Naturally Tokyo

Found in translation?

A case study of Dutch

Earth, Wind, and Fire

system integration & optimization

in an office building in Tokyo

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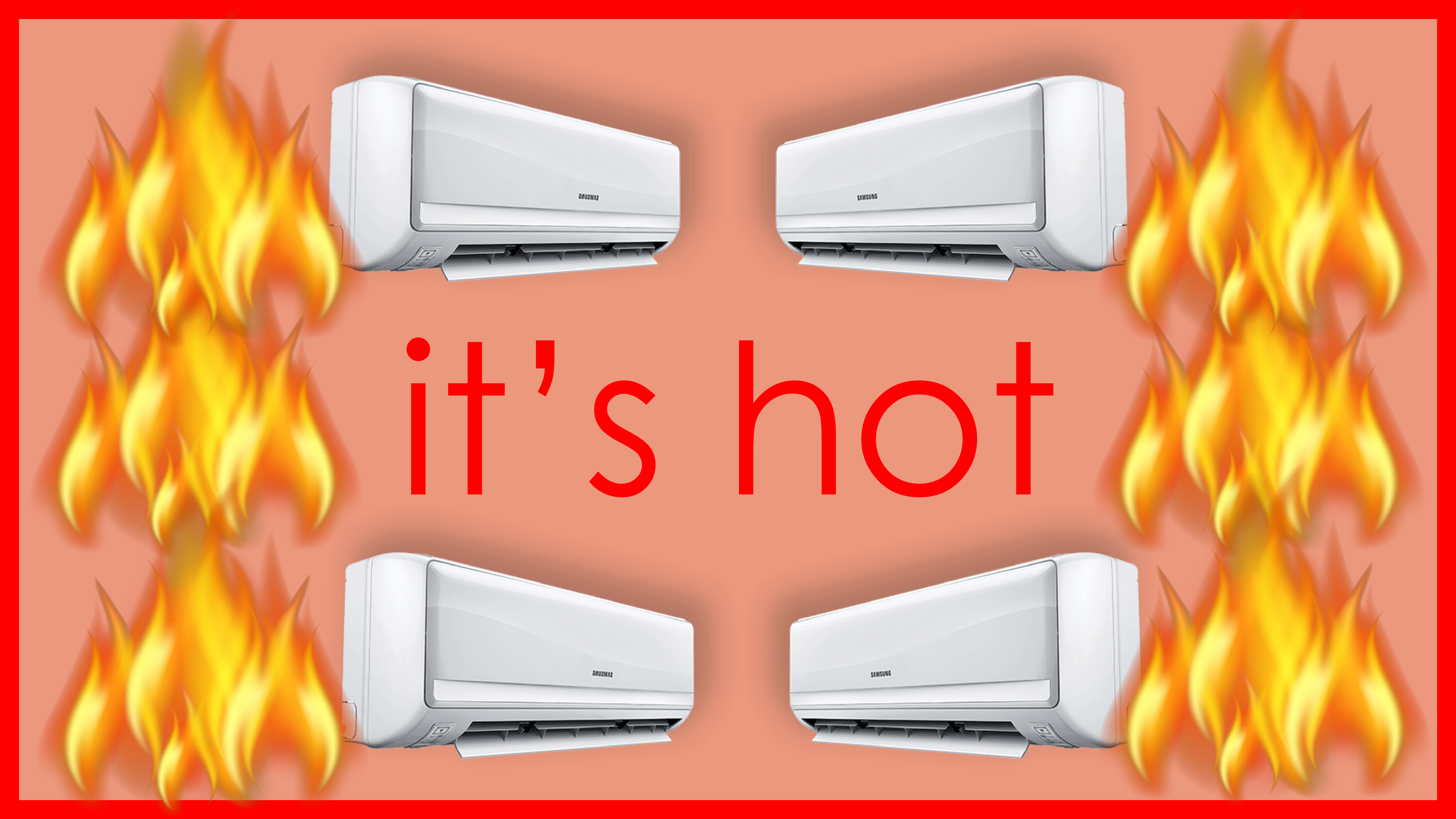
Delegate of examiner:
Dr. Dirk van den Heuvel

P5 | 9 July 2021
Puji Nata Djaja | 5020379

"I want you to act as if the house is on fire, because it is."


it’s hot

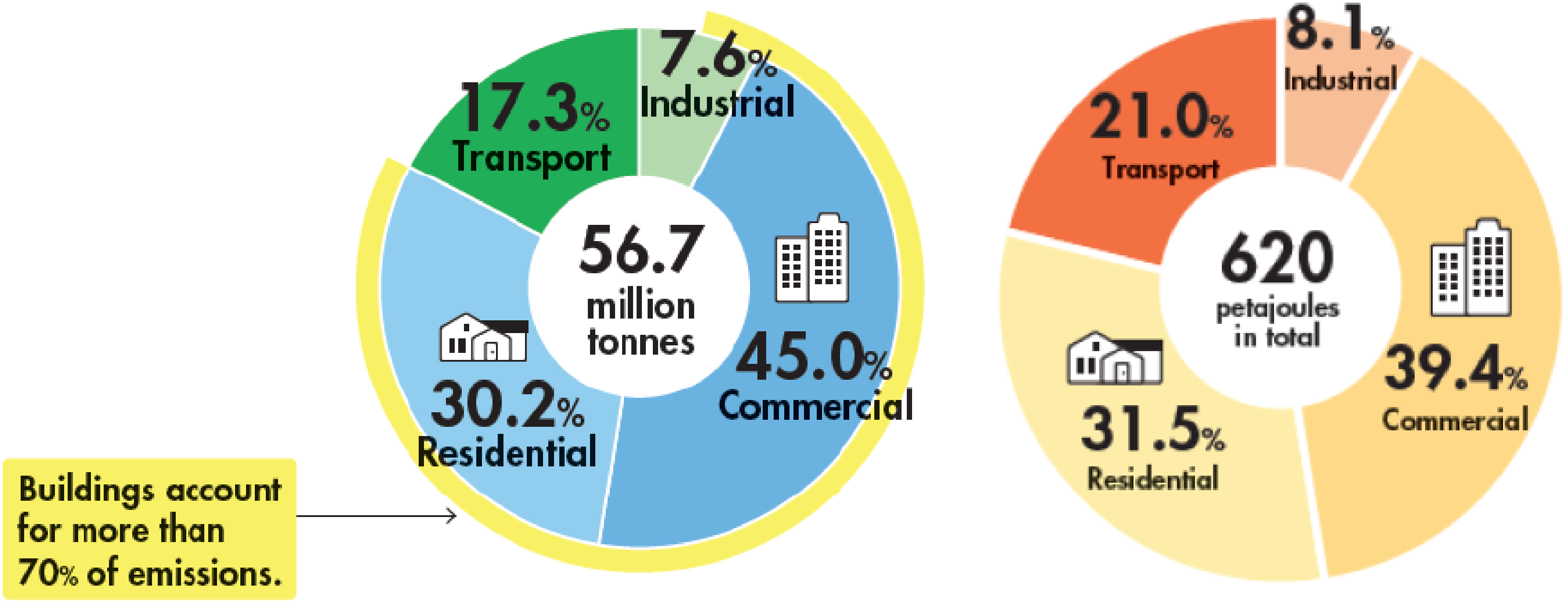


Figure 1 Sectoral Breakdown of energy-related CO2 emission (left) and energy consumption (right) in Tokyo in 2016 (Tokyo Metropolitan Government, 2019)


Japan raises emissions reduction target to 46% by 2030

By MARI YAMAGUCHI April 22, 2021

(APnews.com, 2021)


NIKKEI Asia

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COMMENT

Making Japan carbon neutral by 2050 is huge challenge

Technological innovations and bold social changes are called essential

(Asia.nikkei.com, 2021)

“Is the Dutch **Earth, Wind and Fire system** (EWF), in place of the existing **air-conditioning system**, an efficient **energy-retrofitting method** to achieve **energy-neutrality** in an **office building in Tokyo** without compromising **thermal comfort** of users?”

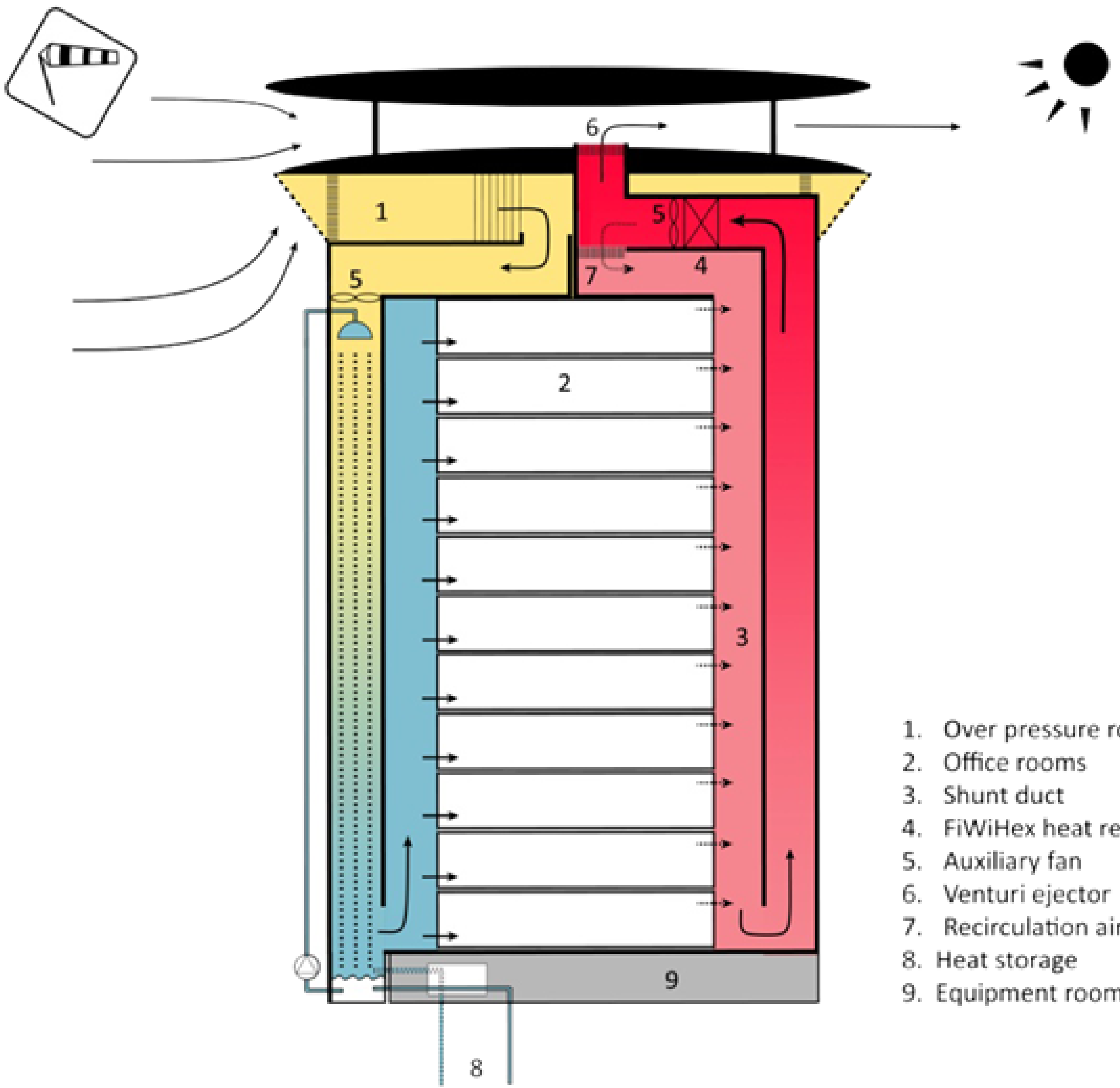
EWE

WIND: Ventec/ Power Roof

Energy production

EARTH: Climate Cascade

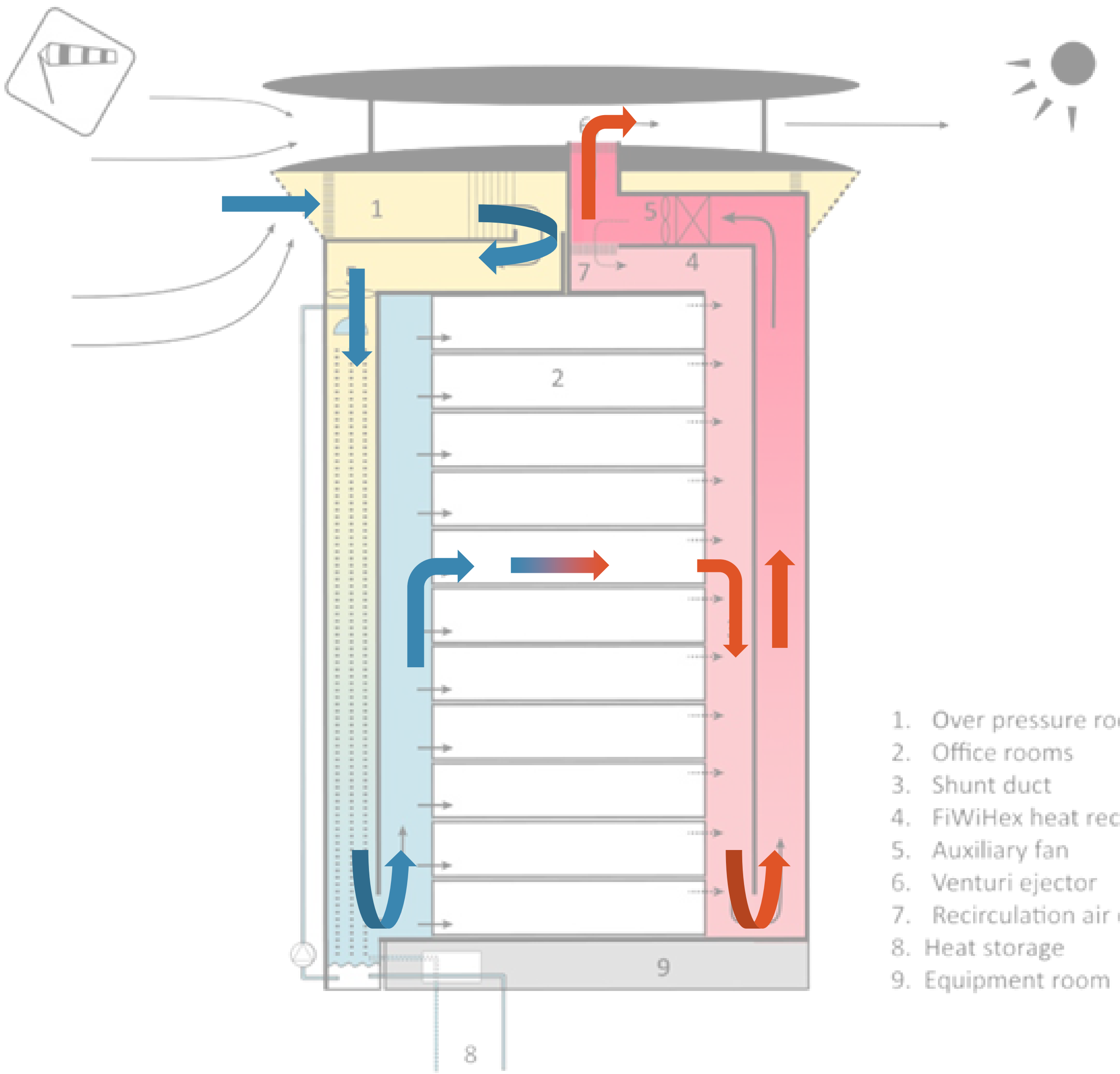
Air supply



FIRE: Solar Chimney

Air exhaust

1. Over pressure room
2. Office rooms
3. Shunt duct
4. FiWiHex heat recovery
5. Auxiliary fan
6. Venturi ejector
7. Recirculation air damper
8. Heat storage
9. Equipment room



1. Over pressure room
2. Office rooms
3. Shunt duct
4. FiWiHex heat recovery
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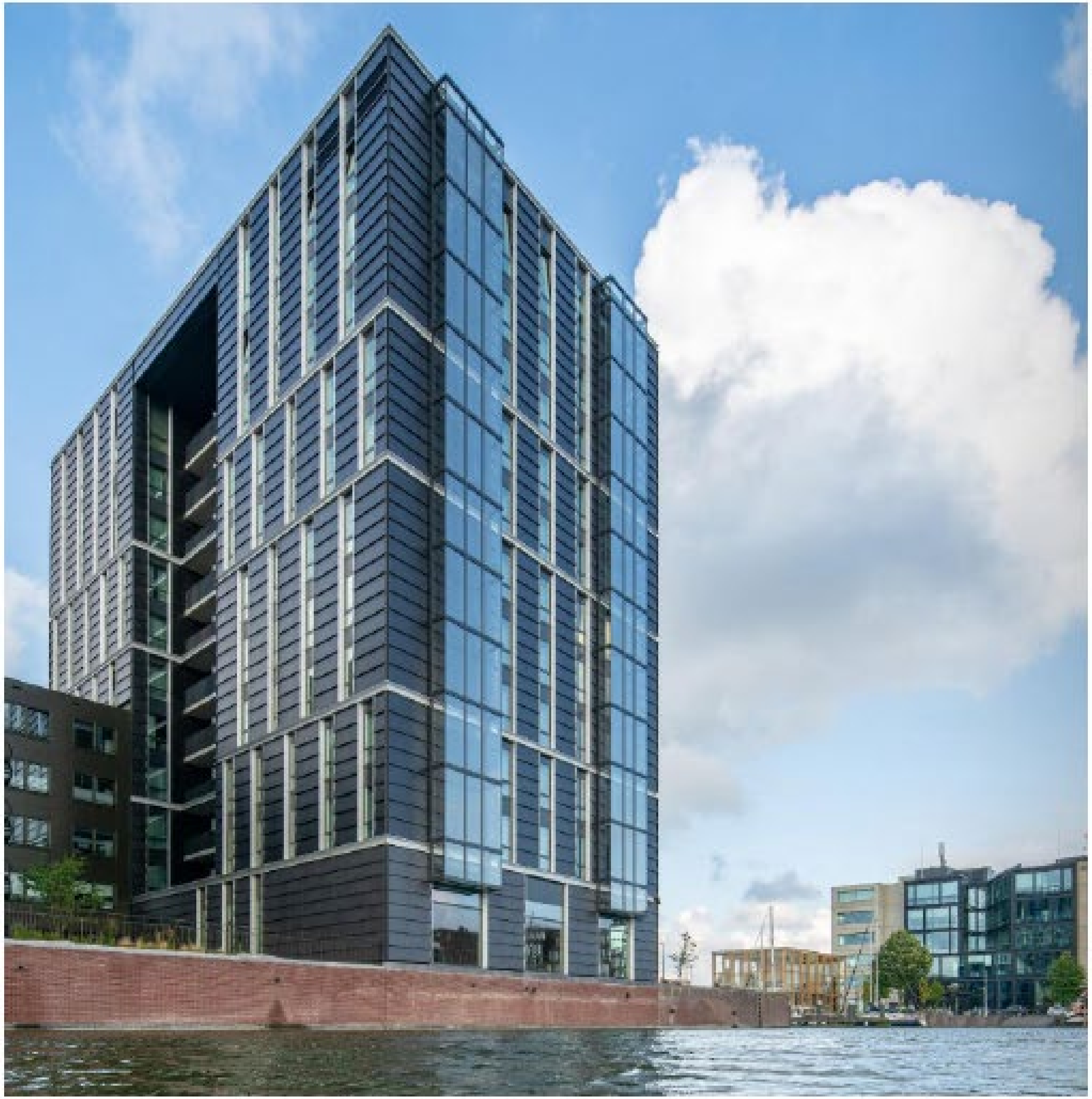
The Four Elements Hotel, Amsterdam



(OZ architect, 2019)

MFO-2 building, Erasmus University Rotterdam

(Paul de Ruiter Architects, 2021)


Imperial Palace
Kokyogaien National Garden
Tokyo Station
Nihonbashi
Layers
3D
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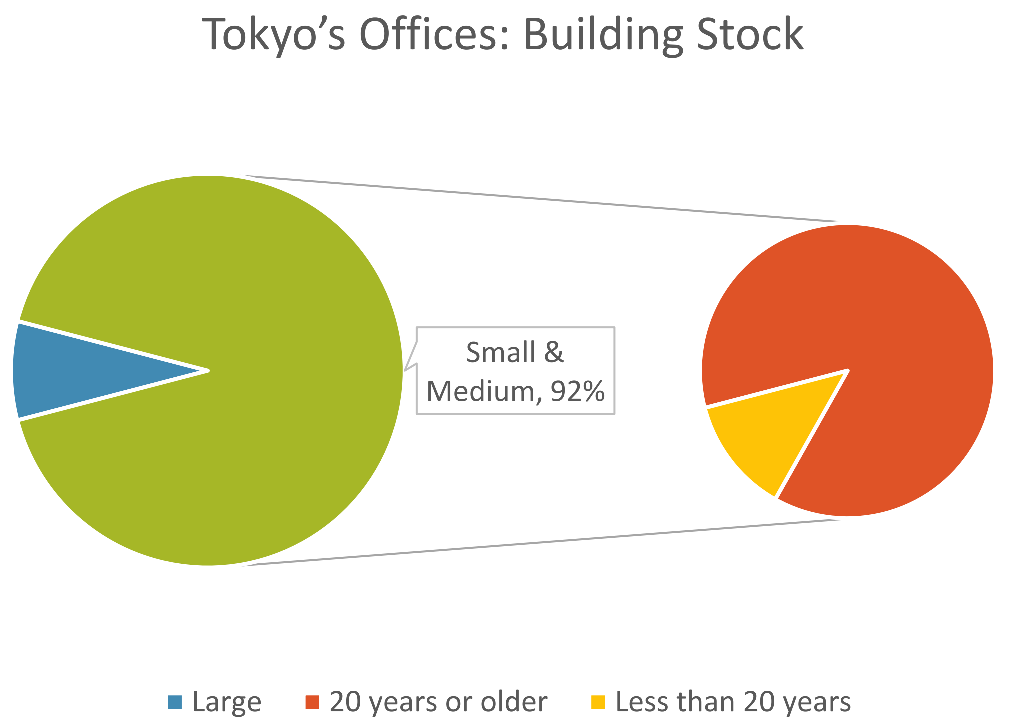
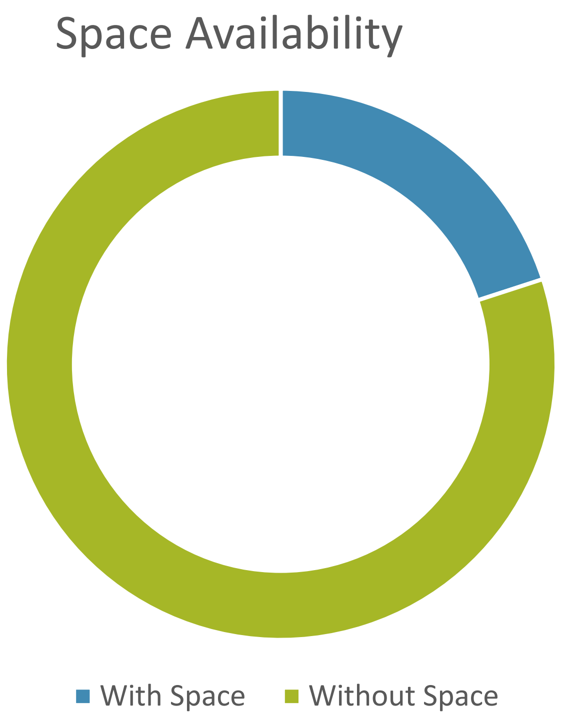
100 m



(Xymax Real Estate Institute , 2020)



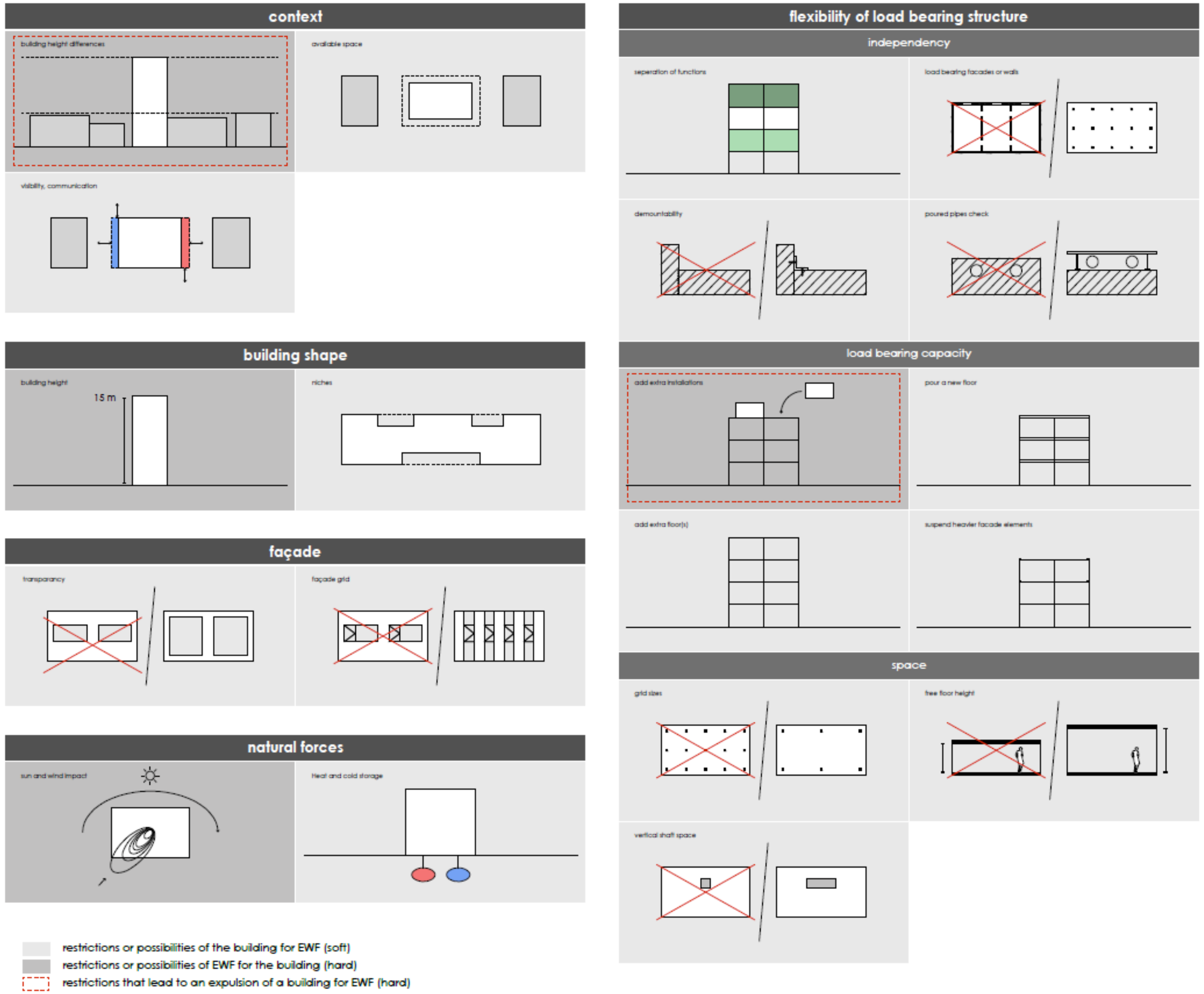
EWF Integration Criteria

Compulsory:

- Higher than its surrounding (for Power Roof)
- No load-bearing facades or walls
- Has sufficient load-bearing capacity for possible installation i.e. Power Roof

Additional:

- Space availability on site
- Building height is over 15m
- Free-floor height
- Available vertical shaft
- etc



(Swier, 2015)


Layers
2D
Google
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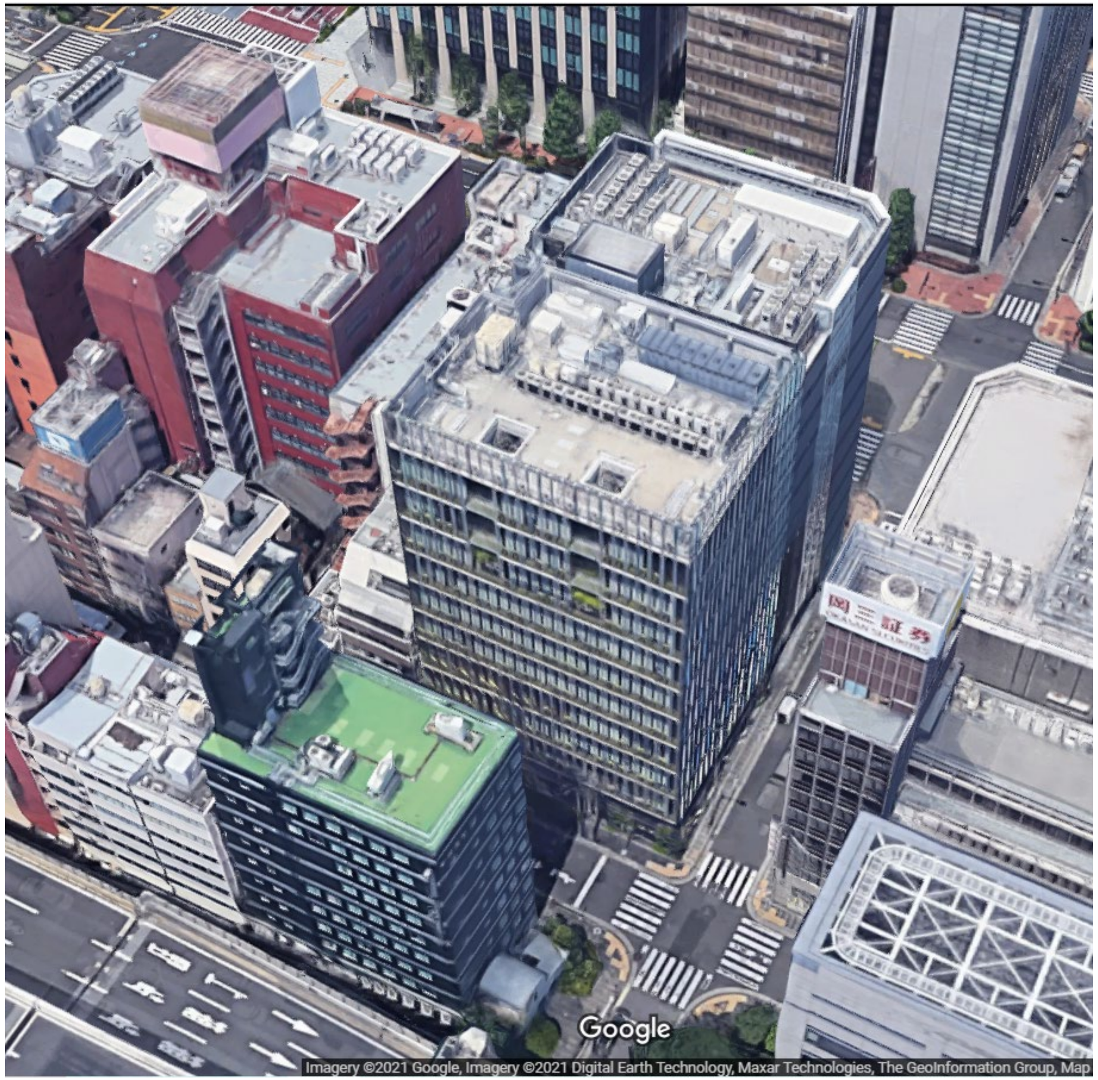
50 m

Case study: NK Building

South view



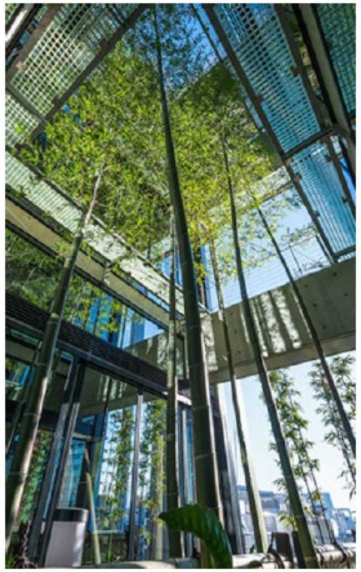
East view

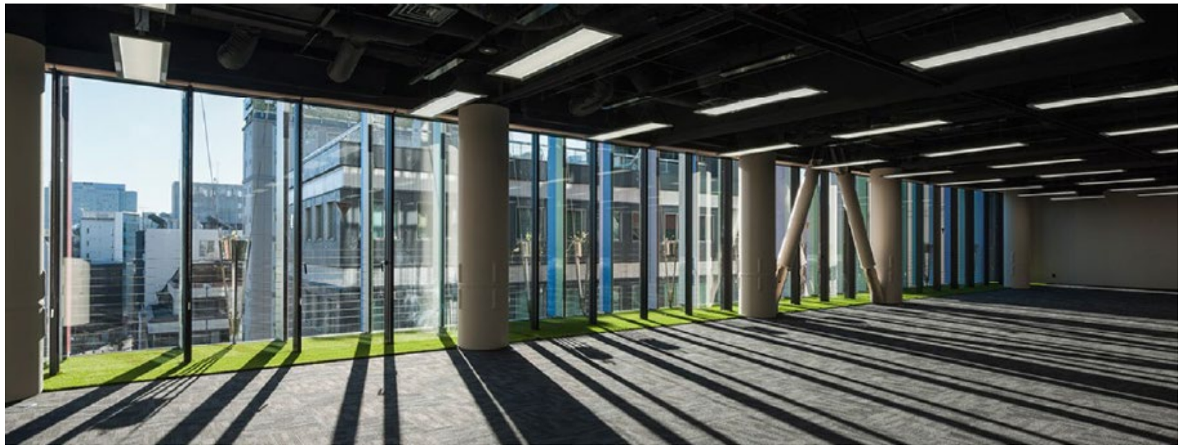
Case study: NK Building

North view

West view

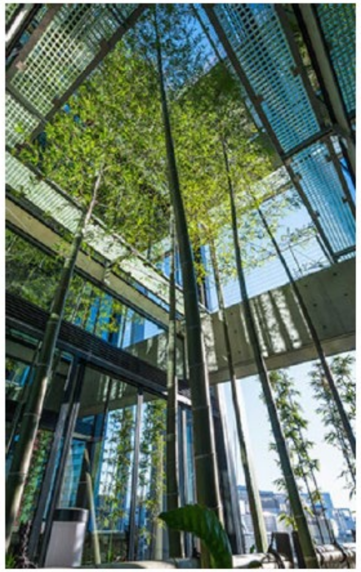
Case study: NK Building

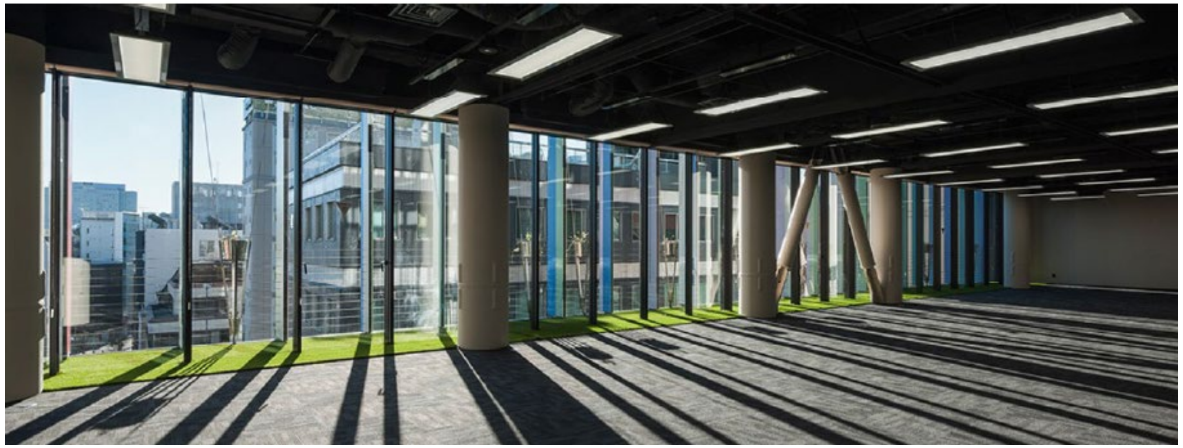




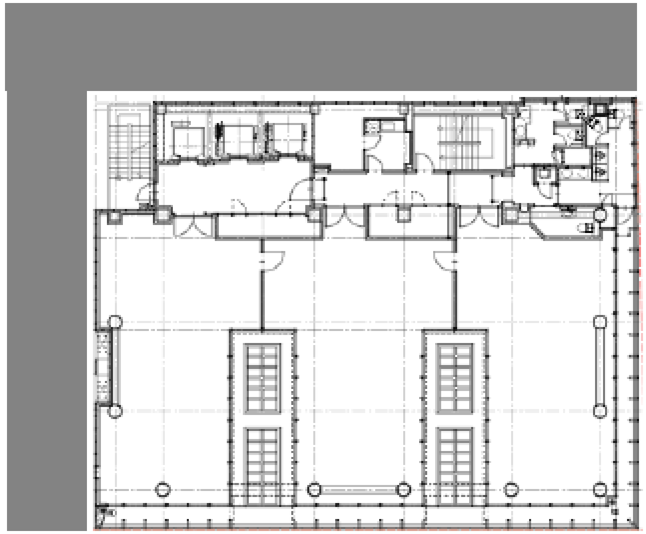
Location	*1-16-3 Nihonbashi, Chuo-ku, Tokyo*
Date of completion	2016
Total floor area	5,116.39 m^2
Typical floor area	391.30 m^2 / 118.37 tsubo
Structure	Steel structure, with vibration damping
Building scale	1 basement floor, 10 floors above ground
Air-conditioning	Individual air-conditioning
Design	Flying Pumpkins & Team FP

Case study: NK Building

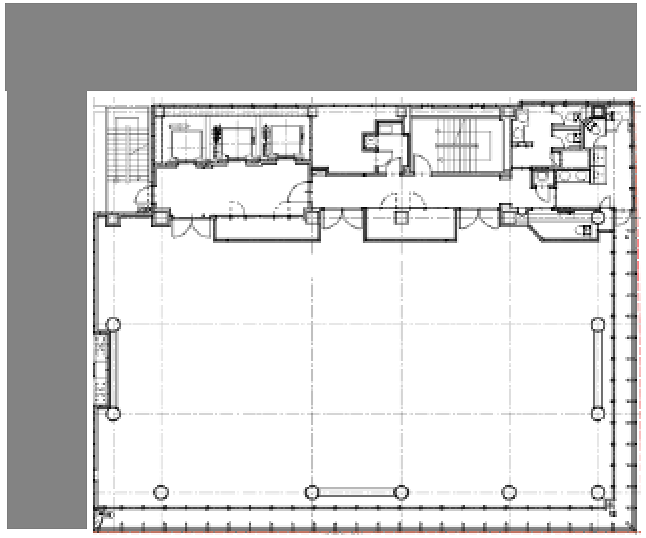




8 -10



3 - 7



20.5 x 26 m

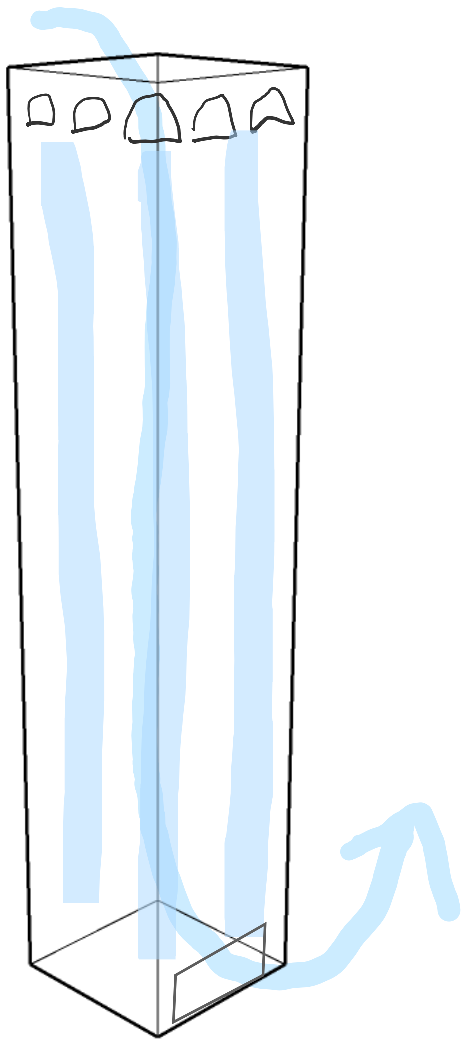
How do I design CC and SC?

First:

Climate Analysis

Excel calculation

Climate Cascade (CC)



CC Design Steps

Climate analysis
- Temperature
- Relative humidity
- Ground water temperature

Design parameter
- Air velocity
- Water/air factor (incl. no of spray heads)
- (With/without after-cooling)

Outcome
- CC size
- Achieved pressure

Air velocity
3 m/s

lower → *higher*

bigger ← CC size → *smaller*

lower ← Hydraulic pressure → *higher*

lower ← Water velocity → *higher*

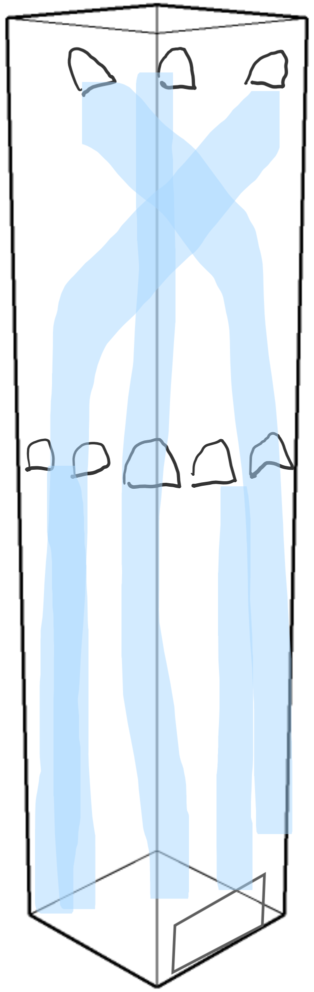
Climate Cascade (CC)

Tokyo ≦16.5°C cooling: when T outside air ≧ 24°C

Scenario	Height [m]	Necessary Pressure [Pa]	No of spray-heads	Outgoing air temperature T33 [°C]	Achieved Pressure T24 [Pa]	Fan Energy [MWh]	Pump Energy [MWh]	Pump Energy [kWh/m2]	Heating Energy [MWh]	Heating Energy [kWh/m2]	Incoming water temperature	Cooling Energy [MWh]	Cooling Energy [kWh/m2]	Amount of water [ton]	Total Energy [kWh/m2]
1	**44**	100	**16**	16.4	307	0*	54	11	27	6	**13**	154	32	243,000	49
2	**44**	100	**10**	16.42	192	0*	34	7	33	7	**11**	199	42	152,000	56
3	**22**	100	**10**	16.42	96	0*	17	4	32	7	**11**	199	42	152,000	53
4	**22**	100	**12**	16.5	115	0*	20	4	28	6	**12**	177	37	182,000	47
5	**22**	100	**12**	16.87	115	0*	20	4	27	6	**12.5**	147	31	182,000	41
6	**22**	100	**9**	16.14	86	0*	15	3	36	8	**10**	226	48	137,000	59

* Natural draft by EWF saved 1.68 MWh of Fan energy

Climate Cascade (CC)

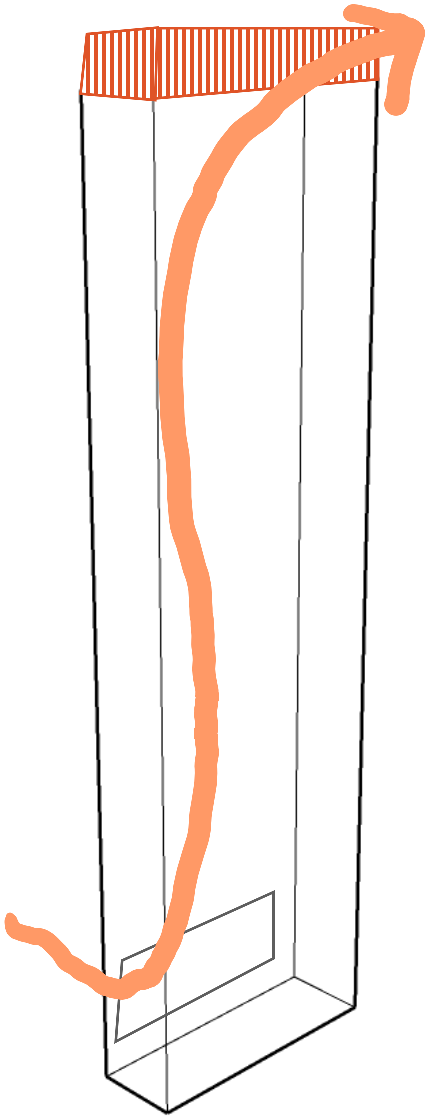


W x L x H	: 1.08 x 1.08 x 44m
Spray heads	: 3 at the top (44 m)
	9 at 22m
Pressure loss	: 100 Pa
Air velocity	: 3 m/s
Ventilation	: 12,650 m^3/h
	50 m^3/h/person
Air temperature into room	: 16.5°C
Water temperature	: Cooling mode 12.5°C (cooled)
	Heating mode 15°C (ground temp.)

Climate Cascade (CC)

Air						Water				Room		Pressure			n_sprayheads
θe- ^0C	φ_e -%	x_e -g/kg	θ_{uit}- ^0C	φ_{uit} -%	x_{uit} -g/kg	θ_{in}- ^0C	θ_{uit}- ^0C	Vin - m3/s	m_wat_in	θ_i- ^0C	φ -%	p_{hydr}-Pa	p_{th} -Pa	p_{tot} -Pa	
33	55	20.75	16.87	100.00	12.02	12.5	16.87	0.008	8.4	28	70.7	287.8	-11.4	299.2	12
30	66	17.69	16.77	100.00	11.94	12.5	16.77	0.006	6.3	28	70.2	215.9	-9.5	225.3	9
24	79	14.82	16.64	100.00	11.84	12.5	16.64	0.004	3.5	20	66.6	119.9	-5.4	125.3	5
18	71	9.13	15.28	96.05	10.40	15	14.91	0.001	0.7	20	60.4	24.0	-2.1	26.0	1
12	68	5.91	13.73	100.00	9.78	15	13.73	0.008	8.4	20	59.3	287.8	1.3	286.5	12
6	68	3.93	12.75	100.00	9.16	15	12.75	0.008	8.4	20	57.6	287.8	5.4	282.4	12
0	49	1.84	11.74	100.00	8.57	15	11.74	0.008	8.4	20	53.9	287.8	9.7	278.2	12
-2	50	1.59	11.49	100.00	8.43	15	11.49	0.008	8.4	20	53.0	287.8	11.2	276.6	12

Solar Chimney (SC)



SC Design Steps

Climate analysis
- Temperature
- Solar radiation

Design parameter
- Air velocity

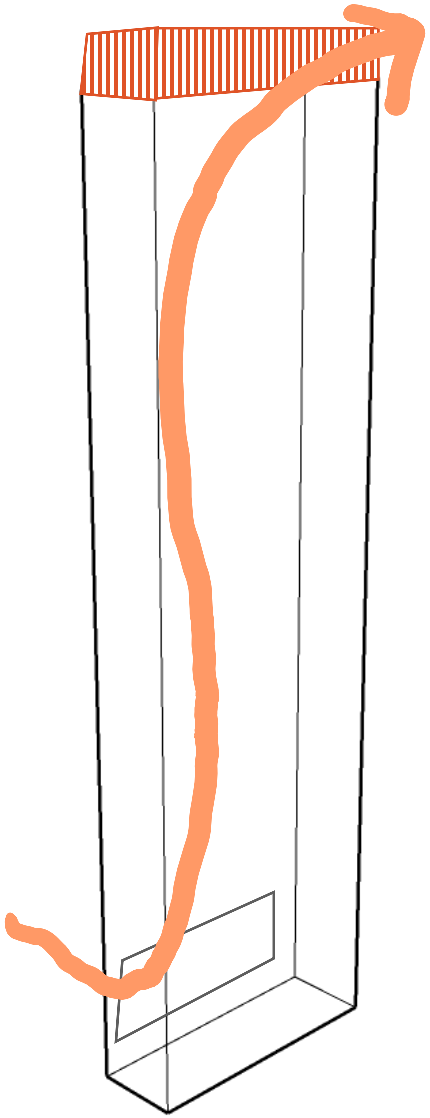
Outcome
- SC size
- Achieved thermal draft
- Collected heat

Air velocity
1.5 m/s

lower ⟶ *higher*

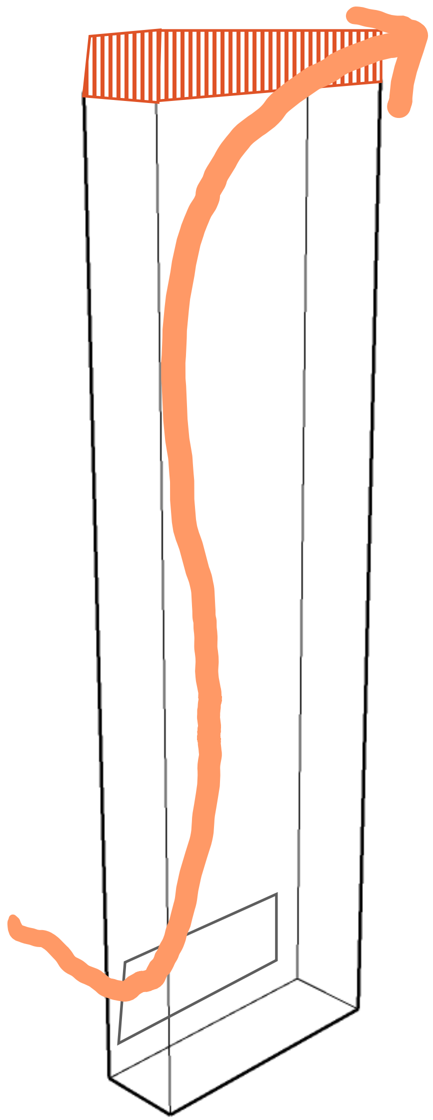
bigger ←	SC size	→ *smaller*
higher ←	Collected heat	→ *lower*
higher ←	Thermal draft	→ *lower*

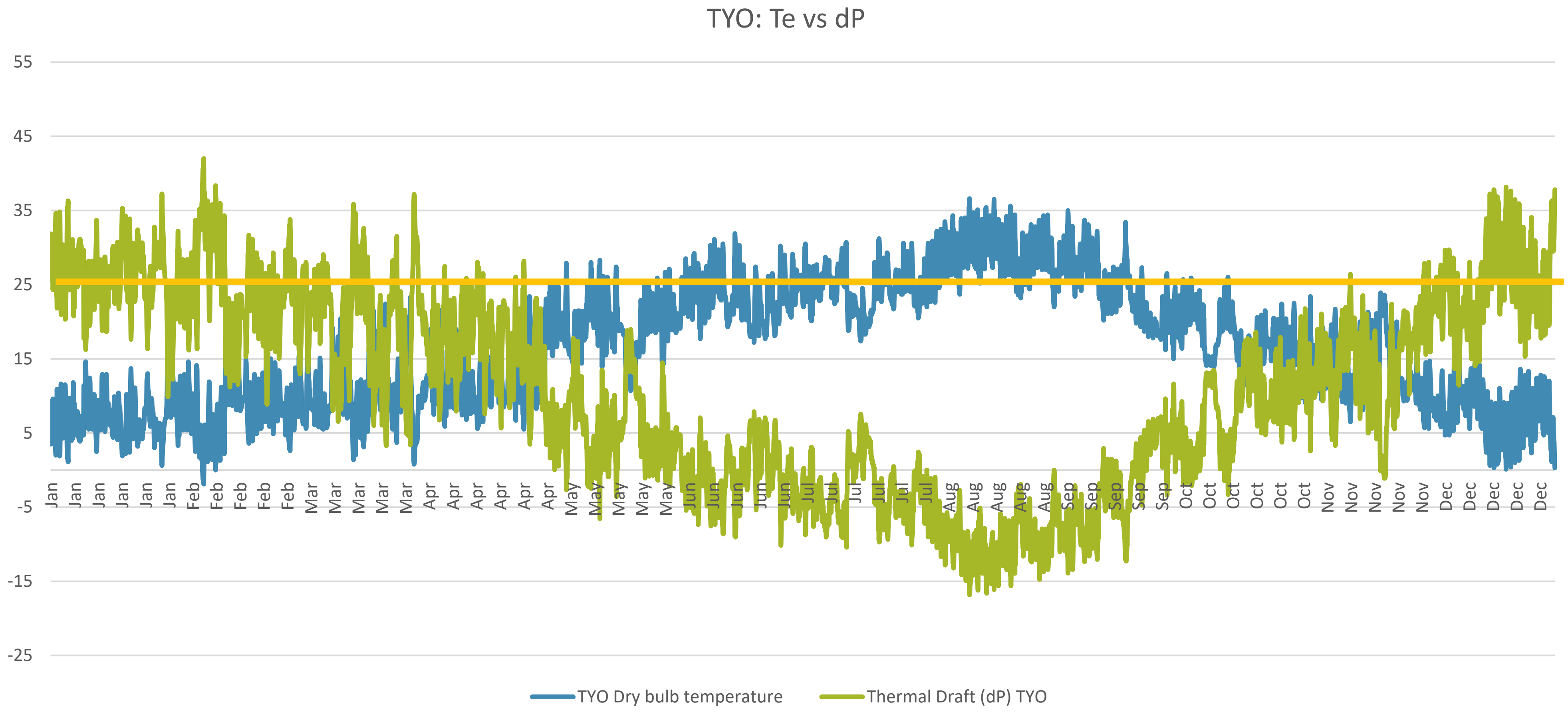
Solar Chimney (SC)



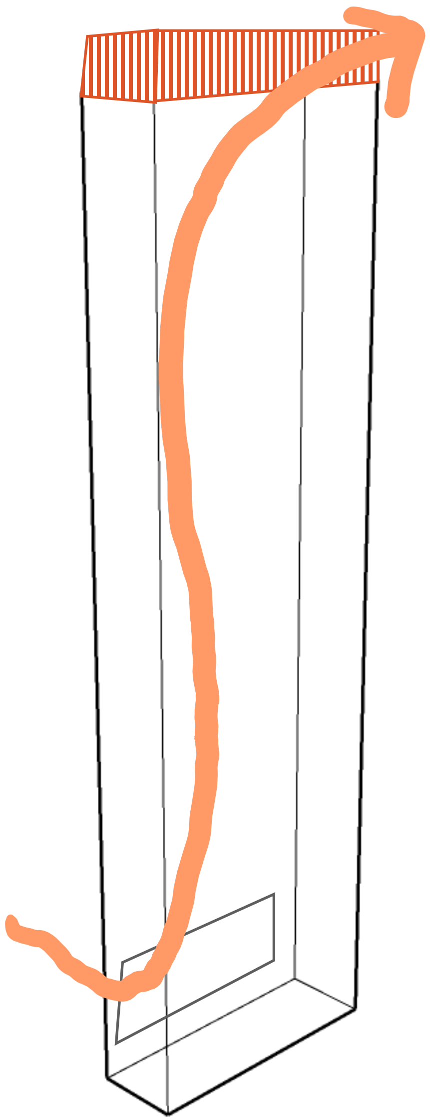
W x L x H	: 0.65 x 2 x 44m x 2 chimney
Pressure loss	: 25 Pa
Air velocity	: 1.5 m/s
Heat recovery	: Microchannel

Solar Chimney (SC)





Solar Chimney (SC)



Months	Average of Te [°C]	Average of Q [W/m2]	Average of Thermal Draft [Pa]	Sum of Fan energy [MWh]	Sum of Heat Recovered [MWh]	Average of T at top of SC
Off	**15.00**	**21**	**8.84**	**0.04**	**21**	**20**
Office hour	**18.39**	**303**	**5.40**	**0.21**	**204**	**23**
1	8.53	198	21.15	0.00	12	22
2	10.54	315	18.55	0.00	18	23
3	12.57	332	15.24	0.00	20	23
4	15.18	422	11.42	0.01	25	24
5	21.48	393	0.78	0.02	18	24
6	24.92	361	-4.99	0.03	14	24
7	25.49	234	-6.91	0.03	21	22
8	31.36	475	-14.10	0.04	18	25
9	25.73	256	-7.06	0.03	20	23
10	18.98	221	3.50	0.02	13	22
11	15.94	229	8.62	0.01	13	22
12	9.74	206	19.06	0.00	12	22
Grand Total	**16.55**	**150**	**7.27**	**0.25**	**225**	**21**

Second:

Integration (placement)

3 different proposals

Shouchikubai philosophy

Shou	*Chiku*	*Bai*
松	竹	梅
Pine	Bamboo	Plum
Strength	*Longevity*	*Beauty*

(source: jing.fm)

3 different proposals

***Shouchikubai** philosophy in design*

Shou

松

Advanced

Pine

Chiku

竹

Moderate

Bamboo

Bai

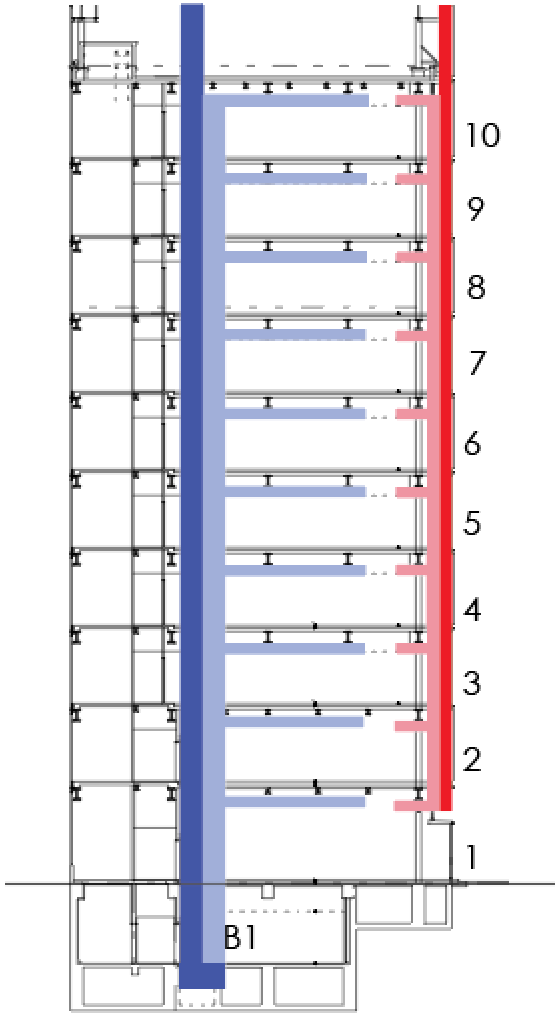
梅

Basic

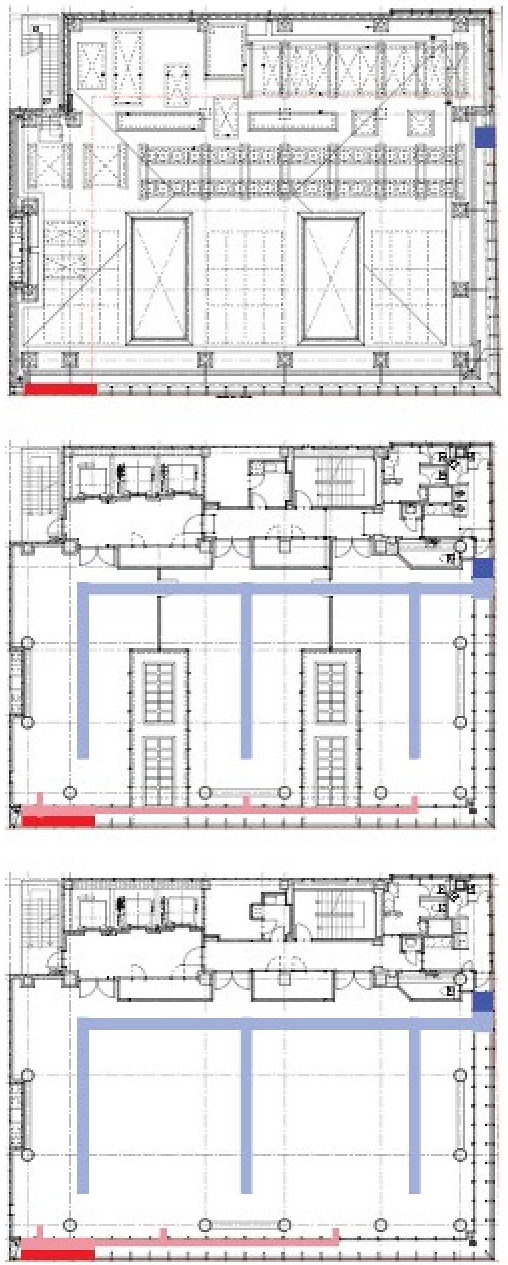
Plum

(source: jing.fm)

3 different proposals



Basic design



RF

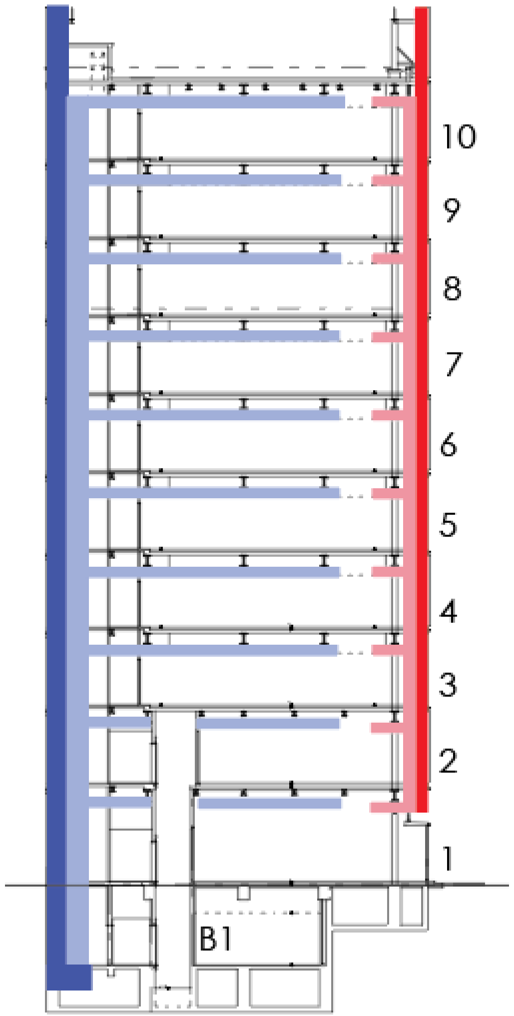
8 -10

3 - 7

梅

Plum

3 different proposals

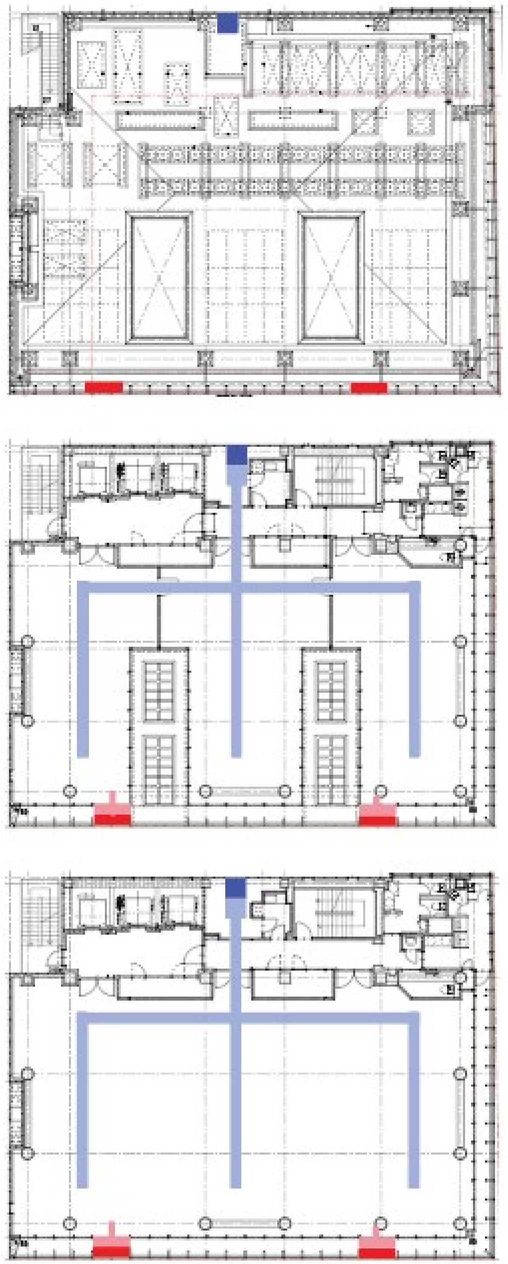


Moderate design

RF

8 -10

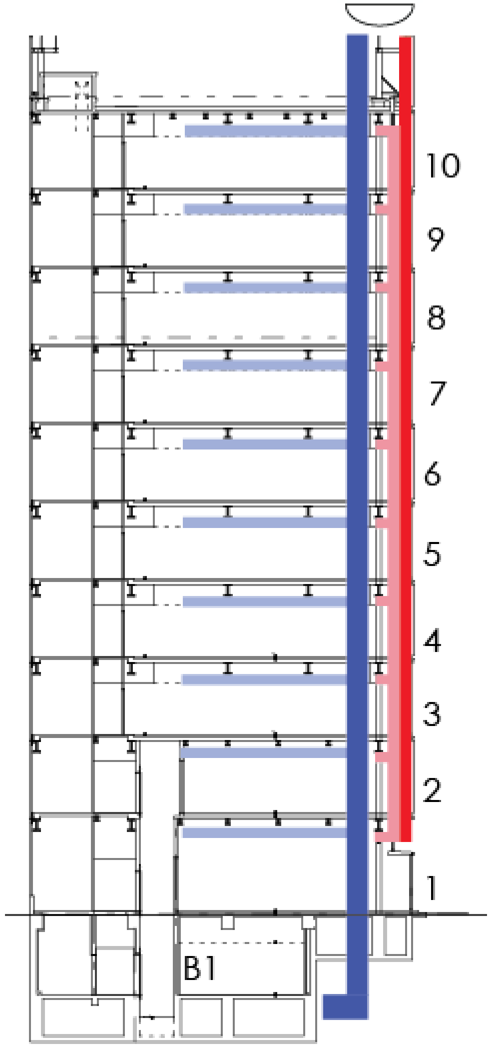
3 - 7



竹

Bamboo

3 different proposals

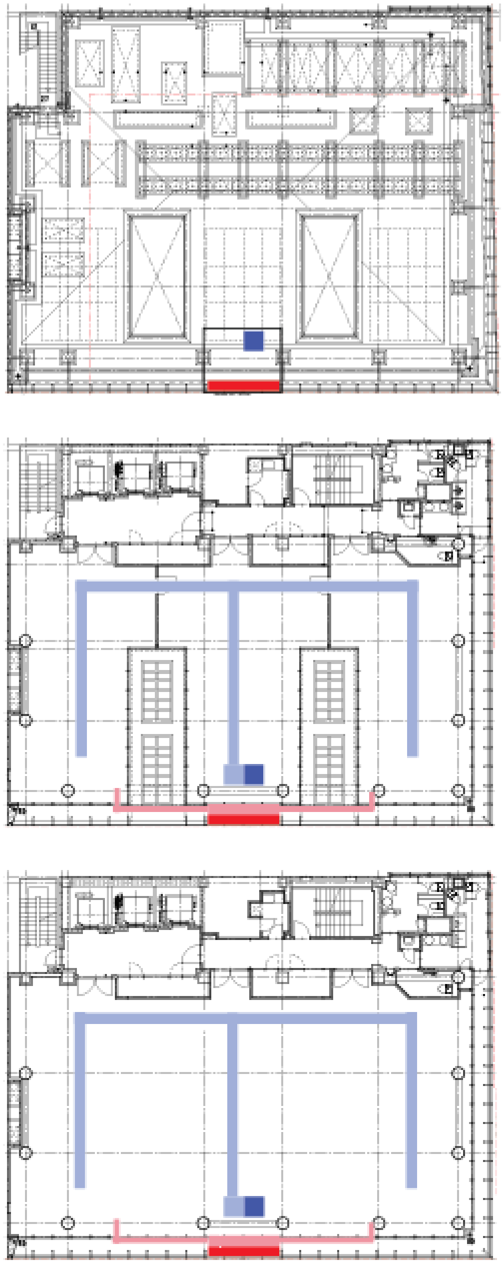


Advanced design

RF

8 -10

3 - 7



松

Pine

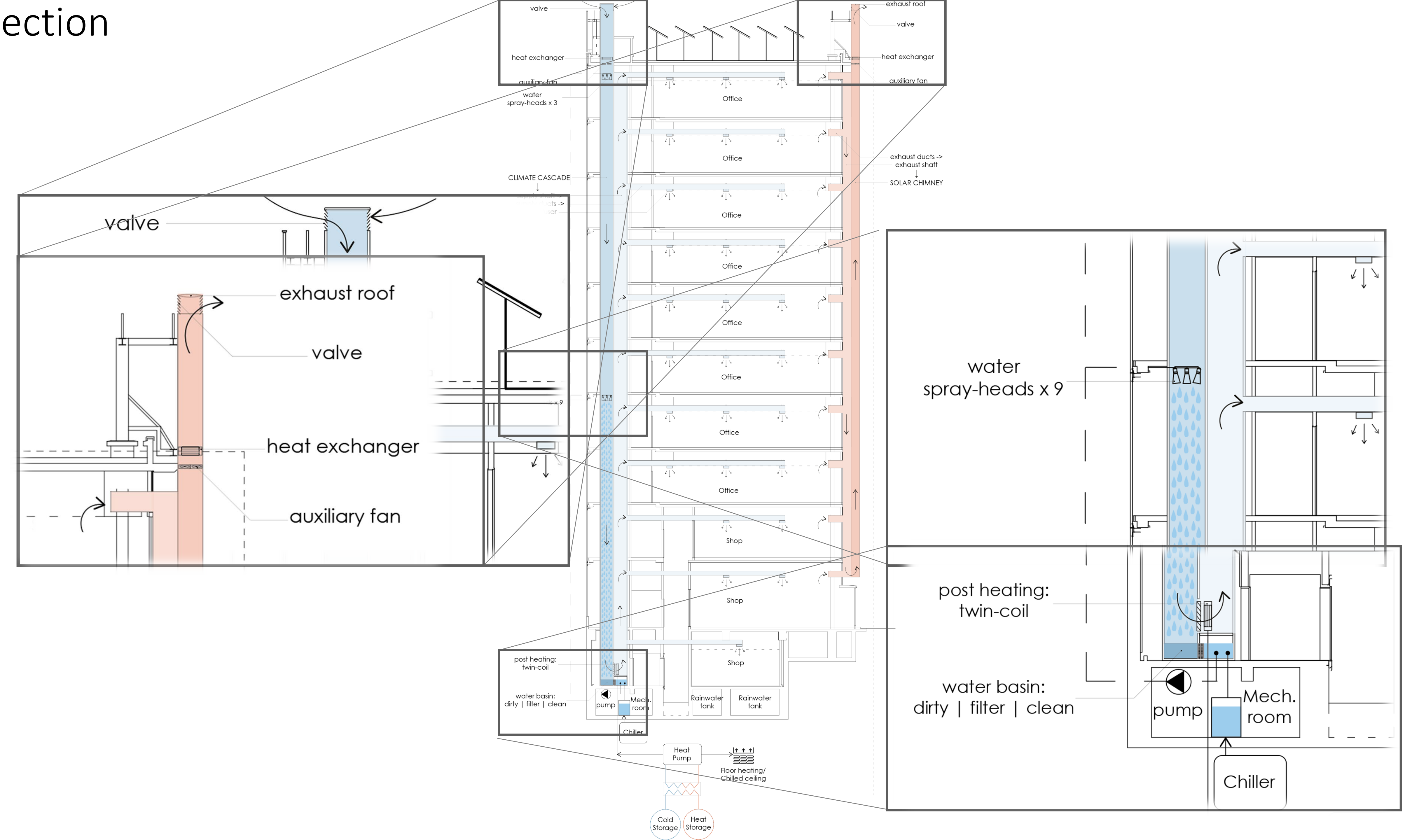
3 different proposals

No.	Category	Plum	Bamboo	Pine
1	Performance (HR)	○	○	○
2	Material (quantity)	○	○	○
3	Visual comfort	△	△	✕
4	Maintenance	△	△	○
5	Space use	△	○	✕
6	Aesthetic	△	○	△

○ = 👍, △ = 😐, ✖ = 👎

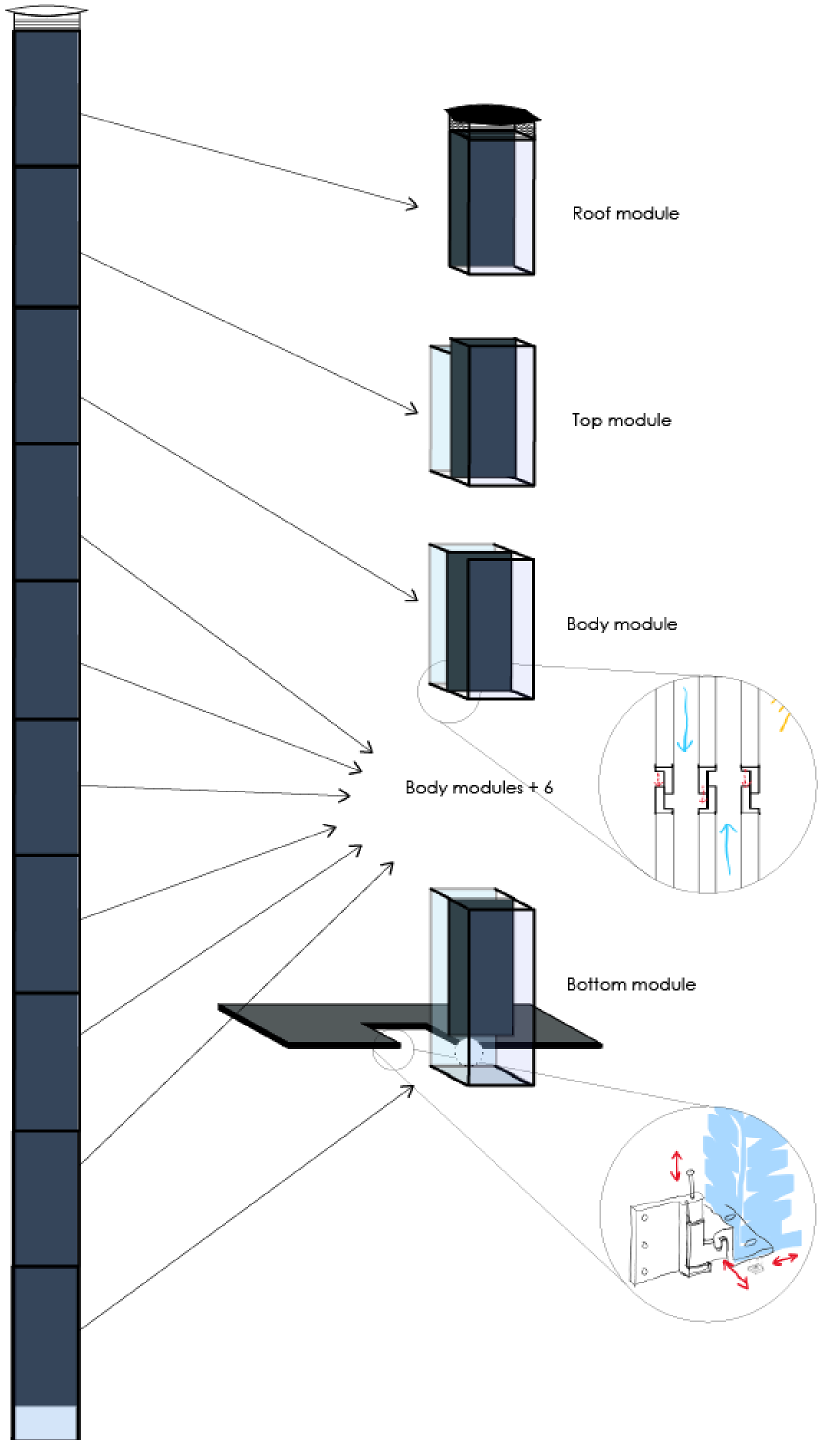
Final Design

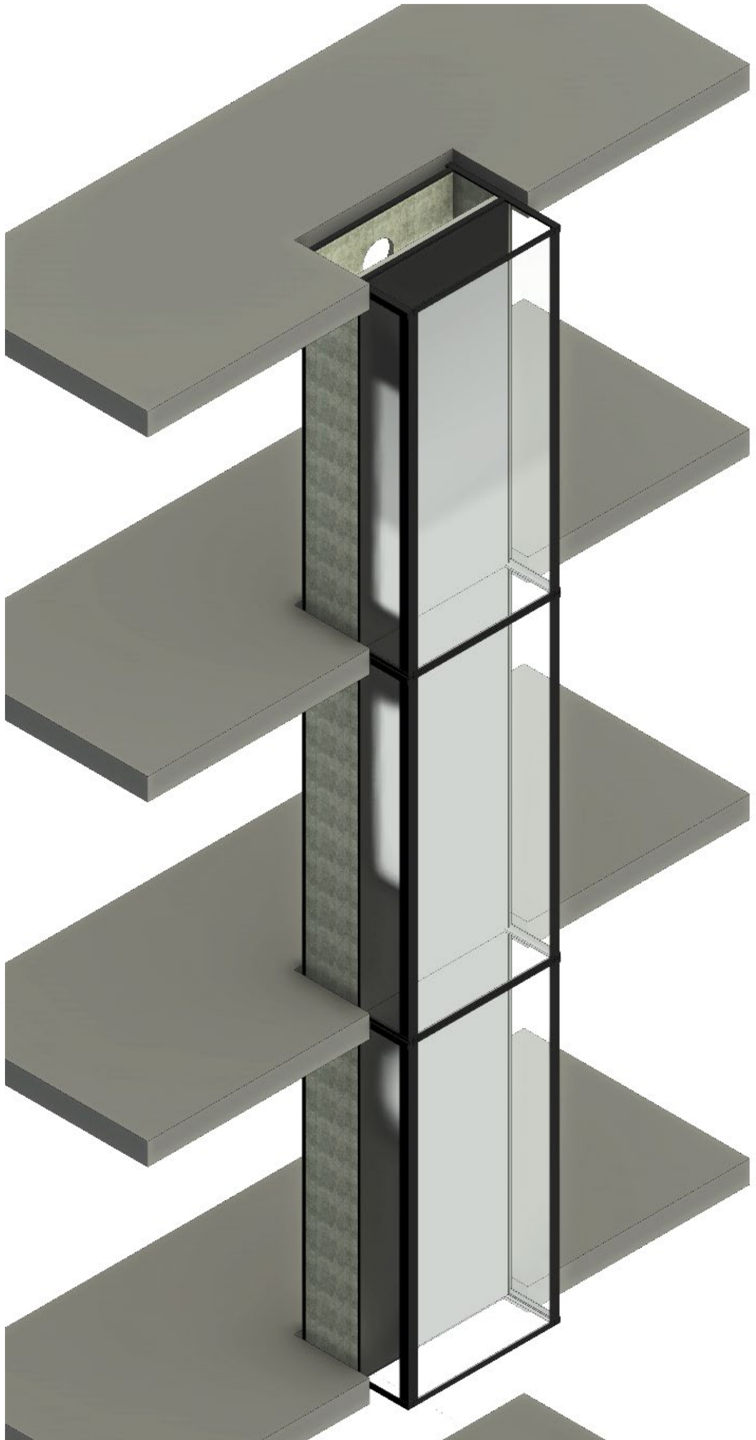
Section


valve
heat exchanger
auxiliary fan
water
spray-heads x 3
exhaust roof
valve
heat exchanger
auxiliary fan
Office
Office
Office
Office
Office
Office
Office
Office
Shop
Shop
Shop
exhaust ducts ->
exhaust shaft
SOLAR CHIMNEY
CLIMATE CASCADE
valve
exhaust roof
valve
heat exchanger
auxiliary fan
water
spray-heads x 9
post heating:
twin-coil
water basin:
dirty | filter | clean
pump
Mech.
room
Chiller
post heating:
twin-coil
water basin:
dirty | filter | clean
pump
Mech.
room
Chiller
Rainwater
tank
Rainwater
tank
Heat
Pump
Floor heating/
Chilled ceiling
Cold
Storage
Heat
Storage

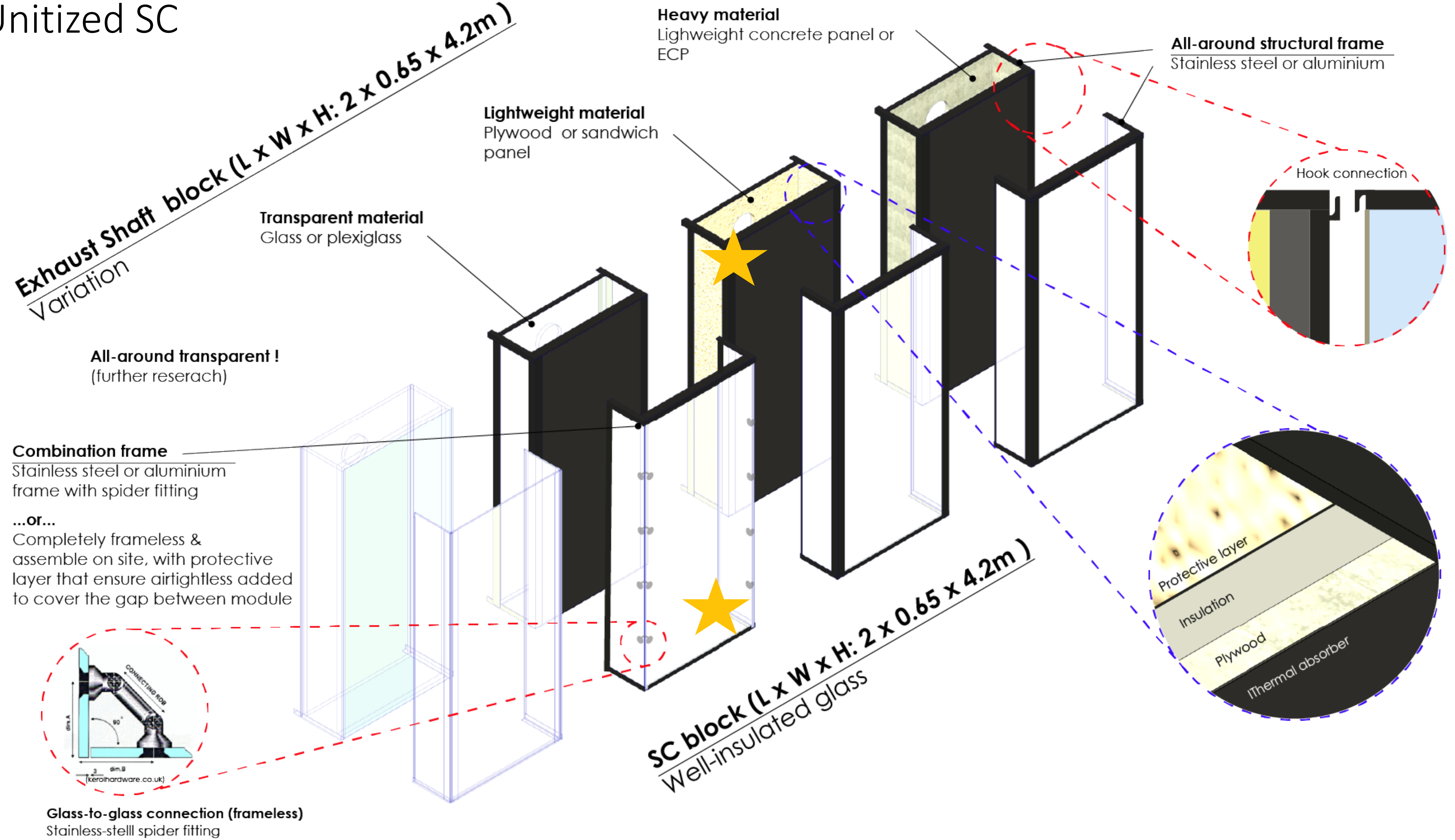
Impressions

Unitized SC

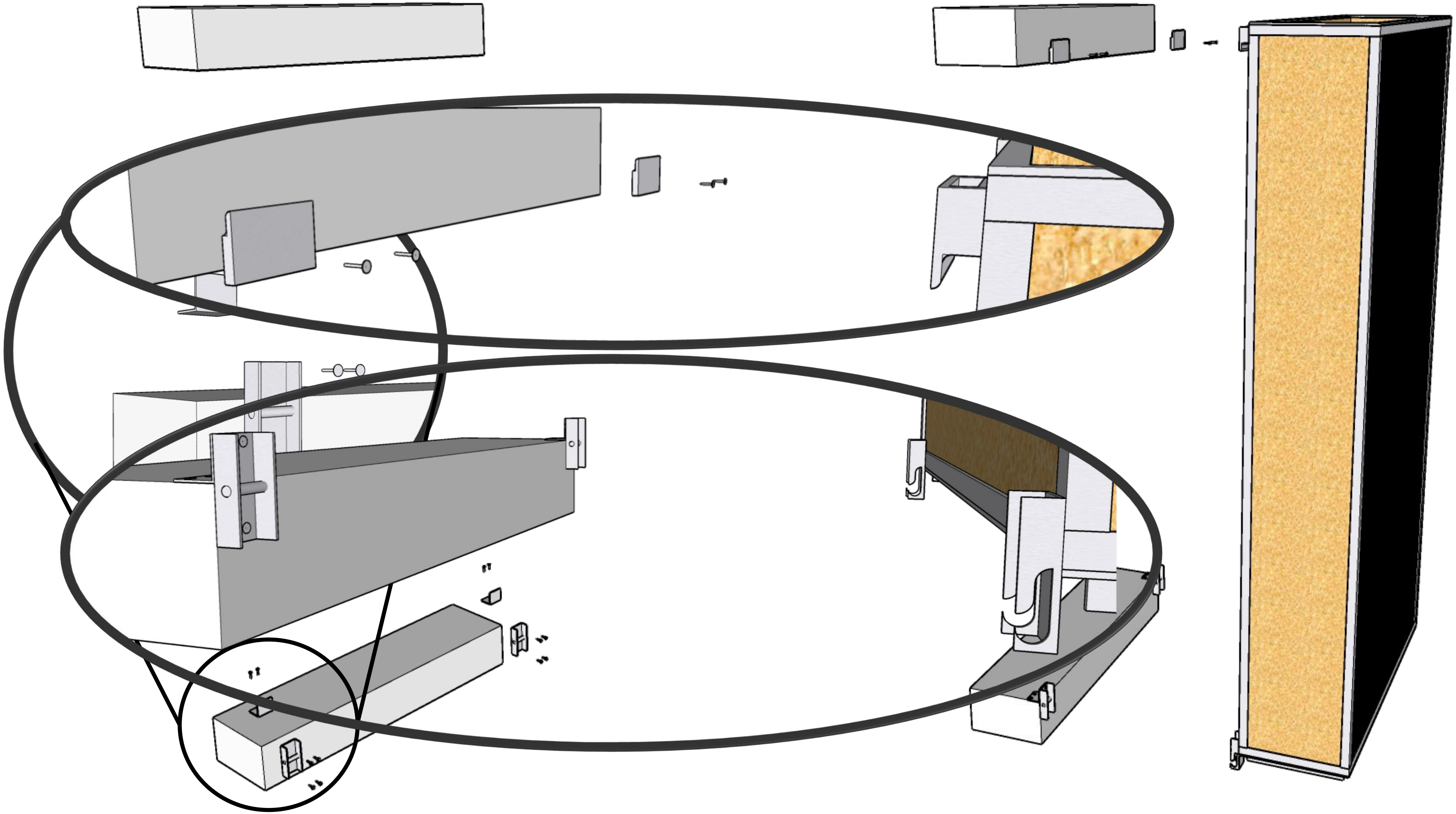

Roof module
Top module
Body module
Body modules + 6
Bottom module



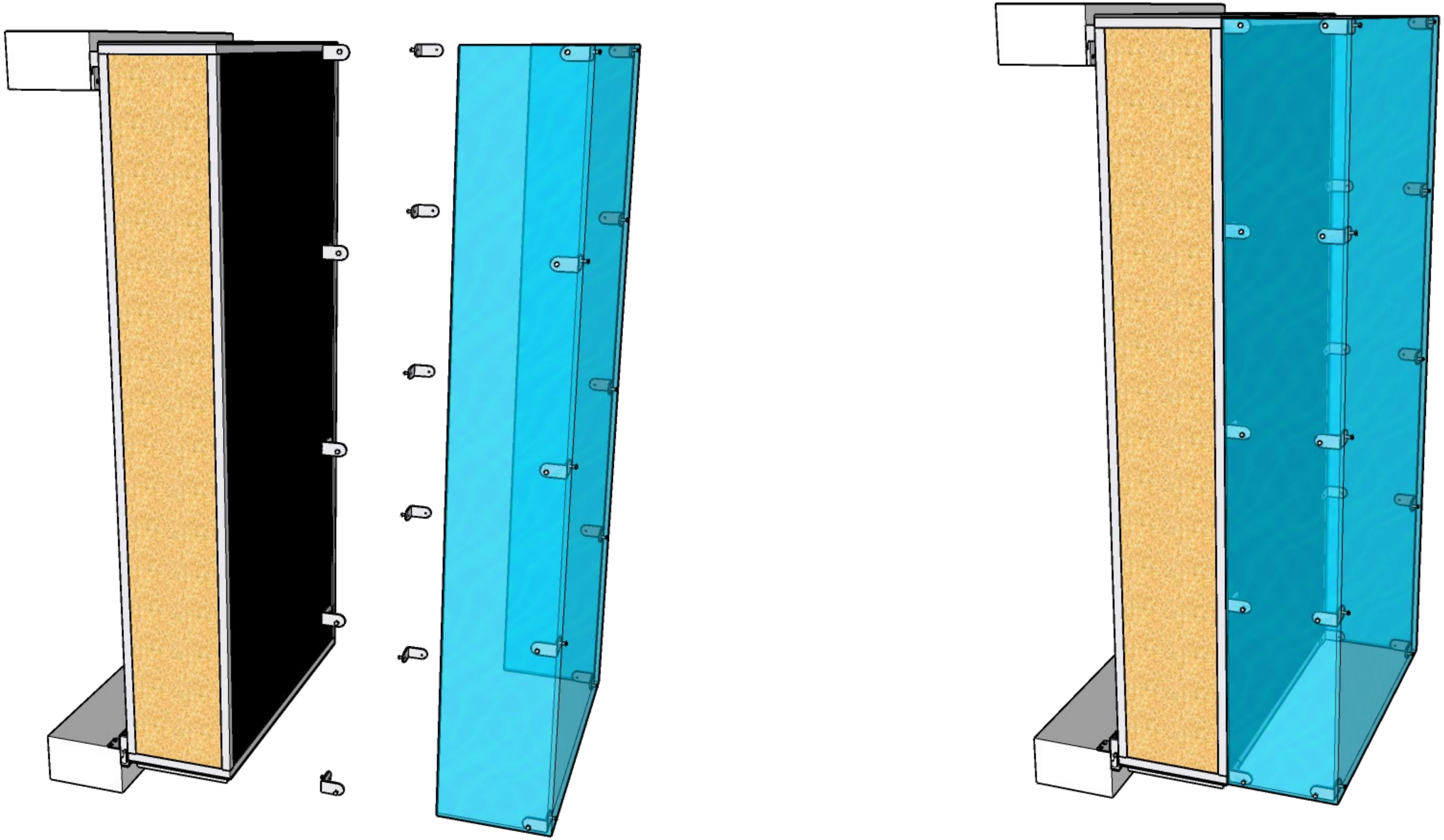
Unitized SC


Exhaust Shaft block (L x W x H: 2 x 0.65 x 4.2m)
Variation
Heavy material
Lighweight concrete panel or ECP
All-around structural frame
Stainless steel or aluminium
Lightweight material
Plywood or sandwich panel
Transparent material
Glass or plexiglass
Hook connection
All-around transparent !
(further reserach)
Combination frame
Stainless steel or aluminium frame with spider fitting
...or...
Completely frameless & assemble on site, with protective layer that ensure airtightless added to cover the gap between module
Protective layer
Insulation
Plywood
Thermal absorber
SC block (L x W x H: 2 x 0.65 x 4.2m)
Well-insulated glass
CONNECTING ROD
(kerolhardware.co.uk)
Glass-to-glass connection (frameless)
Stainless-stell spider fitting

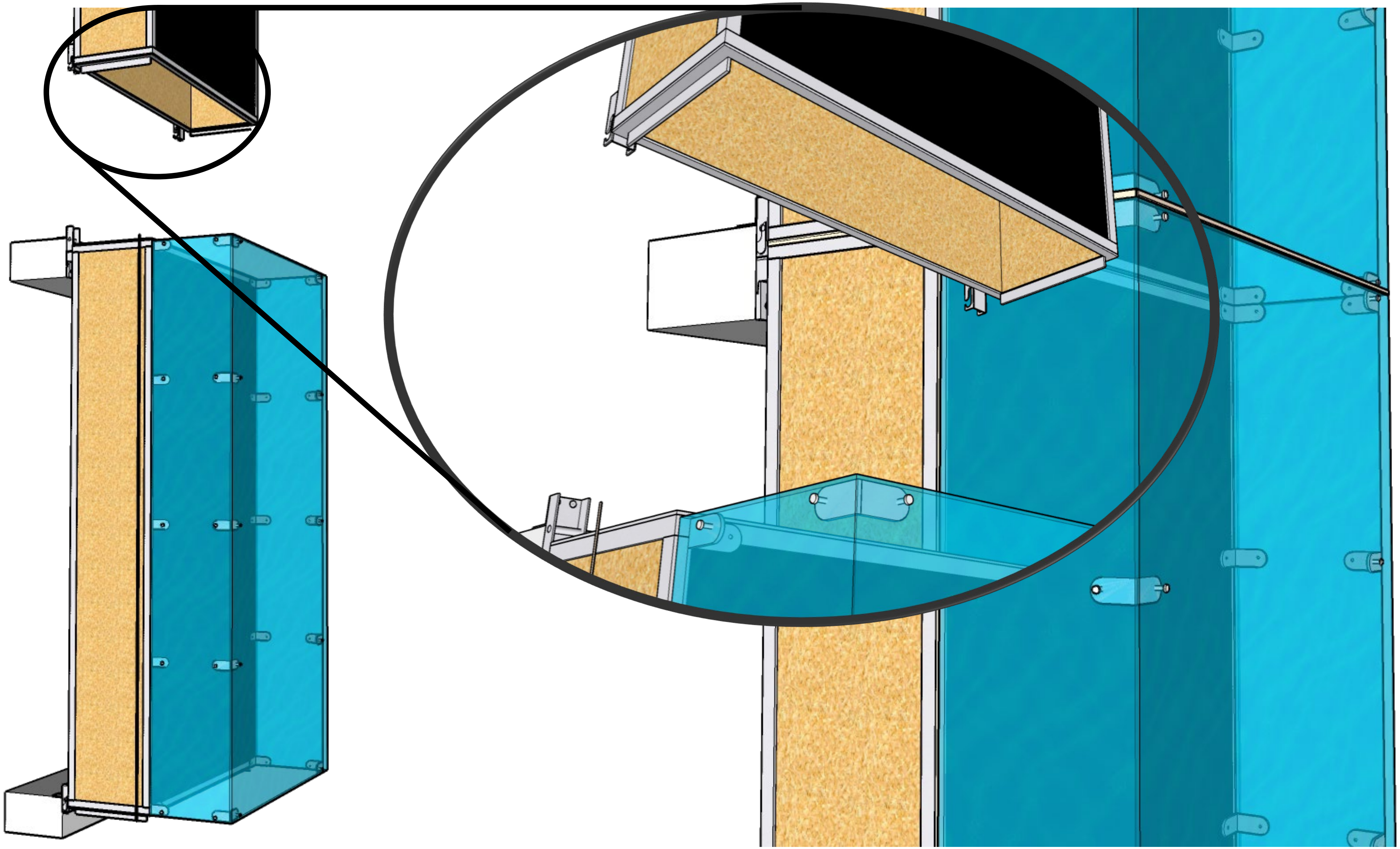
Order of Assembly



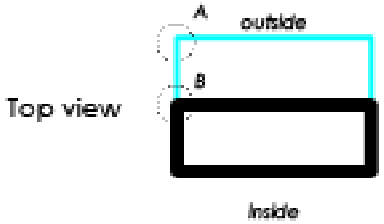
Order of Assembly

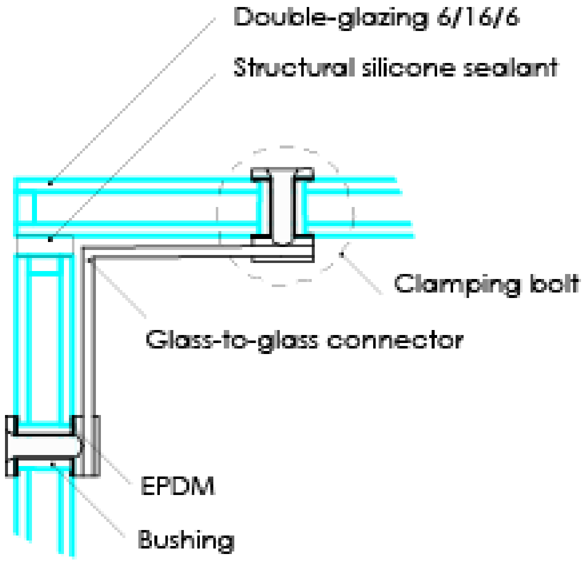


Order of Assembly

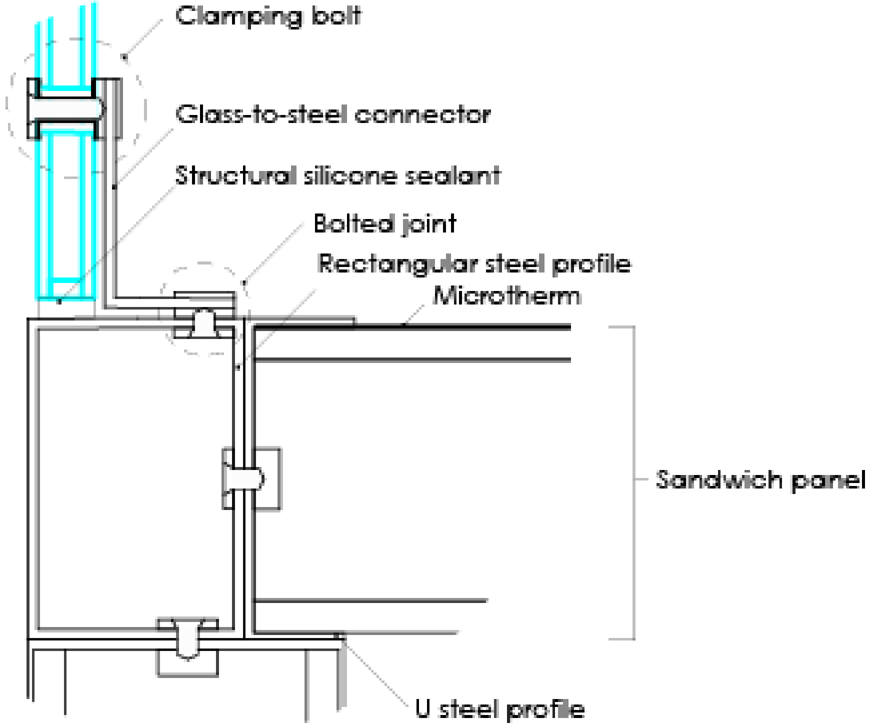


Details: connection within module



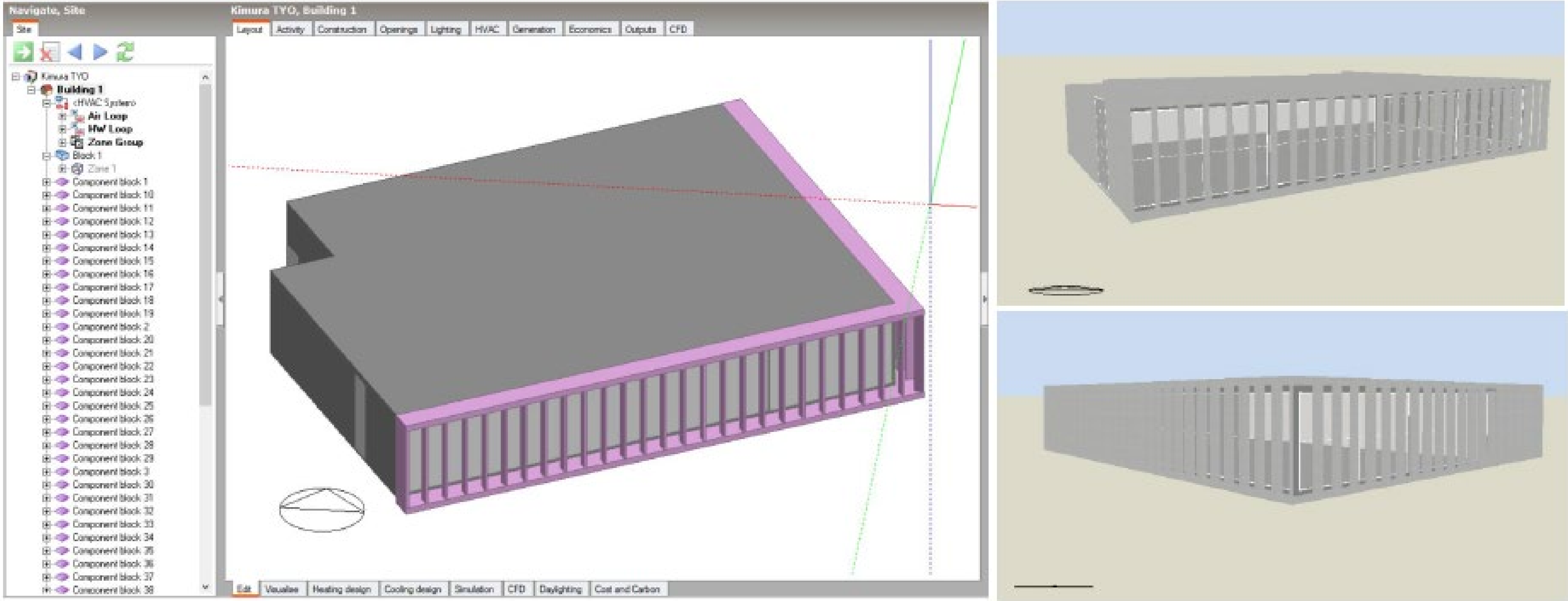


Detail A



Detail B

DesignBuilder Simulation



Navigate, Site
Site
Kimura TYO, Building 1
Layout
Activity
Construction
Openings
Lighting
HVAC
Generation
Economics
Outputs
CFD
Kimura TYO
Building 1
<HVAC System>
Air Loop
HW Loop
Zone Group
Block 1
Zone 1
Component block 1
Component block 10
Component block 11
Component block 12
Component block 13
Component block 14
Component block 15
Component block 16
Component block 17
Component block 18
Component block 19
Component block 2
Component block 20
Component block 21
Component block 22
Component block 23
Component block 24
Component block 25
Component block 26
Component block 27
Component block 28
Component block 29
Component block 3
Component block 30
Component block 31
Component block 32
Component block 33
Component block 34
Component block 35
Component block 36
Component block 37
Component block 38
Edit
Visualise
Heating design
Cooling design
Simulation
CFD
Daylighting
Cost and Carbon

3 different HVAC settings

No.		Existing	EWF design	Conventional
1	Construction	Wall 1 (SW & NW): ECP t60 R 0.14 Wall 2 (SE & NE): Curtain wall (DB template)		
2	Occupancy & Schedule	0.2 people/m^2		
3	HVAC system	VRF with HR and DOAS	Ventilation (mechanical): VAV with no reheat, Constant air supply of 16.5°C Space heating & cooling: Underfloor heating & chilled ceiling	VAV reheat, DX cooling with Dehumidification

2 different comparisons

No.		Existing	EWF design	Conventional
1	Construction		Wall 1 (SW & NW): ECP t60 R 0.14 Wall 2 (SE & NE): Curtain wall (DB template)	
2	Occupancy & Schedule		0.2 people/m^2	
3	HVAC system	VRF with HR and DOAS	<u>Ventilation (mechanical):</u> VAV with no reheat, Constant air supply of 16.5°C <u>Space heating & cooling:</u> Underfloor heating & chilled ceiling	VAV reheat, DX cooling with Dehumidification

4 different variations

	comfort ← Priority line → *energy*				
	Variation 1	**Existing**	**New**	**Variation 2**	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

Comparison 1: EWF – Existing (VRF)

	Variation 1	Existing	New	Variation 2	
Priority line	*comfort* ←			→ *energy*	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

	Variation 1			**Existing**			**New**			**Variation 2**			
Comparison	Existing	EWF	**%**	Existing	EWF	**%**	Existing	EWF	**%**	Existing	EWF	**%**	
Heating	3	15	**371**	2	14	**720**	3	10	**197**	2	10	**495**	kWh/m2
Cooling	29	77	**164**	27	72	**161**	22	67	**205**	21	63	**201**	kWh/m2
Ventilation	50	31	**-38**	29	29	**0**	48	25	**-47**	27	23	**-15**	kWh/m2
Total	82	123	**50**	58	114	**96**	73	101	**39**	50	96	**94**	kWh/m2

Average difference %	
Heating	**446**
Cooling	**183**
Ventilation	**-25**
Total	**70**

Old & New difference %	
Heating	**475**
Cooling	**143**
Ventilation	**-14**
Total	**74**

Comparison 1: EWF – Existing (VRF)

comfort ← Priority line → energy

	Variation 1	Existing	New	Variation 2	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

Existing system	Variation 1	Existing	New	Variation 2	
Hours at and above 27°C	26	0	2102	2288	hours
Discomfort % in a year	0	0	24	26	%
Comfort % in a year	**100**	**100**	**76**	**74**	%
Hours at and above 29°C	0	0	41	0	hours
Discomfort % in a year	0	0	0	0	%
Comfort % in a year	**100**	**100**	**100**	**100**	%

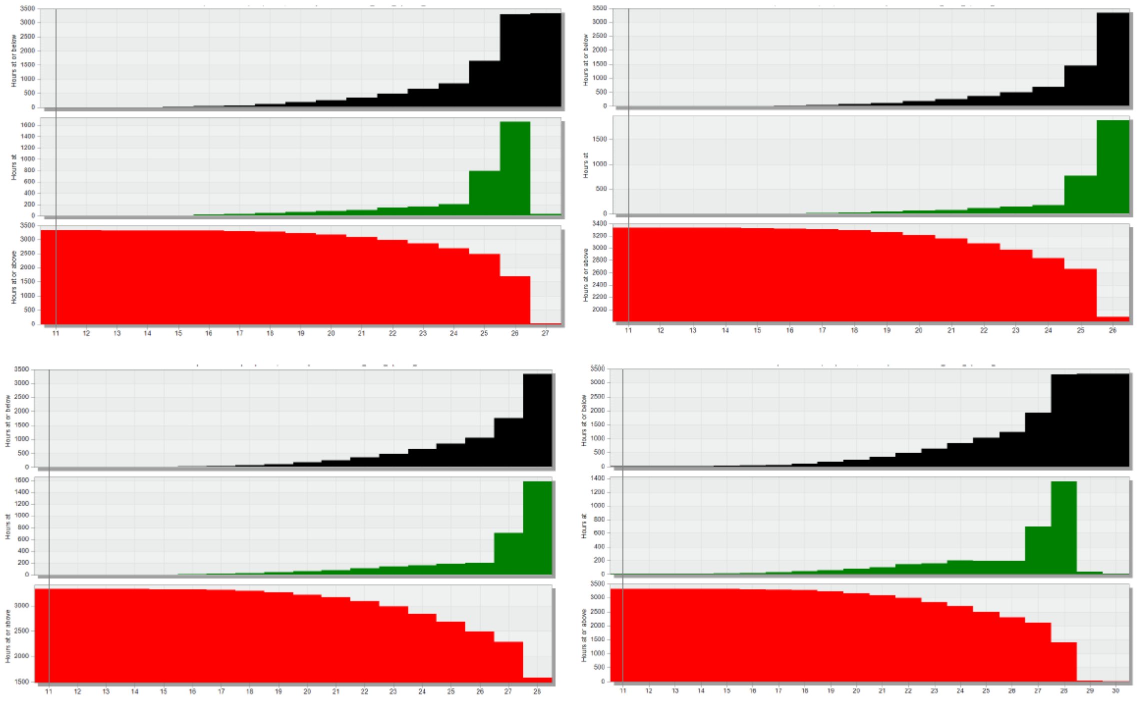
EWF with climate ceiling	Variation 1	Existing	New	Variation 2	
Hours at and above 27°C	0	0	741	741	hours
Discomfort % in a year	0	0	8	8	%
Comfort % in a year	**100**	**100**	**92**	**92**	%
Hours at and above 29°C	0	0	0	0	hours
Discomfort % in a year	0	0	0	0	%
Comfort % in a year	**100**	**100**	**100**	**100**	%

Comparison 1: EWF – Existing (VRF)

comfort ← Priority line → energy

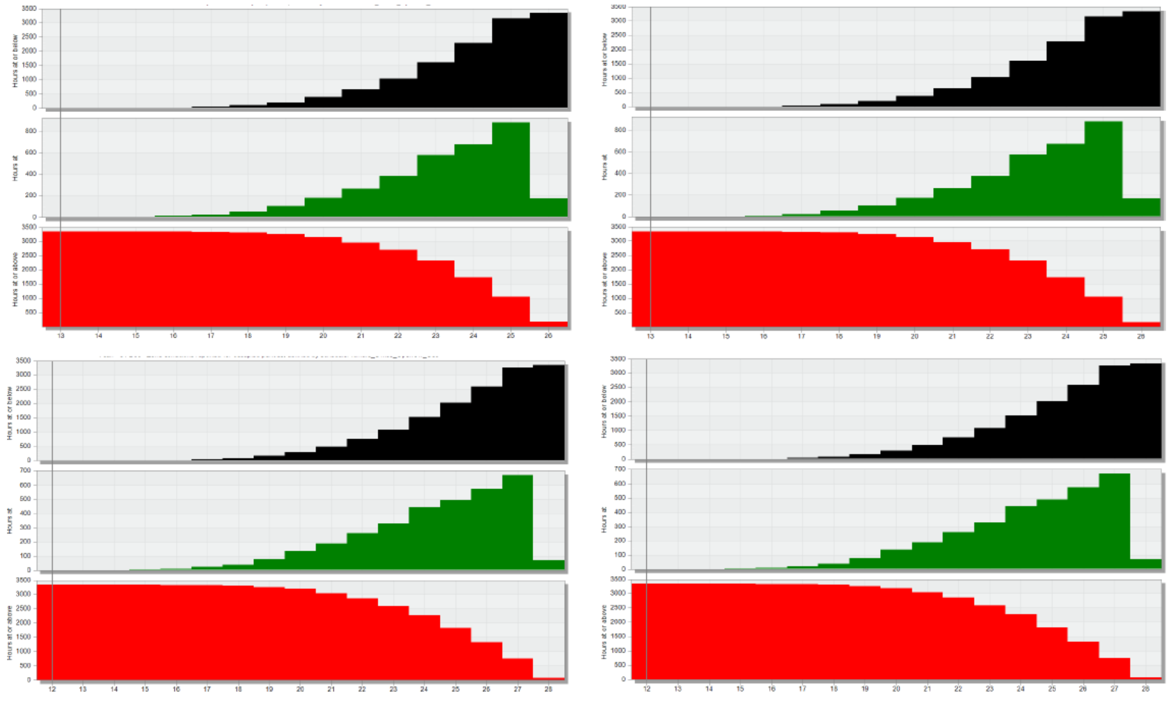
	Variation 1	Existing	New	Variation 2	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

Existing (VRF)



From top-left clockwise: Variation 1, Existing, New, and Variation 2.

EWF



From top-left clockwise: Variation 1, Existing, New, and Variation 2.

Comparison 2: EWF – Conventional (VAV)

	comfort ← Priority line → energy				
	Variation 1	Existing	New	Variation 2	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

	Variation 1			Existing			New			Variation 2			
Comparison	Existing	EWF	%	Existing	EWF	%	Existing	EWF	%	Existing	EWF	%	
Heating	72	15	**-79**	64	14	**-79**	2	10	**414**	1	10	**626**	kWh/m2
Cooling	152	77	**-49**	135	72	**-47**	89	67	**-25**	86	63	**-27**	kWh/m2
Ventilation	44	31	**-29**	44	29	**-34**	35	25	**-28**	35	23	**-33**	kWh/m2
Total	268	123	**-54**	243	114	**-53**	126	101	**-19**	122	96	**-21**	kWh/m2

Average difference %	
Heating	**220**
Cooling	**-37**
Ventilation	**-31**
Total	**-37**

Old & New difference %	
Heating	**-85**
Cooling	**-50**
Ventilation	**-43**
Total	**-58**

Comparison 2: EWF – Conventional (VAV)

	comfort ← Priority line → energy				
	Variation 1	Existing	New	Variation 2	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

Conventional system	**Variation 1**	**Existing**	**New**	**Variation 2**	
Hours at and above 27°C	0	0	851	851	hours
Discomfort % in a year	0	0	10	10	%
Comfort % in a year	**100**	**100**	**90**	**90**	%
Hours at and above 29°C	0	0	0	0	hours
Discomfort % in a year	0	0	0	0	%
Comfort % in a year	**100**	**100**	**100**	**100**	%

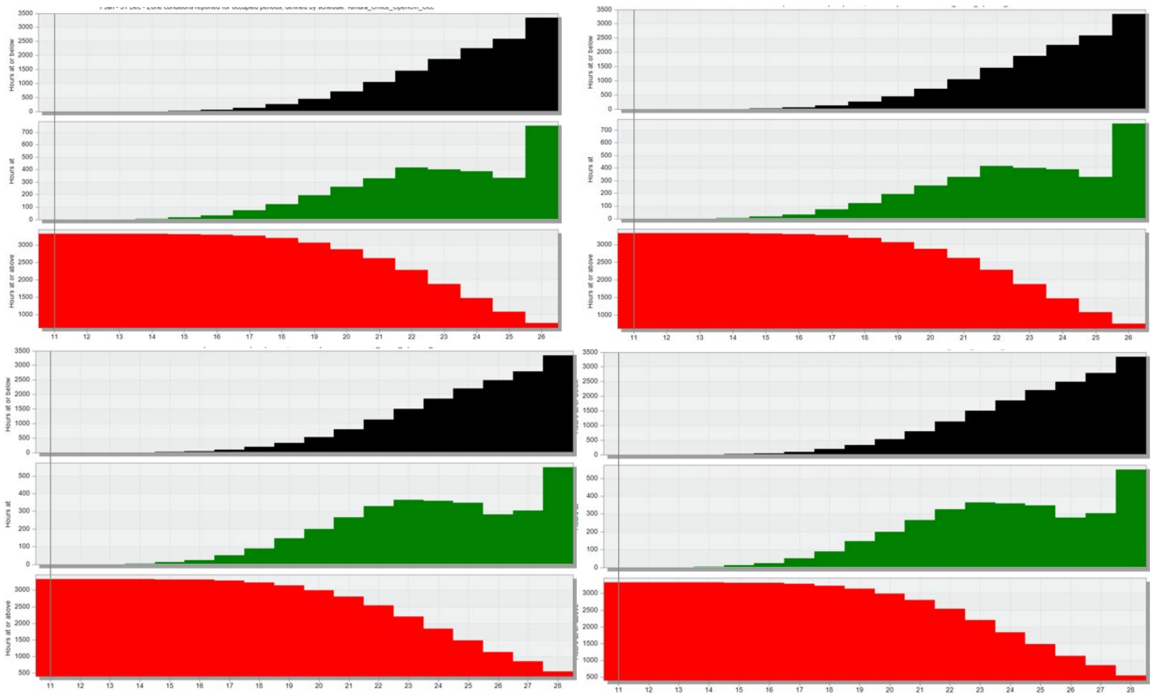
EWF with climate ceiling	**Variation 1**	**Existing**	**New**	**Variation 2**	
Hours at and above 27°C	0	0	741	741	hours
Discomfort % in a year	0	0	8	8	%
Comfort % in a year	**100**	**100**	**92**	**92**	%
Hours at and above 29°C	0	0	0	0	hours
Discomfort % in a year	0	0	0	0	%
Comfort % in a year	**100**	**100**	**100**	**100**	%

Comparison 2: EWF – Conventional (VAV)

comfort ← Priority line → energy

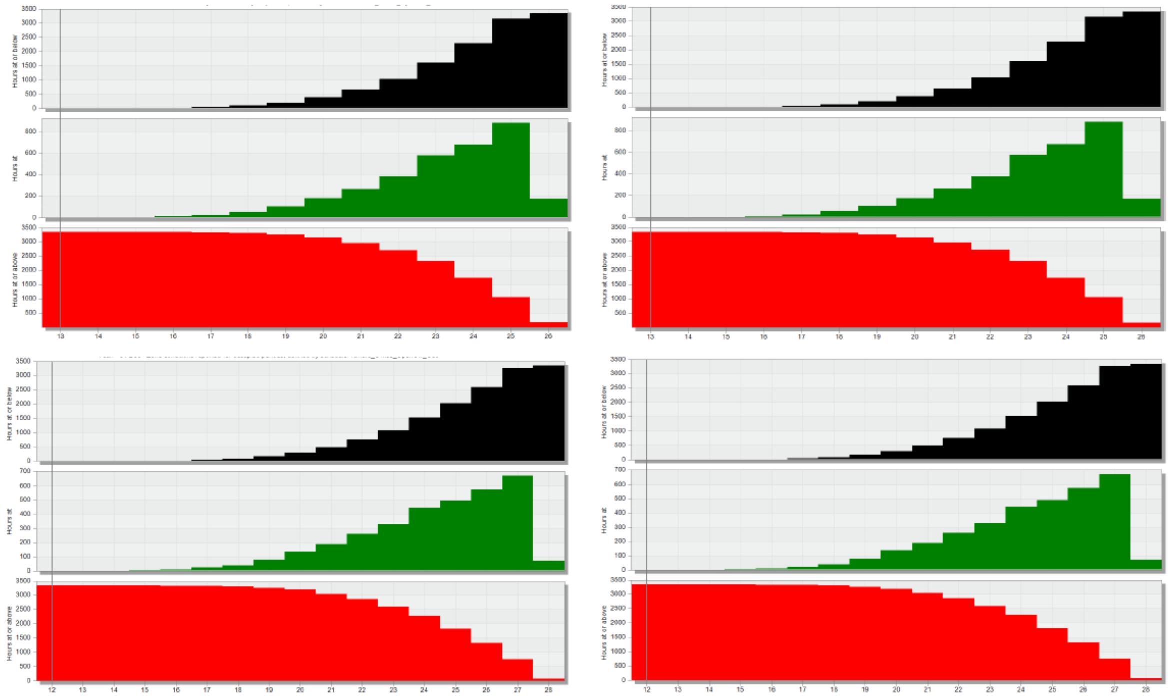
	Variation 1	Existing	New	Variation 2	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

Conventional (VAV)



From top-left clockwise: Variation 1, Existing, New, and Variation 2.

EWF

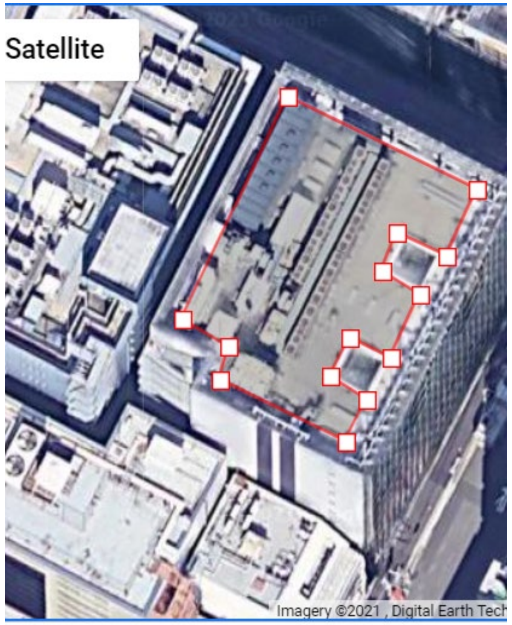


From top-left clockwise: Variation 1, Existing, New, and Variation 2.

Energy neutrality & benchmarking

Power Roof: PV Yield

Optimistic



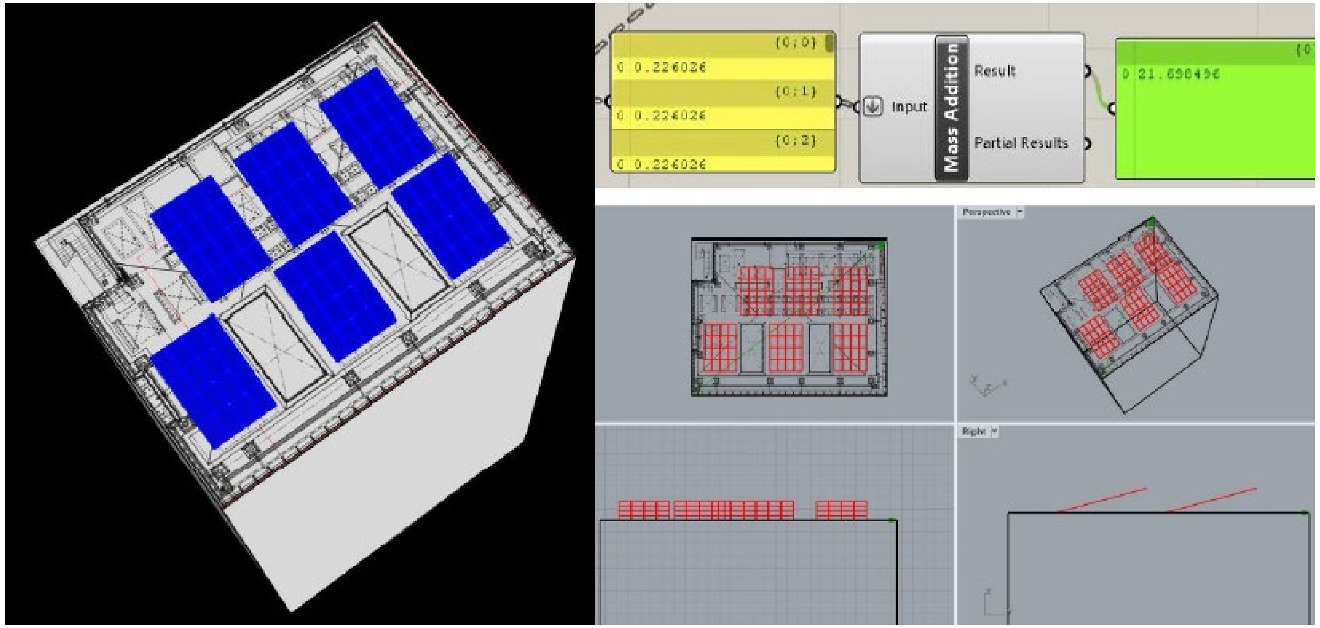
SYSTEM INFO

Modify the inputs below to run the simulation.

DC System Size (kW):	62.4
Module Type:	Premium
Array Type:	Fixed (roof mount)
System Losses (%):	14.08
Tilt (deg):	40
Azimuth (deg):	135

(PVWatts® Calculator)

Realistic



(Grasshopper)

Zero energy?

Annual energy consumption per m^2	Existing	New	
Heating	2	10	kWh/m2
Cooling	27	67	kWh/m2
Ventilation	29	25	kWh/m2
Lighting	81	81	kWh/m2
Computers etc.	56	56	kWh/m2
Total energy consumption per m^2	196	239	kWh/m2
Annual energy production per m^2			
BAPV on Power Roof *(optimistic)*	0	172	kWh/m2
% to energy consumption	0	72	%
BAPV on Power Roof *(realistic)*	0	56	kWh/m2
% to energy consumption	0	24	%

Not zero energy

Benchmarking: Primary energy

Annual energy consumption per m² (primary energy)	Existing	New	%	
Heating	4	10	**155**	MJ/m2
Cooling	67	33	**-51**	MJ/m2
Ventilation	283	244	**-14**	MJ/m2
Lighting	794	794	**0**	MJ/m2
Computers etc.	551	551	**0**	MJ/m2
Total energy consumption per m² (primary energy)	1699	1631	**-4**	MJ/m2

Below average

Note:

Primary energy coefficients: Electricity: 9.76 MJ/kWh, City gas: 45 MJ/m3

COP used are as follows:

Existing heating (VRF) 4, existing cooling (VRF) 4

New heating (GSHP) 9, new cooling (direct groundsource) 20

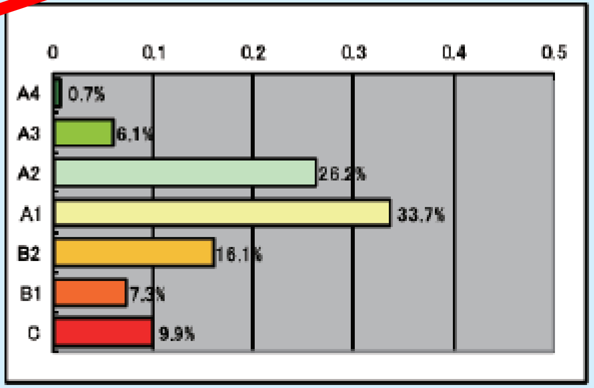
Benchmarking: Carbon Report

95.4 kg-CO^2/m^2
(Range B2)

Below average

Medium-sized Buildings for Rent (3,000 m² or larger but smaller than 10,000 m²)

Range	Basis	Emission Intensity (kg/m²)			Number of Facilities	Percentage	Average Floor Area
A4	0.25 or less	19.6 or less			7	0.7%	4988.83
A3	More than 0.25 but 0.50 or less	More than 19.6 but 39.1 or less			58	6.1%	5063.63
A2	More than 0.50 but 0.75 or less	More than 39.1 but 58.6 or less			250	26.2%	5526.83
A1	More than 0.75 but 1.00 or less	More than 58.6 but 78.1 or less			321	33.7%	5444.23
B2	More than 1.00 but 1.25 or less	More than 78.1 but 97.7 or less			153	16.1%	5930.80
B1	More than 1.25 but 1.50 or less	More than 97.7 but 117.2 or less			70	7.3%	5981.22
C	More than 1.50	More than 117.2			94	9.9%	5537.81
		Average intensity	78.1	Total	953	100%	5566.20



(TMG, 2012)

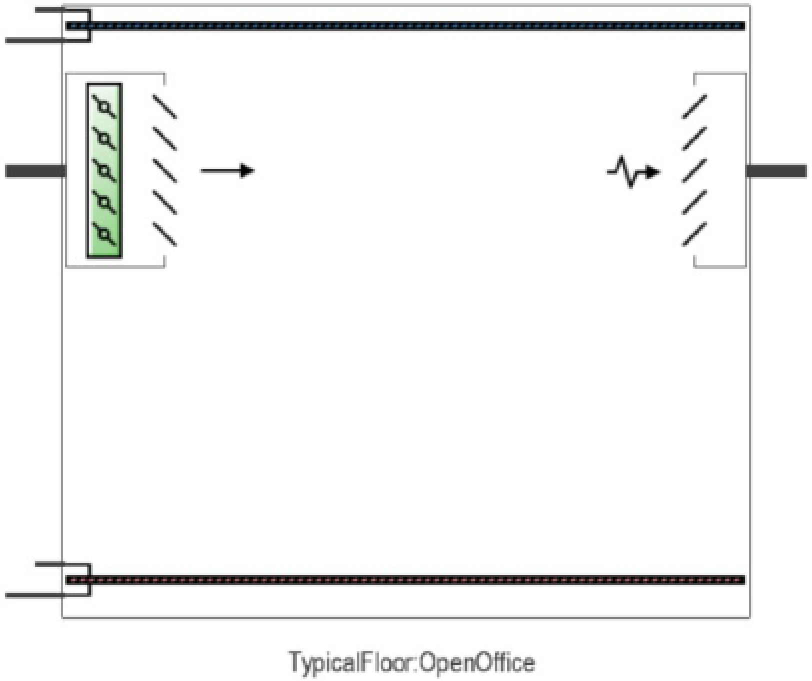
Improvement

Hybrid system:

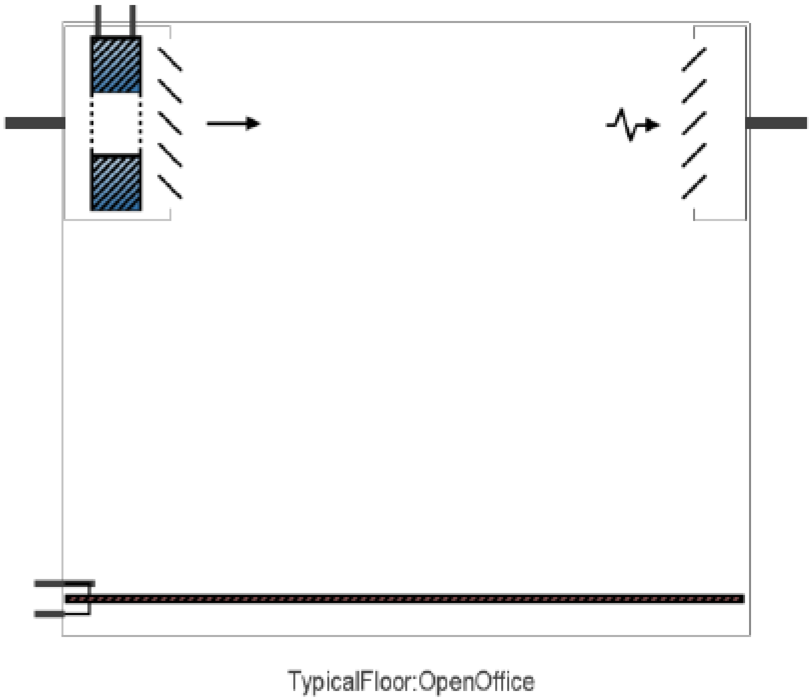
EWF with chilled beams

Comparison 3: EWF – EWF with chilled beams

EWF with chilled ceiling and underfloor heating



EWF with chilled beams and underfloor heating



Comparison 3: EWF – EWF with chilled beams

comfort ← Priority line → energy

	Variation 1	Existing	New	Variation 2	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

	Variation 1			Existing			New			Variation 2			
Comparison	EWF	EWF2	**%**	EWF	EWF2	**%**	EWF	EWF2	**%**	EWF	EWF2	**%**	
Heating	15	4	**-74**	14	4	**-71**	10	4	**-63**	10	4	**-66**	kWh/m2
Cooling	77	81	**5**	72	81	**13**	67	73	**10**	63	73	**16**	kWh/m2
Ventilation	31	31	**0**	29	29	**0**	25	25	**0**	23	23	**0**	kWh/m2
Total	123	116	**-6**	114	114	**0**	101	102	**0**	96	100	**4**	kWh/m2

Energy: marginally better

Average difference %	
Heating	**-69**
Cooling	**11**
Ventilation	**0**
Total	**-1**

Old & New difference %	
Heating	**-74**
Cooling	**2**
Ventilation	**-14**
Total	**-11**

Comparison 3: EWF – EWF with chilled beams

	comfort ←	Priority line		→ energy	
	Variation 1	Existing	New	Variation 2	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

EWF with climate ceiling	**Variation 1**	**Existing**	**New**	**Variation 2**	
Hours at and above 27°C	0	0	741	741	hours
Discomfort % in a year	0	0	8	8	%
Comfort % in a year	**100**	**100**	**92**	**92**	%
Hours at and above 29°C	0	0	0	0	hours
Discomfort % in a year	0	0	0	0	%
Comfort % in a year	**100**	**100**	**100**	**100**	%

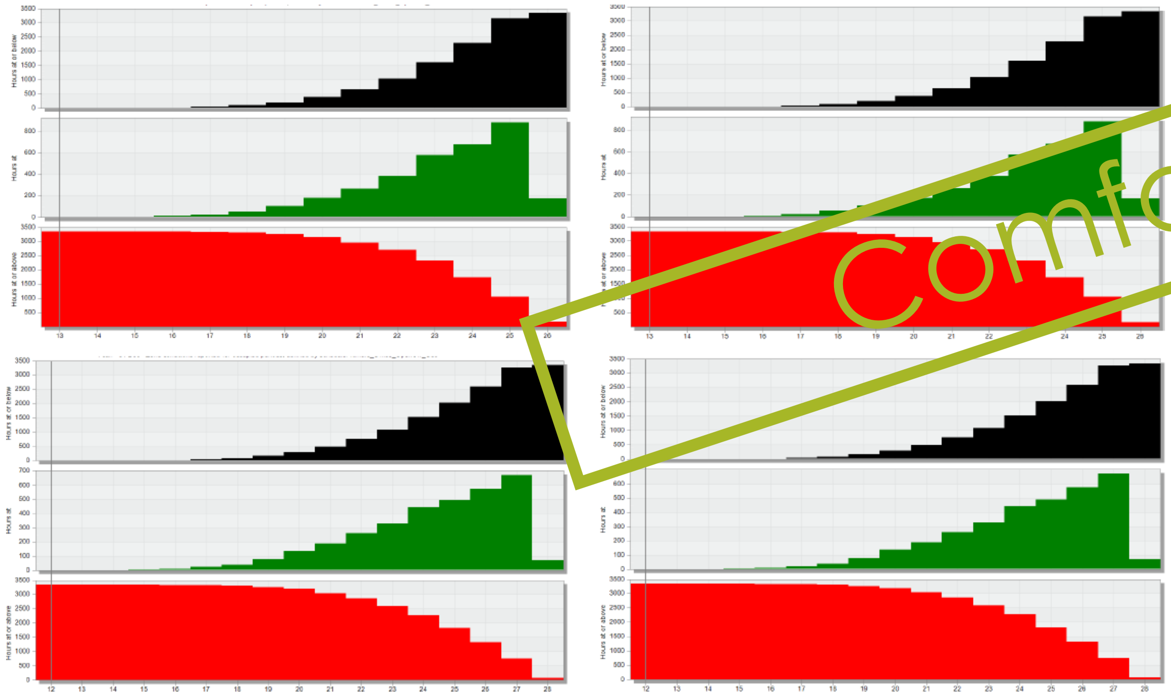
EWF with chilled beams	**Variation 1**	**Existing**	**New**	**Variation 2**	
Hours at and above 27°C	33	33	50	50	hours
Discomfort % in a year	0	0	1	1	%
Comfort % in a year	**100**	**100**	**99**	**99**	%
Hours at and above 29°C	0	3	3	3	hours
Discomfort % in a year	0	0	0	0	%
Comfort % in a year	**100**	**100**	**100**	**100**	%

Comparison 3: EWF – EWF with chilled beams

comfort ⟵ **Priority line** ⟶ *energy*

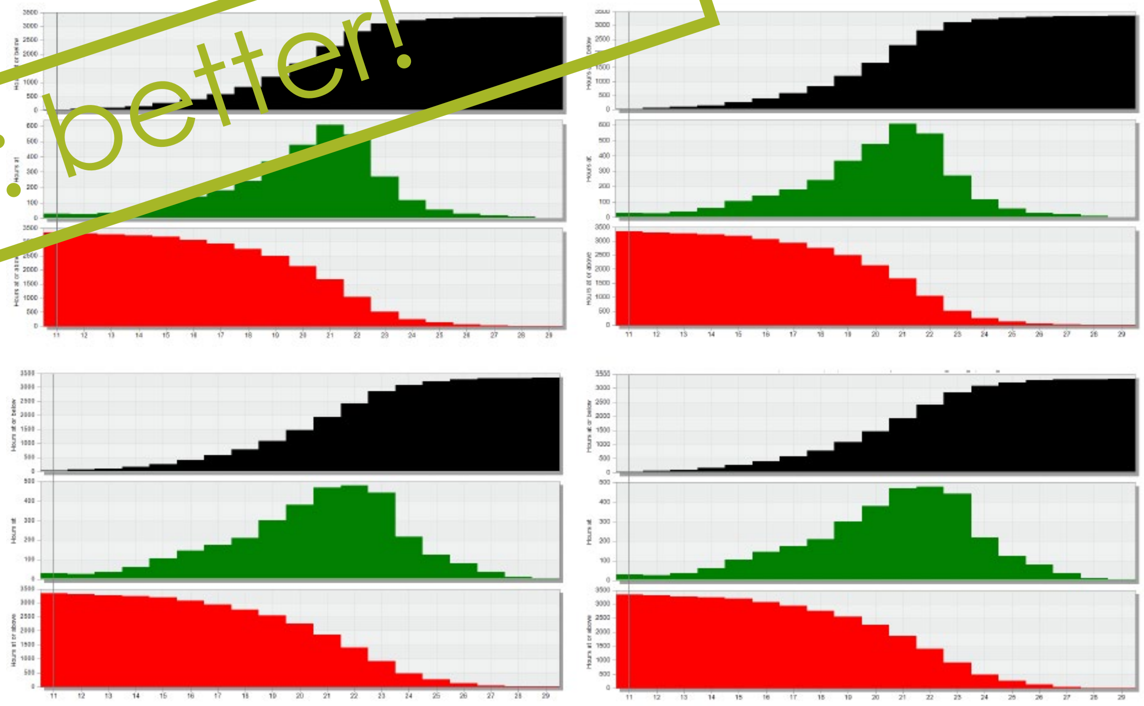
	Variation 1	Existing	New	Variation 2	
Ventilation amount	50	25	50	25	m3/h/person
Comfort design condition					
Heating mode	22	22	20	20	°C
	40	40	40	40	% RH
Cooling mode	26	26	28	28	°C
	50	50	70	70	% RH

EWF



From top-left clockwise: Variation 1, Existing, New, and Variation 2.

EWF with chilled beams



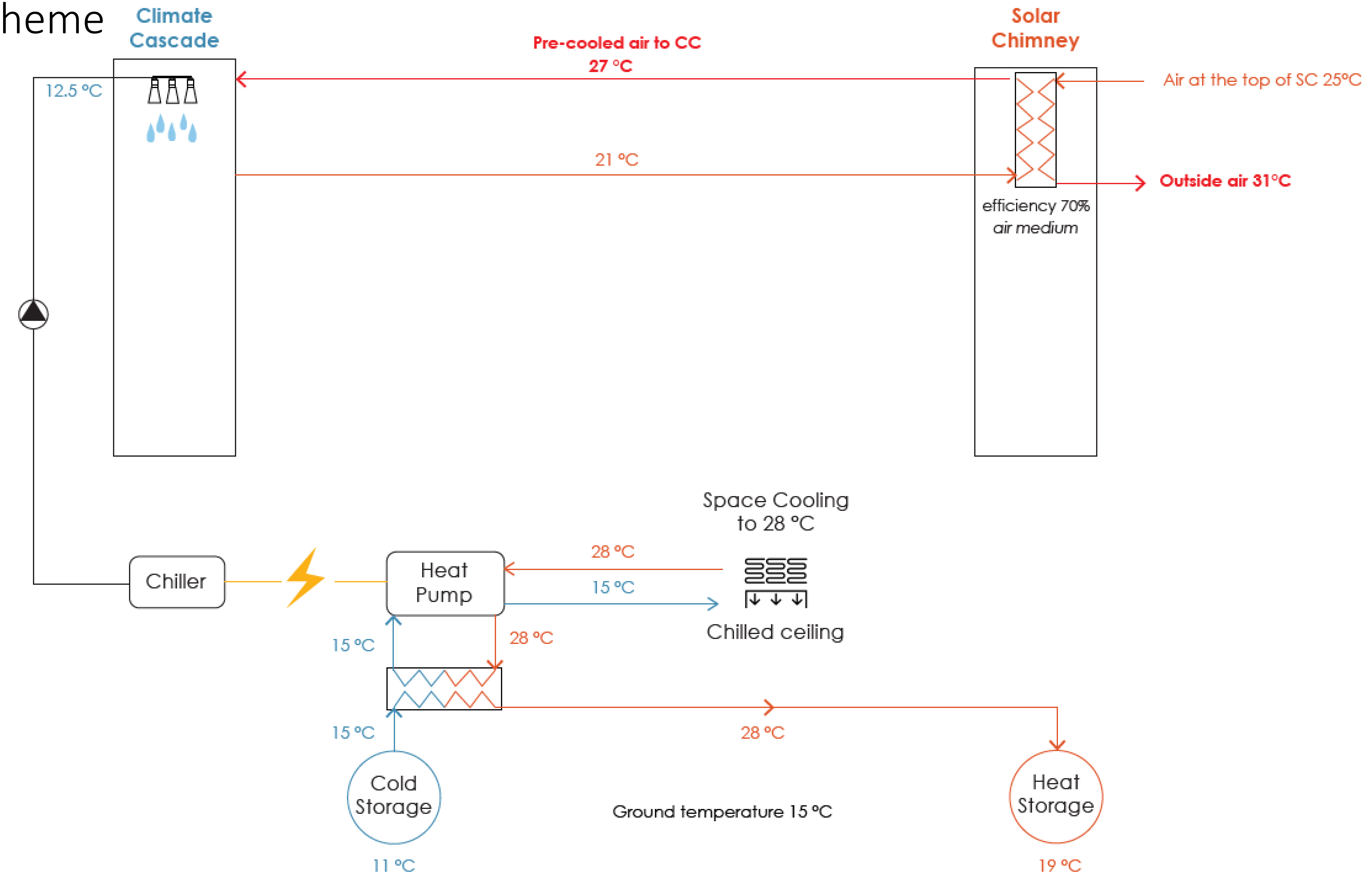
From top-left clockwise: Variation 1, Existing, New, and Variation 2.

Comfort: better!

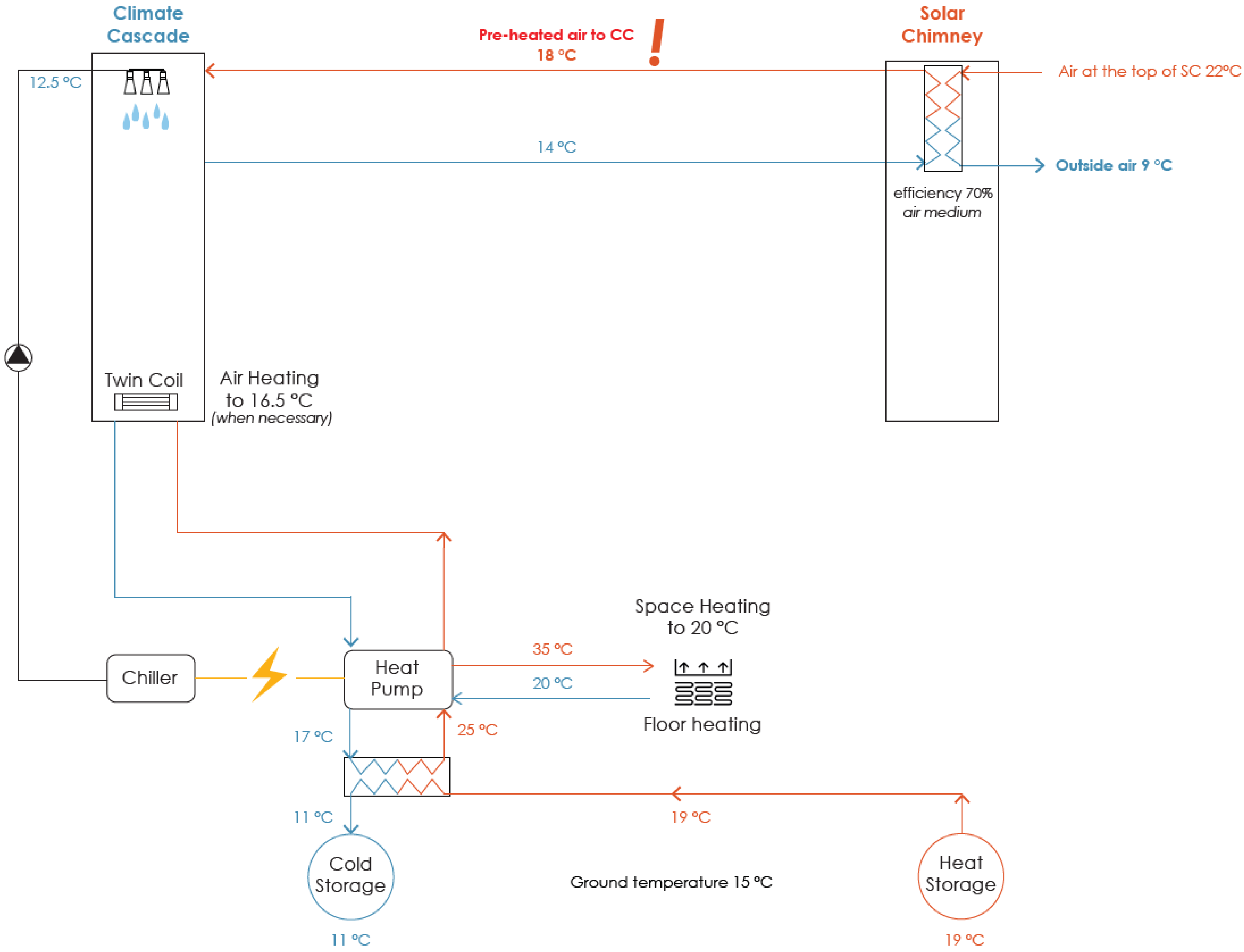
Reuse (heat/cold):

Heat Recovery

Summer scheme



Winter scheme



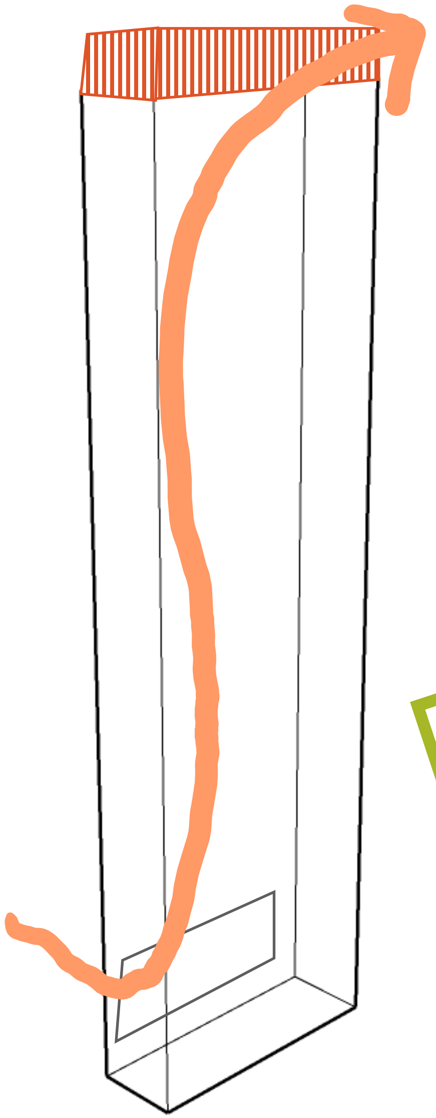
Algorithm

Seasons	Te<=Thr	Te>Thr	Total	
Autumn	1505	679	2184	if [Te >= 16.5 AND Thr >= 16.5] then [min between Te&Thr], else if Te <= 16.5 then [default], else [min between Te&Thr]
Spring	2069	139	2208	if [Te >= 16.5 AND Thr >= 16.5] then [min between Te&Thr], else if Te <= 16.5 then [default], else [min between Te&Thr]
Summer	309	1899	2208	Choose the minimum between Te and Thr (ignore 16.5)
Winter	2184		2184	Always ignore Te, choose the minimum between Thr and 16.5
Total hours in 2020			8784	[default]=minimum between "16.5", and "that which is closest to 16.5"

Examples

No	Date & time	Te	Thr	relation	CC Tin
1	01/01/2020 10:00	5.8	18.8	Te<=Thr	16.5
2	06/02/2020 13:00	6.1	21.7	Te<=Thr	16.5
3	22/03/2020 15:00	21.8	24.7	Te<=Thr	21.8
4	17/04/2020 17:00	14.9	20.5	Te<=Thr	16.5
5	14/05/2020 18:00	22	23.0	Te<=Thr	22
6	11/06/2020 09:00	27.3	27.1	Te>Thr	27.1
7	20/07/2020 13:00	30.7	28.3	Te>Thr	28.3
8	05/08/2020 15:00	33.4	30.1	Te>Tr	30.1
9	06/09/2020 20:00	25.6	23.1	Te>Tr	23.1
10	04/10/2020 09:00	20.7	22.5	Te<=Tr	20.7
11	21/11/2020 20:00	13.8	19.5	Te<=Tr	16.5
12	29/12/2020 20:00	8.3	17.8	Te<=Tr	16.5

Results



HR - energy saving	✗	✓	%	
Heating	6	5	-23	kWh/m2
Cooling	11	4	-59	kWh/m2

Heat/cold reuse: success!

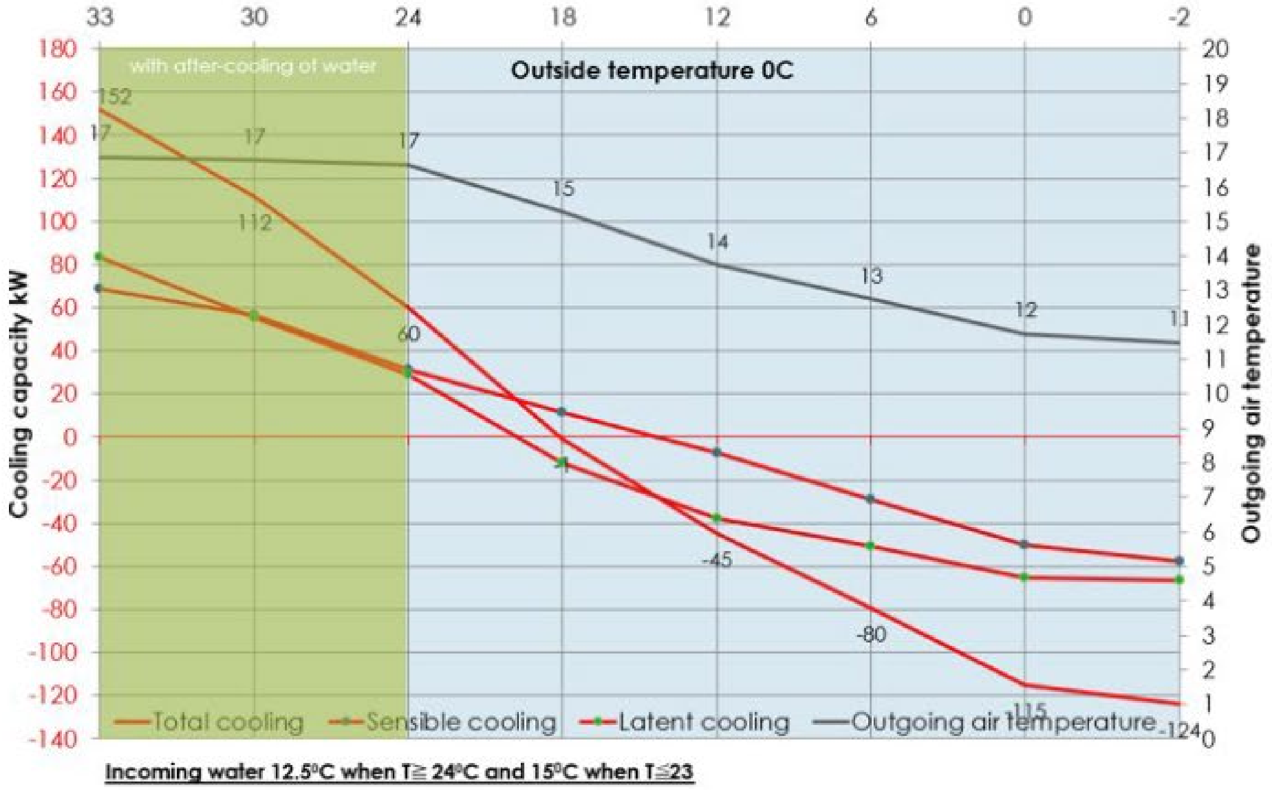
Comparison

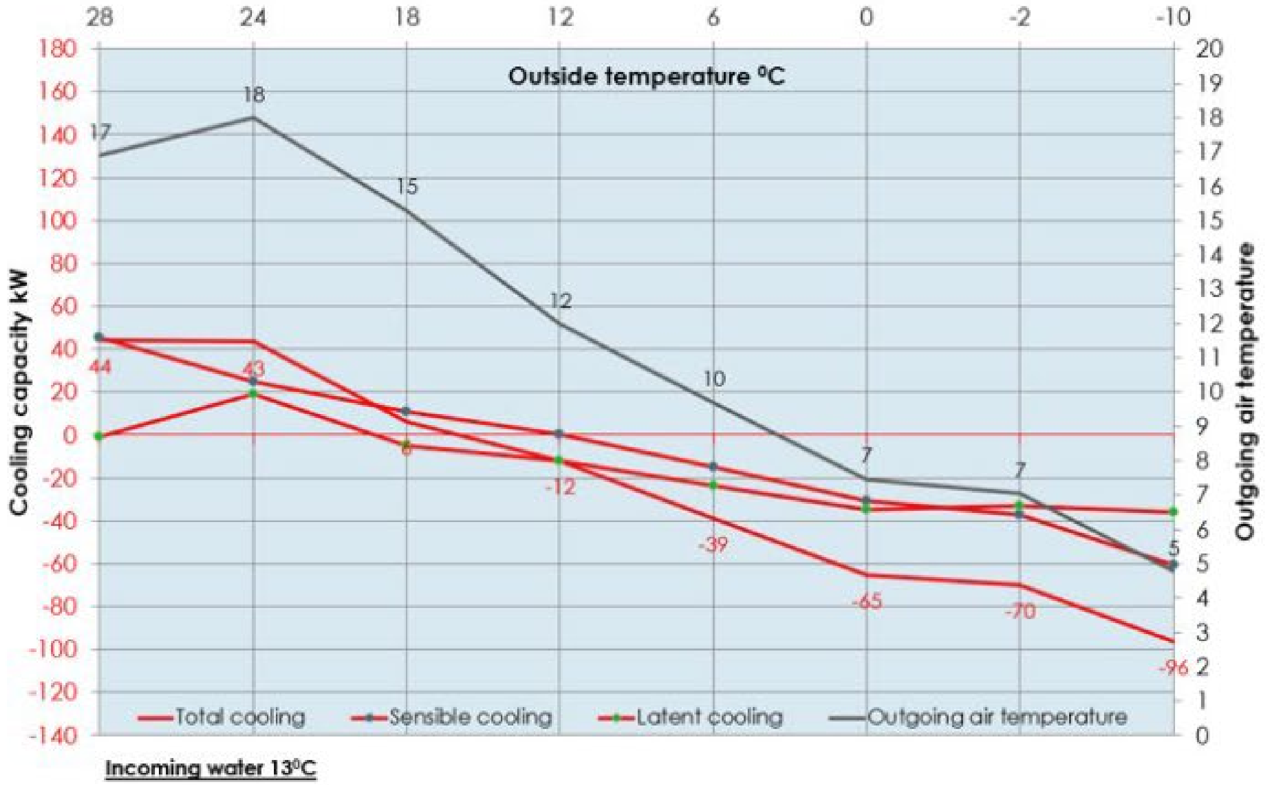
Tokyo - Amsterdam

CC

Pre-cool the water is necessary

Pre-cool the water is NOT necessary





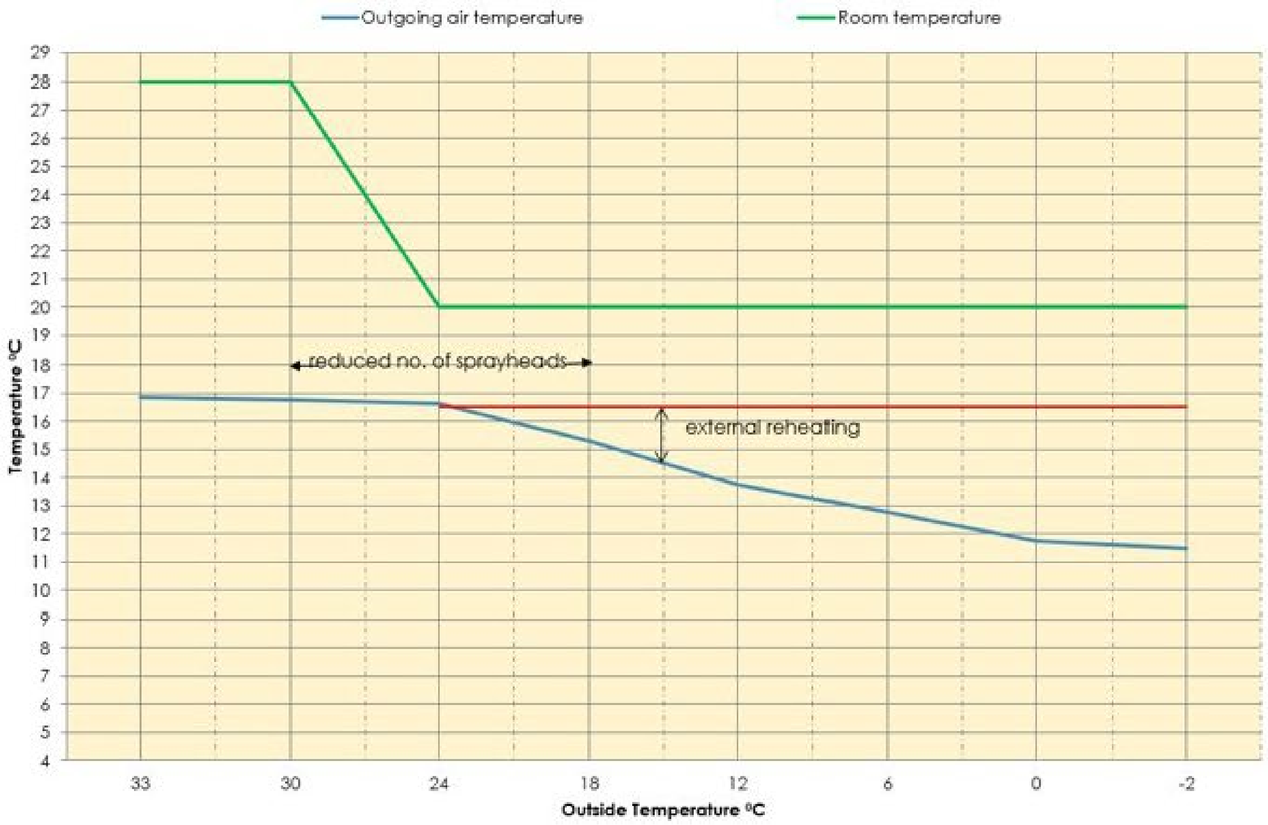
Tokyo

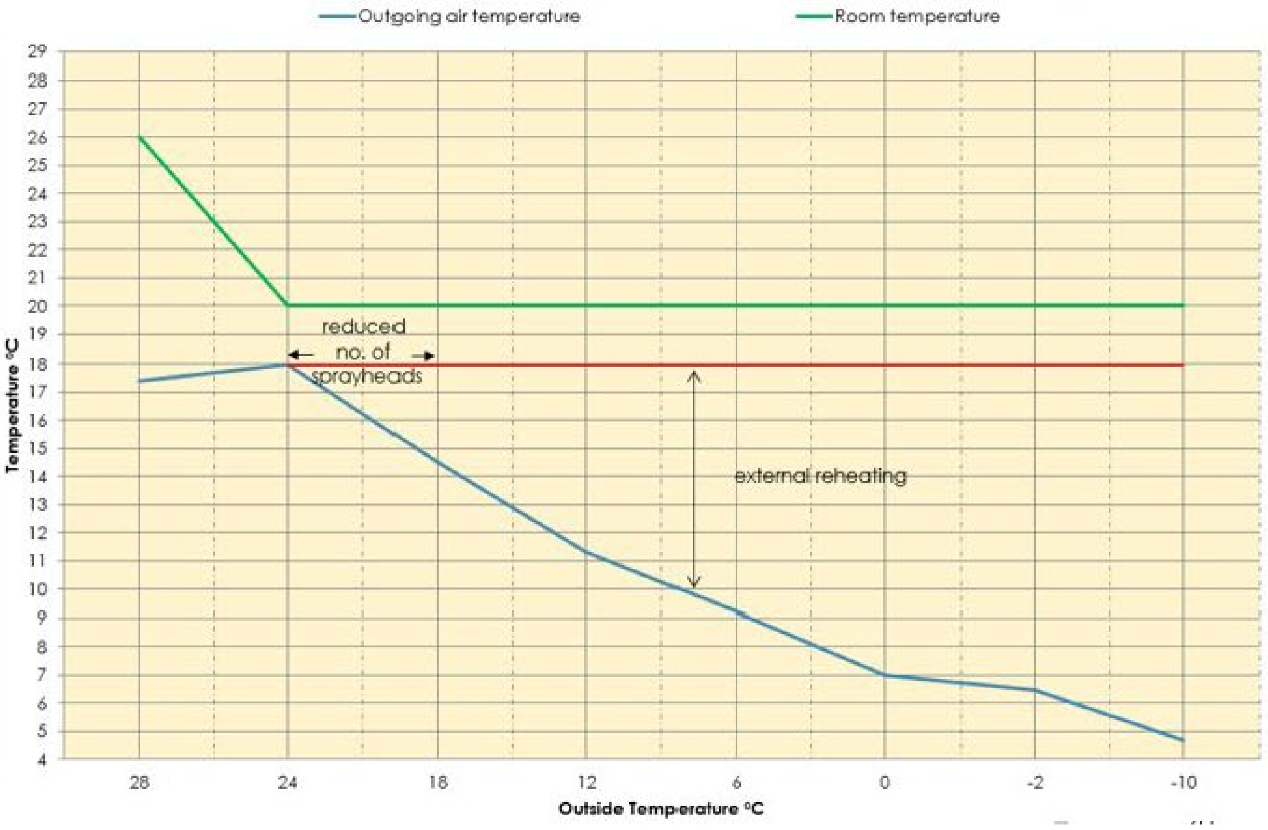
Amsterdam

CC

External heating energy is less

External heating energy is more





Tokyo

Amsterdam

CC

Tokyo ≦16.5°C cooling: when T outside air ≧ 24°C

Scenario	Height [m]	Necessary Pressure [Pa]	No of spray-heads	Outgoing air temperature T33 [°C]	Achieved Pressure T24 [Pa]	Fan Energy [MWh]	Pump Energy [MWh]	Pump Energy [kWh/m2]	Heating Energy [MWh]	Heating Energy [kWh/m2]	Incoming water temperature	Cooling Energy [MWh]	Cooling Energy [kWh/m2]	Amount of water [ton]	Total Energy [kWh/m2]
1	**44**	100	**16**	16.4	307	0*	54	11	27	6	**13**	154	32	243,000	49
2	**44**	100	**10**	16.42	192	0*	34	7	33	7	**11**	199	42	152,000	56
3	**22**	100	**10**	16.42	96	0*	17	4	32	7	**11**	199	42	152,000	53
4	**22**	100	**12**	16.5	115	0*	20	4	28	6	**12**	177	37	182,000	47
5	**22**	100	**12**	16.87	115	0*	20	4	27	6	**12.5**	147	31	182,000	41
6	**22**	100	**9**	16.14	86	0*	15	3	36	8	**10**	226	48	137,000	59

* Natural draft by EWF saved 1.68 MWh of Fan energy

in average -> 51

Tokyo: 51 kWh/m²

Amsterdam ≦18°C cooling: when T outside air ≧ 24°C

Scenario	Height [m]	Necessary Pressure [Pa]	No of spray-heads	Outgoing air temperature T28 [°C]	Achieved Pressure T24 [Pa]	Fan Energy [MWh]	Pump Energy [MWh]	Pump Energy [kWh/m2]	Heating Energy [MWh]	Heating Energy [kWh/m2]	Incoming water temperature T24 [°C]	Cooling Energy [MWh]	Cooling Energy [kWh/m2]	Amount of water [ton]	Total Energy [kWh/m2]
1	**44**	100	**4**	16.8	150	0*	18	4	85	18	**13**	0	0	82,000	**22**

* Natural draft by EWF saved 1.62 MWh of Fan energy

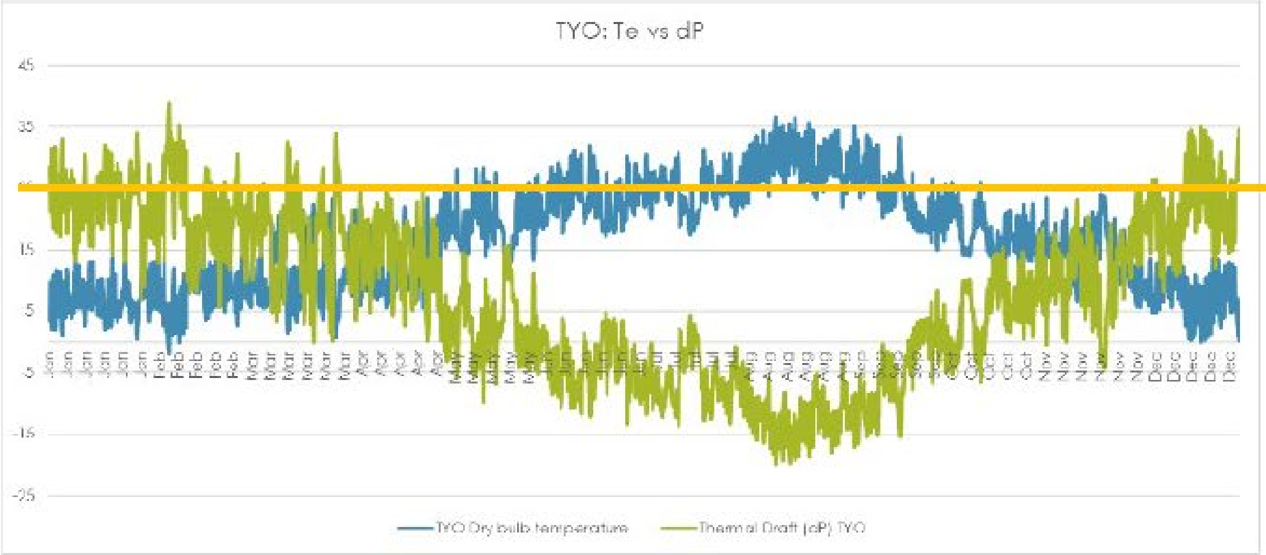
Amsterdam: 22 kWh/m²

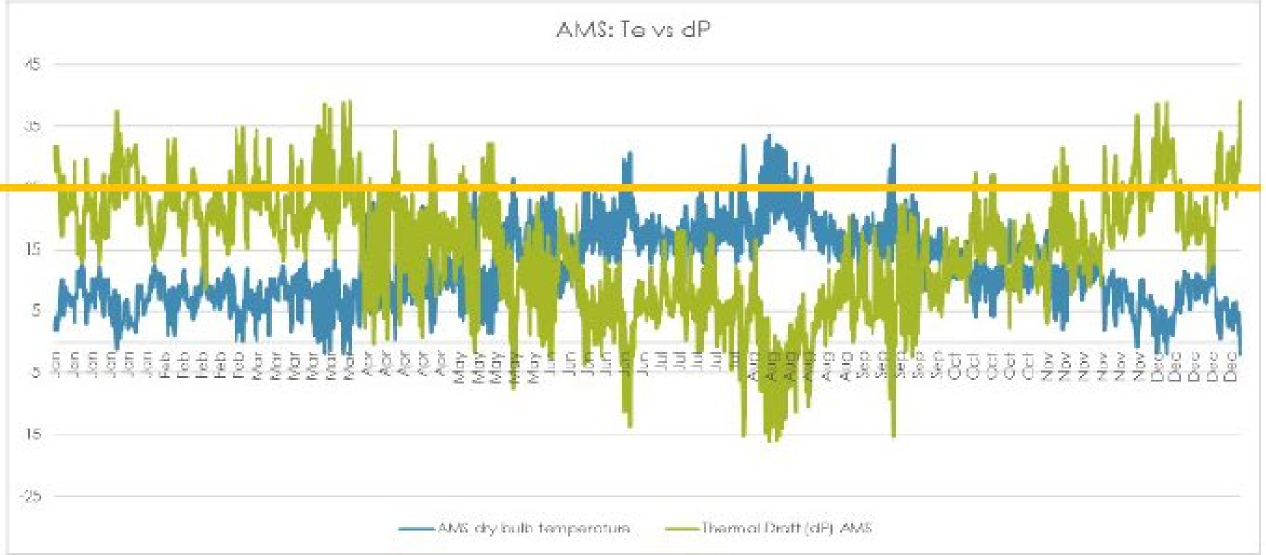
Tokyo Amsterdam

SC

Thermal draft is less, fan energy is more

Thermal draft is more, fan energy is less





Tokyo

Amsterdam

SC

More heat recovered for reuse

Less heat recovered for reuse

Solar Chimney	TYO	AMS	
Fan energy	0.1	0.0	kWh/m2
Heat recovered	48	37	kWh/m2

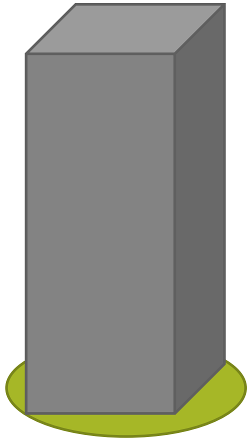
Tokyo

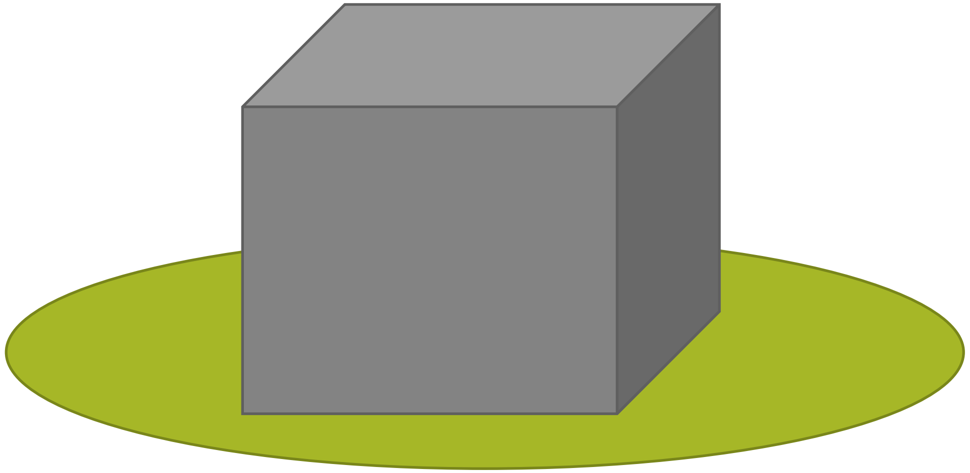
Amsterdam

Urban setting

Compact, tight in space

Less compact, less tight in space





Tokyo

Amsterdam

Comparison study

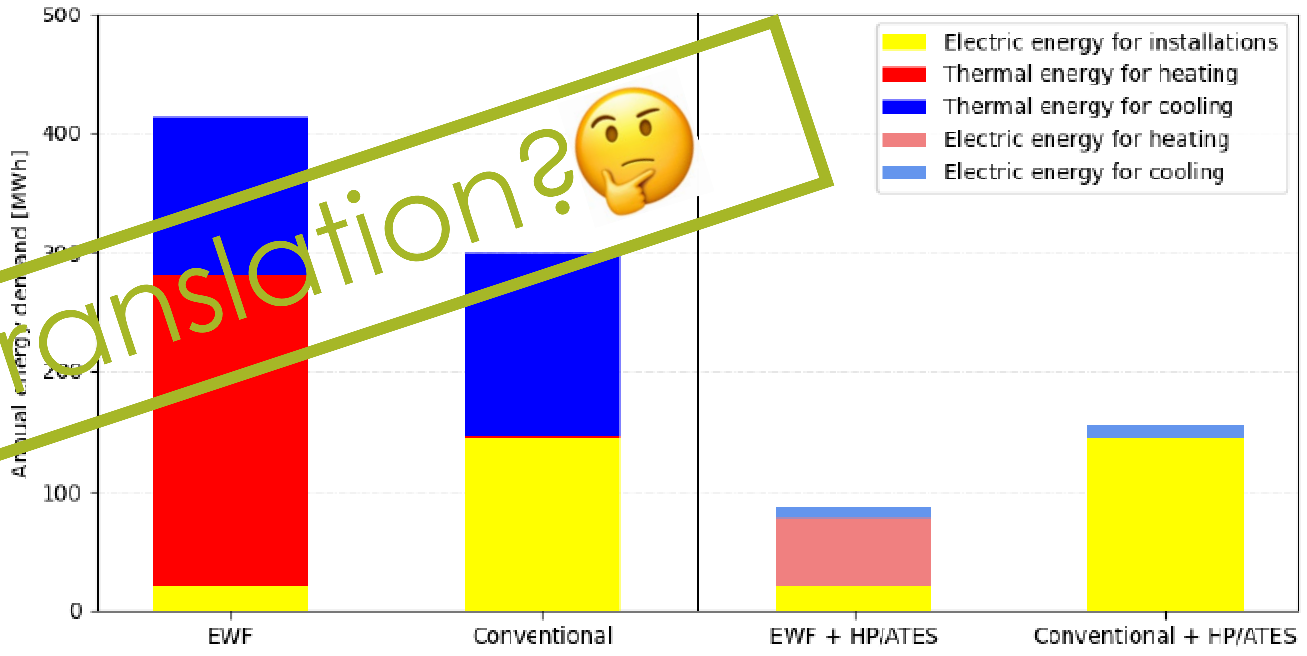
37% building related energy reduction

44% electric energy reduction

	Variation 1			Existing			New			Variation 2			
Comparison	Existing	EWF	%	Existing	EWF	%	Existing	EWF	%	Existing	EWF	%	
Heating	72	15	**-79**	64	14	**-79**	2	10	**414**	1	10	**626**	kWh/m2
Cooling	152	77	**-49**	135	72	**-47**	89	67	**-25**	86	63	**-27**	kWh/m2
Ventilation	44	31	**-29**	44	29	**-34**	35	25	**-28**	35	23	**-33**	kWh/m2
Total	268	123	**-54**	243	114	**-53**	126	101	**-19**	122	96	**-21**	kWh/m2

Average difference %	
Heating	**220**
Cooling	**-37**
Ventilation	**-31**
Total	**-37**

Old & New difference %	
Heating	**-85**
Cooling	**-50**
Ventilation	**-43**
Total	**-58**



Found in translation?

(Teeling. 2020)

Tokyo

Amsterdam

Conclusion

Answering the research question

"Is the Dutch **Earth, Wind and Fire system** (EWF),

in place of the existing **air-conditioning system**,

an efficient **energy-retrofitting method** to achieve **energy-neutrality** in an **office building in Tokyo**

without compromising **thermal comfort** of users?"

No, it is **not efficient** at all for the case of NK Building, as it turned out that the existing air-conditioning system is already energy efficient.

However, **as a ventilation system**, EWF contributed to **15% energy reduction** proving the fact that the natural ventilation concept of EWF works.

Thermal comfort is also improved, from 75% to 92% comfort hours, with more balance temperature distribution.

Elaboration

"Is the Dutch **Earth, Wind and Fire system** (EWF),

in place of the existing **air-conditioning system**,

an efficient **energy-retrofitting method** to achieve **energy-neutrality** in an **office building in Tokyo**

without compromising **thermal comfort** of users?"

Moreover, when **compared to a conventional air-conditioning system**, EWF uses **40% less energy** overall, with better thermal comfort.

On the other hand, **energy neutrality is not achieved**, and is very challenging without reducing the energy consumption first.

Limitation

- COVID-19 pandemic
- Accuracy of simulating EWF in DB

Recommendation

- Many *exciting* topic for follow up research:
  - EWF design without ATES -> use chiller to cool the CC water in Tokyo or other cities with similar climate
  - Integration of unitized SC with PV, PV/T, or Thermal Collector -> prioritizing electricity or heat gain
  - And more…
- Develop a standardized and easy-to-use Excel calculation for both CC and SC
- New template for EWF in DB, or any other dynamic simulation software

"I want you to act as if the house is on fire, otherwise…"

… comfort will be a luxury

… it's getting even hotter!

… the relation between human & nature is getting worse

… *(fill your own answer)*

EWF is a concept that bridge architect and mechanical engineers,

but most importantly,

It’s trying to bridge nature back into our life.

Thank you!

Dank u wel!

ご清聴ありがとうございます