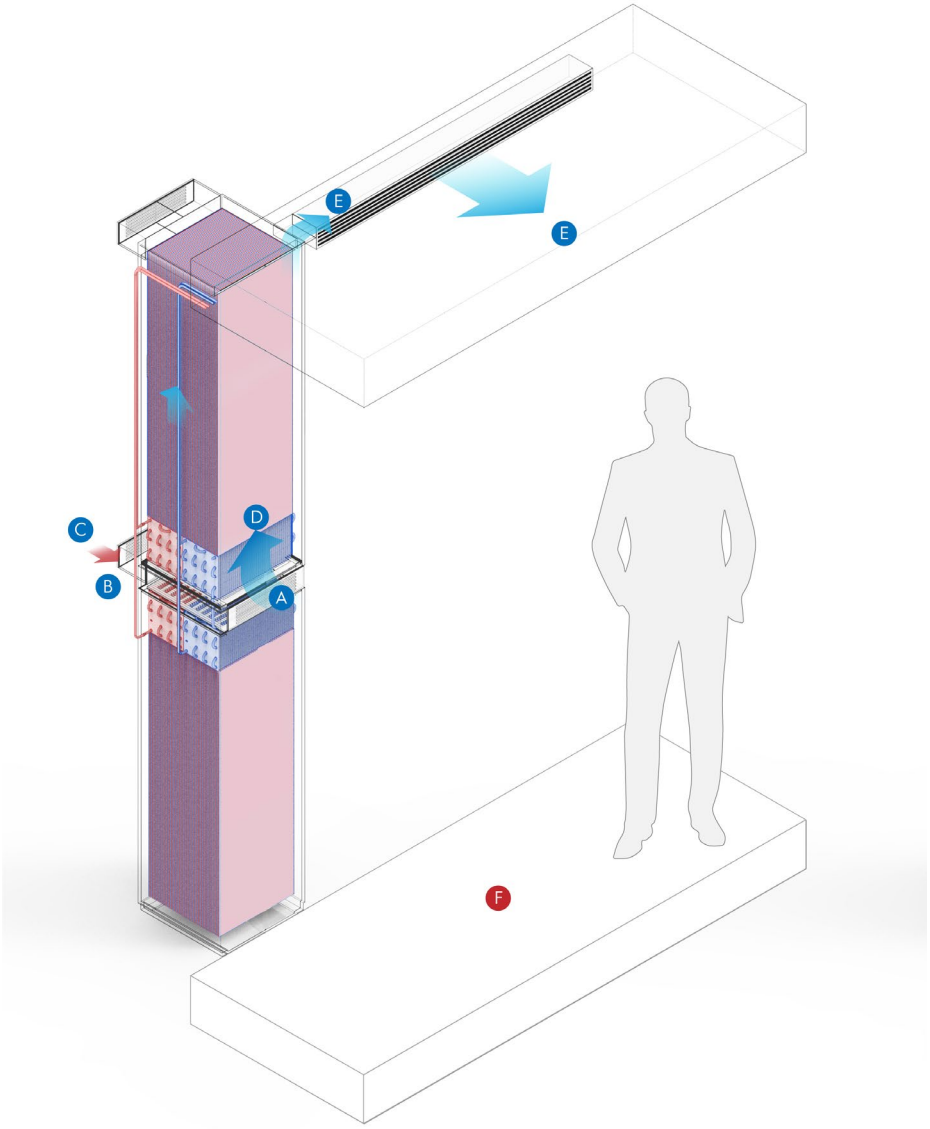


Shade Integrated System
3.0m high



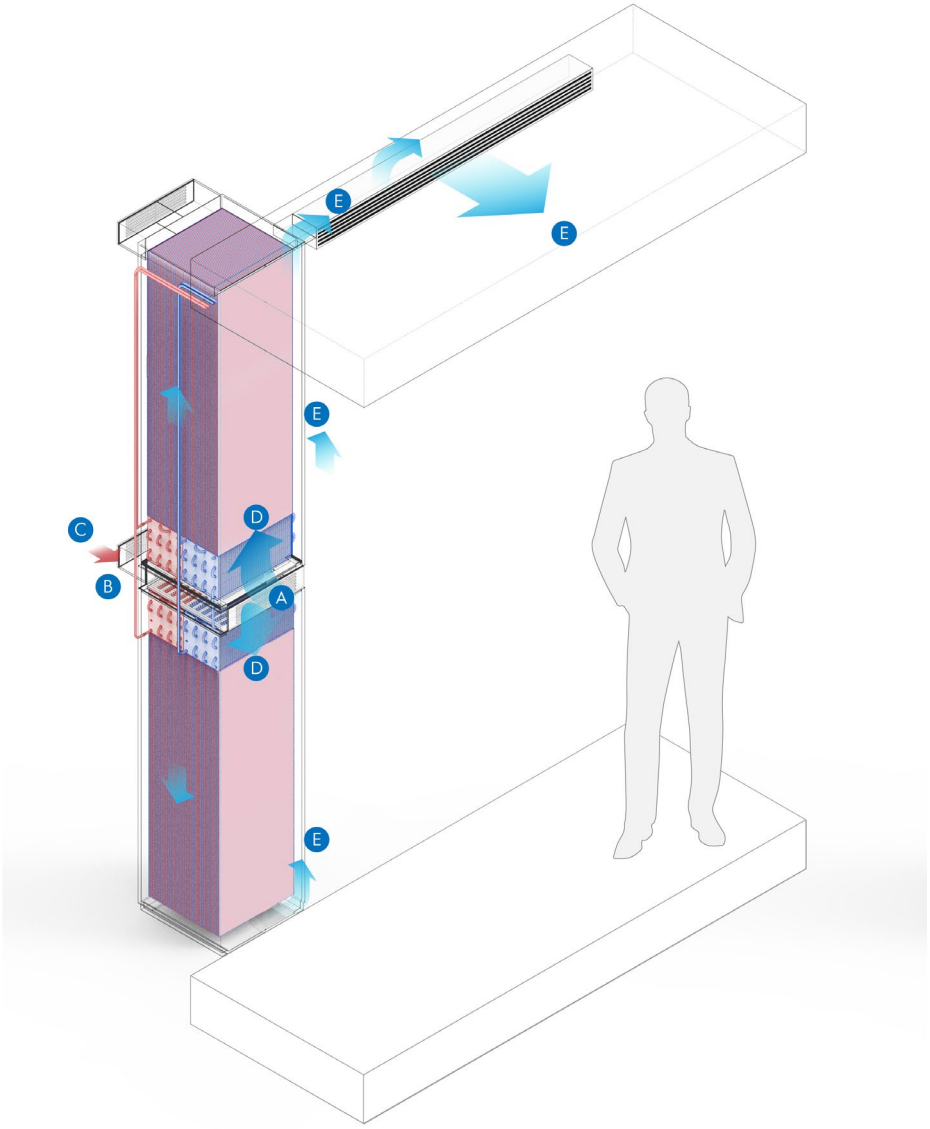
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

Variation 02 - Shade System



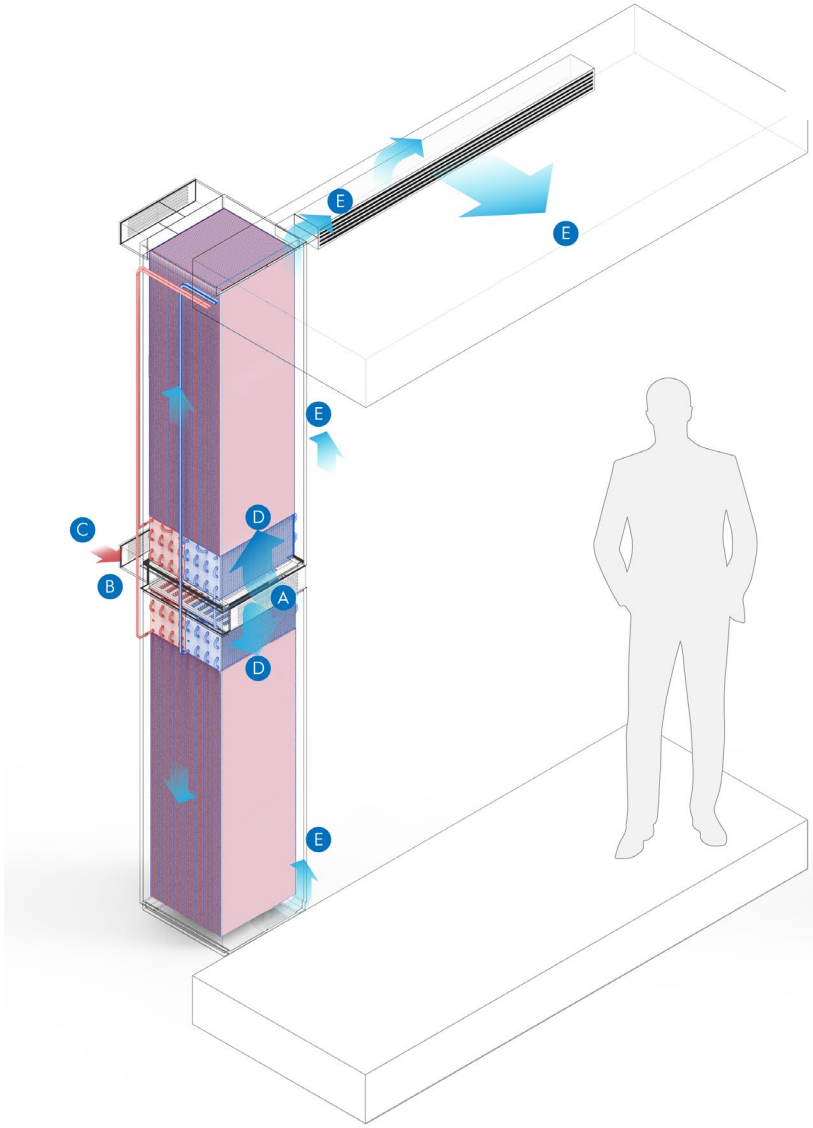
A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

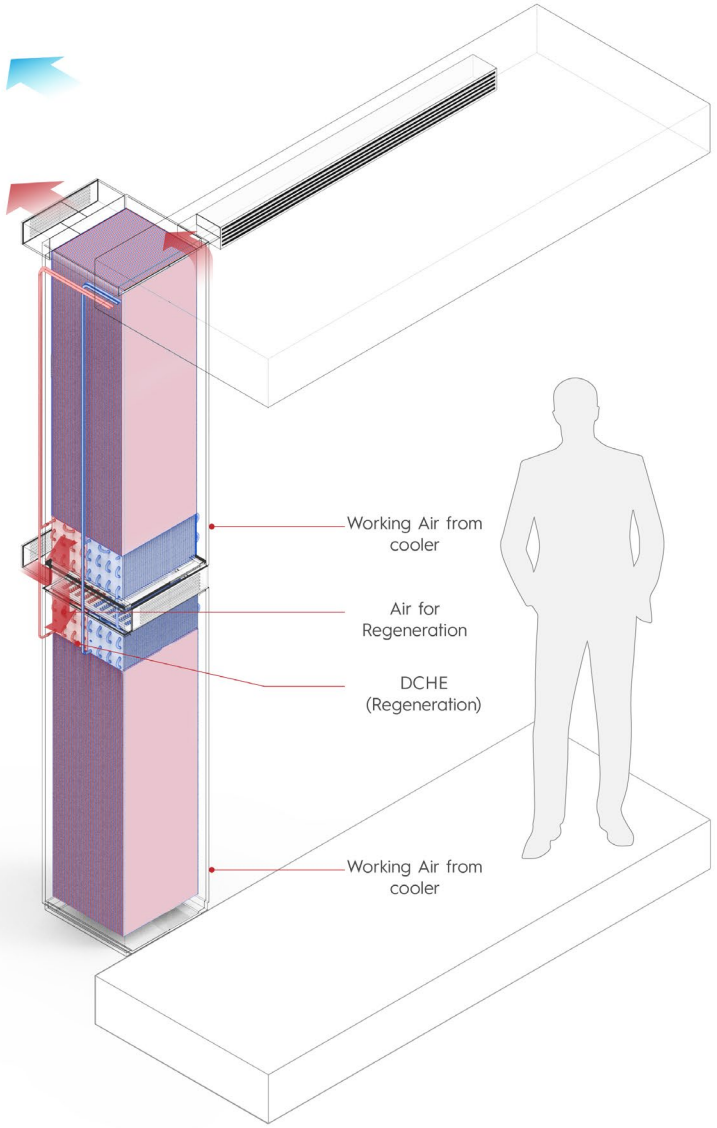
Variation 02 - Shade System



A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

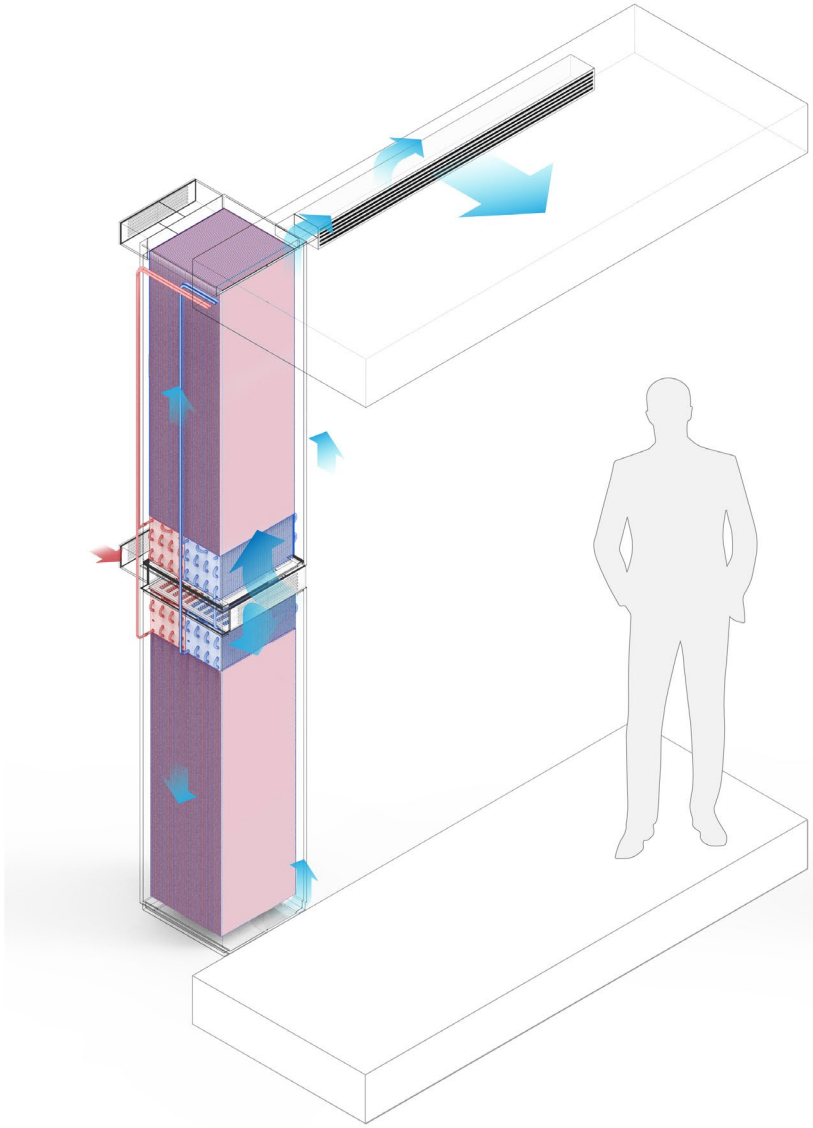
Variation 02 - Shade System

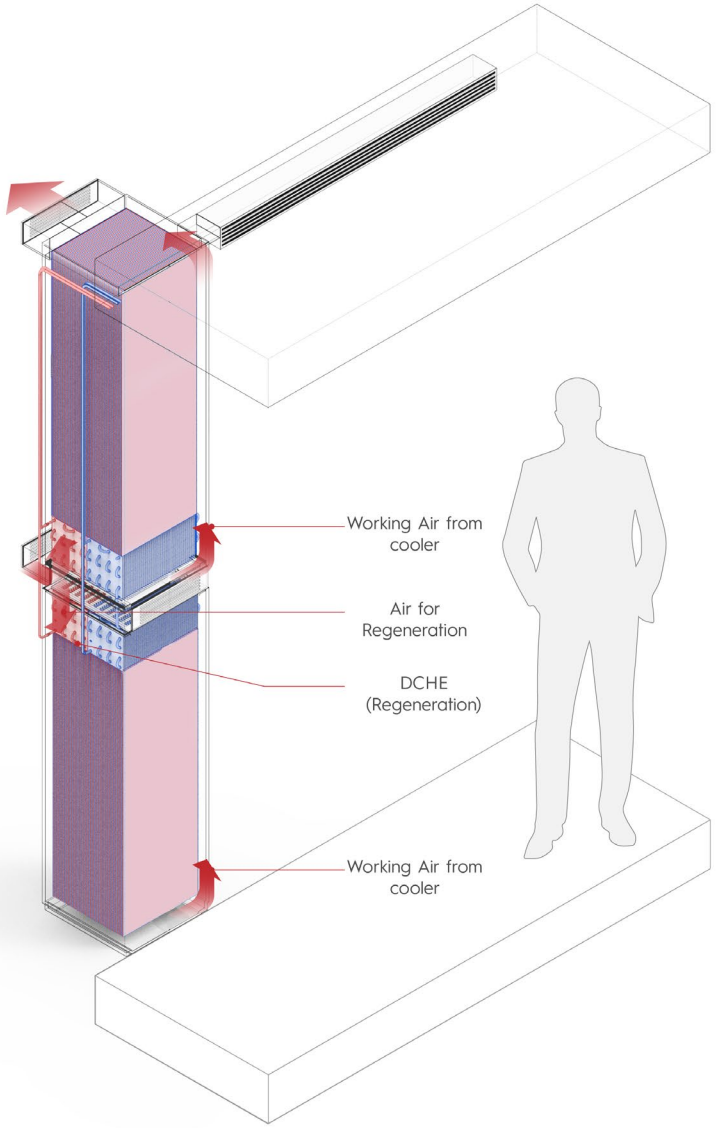




A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

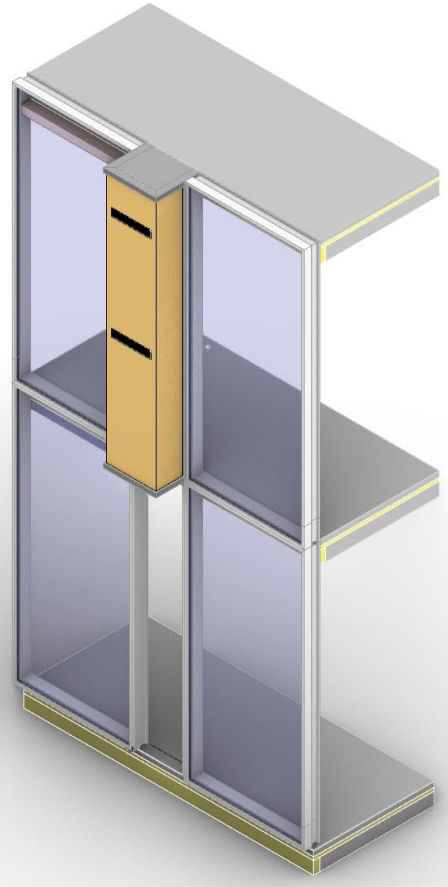
Variation 02 - Shade System



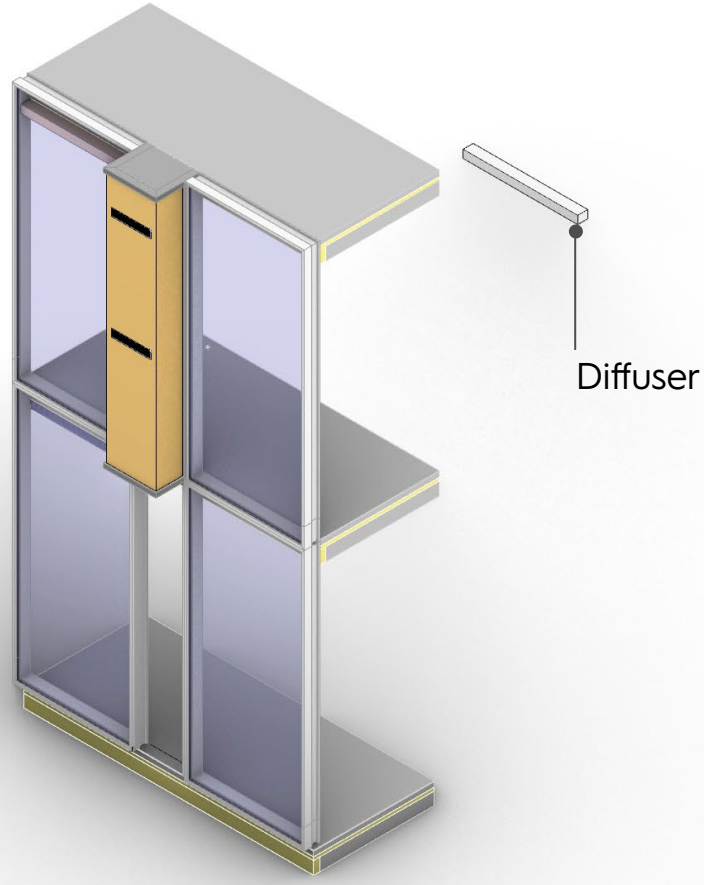


A Re-circulated air B After Mixing C Outdoor Air D De-humidified air E Supply Air F Room Condition G Exhaust Air

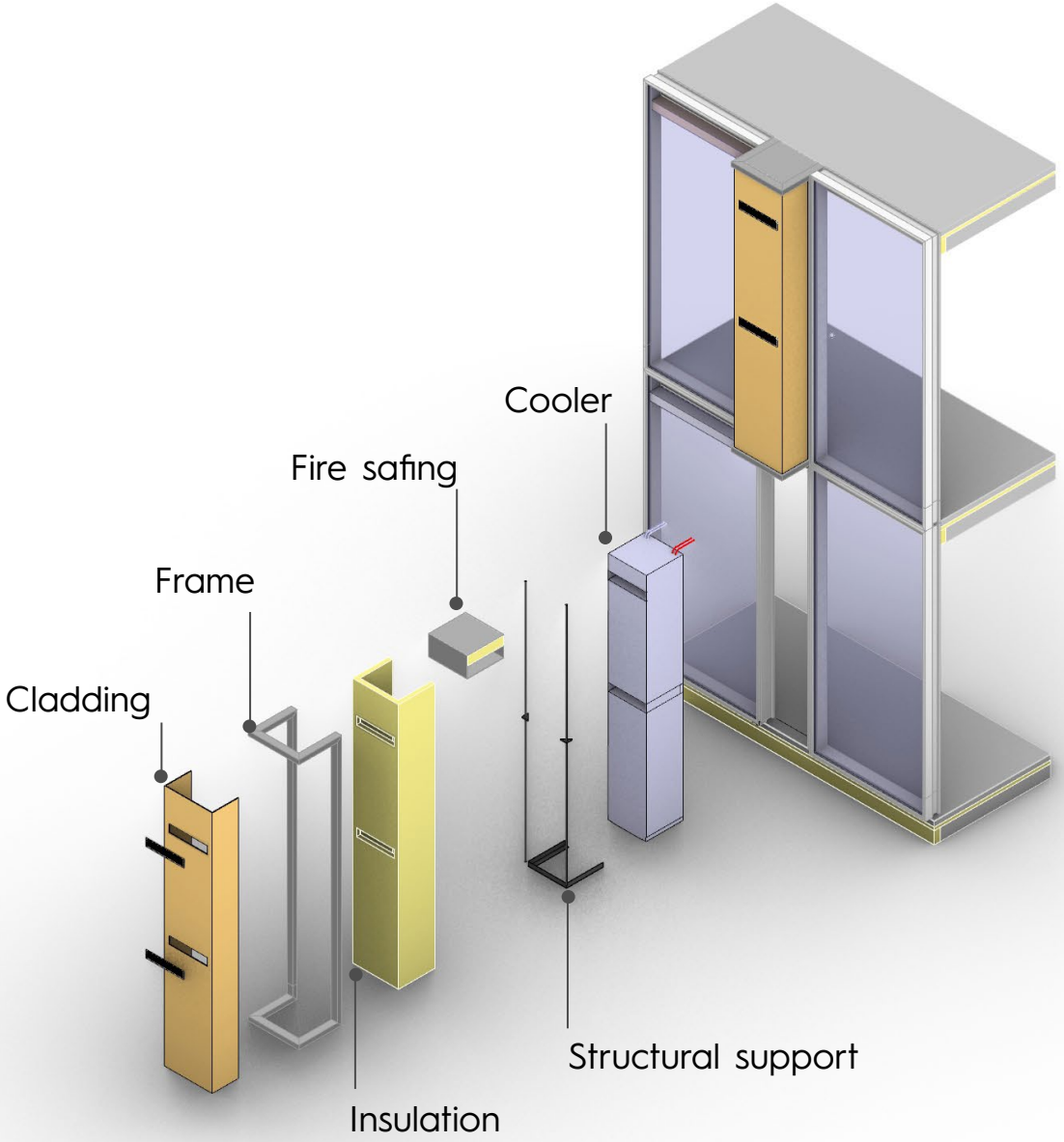
Variation 02 - Shade System



Shade Integrated System



Shade Integrated System



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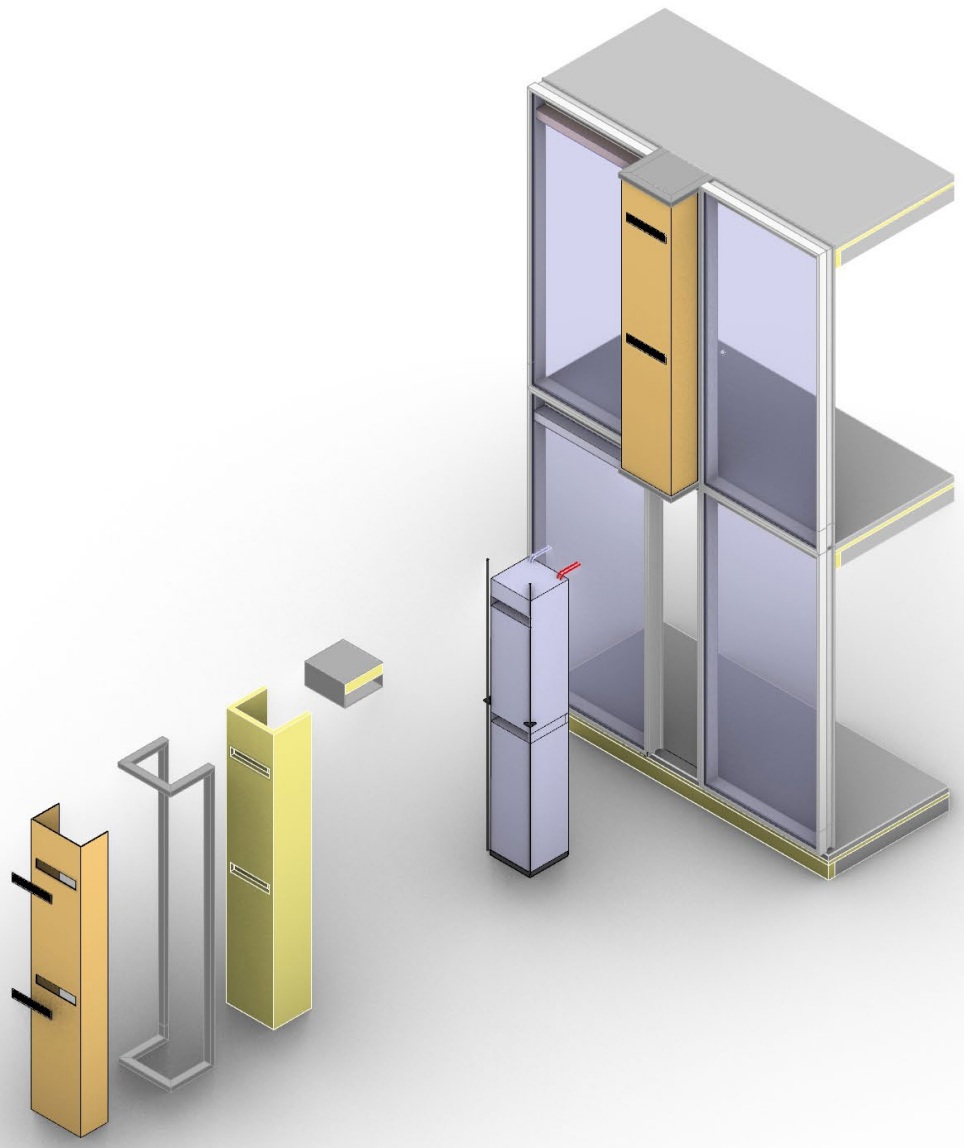
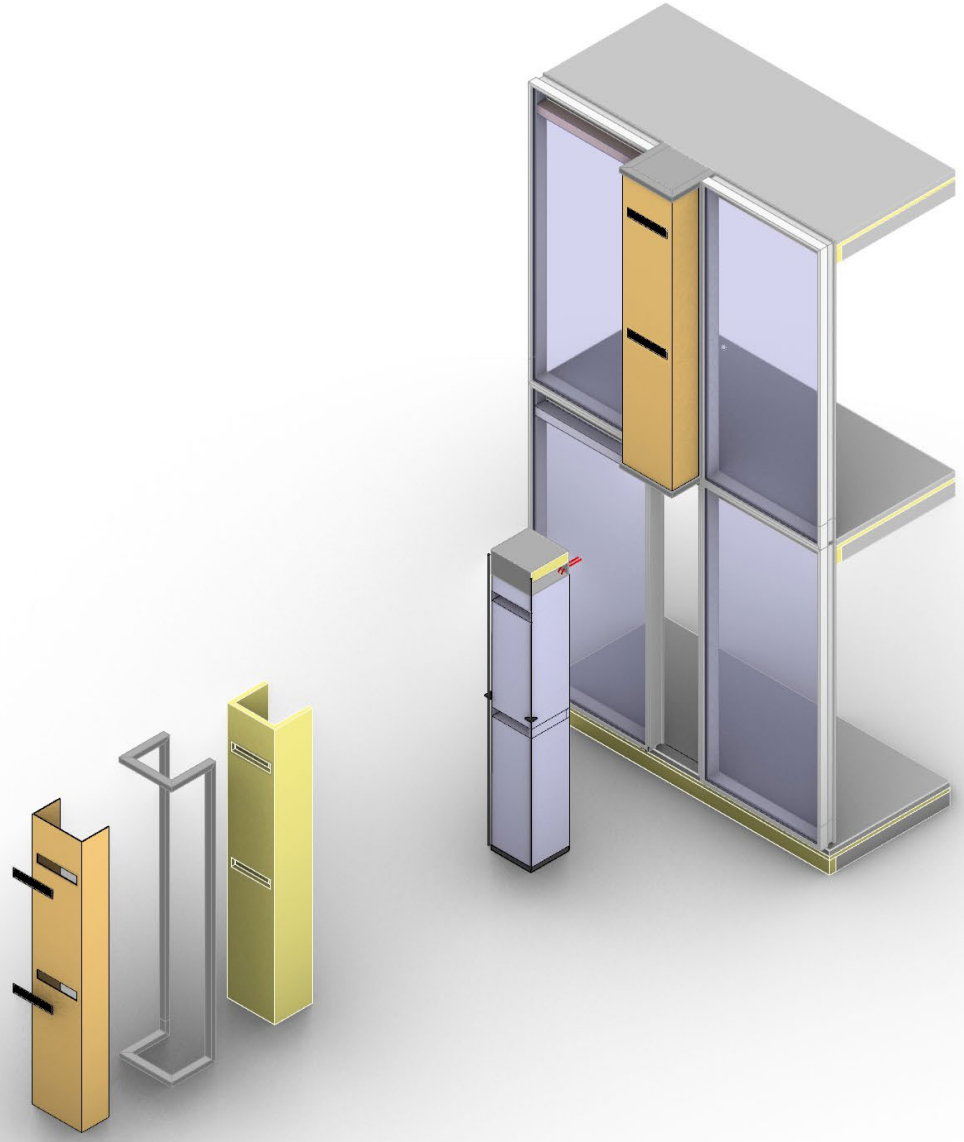


Shade Integrated System



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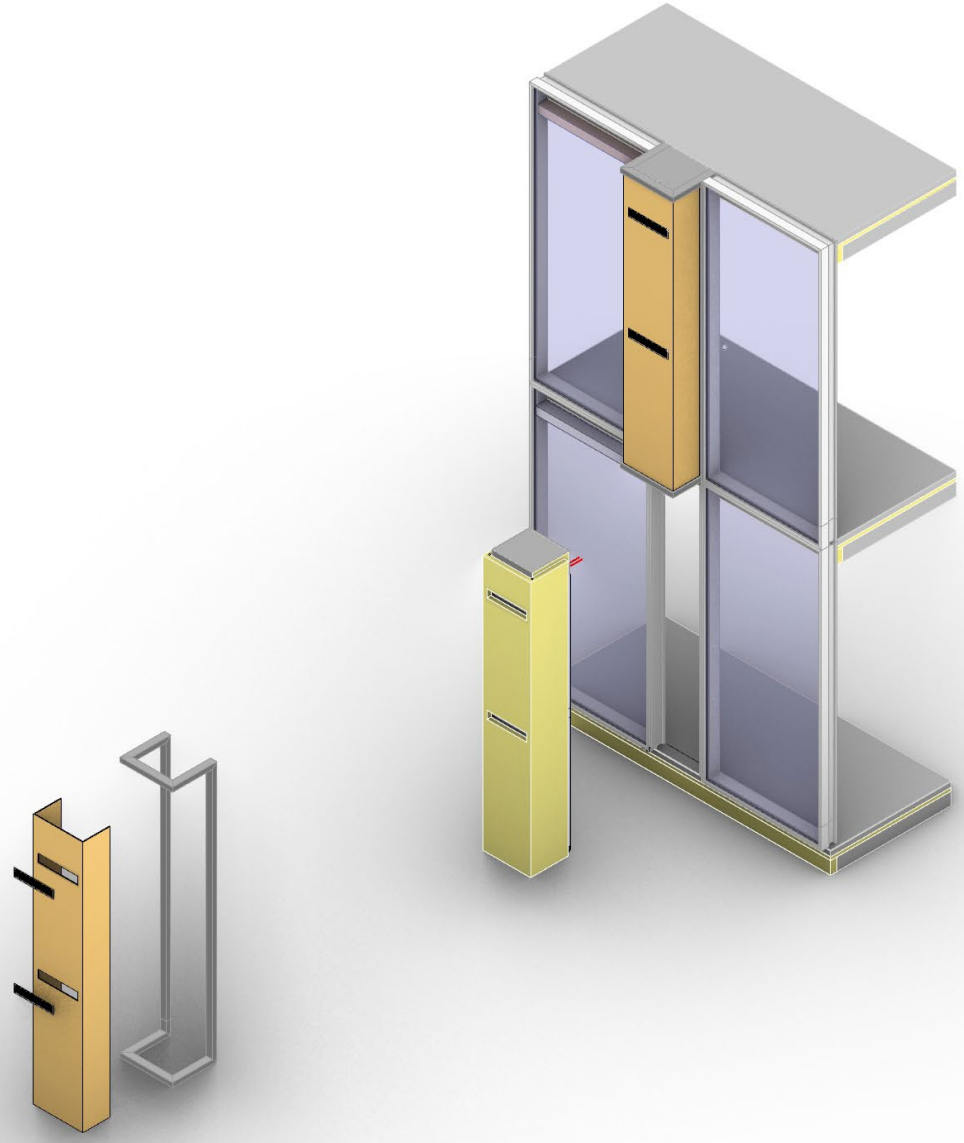

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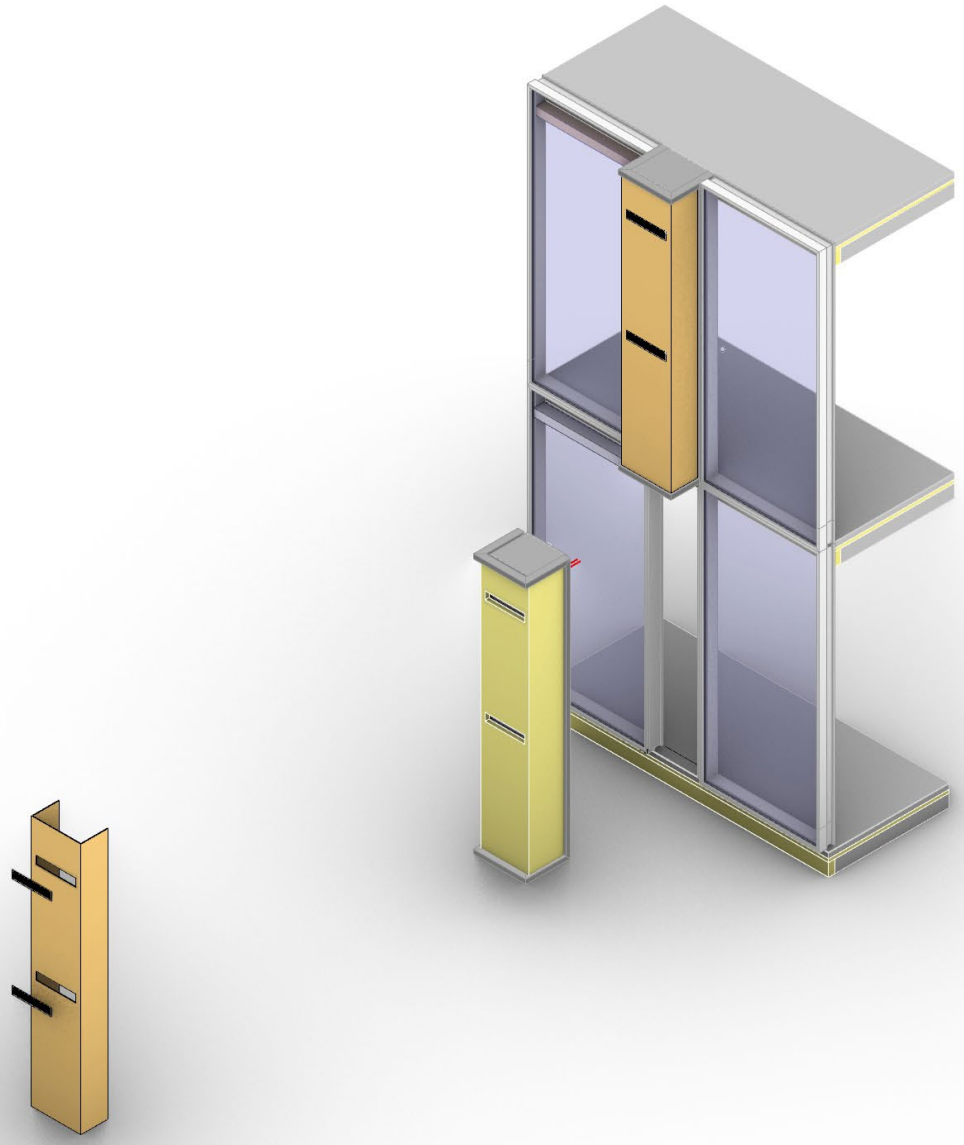

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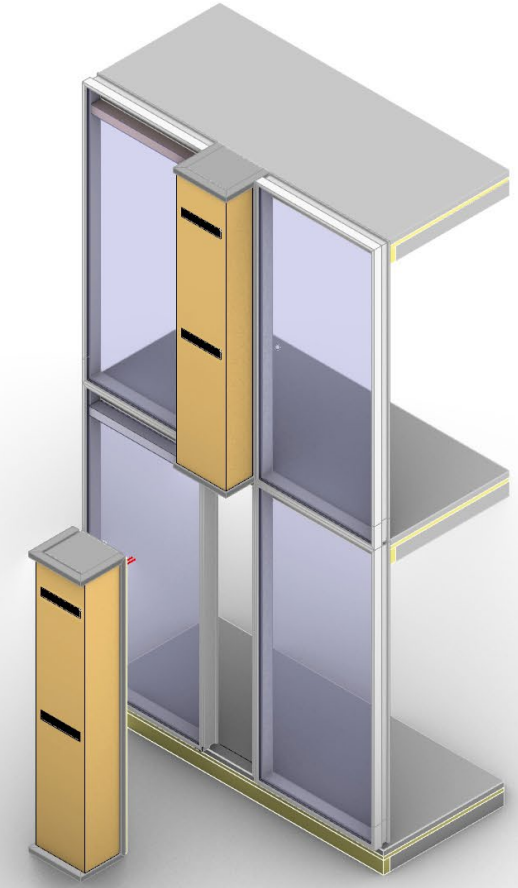
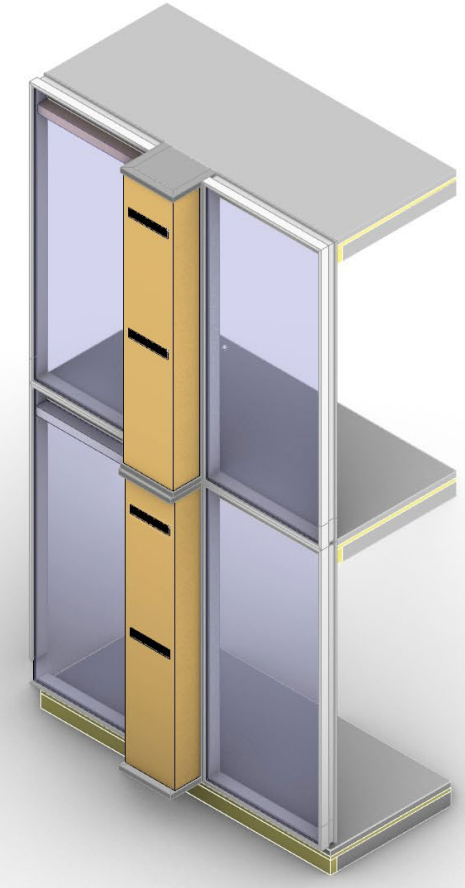
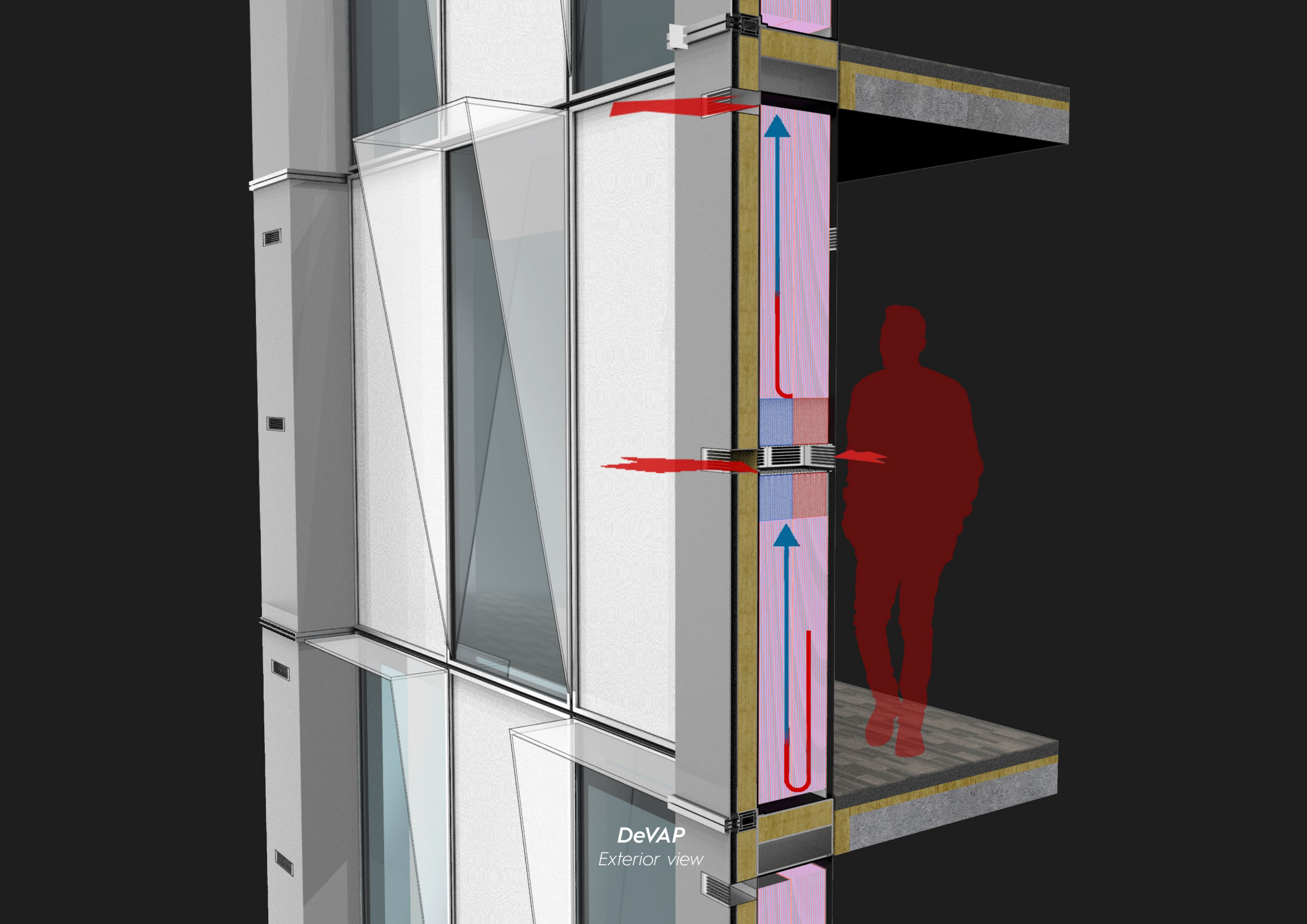
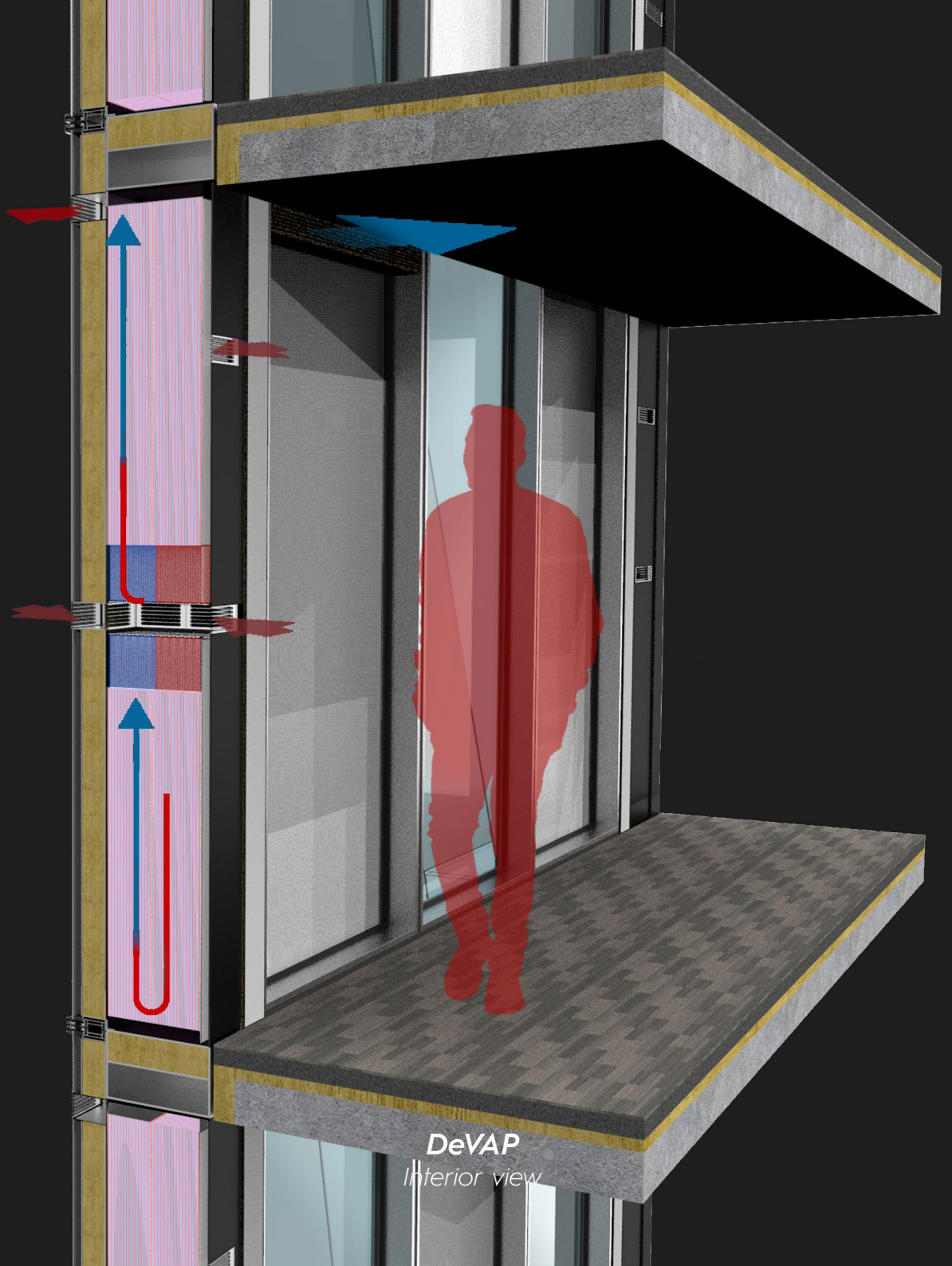


Shade Integrated System



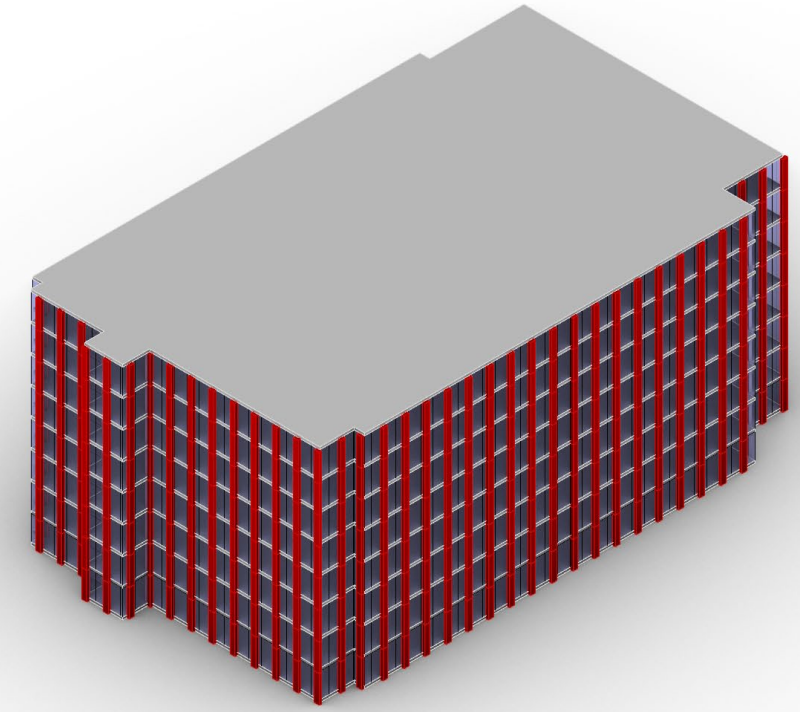
Shade Integrated System


DeVAP
Exterior view



DeVAP
Interior view

No. Passive Strategy



57.8

WWR

115.1 W/m2

Cooling load per m2

77

No. of Devices

No. of Devices vs Cooling Load

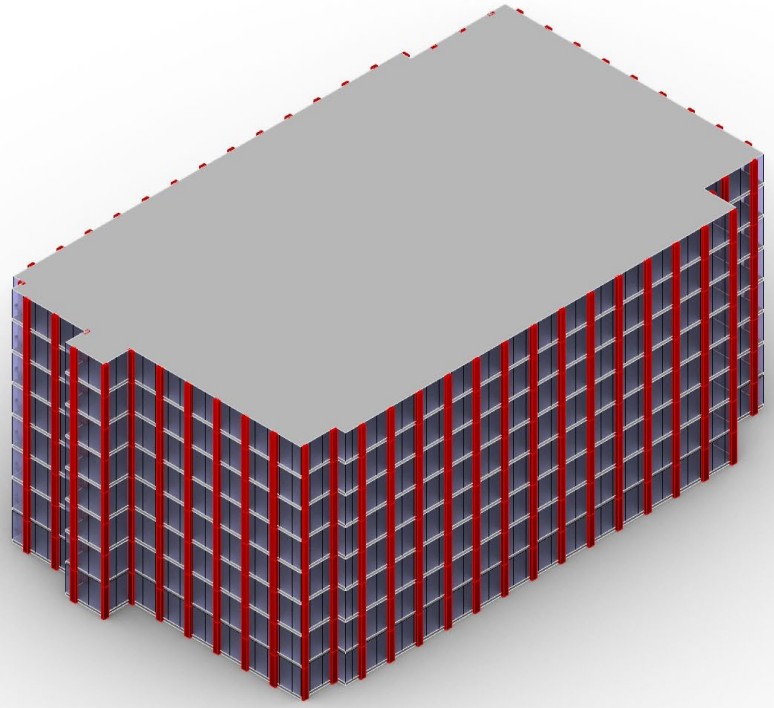
Ventilation / Internal heat gains

Lighting

Equipment

Fresh air

Infiltration



68
WWR

84.2 W/m2
Cooling load per m2

57
No. of Devices

No. of Devices vs Cooling Load

Ventilation / Internal heat gains

Lighting

Equipment

Fresh air

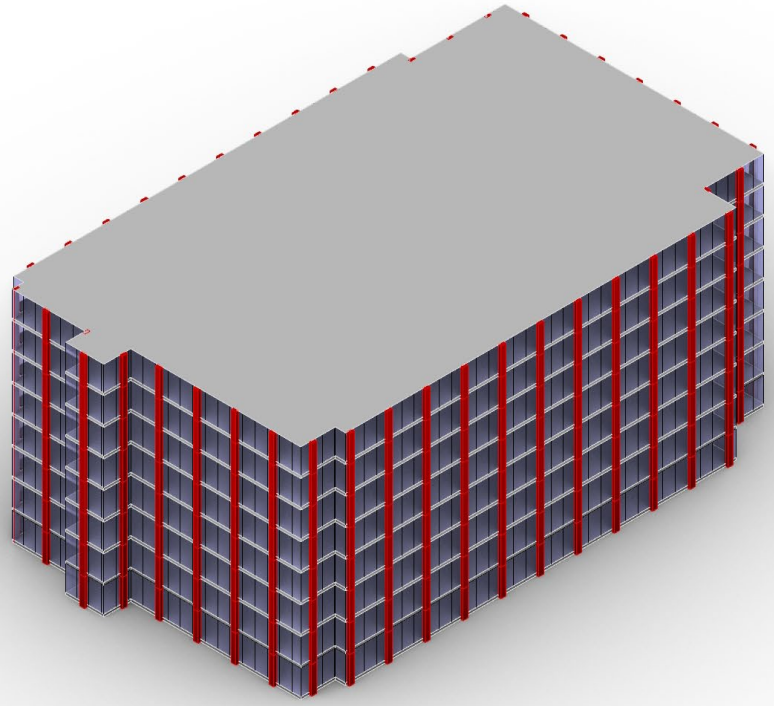
Infiltration

U-Value

Wall

Glazing

Roof



76

WWR

64 W/m2

Cooling load per m2

43

No. of Devices

No. of Devices vs Cooling Load

Ventilation / Internal heat gains

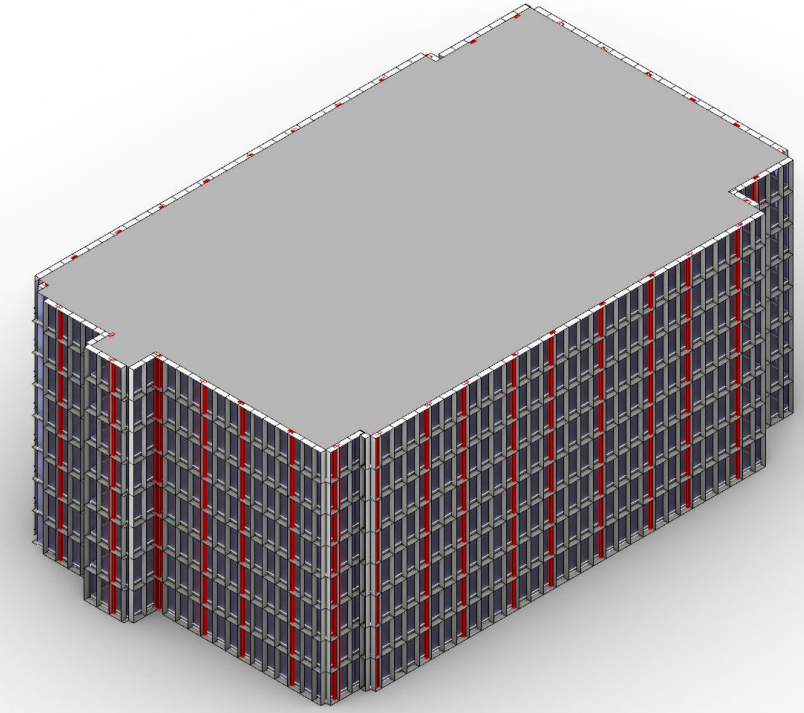
- Lighting
- Equipment
- Fresh air
- Infiltration

U-Value

- Wall
- Glazing
- Roof

Shading Strategy

- Horizontal
- Vertical
- Egg Crate



80
WWR

55 W/m2
Cooling load per m2

37
No. of Devices

No. of Devices vs Cooling Load

Ventilation / Internal heat gains

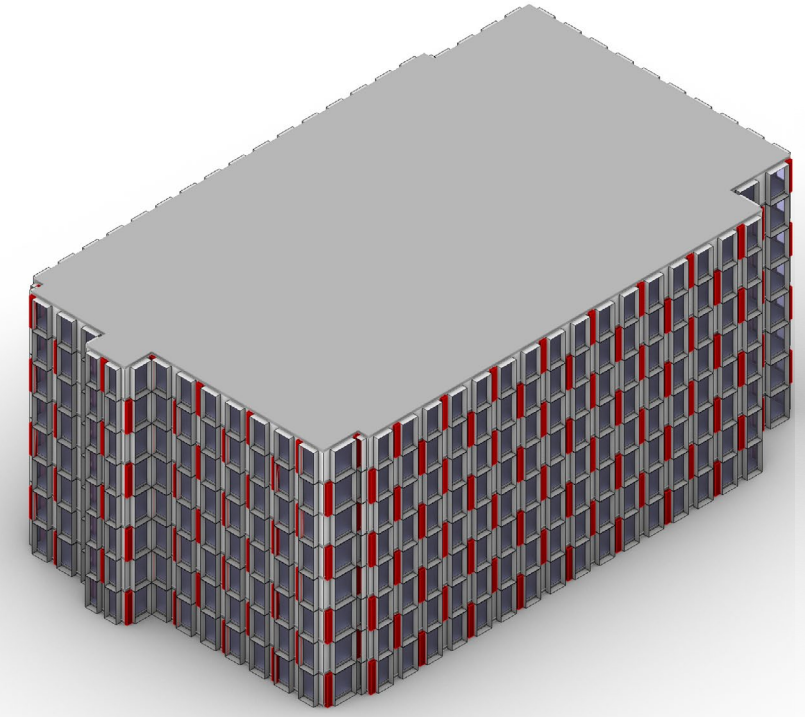
- Lighting
- Equipment
- Fresh air
- Infiltration

U-Value

- Wall
- Glazing
- Roof

Shading Strategy

- Horizontal
- Vertical
- Egg Crate



80
WWR

55 W/m2
Cooling load per m2

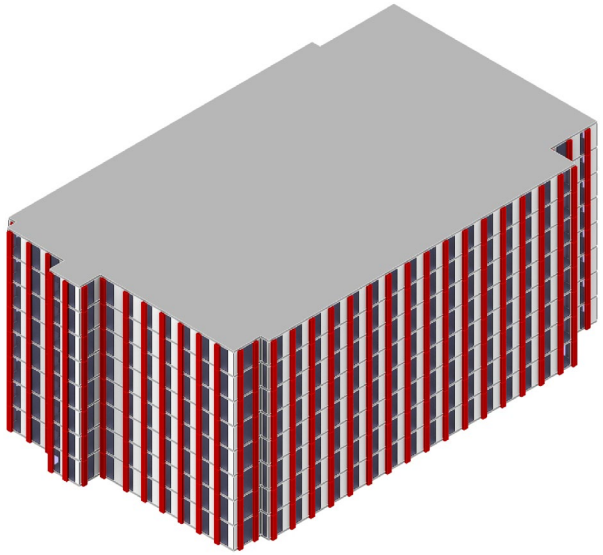
37
No. of Devices

No. of Devices vs Cooling Load

40 WWR

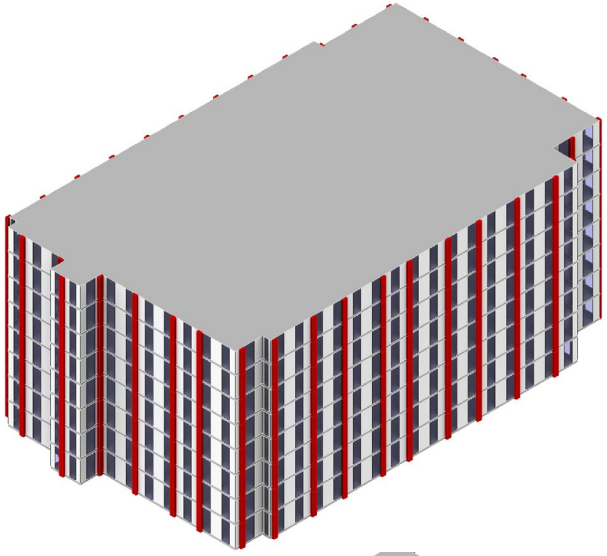
Case 1

Cooling load
178 kW
Cooling load per m2
102.7 W/m2
No. of Devices per floor
70



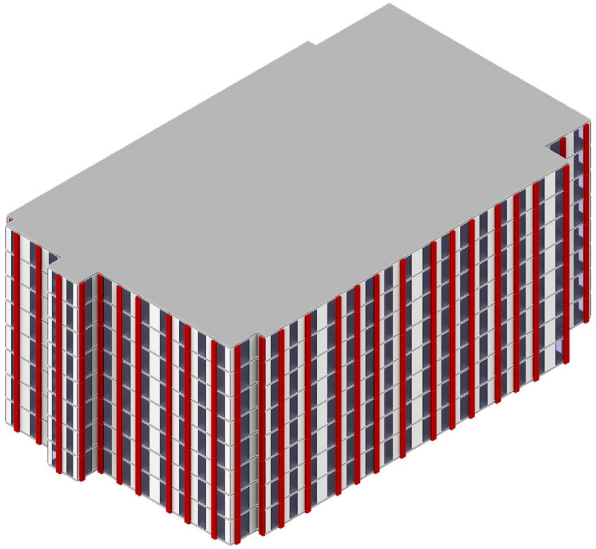
Case 3

Cooling load
96.9 kW
Cooling load per m2
55.7 W/m2
No. of Devices per floor
37



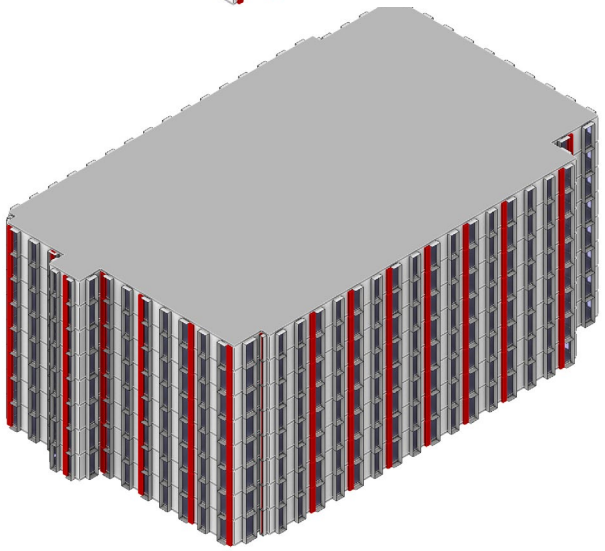
Case 2

Cooling load
142 kW
Cooling load per m2
81.6 W/m2
No. of Devices per floor
55



Case 4

Cooling load
82.5 kW
Cooling load per m2
47.4 W/m2
No. of Devices per floor
32

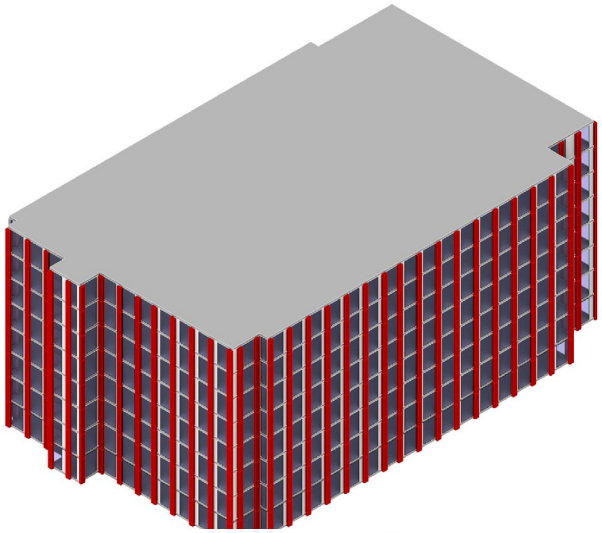


Design Variation @ 40WWR

60 WWR

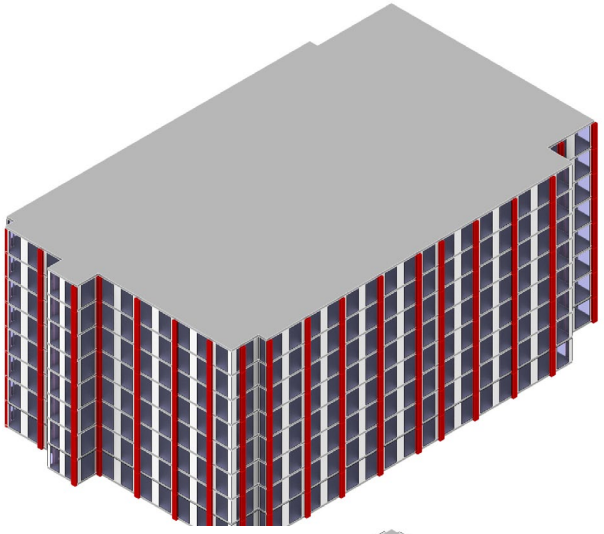
Case 1

Cooling load
190.7 kW
Cooling load per m2
109.6 W/m2
No. of Devices per floor
75



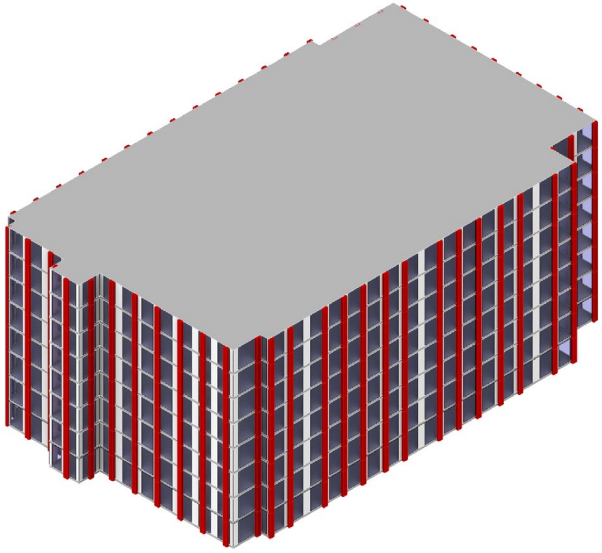
Case 3

Cooling load
99.5 kW
Cooling load per m2
57.2 W/m2
No. of Devices per floor
38



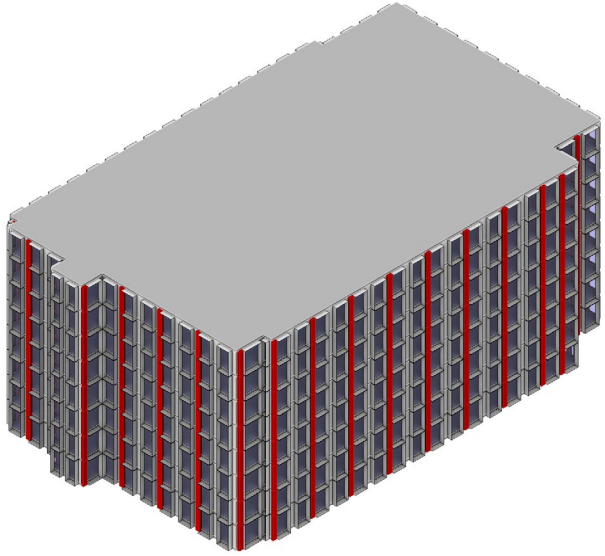
Case 2

Cooling load
144.9 kW
Cooling load per m2
83.3 W/m2
No. of Devices per floor
56



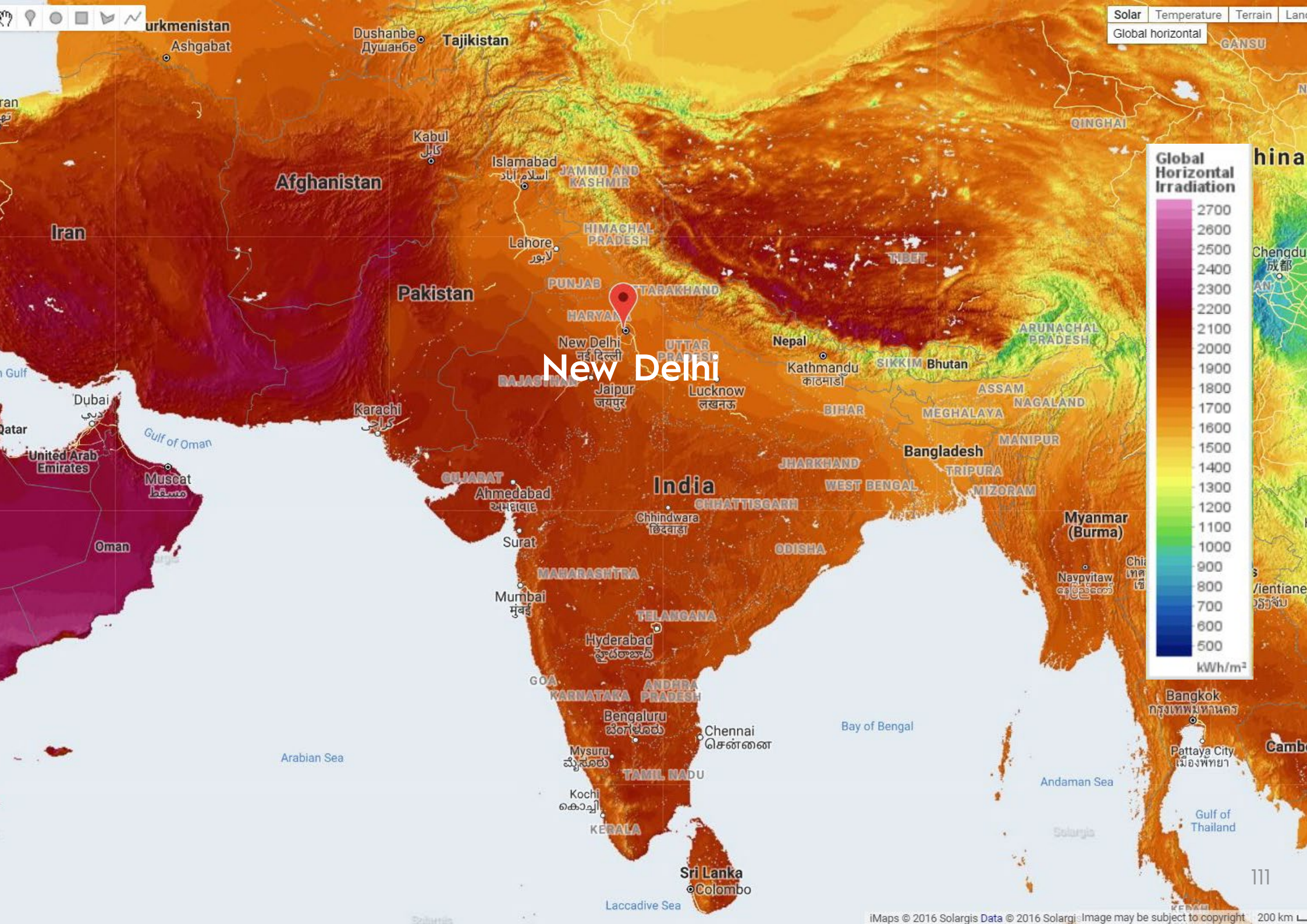
Case 4

Cooling load
87.0 kW
Cooling load per m2
50.0 W/m2
No. of Devices per floor
33



Design Variation @ 60WWR

Energy


Solar
Temperature
Terrain
Global horizontal
Global Horizontal Irradiation
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
kWh/m²
New Delhi
Afghanistan
Iran
Pakistan
India
Nepal
Bhutan
Bangladesh
Myanmar (Burma)
Sri Lanka
Dubai
Karachi
Muscat
Oman
United Arab Emirates
Qatar
Gulf of Oman
Arabian Sea
Bay of Bengal
Andaman Sea
Gulf of Thailand
Laccadive Sea
Ashgabat
Dushanbe
Tajikistan
Kabul
Islamabad
Lahore
Jaipur
Lucknow
Kathmandu
Ahmedabad
Surat
Mumbai
Chhindwara
Hyderabad
Bengaluru
Chennai
Mysuru
Kochi
Colombo
Navpyitaw
Bangkok
Pattaya City
Chengdu
Vientiane
JAMMU AND KASHMIR
HIMACHAL PRADESH
PUNJAB
HARYANA
UTTARAKHAND
UTTAR PRADESH
RAJASTHAN
TIBET
QINGHAI
GANSU
ARUNACHAL PRADESH
SIKKIM
ASSAM
NAGALAND
MEGHALAYA
MANIPUR
TRIPURA
MIZORAM
BIHAR
JHARKHAND
WEST BENGAL
CHHATTISGARH
ODISHA
GUJARAT
MAHARASHTRA
TELANGANA
GOA
KARNATAKA
ANDHRA PRADESH
TAMIL NADU
KERALA
111
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Energy

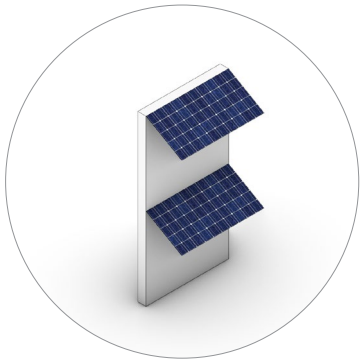
Heat

Solar Integration

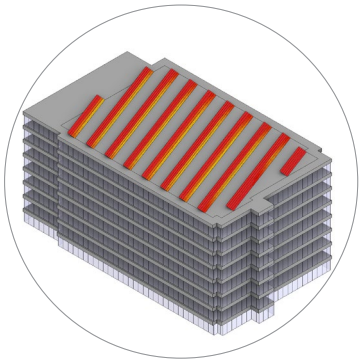
Energy

Heat

Solar Integration



Module



Roof

PV Integration

Maximum Energy produced

351
kWh/m^2

Slope

27°

Orientation

South

West

South

East

Legend
(Kwh/m2)

2150

1935

1720

1505

1290

1075

860

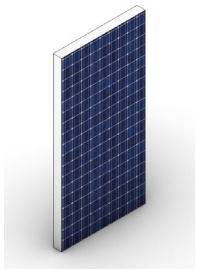
645

430

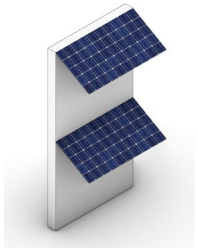
215

0

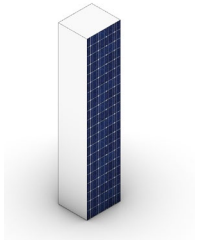
Option 1



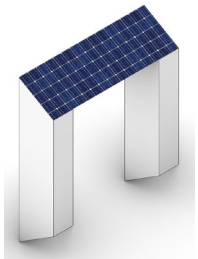
Option 1.1



Option 2



Option 2.1



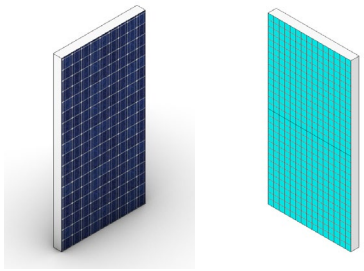
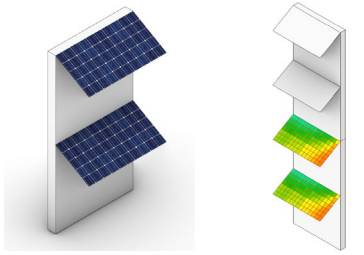
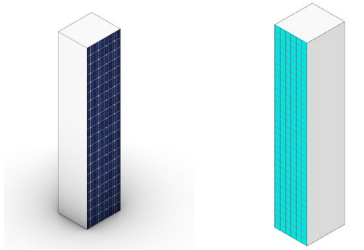
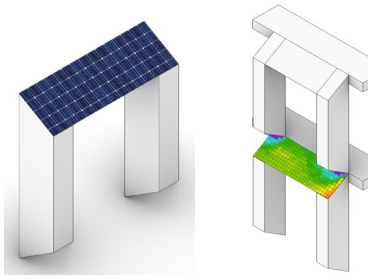
Maximum Energy produced

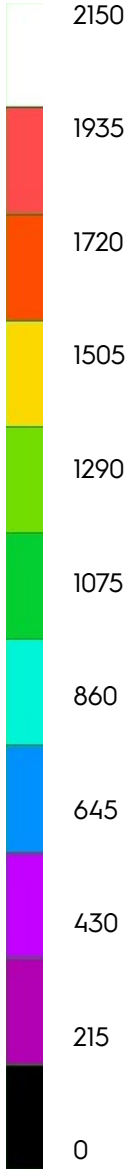
351
kWh/m²

Module

Maximum Energy produced

351 kWh/m²

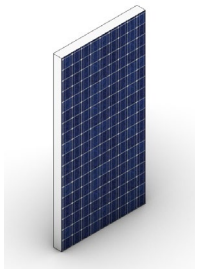
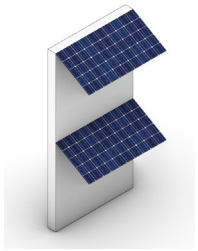
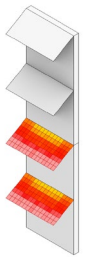
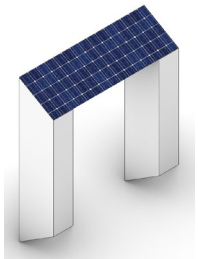
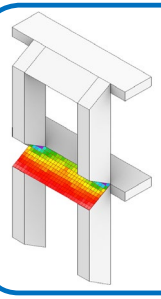
	West	South	East
Option 1		142 Energy/m²	200 Energy/m²	142 Energy/m²
Option 1.1		226 Energy/m²	320 Energy/m²	225 Energy/m²
Option 2		143 Energy/m²	202 Energy/m²	142 Energy/m²
Option 2.1		203 Energy/m²	272 Energy/m²	202 Energy/m²



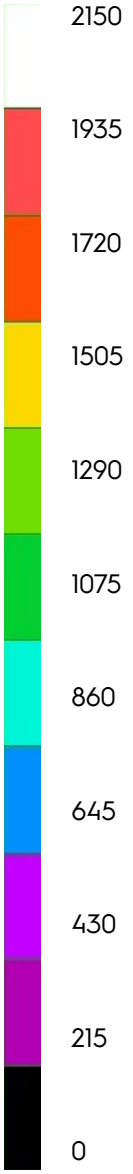
Module

Maximum Energy produced

351 kWh/m²

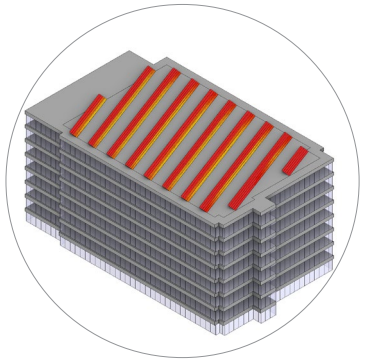
	West	South	East
Option 1	 142 Energy/m²	200 Energy/m²	142 Energy/m²
Option 1.1	 226 Energy/m²	**320 Energy/m²** 	225 Energy/m²
Option 2	 143 Energy/m²	202 Energy/m²	142 Energy/m²
Option 2.1	 203 Energy/m²	**272 Energy/m²** 	202 Energy/m²

Legend (Kwh/m2)



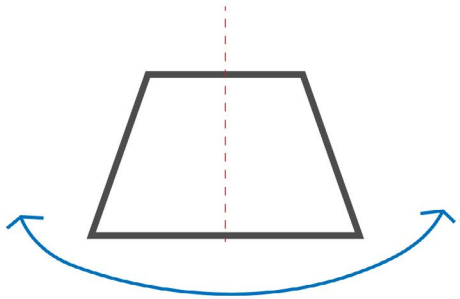
Module

Module

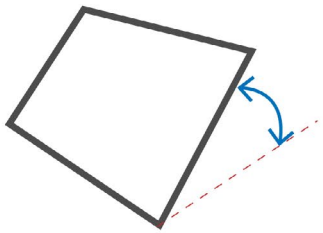


Roof

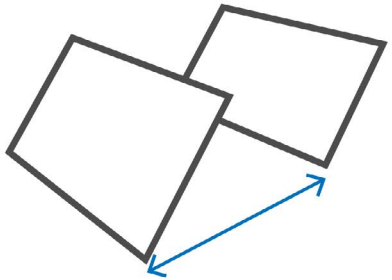
PV Integration



Azimuth Angle

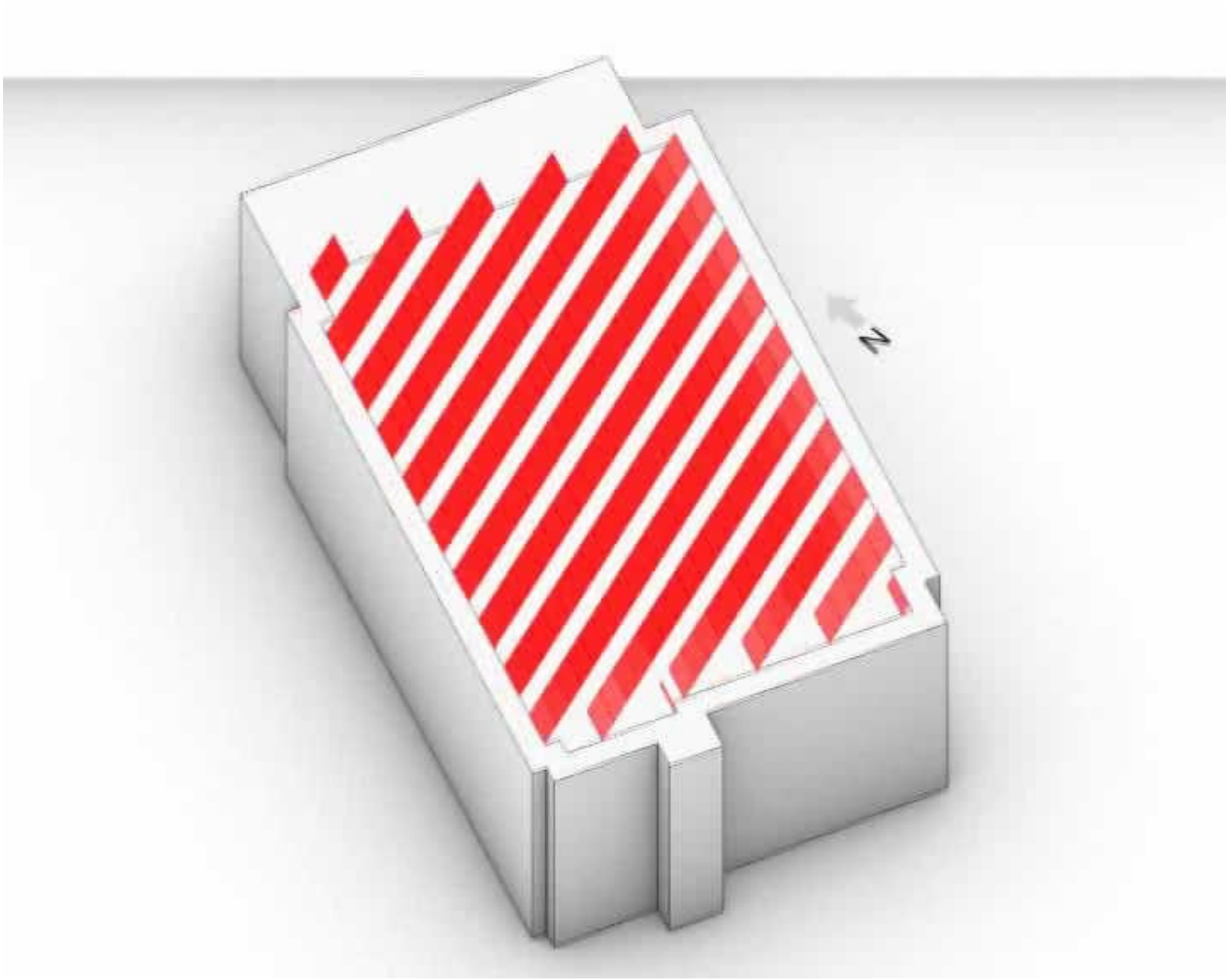


Slope

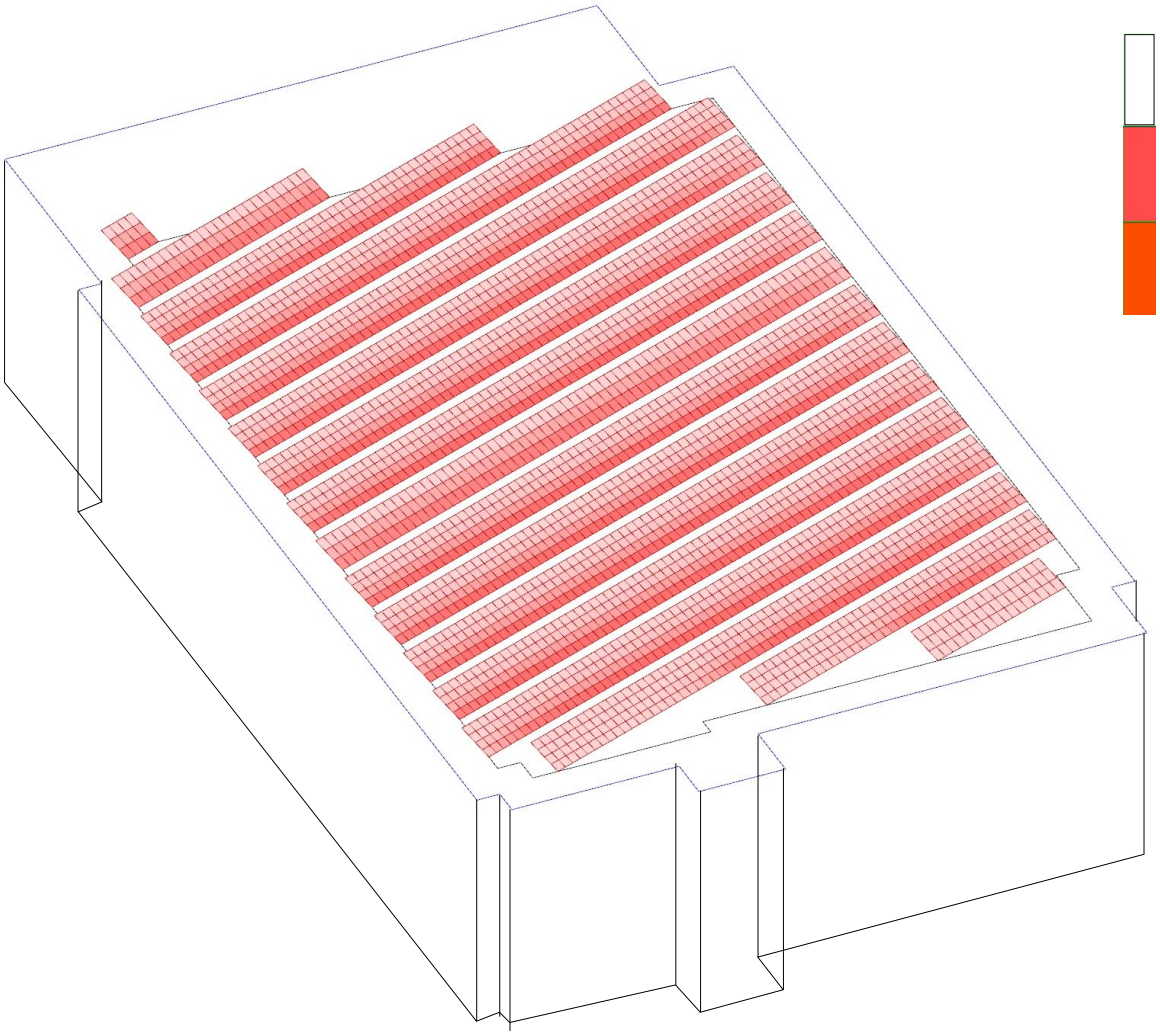


Distance between Panels

PV Parameters



Simulation



Legend
(Kwh/m2)

2150
1935
1720

3.2m
Distance

0°
Azimuth

2 m
Height of panel

27°
Slope

370.30
kWh/m2

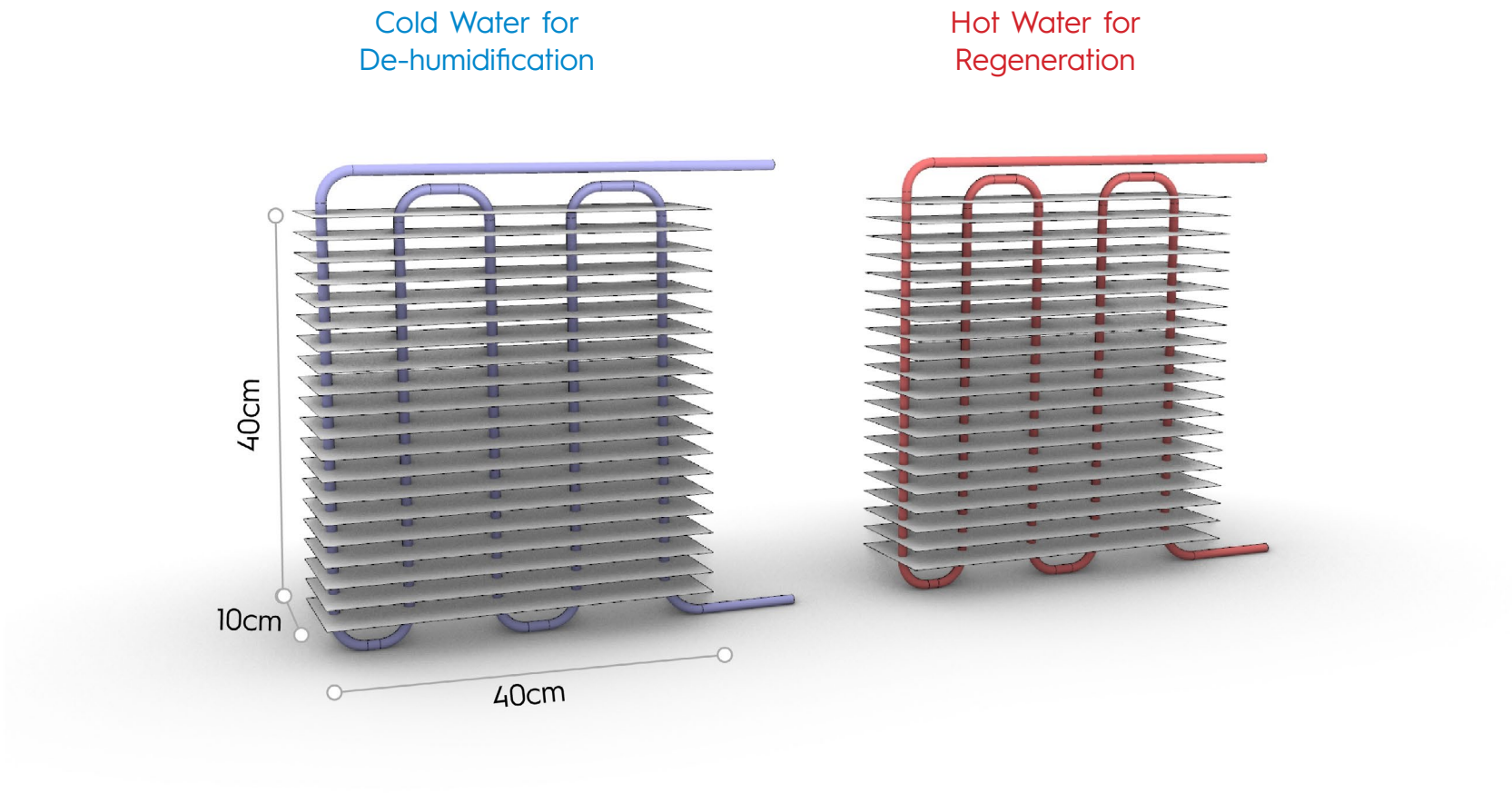
352 MWh.Ann
Total Output

Roof Integration

Energy

Heat

Solar Integration



Desiccant Coated Heat Exchanger

Flat Plate

Evacuated Tube

Solar Collector

450 Wh/m^2

Average Solar Radiation for Delhi

0.8

Efficiency of evacuated collector

426.3 kW

Heating Required

1392.84 m^2

Req. Panel Area

294.4 kW

Heat Produced

952.31 m^2

Panel Area Available

Heat from Solar Collector

450 Wh/m^2

Average Solar Radiation for Delhi

0.8

Efficiency of evacuated collector

426.3 kW

Heating Required

294.4 kW

Heat Produced

1392.84 m^2

Req. Panel Area

952.31 m^2

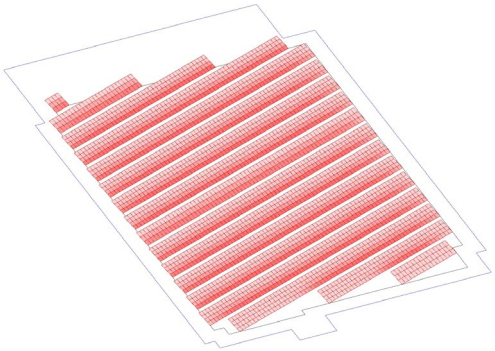
Panel Area Available

HEAT PUMP FOR ADDITIONAL HEAT

Heat from Solar Collector

426.3 kW

Heating Required

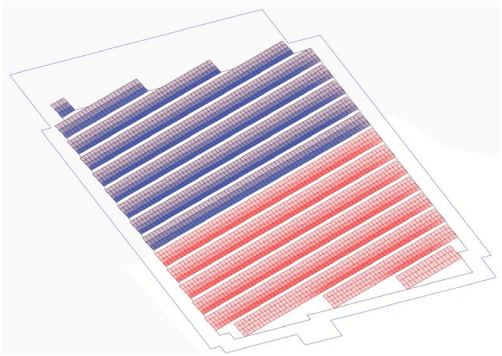


CASE 1

100% S.C

+

Heat Pump

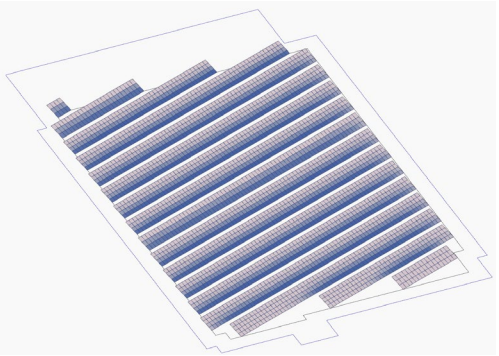


CASE 2

50% S.C + 50% P.V

+

Heat Pump



CASE 3

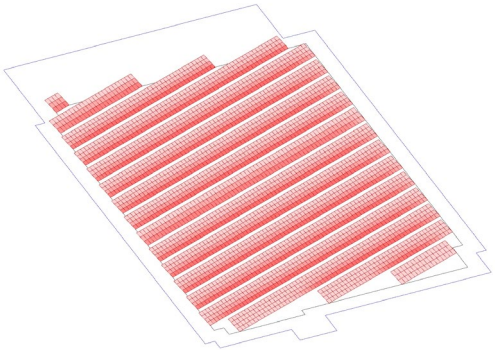
100% P.V

+

Heat Pump

Combination Of SC/PV/Heat Pump

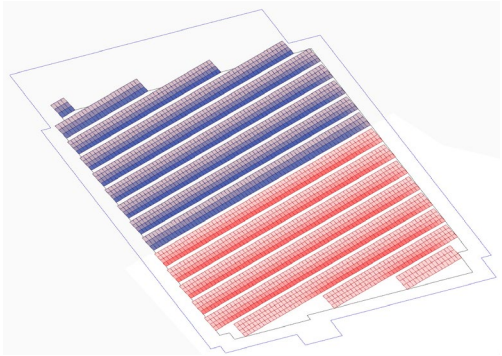
426.3 kW
Heating Required



CASE 1
100% S.C
+

Heat Pump

- 87,120 kWh.ann

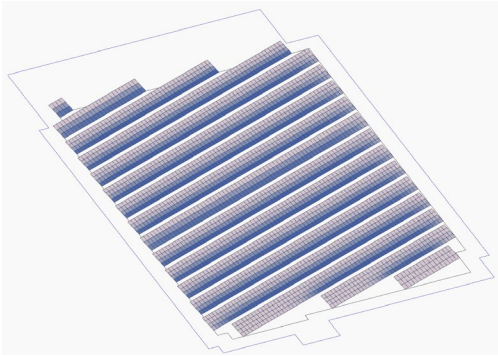


CASE 2
50% S.C + 50% P.V
+

Heat Pump

Power required

- 46,877 kWh.ann



CASE 3
100% P.V
+

Heat Pump

+ 28,646 kWh.ann

Combination Of SC/PV/Heat Pump

426.3 kW

Heating Required

CASE 1

100% S.C

+

Heat Pump

- 87,120 kWh.ann

CASE 2

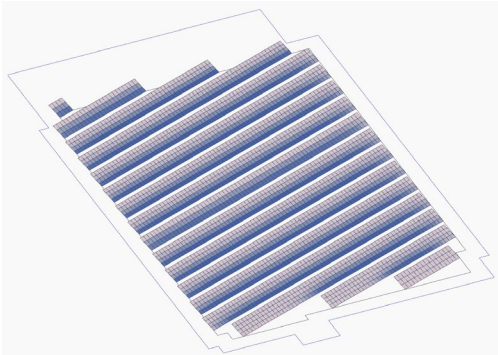
50% S.C + 50% P.V

+

Heat Pump

Power required

- 46,877 kWh.ann



CASE 3

100% P.V

+

Heat Pump

+ 28,646 kWh.ann

Combination Of SC/PV/Heat Pump

	Pumping water to Roof			Blower + Misc for the cooler		Heat Pump
Power required	Hot water	Cold water	Cold water for cooler	Primary air	Working air	
per device (kW)	0.0028	0.0028	4.38 E-05	0.13	0.03	0.3
per device for a year (kWh)	10.19	10.19	0.15	451.98	99.97	1,109.58
Total Power per device	1.7 MWh					
Number of devices	292 nos.					
Total Power	4,91 MWh					
Safety Factor 1.25	**614 MWh**					

Power Calculation

	Pumping water to Roof			Blower + Misc for the cooler		Heat Pump
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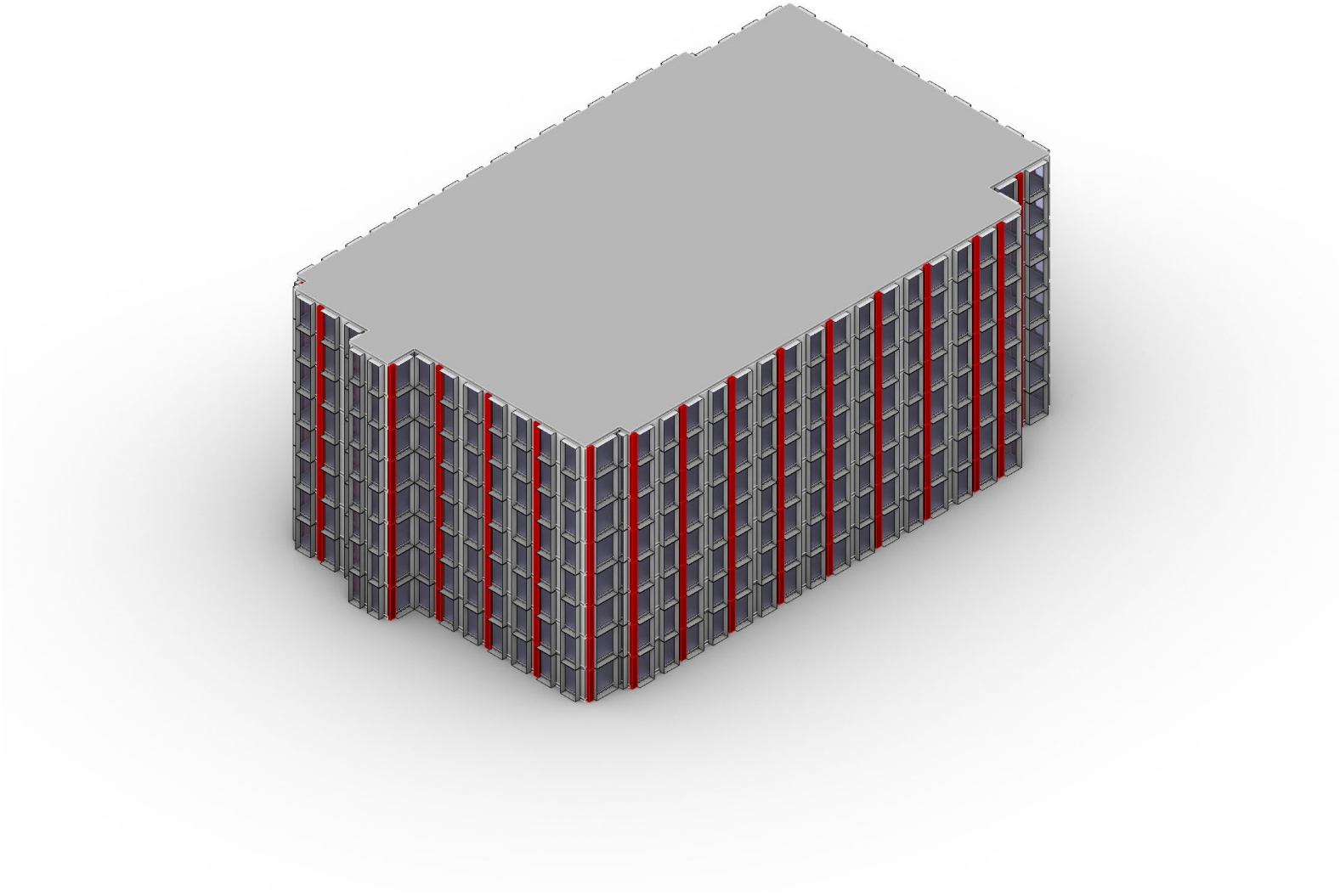
Total Power per device	**1.7MWh**					
Number of devices	292 nos.					
Total Power	4,91 MWh					
Safety Factor 1.25	**614 MWh**					

***Heat Pump** has the **largest** share in total energy*

Power Calculation

Comparison

Conventional / Evaporative Cooling

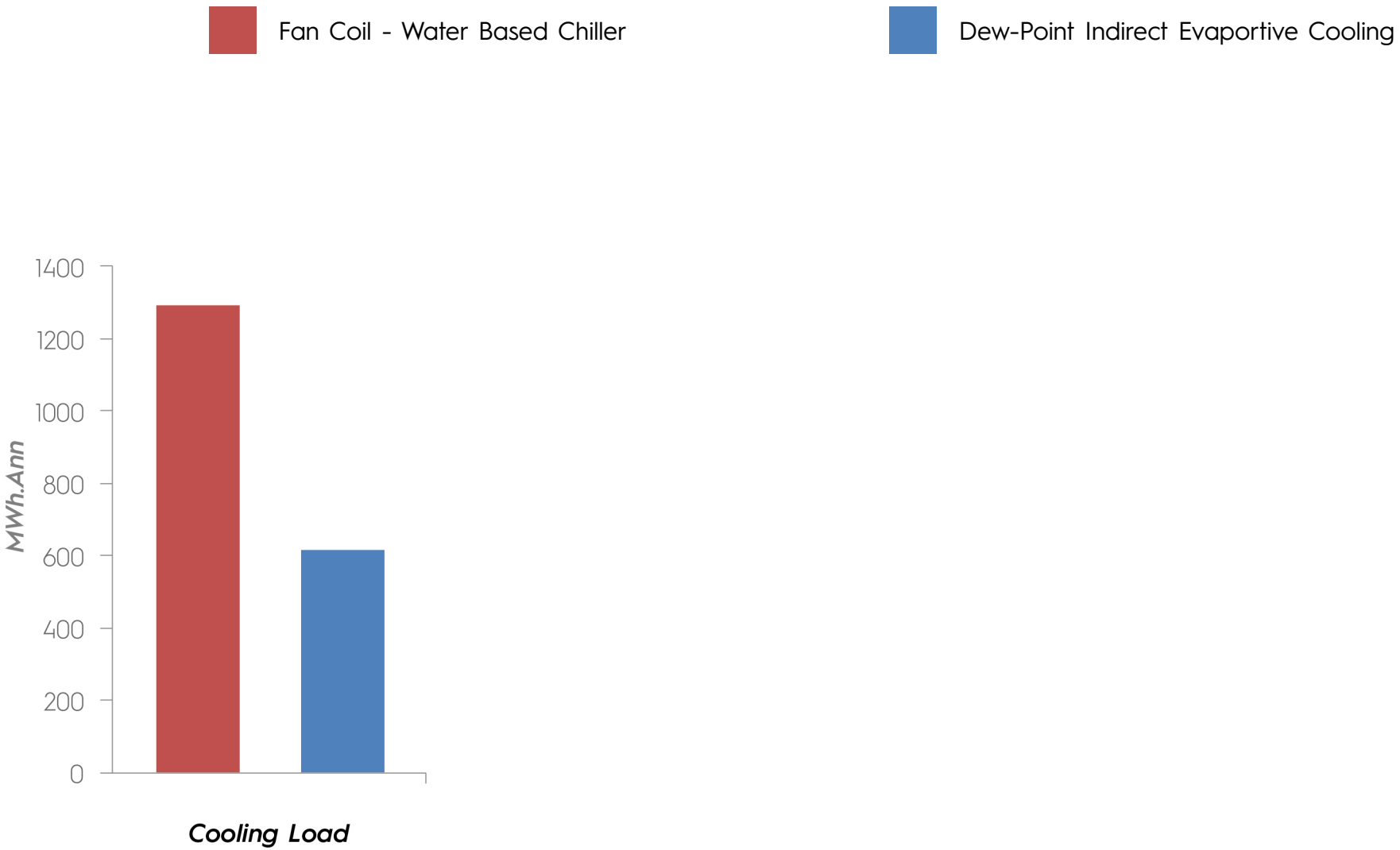


Simulated Building

Fan Coil - Water Based Chiller

Dew-Point Indirect Evaportive Cooling

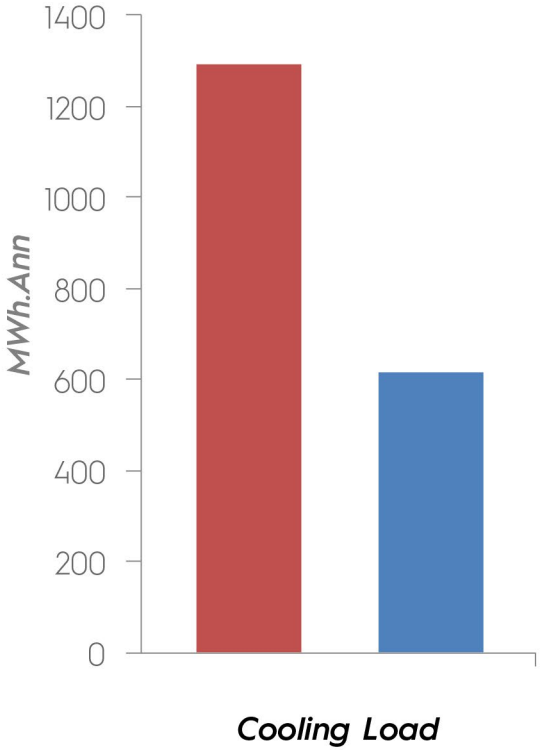
Comparison


Fan Coil - Water Based Chiller
Dew-Point Indirect Evaportive Cooling
1400
1200
1000
800
600
400
200
0
MWh.Ann
Cooling Load
50%

Comparison

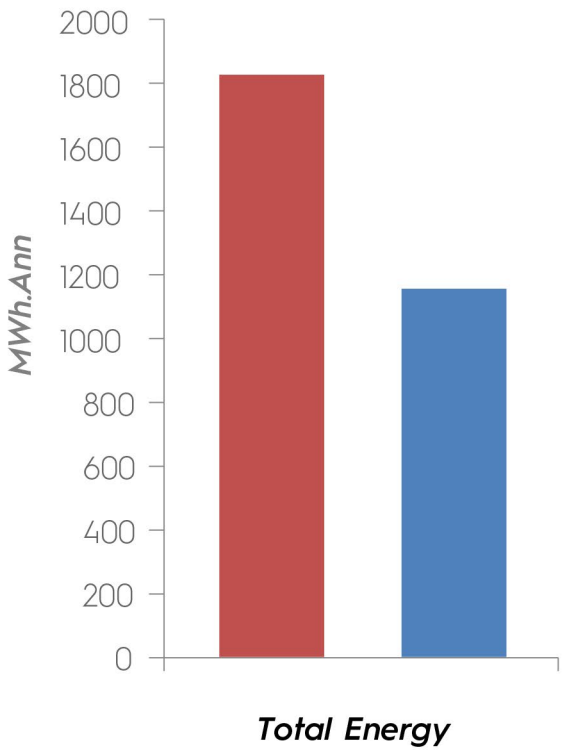
Fan Coil - Water Based Chiller

Dew-Point Indirect Evaportive Cooling



Cooling Load

50%



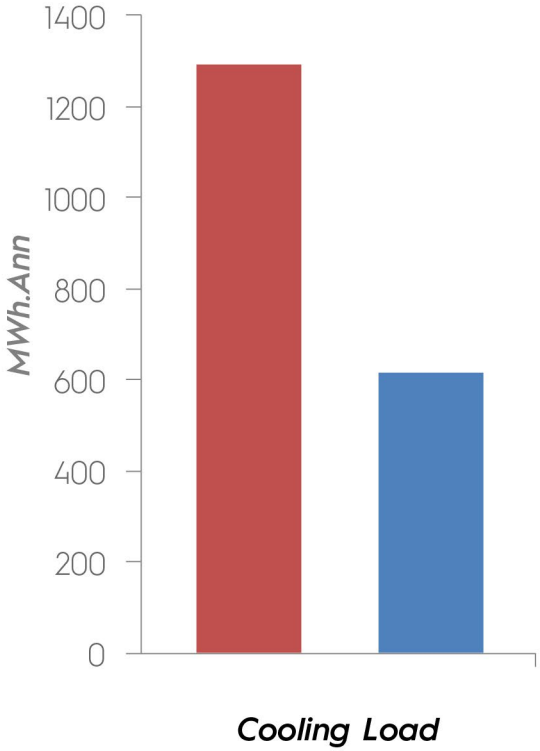
Total Energy

40%

Comparison

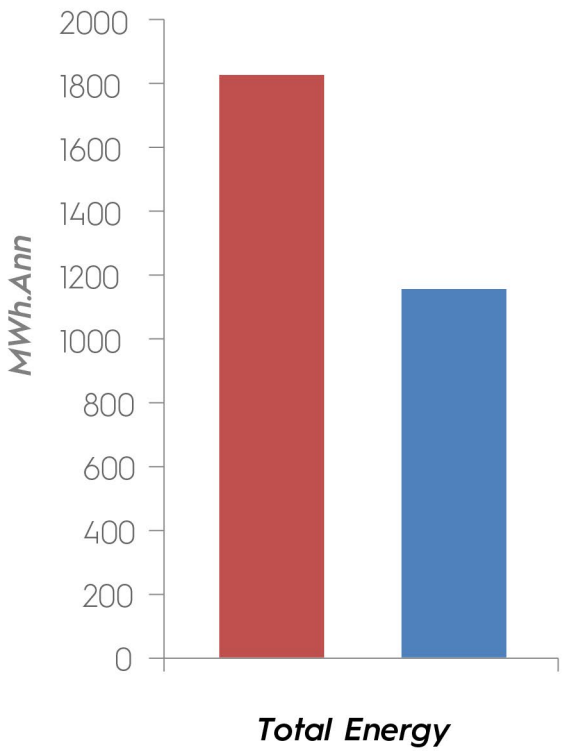
Fan Coil - Water Based Chiller

Dew-Point Indirect Evaportive Cooling



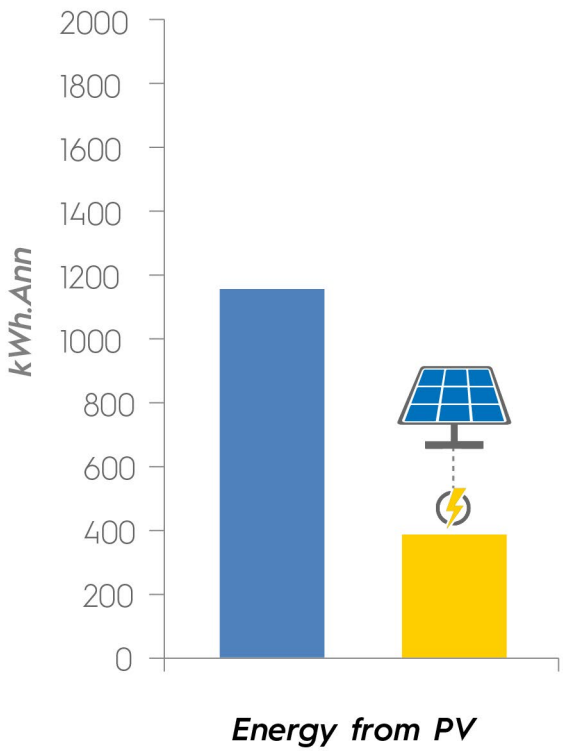
Cooling Load

50%



Total Energy

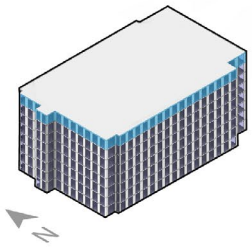
40%



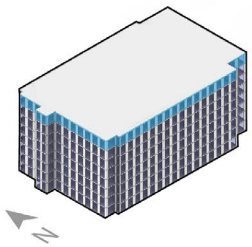
Energy from PV

30%

Comparison



WWR	Location	Floor Area	Cooling load
60%	New Delhi	1792m2	50W/m2/year



WWR	Location	Floor Area	Cooling load
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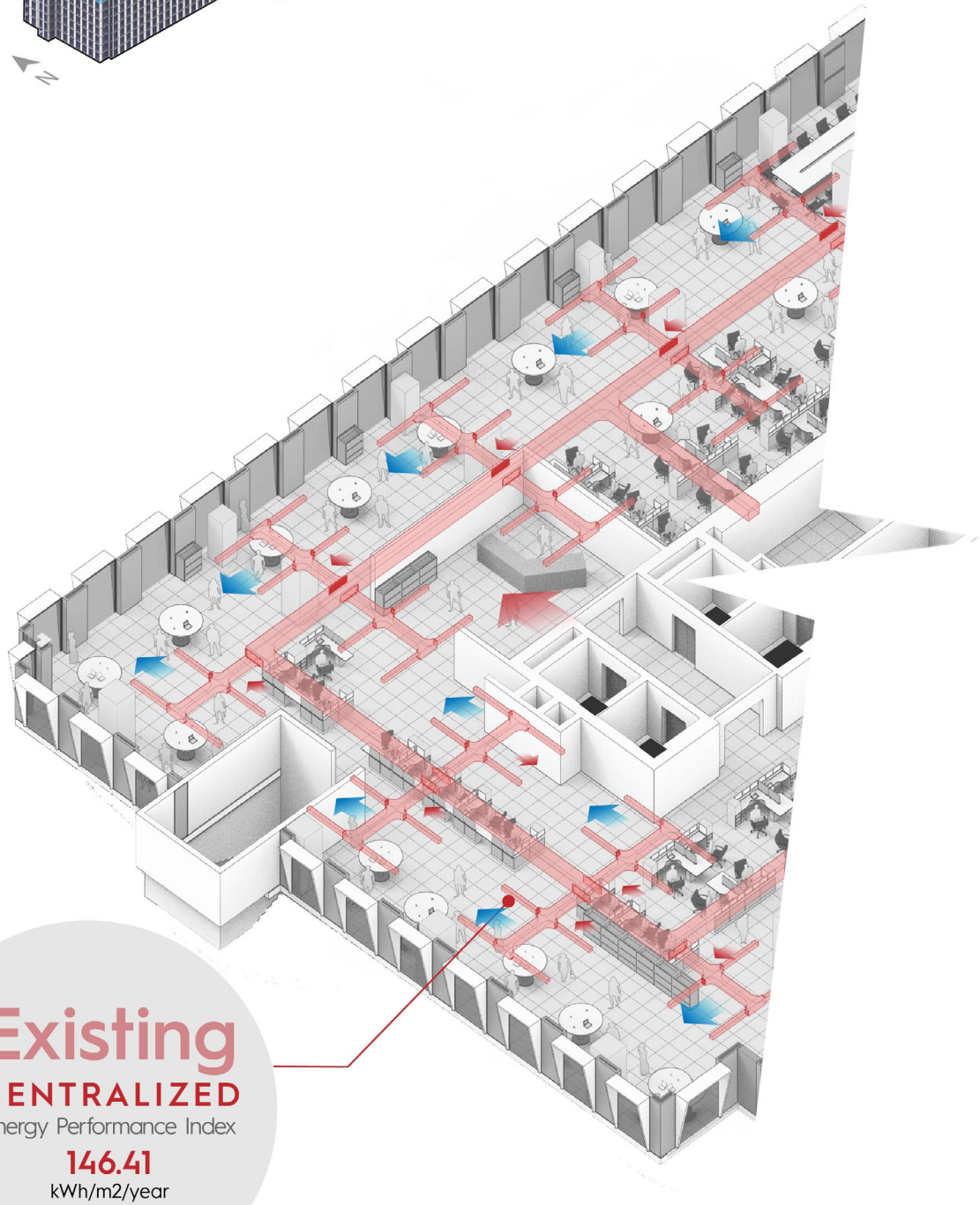


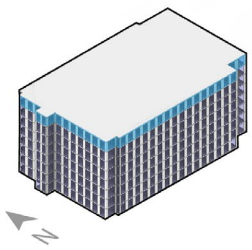
Existing

CENTRALIZED

Energy Performance Index

146.41

kWh/m2/year



WWR	Location	Floor Area	Cooling load
60%	New Delhi	1792m2	50W/m2/year

Proposed

DECENTRALIZED

Energy Performance Index

92.26

kWh/m2/year

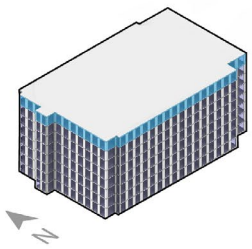
Existing

CENTRALIZED

Energy Performance Index

146.41

kWh/m2/year



WWR	Location	Floor Area	Cooling load
60%	New Delhi	1792m2	50W/m2/year

Proposed

DECENTRALIZED

Energy Performance Index

92.26

kWh/m2/year

40%

ENERGY SAVING

U VALUE

Roof

0.2 W/m²K

150mm Insulated Roof

Glazing

1.7 W/m²K

6/13/6

LoE Double glazing with air

Wall

0.3 W/m²K

100mm Insulated Cavity brick with dense plaster

SHADING

Egg Crate

Combinative mask

0.6m by 0.6m

1.5m spacing

VENTILATION

Infiltration

0.3

ac/h

Fresh air

5.2

l/s - person

Lighting

2

W/m2/ 100 lux

LED linear control

INTERNAL HEAT GAIN

Equipment

9

W/m2

People

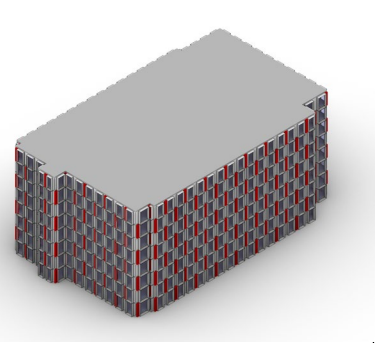
Existing

CENTRALIZED

Energy Performance Index

146.41

kWh/m2/year

				
Name	Wipro	IPB	SkyView	SkyView
Year	2005	2014	2015	2015
WWR%	33	**20**	55	**55**
Glazing	1.8	1.8	1.8	1.5
Solid	0.6	0.5	1.1	0.3
Shading	Horizontal louvers	Recessed	No Shading	Egg Crate
LPD	5.4	5	9.5	9.5
Cooling	Central	**Geothermal**	Central	**Evaporative**
EPI **179 kWh/m2/year**	85	**45.25**	112	**64.26**

Comparison

Ventilating Interiors

Refurbishment Projects

Cost Analysis

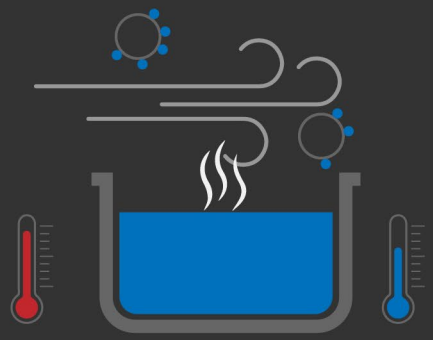
Sustainable moisture removal

Market Scenario

Future works

"Architecture is a three-legged stool:
Climate, Technology, and Culture."

- Charles Correa.



de-VAP
Systems

THANK YOU