Urban morpological map

- Historical building
- Traditional urban fabric
- Recent urban fabric
- Buildings outside the project
- Fabric Alignment
- Old principle roadway
- Fushougou Ditch

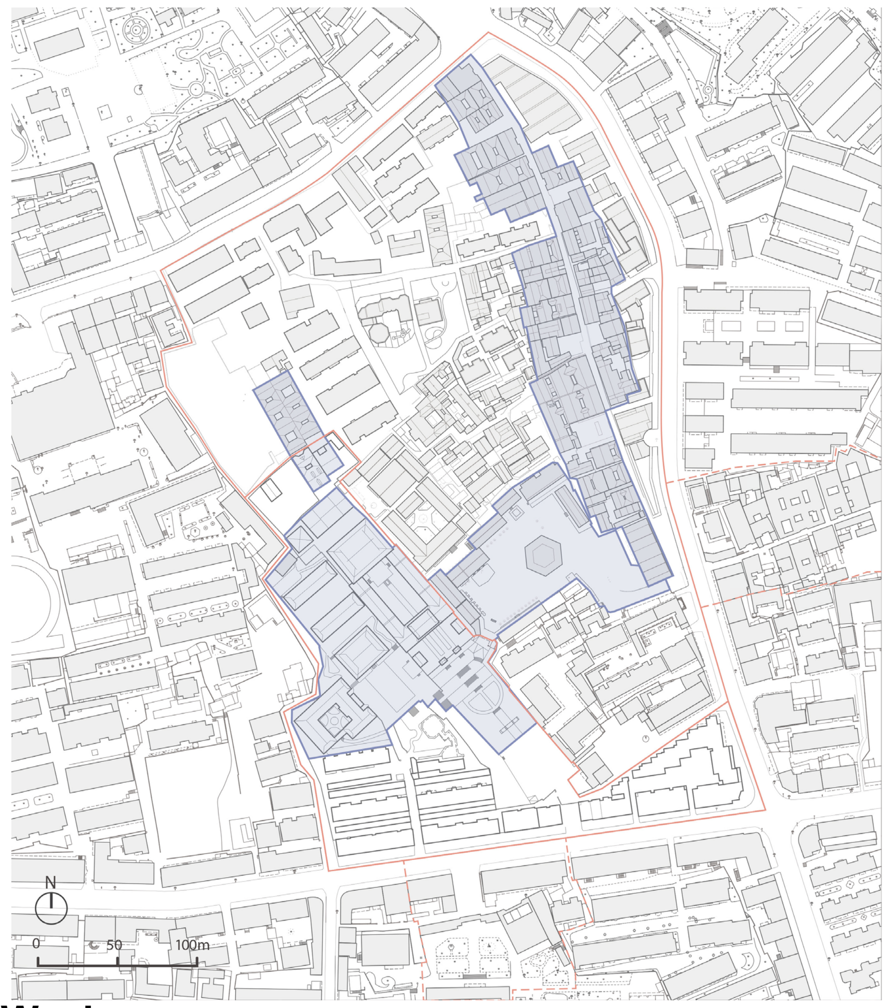
Superposition of past and present status

- Investigation Period
- Present situation
- Inherited fabric

Design Strategy

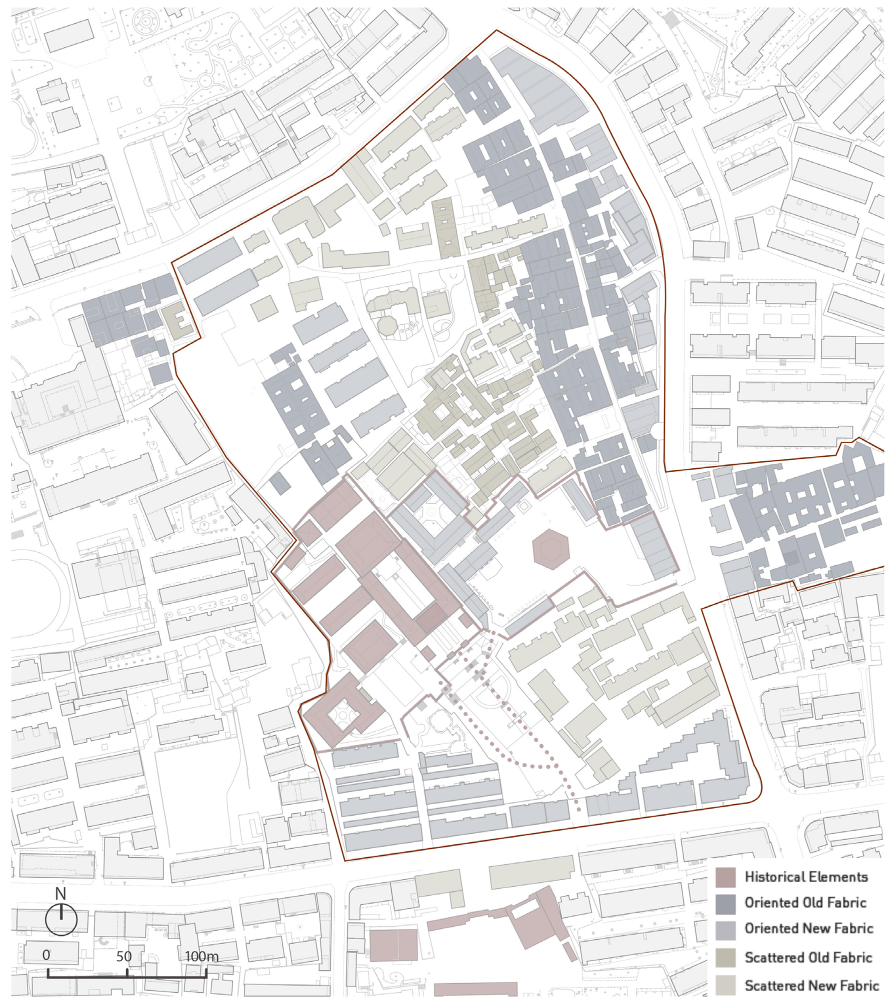
Masterplan 1:2000

Strength

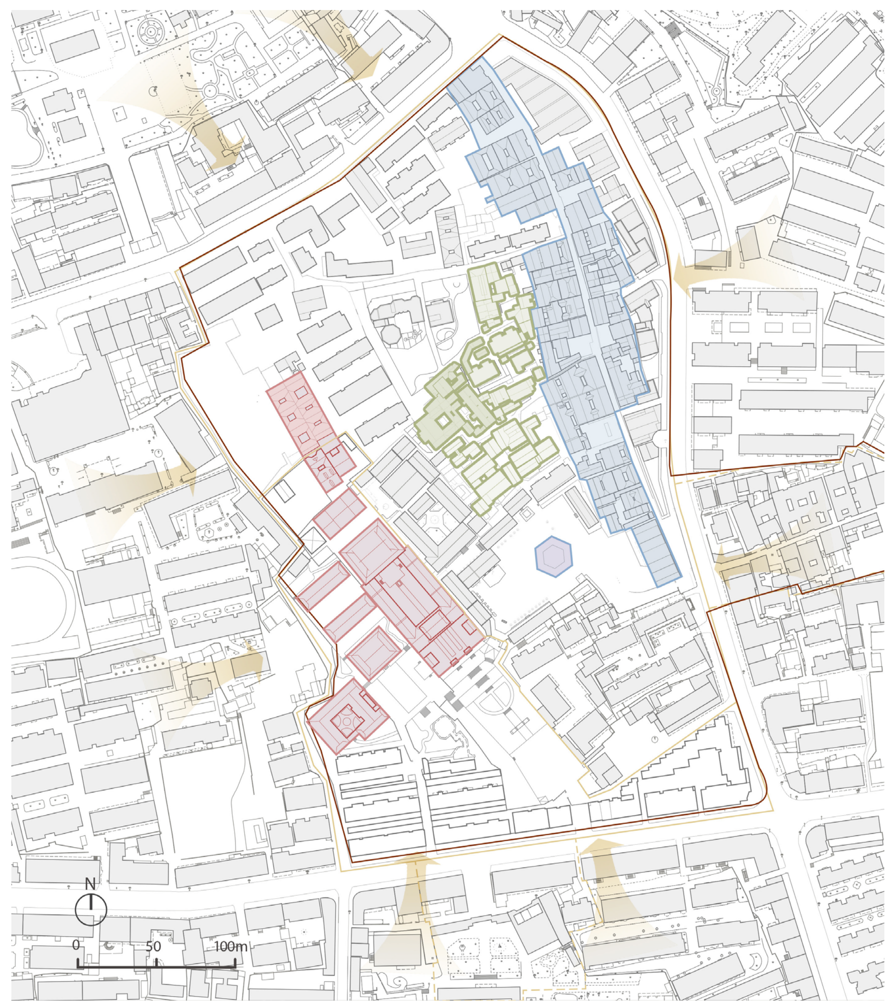


Threats

Weakness



Opportunities



Strength

- Wu Temple, Daucheng Palace, and Pagado provide an important site for cultural heritage within Ganzhou.
- Historical Monuments and Cultural Heritage can act as a tourist attractant.
- One of the main city axis runs through the Confucian Temple.

Historical Urban Morphology

- Historic urban fabric on the north of the site provides examples of traditional couryard houses
- Main street between couryard houses is another imporatant axis of the city

Weakness

- Focus area is surrounded by a variety of typologies and functions, leading to the destruction of the traditional urban fabric.
- The historic axis throught the Confucian Temple is lost due to continual building and rebuilding of the city.
- New concrete buildings tower over the small historic courtyard houses and make traditional streets have lost their appeal.
- Confucian and Wu Temples are surrounded by walls, hiding its presence from the community.
- New function of primary school at the pagado prevents tourists and outsiders from visiting the site.
- Lack of accessible pathways make the cultural heritage sites difficult to access.

Poor Living Environment Quality

- Commercial continuity on the fishbone streets is not strong.
- Lack of green space and public space.
- The parking lot failed to serve the entire neighborhood, leading to many random parking phenomena.
- Many old or dilapidated houses are under great pressure for demolition and high renovation costs.

Opportunities

- Bring new life and tourists to the Confucian Temple, Wu Temple and Pagada.

Repurpose the Historical Urban Fabric

- Reuse the exisiting historical fabric to further attract locals and visitors to the historic site.
- Restore damaged buildings in order to provide a long lasting historic site to the city

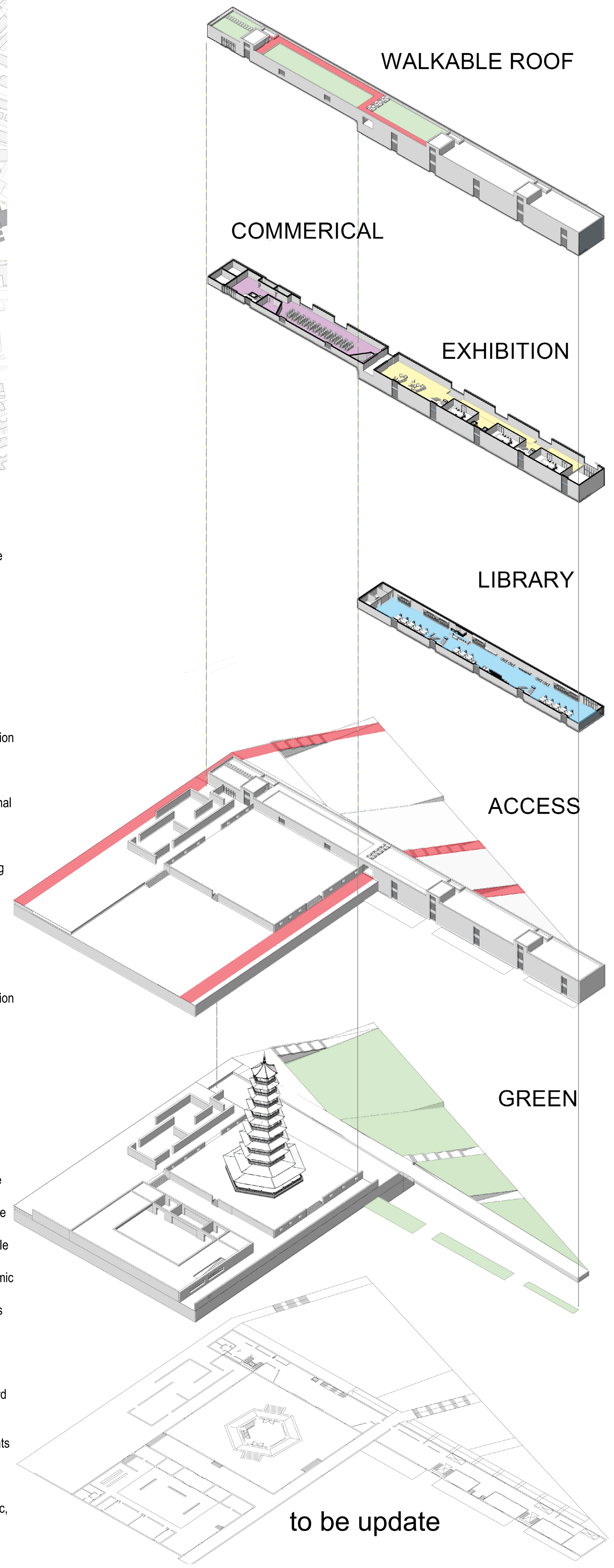
Drive the Growth of Economy

- Promote the economic development of the block through the development of tourism.
- Through the construction of new commercial streets, local characteristic industries will be developed and consumption will be stimulated.
- By developing the economy and improving the infrastructure, it will attract the return of the population.
- Increasing jobs can not only bring a stable life to the locals, but also attract talents to settle in.
- China's good economic environment and stable social order provide a good macroeconomic foundation for the development of tourism.
- The Ganshen high-speed railway, which is about to be completed, will expand Ganzhou's urban tourism circle and attract more tourists.

Threats

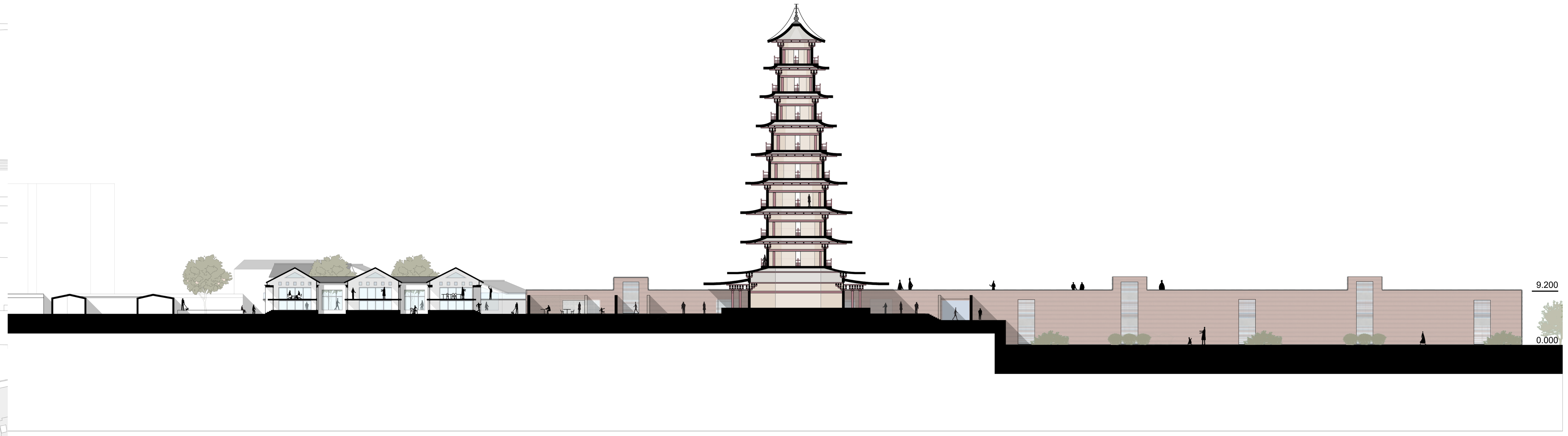
- Focus area is surrounded by a new buildings which tower over the small historic courtyard houses, leading to the destruction of the historical city texture and the gradual loss of culture.
- New develops decrease the visibility of the cultural heritage area and cause local residents to lose their sense of cultural identity.
- The poor living environment may lead to population loss, reduced community vitality, and stagnant economic development.
- The streets in disorderly blocks are very narrow and it is difficult to organize smooth traffic, so there might be great fire hazards.

Axnometric view of site design

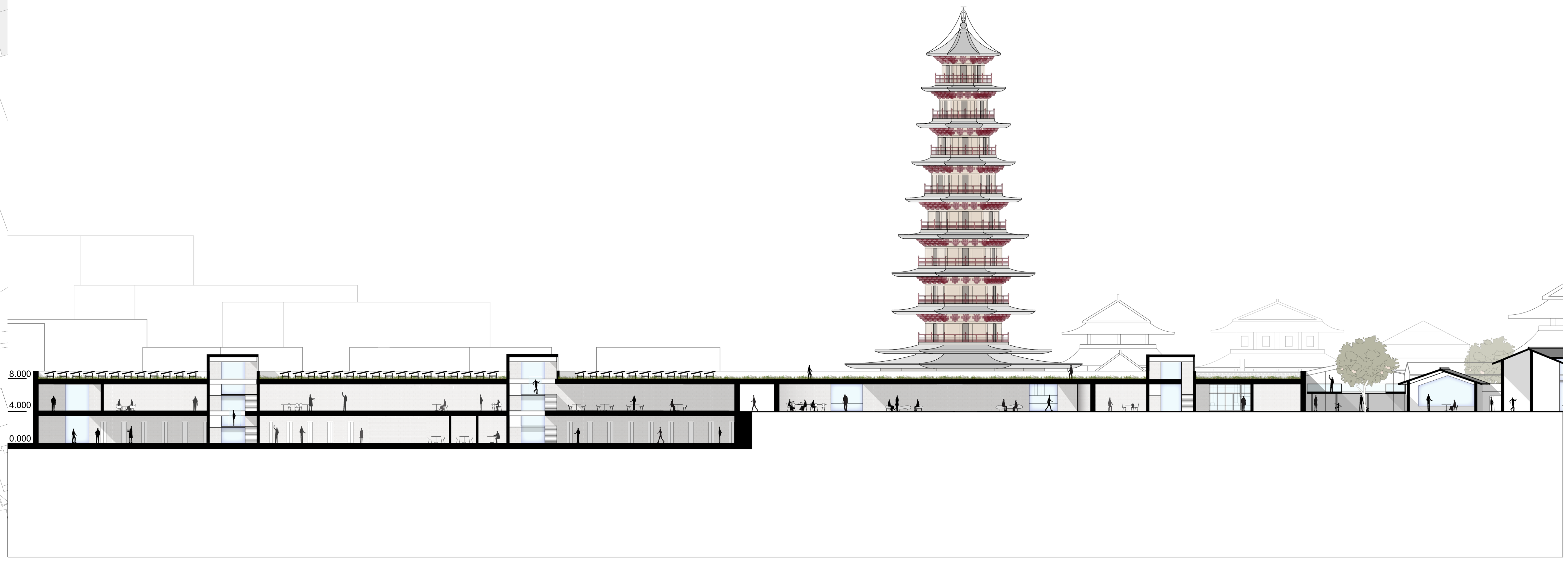


Masterplan in 1:1000

Section A-A



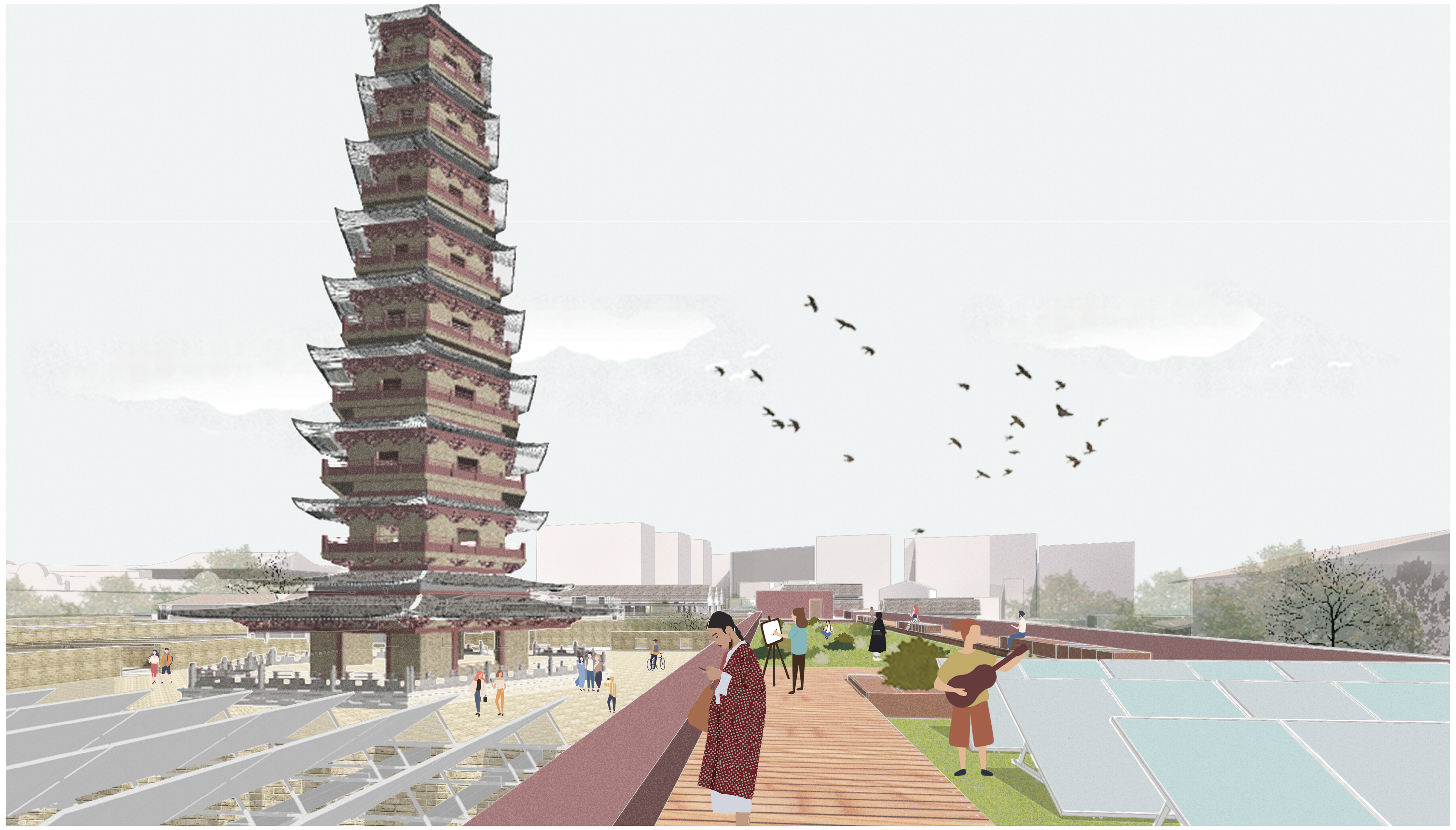
Section B-B



Axnometric view of site design

View of the corridor around the Pagoda

Ground floor entrance view



View of the south-east side on the site

Roof gardens and solar PV

Roof plan 1:500

Groundfloor plan 1:500

Section C-C

Politecnico di Milano - AUIC School
School of Architecture
Master of Science in Architecture and Urban Design
a.a. 2021/22

Supervisor - Prof. Rajendra Singh Adhikari
Luana Filogamo

Students - Li Xinyue 10785967
Zhao Hanqing 10776135

Revitalizing and Sustainable Designing
The Ancient District Representing by Ciyun Pagoda in Ganzhou

Plans and Sections

Building functions

1. Open reading space
2. Bookshelf area
3. Office
4. Cafe and rest
5. Temporary exhibitions
6. Exhibition & Lounge Area
7. Storage room
8. Ciyun Pagoda Square
9. Viewing corridor
10. Educational spaces
11. Outdoor rest area
12. Traditional Culture Workshop
13. Commercial
14. Residence

POLITECNICO MILANO 1863

Politecnico di Milano - AUIC School
School of Architecture
Master of Science in Architecture and Urban Design
a.a. 2021/22

Supervisor - Prof. Rajendra Singh Adhikari
Luana Filogamo

Students - Li Xinyue 10785967
Zhao Hanqing 10776135

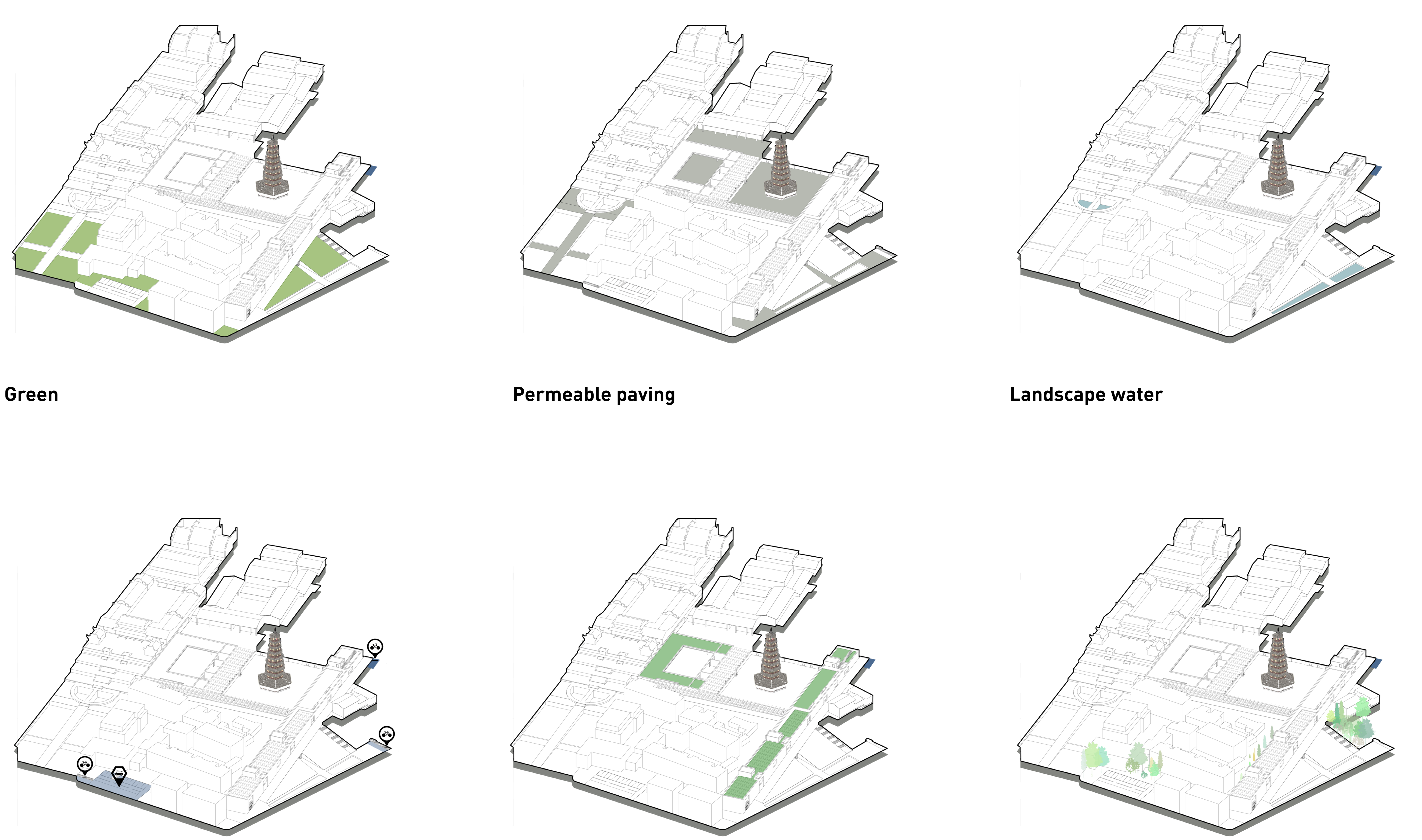
Revitalizing and Sustainable Designing
The Ancient District Representing by Ciyun Pagoda in Ganzhou

1:400 Plans

Perspective section

Current site status

Sustainable site plan



Green

Permeable paving

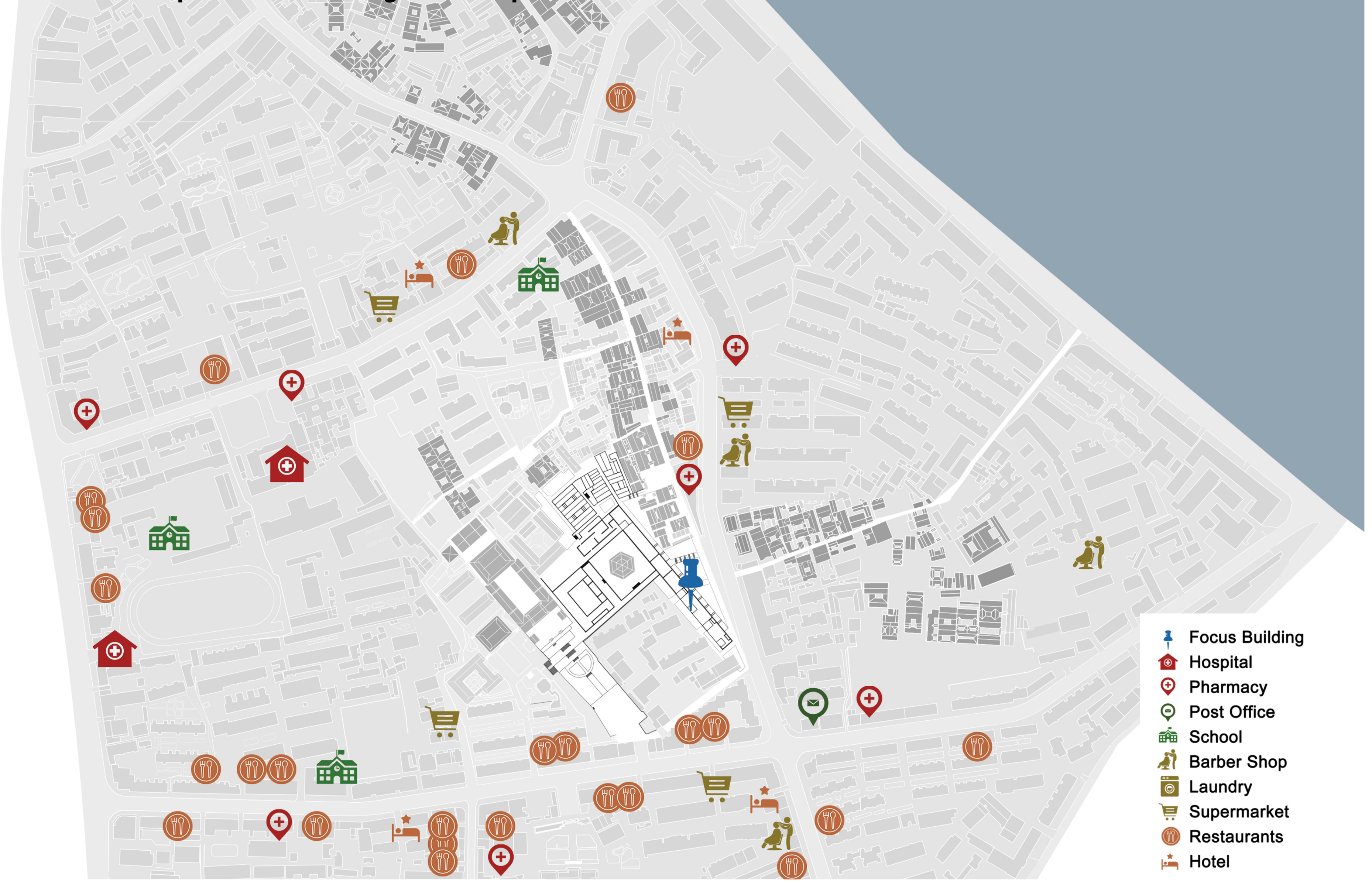
Landscape water

Parking and bicycle parking

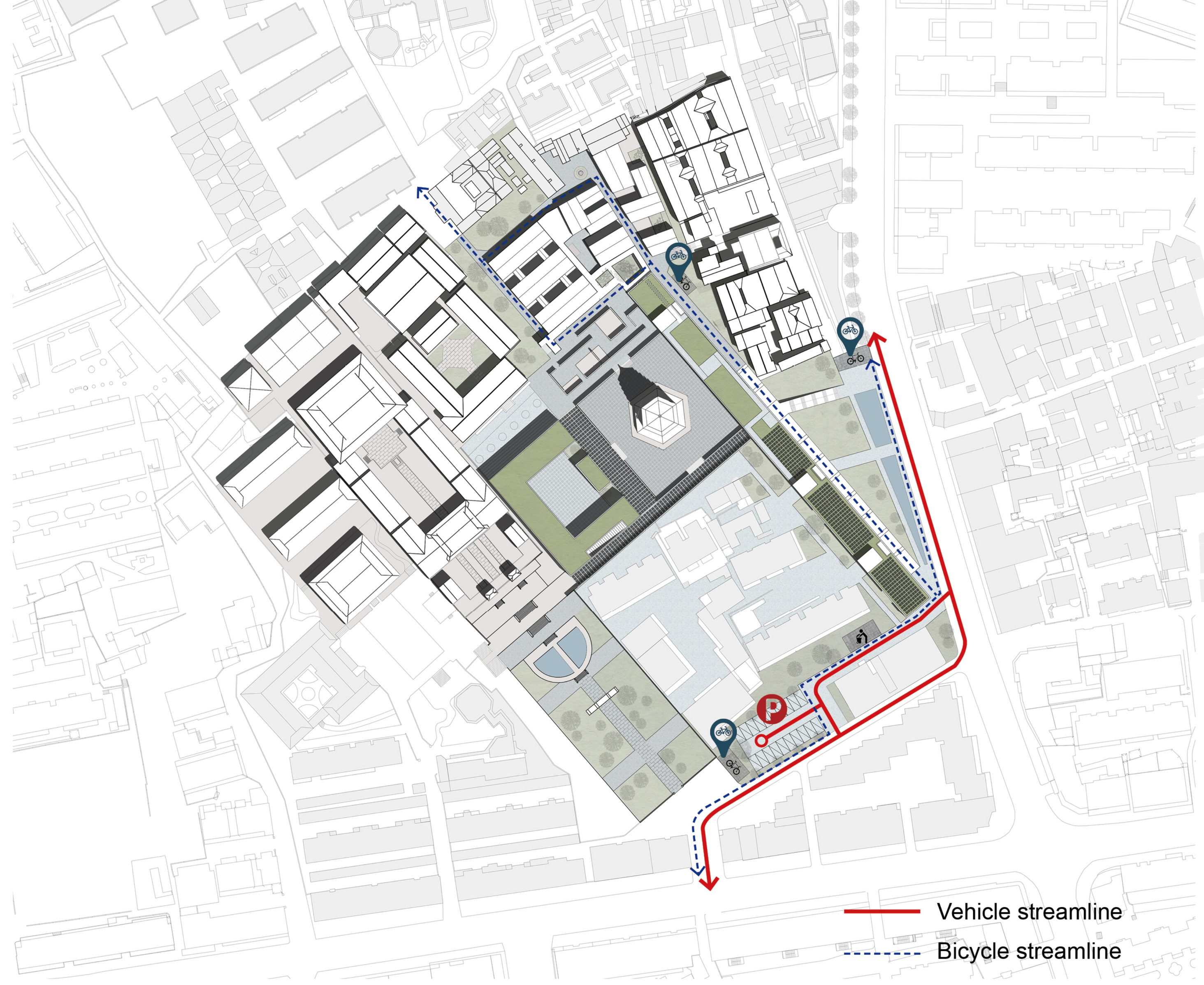
Green Roof

Permeable paving

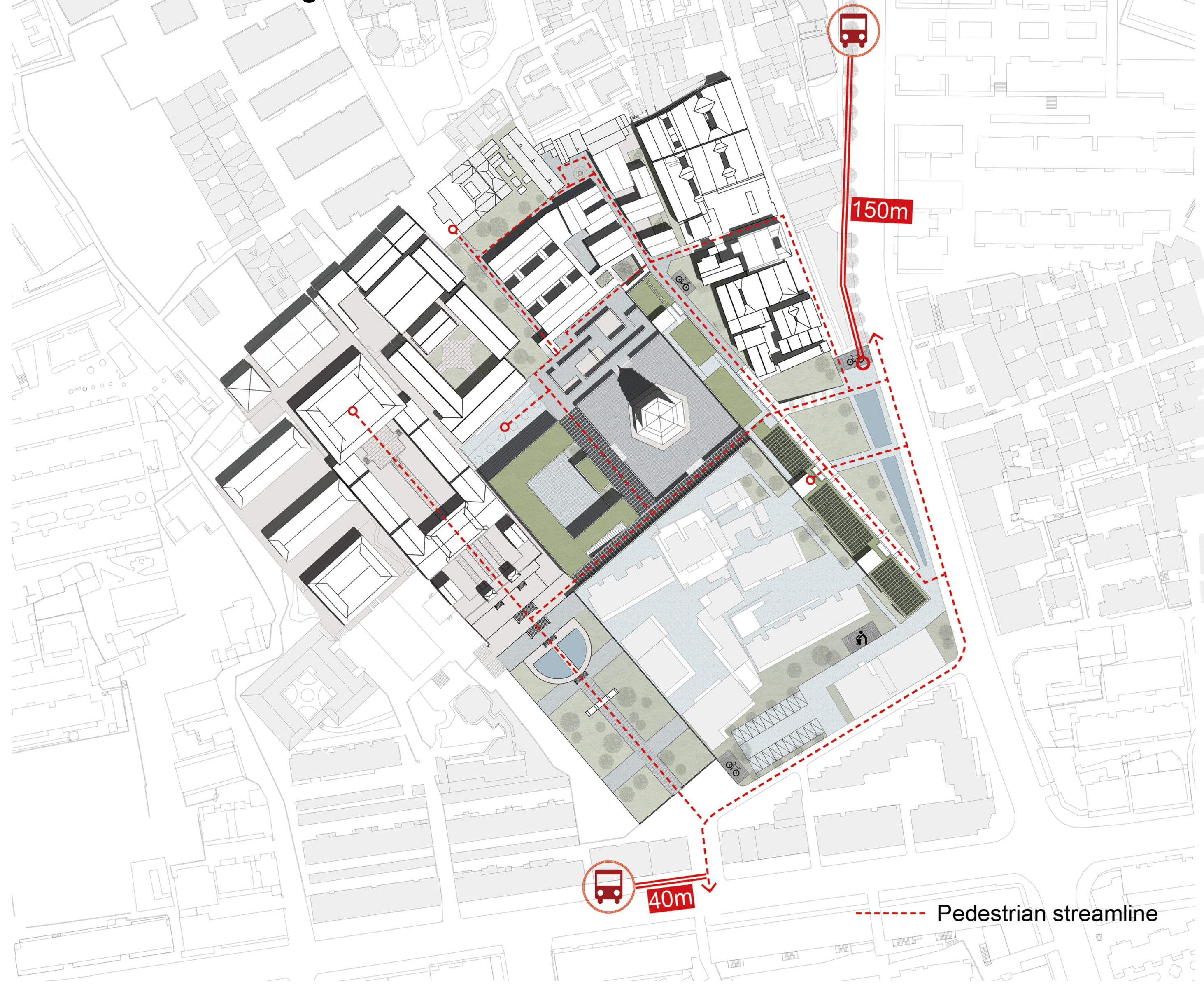
Distribution map of surrounding service points



Traffic flow

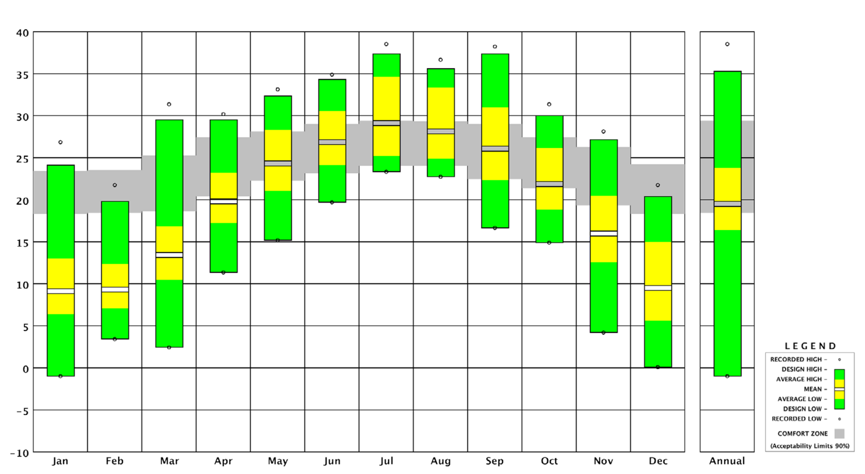


Pedestrian flow diagram

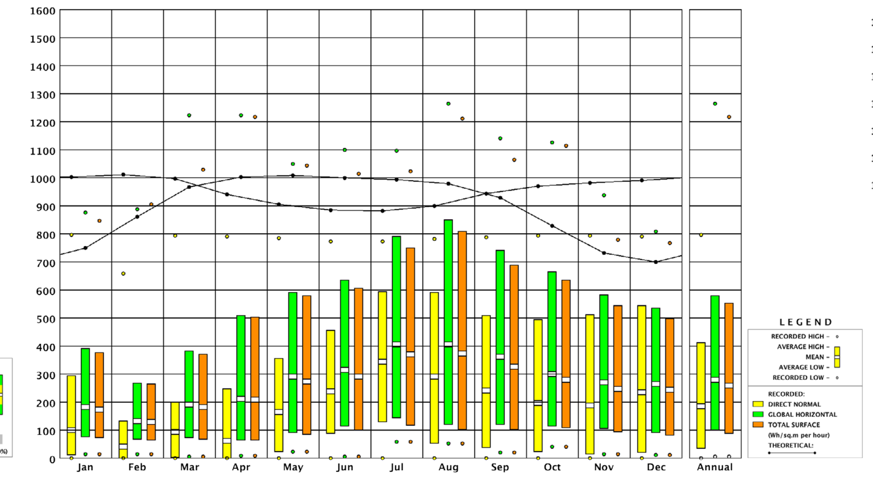


Climate Analysis

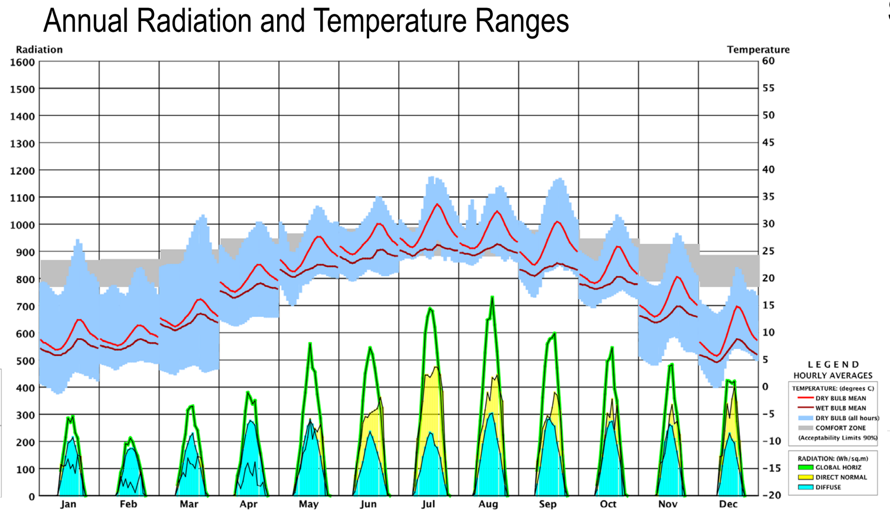
Annual Temperature Range



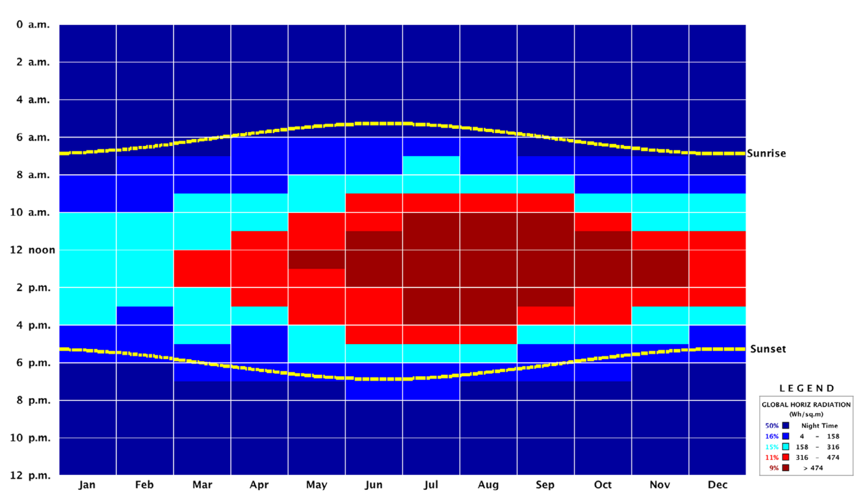
Annual Radiation Ranges



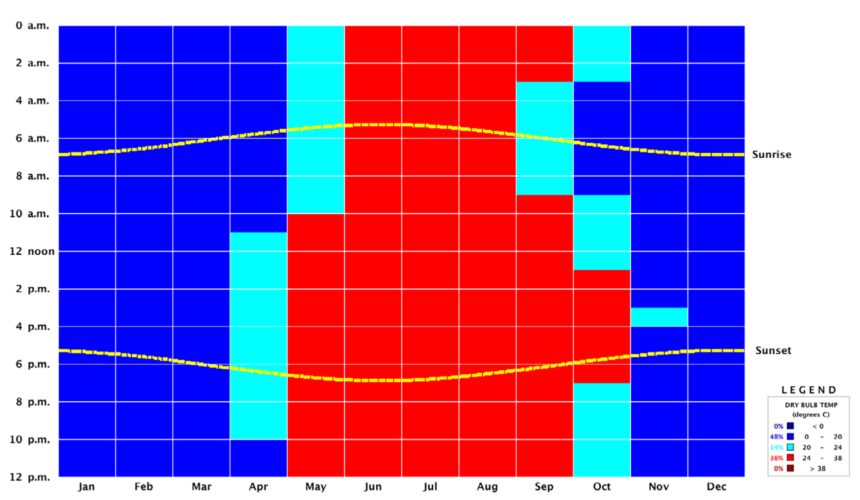
Annual Radiation and Temperature Ranges



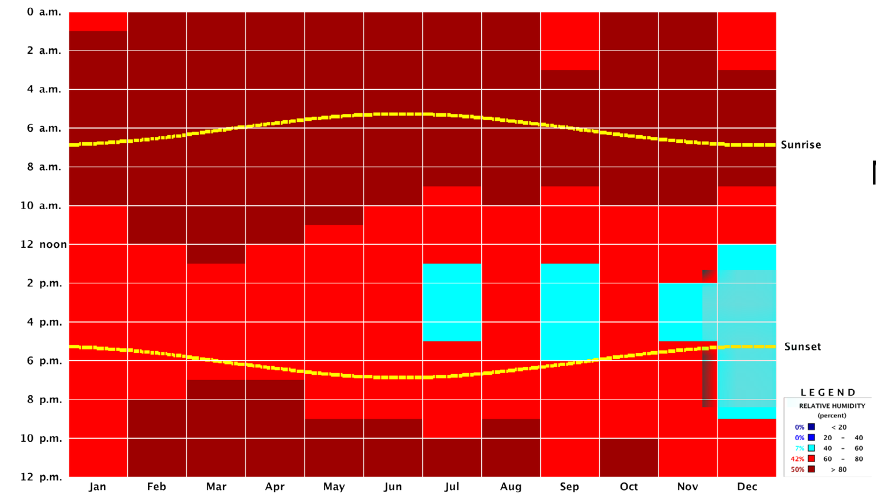
Hourly Global Horizontal Radiation



Hourly Dry Bulb Temperatures



Hourly Relative Humidity



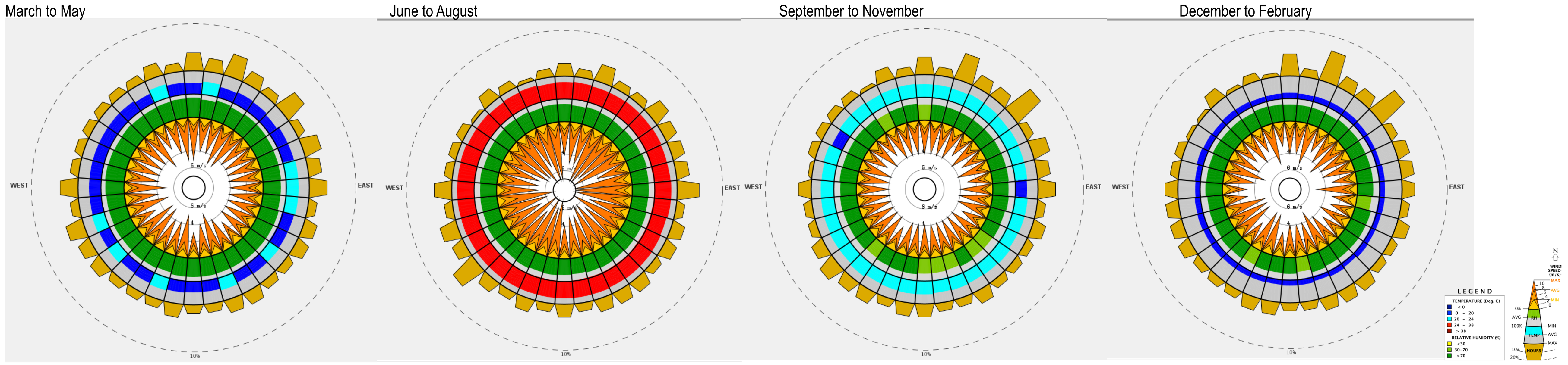
Wind Speed and Direction

March to May

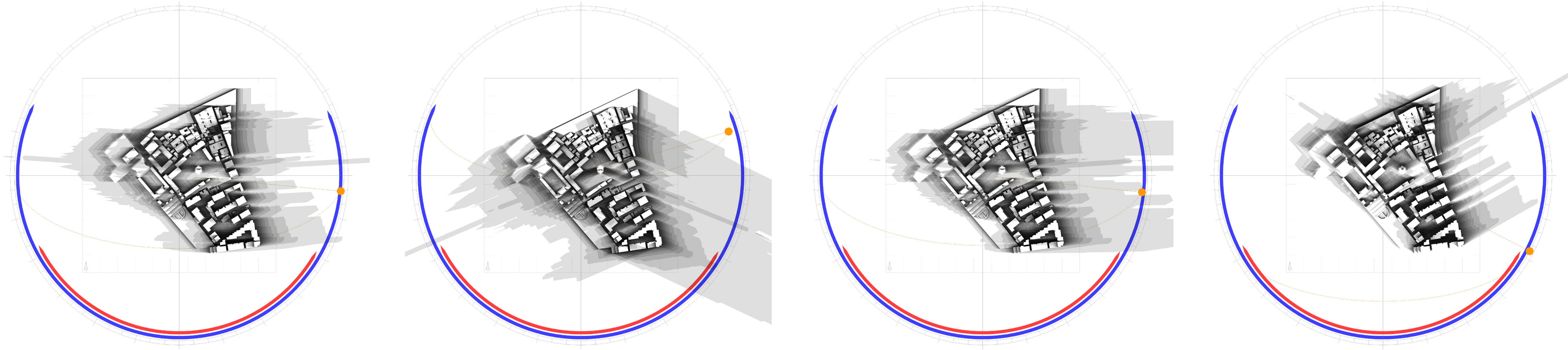
June to August

September to November

December to February



Shadow range of the site



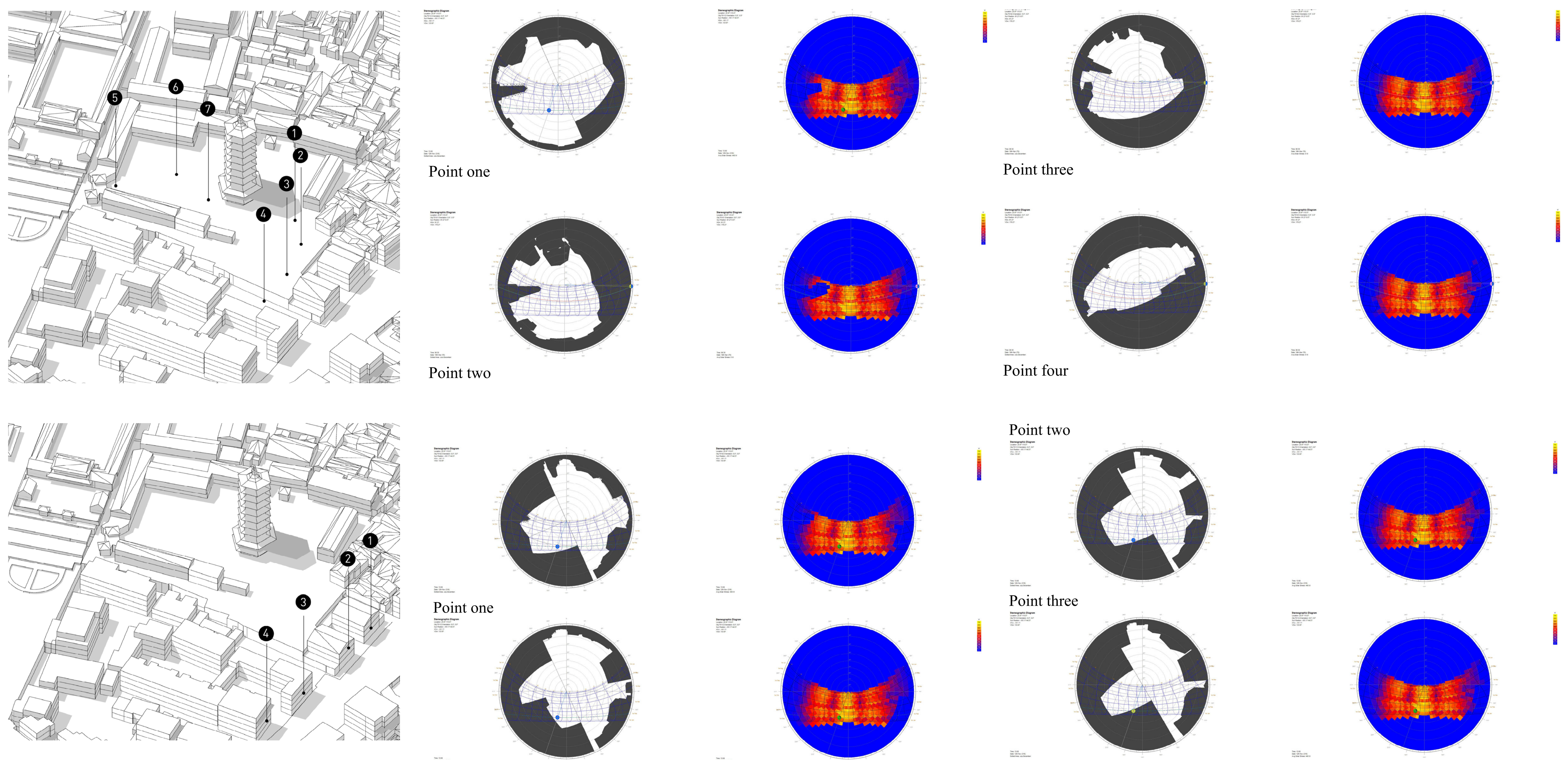
March 21st from 7:00 to18:00

June 21st from 6:00 to19:00

September 21st from 7:00 to18:00

December 21st from 8:00 to17:00

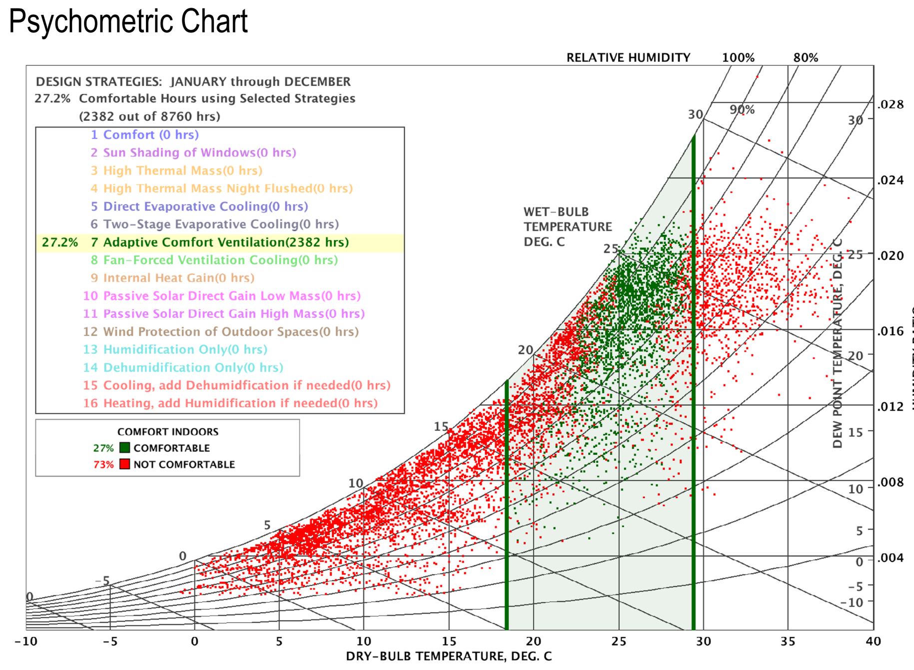
Stereographic diagram of differnt point



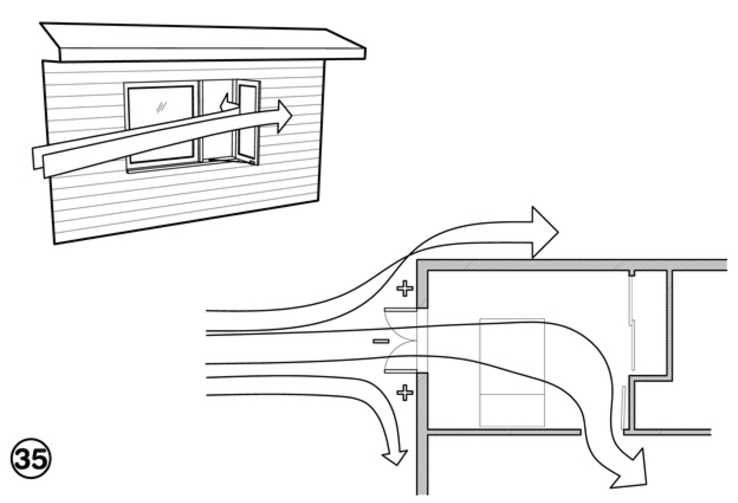
Sustainable Strategies

Ganzhou is a temperate climate with hot summers, with temperatures peaking at approximatley 35 C, and cool mild winters. During the winter months, temperatures rarely dip below 0C. Ganzhou also has a high relative humidity, with a daily average between 60% and 80%. During the summer months, this can create uncomfortable thermal conditions and will require active or passive cooling strategies. Ganzhou also experiences consistent wind speeds throughout the year, between 1 m/s and 8 m/s (between 3km/hour and 28 km/hour). The most prominent wind direction is from the north and for the south.
From the psychometric chart we can see a small portion of the year is comfortable with adapative comfort ventilation, which means we must incorproate other sustainable passive strategies to aid in the comfort conditions of the design. This includs optimising openings for natural ventilaintion as well as creating windo overhangs on the south facades to limit direct solar heating. In addition, we should mininize west facing glazing, and use trees or other shading devices to reduce the direct sunglight. This is particularly important in the summer months to reduce the need for active cooling units. Finally, we will incorporate shaded buffer zones, such as inner courtuards and pathways, to reduce the solar heating as well as capturing the dominant winds to provide cooling to the whole project.

Psychometric Chart



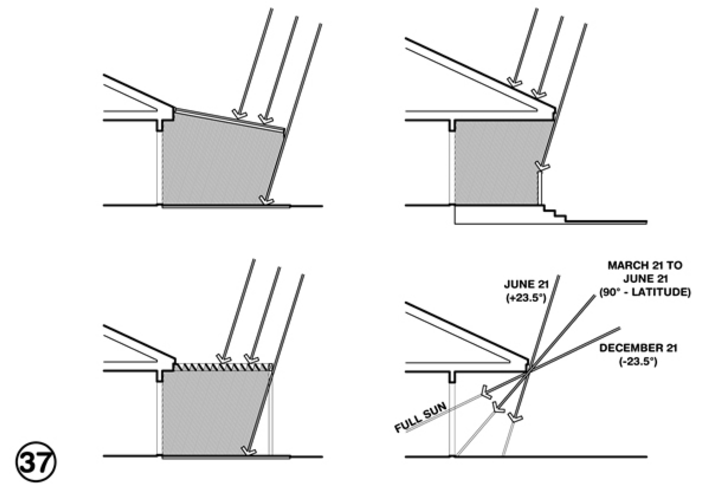
Natural Ventilation



35

Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes

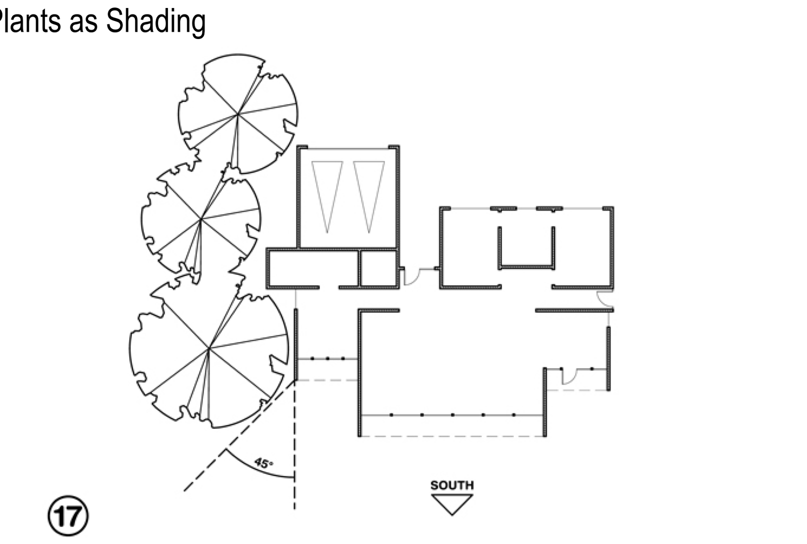
Window Overhangs



37

Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning

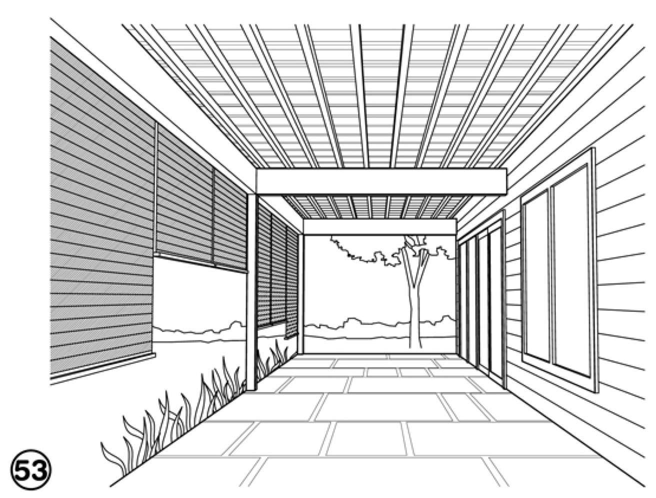
Plants as Shading



17

Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth)

Shaded Buffer Zones

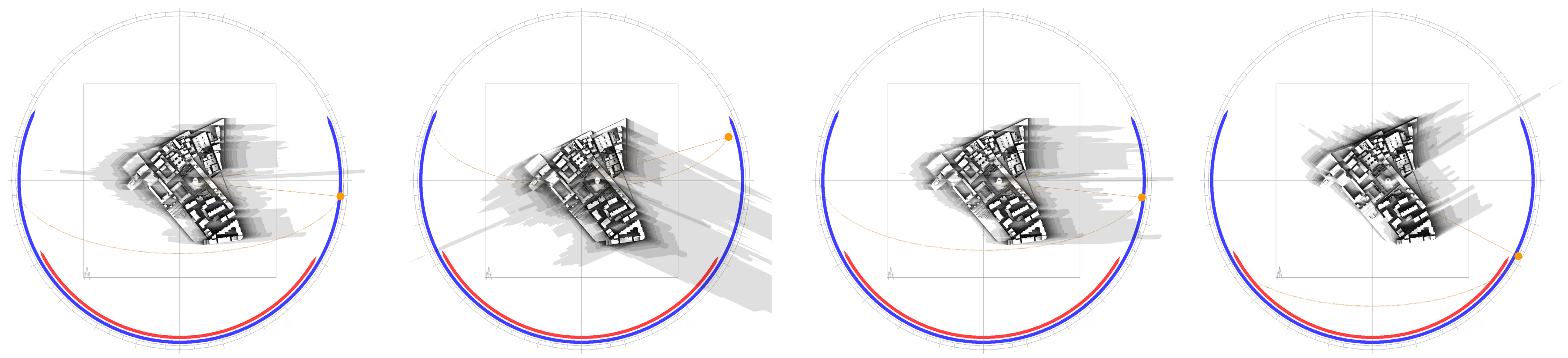


53

Shaded outdoor buffer zones (porch, patio, lanai) oriented to the prevailing breezes can extend living and working areas in warm or humid weather

Shadow range of the design

Through the simulations (Software: Ecotect), we analyzed the shading during the effective illumination time of the sun on the day 21st of the four seasons and made a comparison before and after the refurbishment. On the whole, the shadow projections in spring and autumn is east-west, slightly leaning to south in summer, and relatively north in winter. The crowded courtyard housing provides shading in summer, and the shadows cast by the high-rise areas in the north have not much effect on the site, but it casts shadows on the facade buildings along Houde Road. In summer, because the tower provides a certain level of shading for the school in the square of Ciyun pagoda, the north façade of the school does not receive sufficient sunlight due to the reduction of solar radiation in winter. After the reorganization and use of the site, the school was opened and provide more distance between the buildings. Solar panels will be installed at the south half of the newly added library roof top to provide green energy for the building. The maze as the transitional area in the north also undergoes no direct sunlight which is suitable as an outdoor resting area.



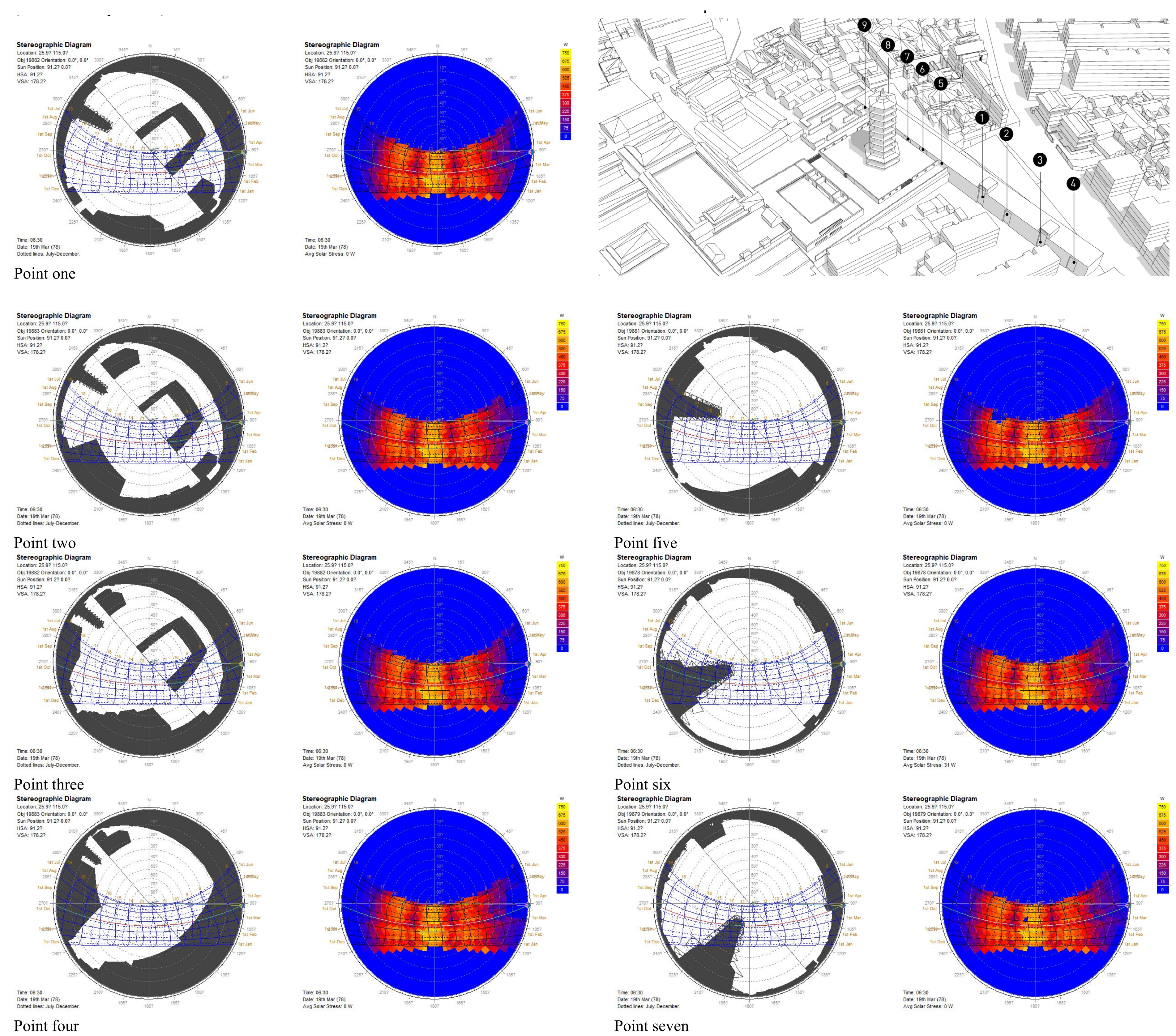
March 21st from 7:00 to18:00

June 21st from 6:00 to19:00

September 21st from 7:00 to18:00

December 21st from 8:00 to17:00

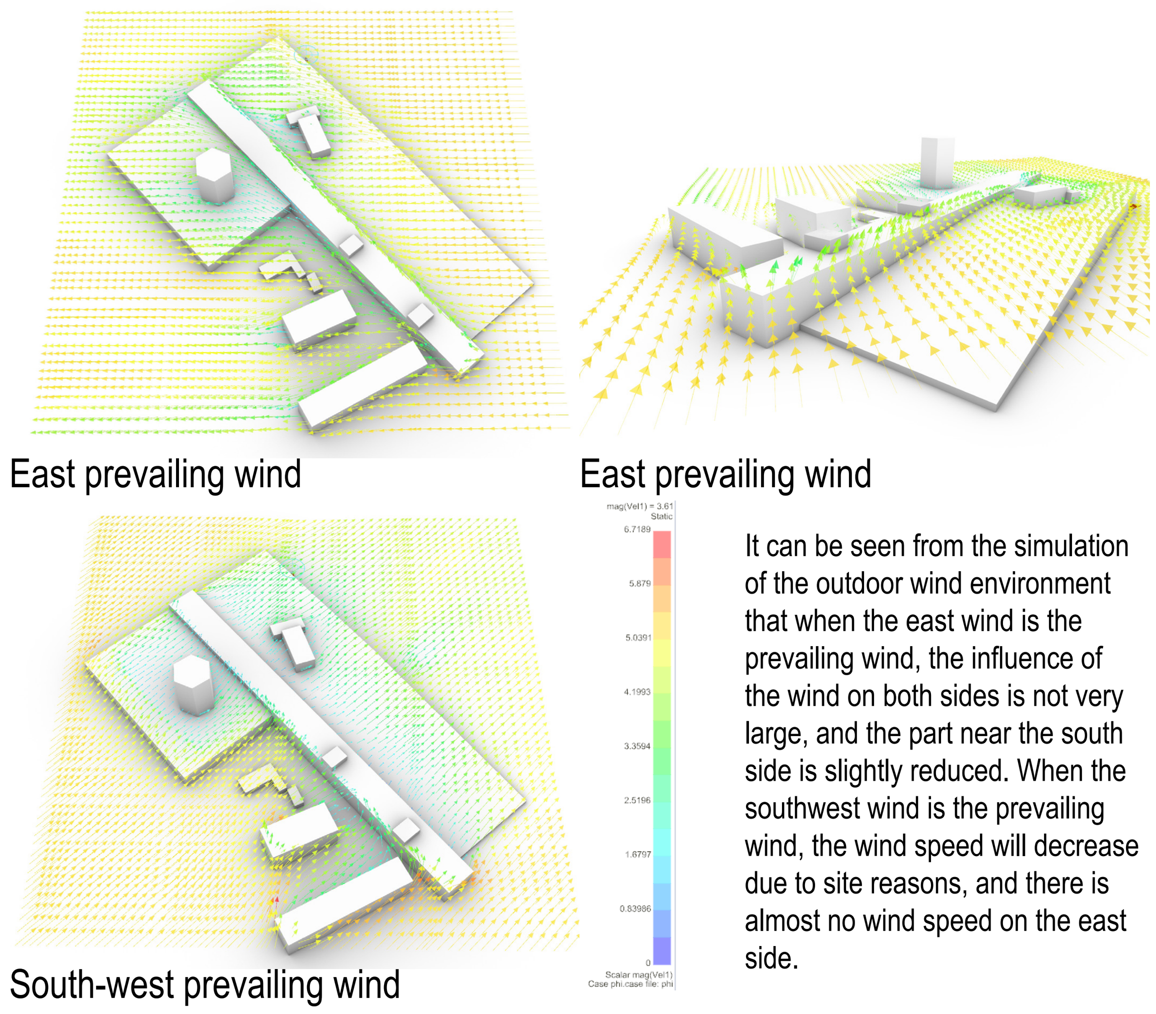
Stereographic diagram of the points on Library



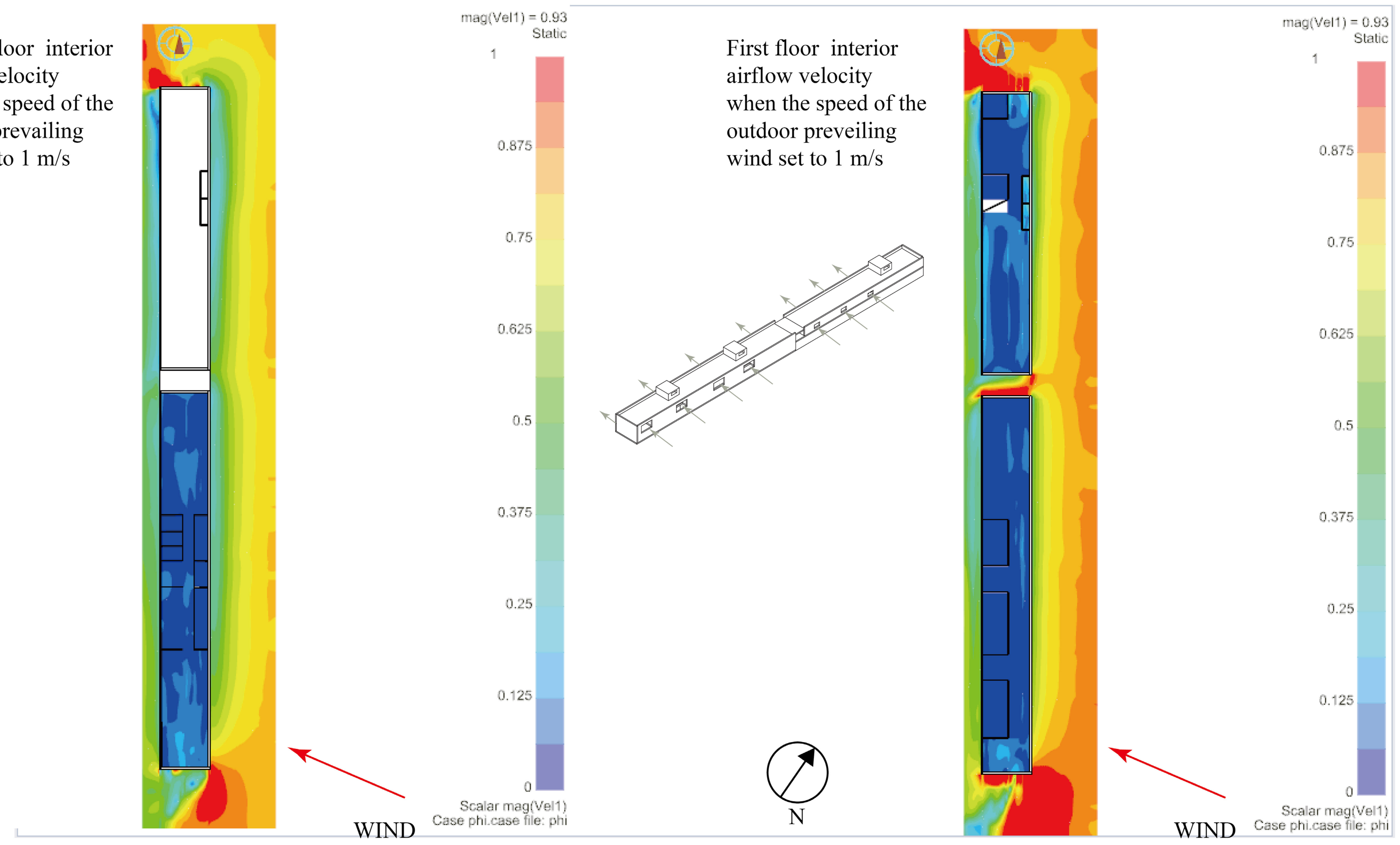
Rain water collection

Natural lighting and ventilation

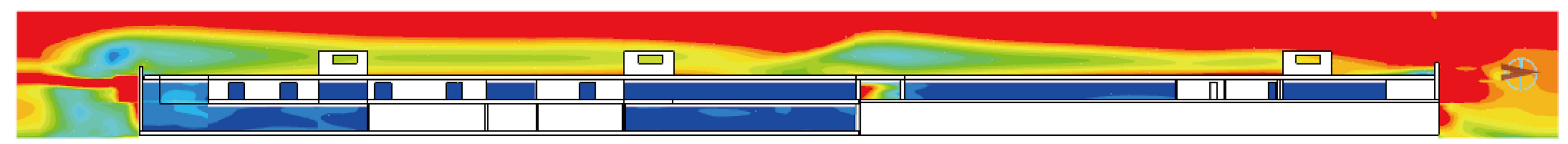
Site wind environment

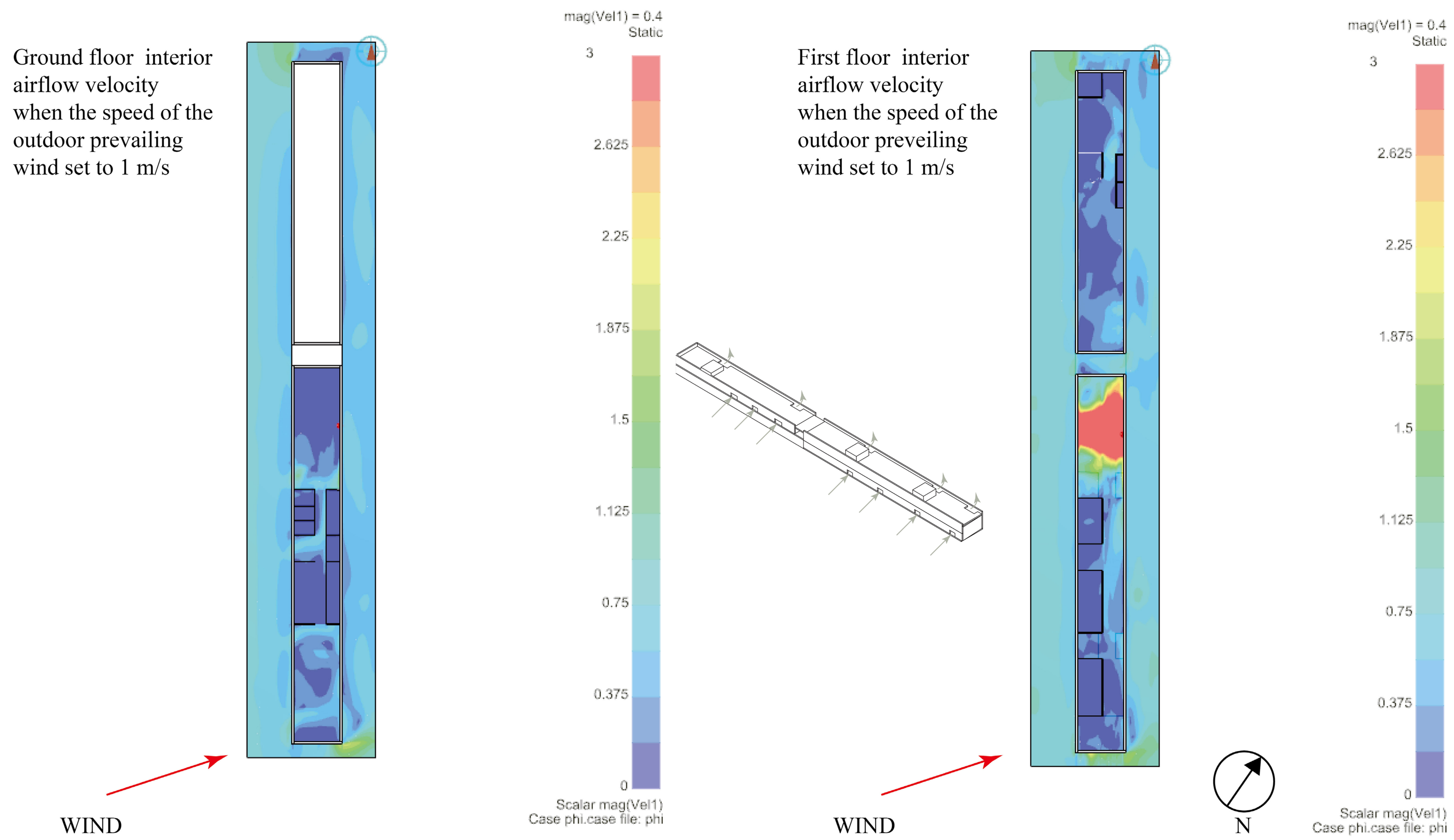


It can be seen from the simulation of the outdoor wind environment that when the east wind is the prevailing wind, the influence of the wind on both sides is not very large, and the part near the south side is slightly reduced. When the southwest wind is the prevailing wind, the wind speed will decrease due to site reasons, and there is almost no wind speed on the east side.

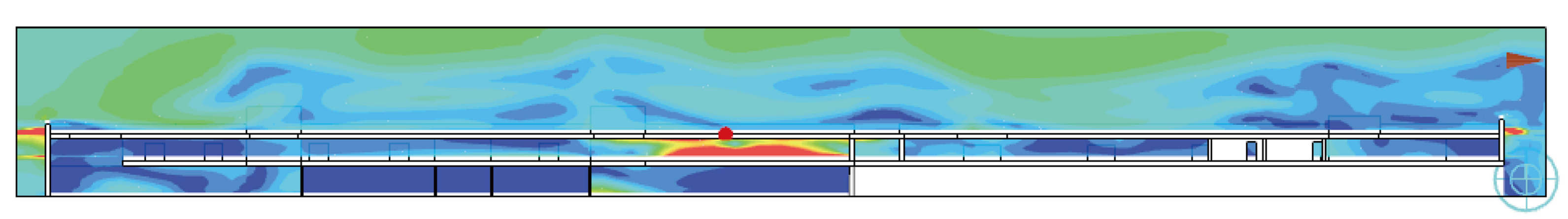


Section

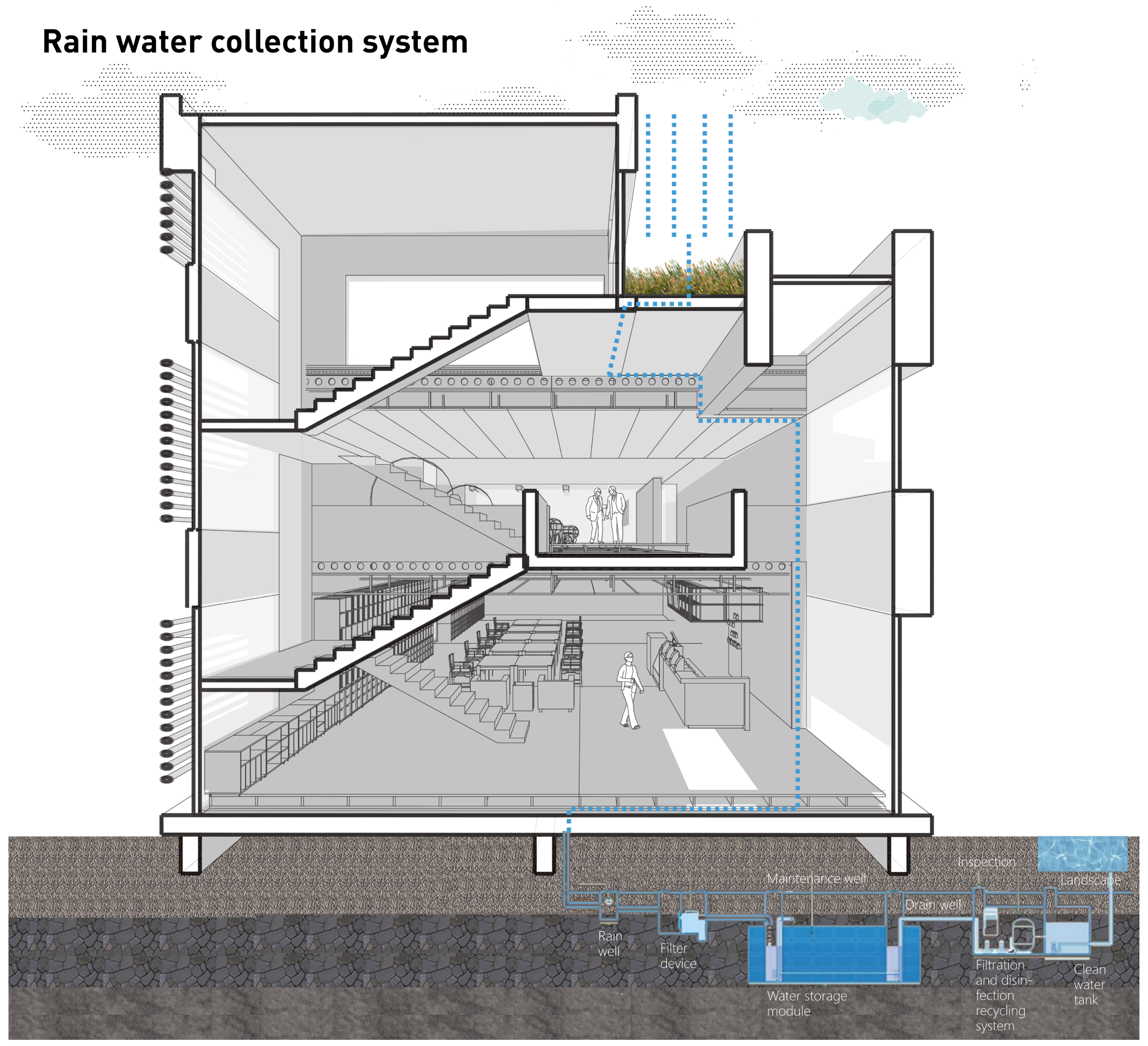




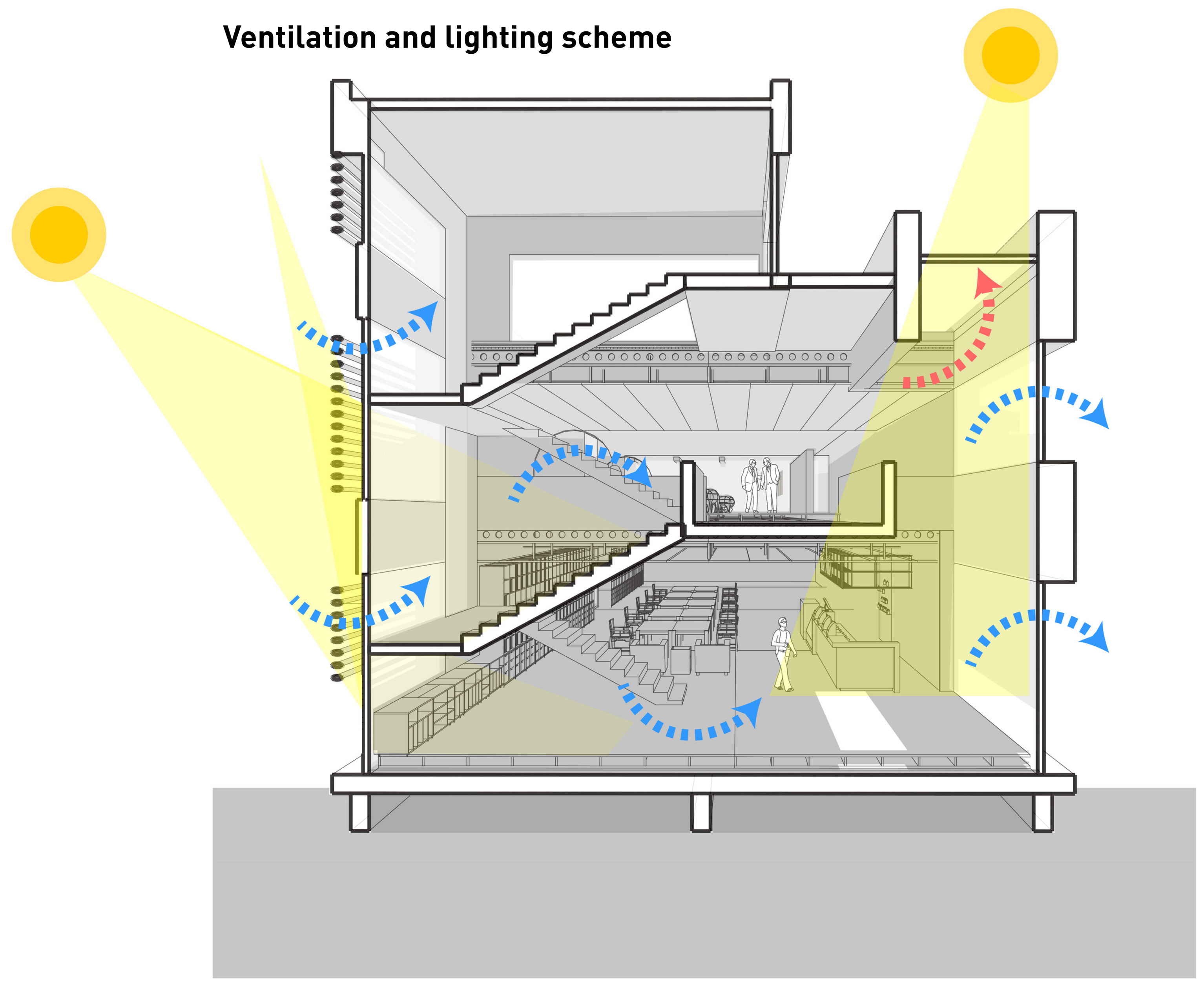
Section



Rain water collection system



Ventilation and lighting scheme



U-VALUE Calculation

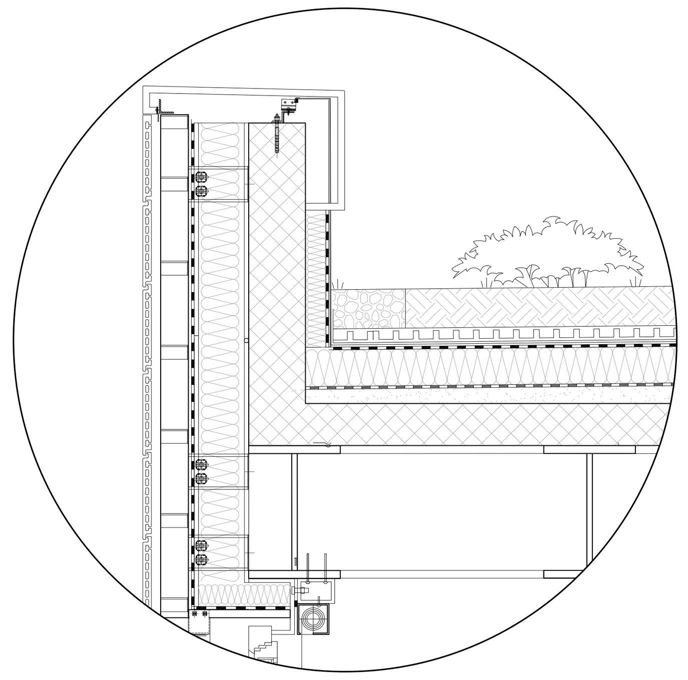
U Value Calculation (d_{roof}=0.70m)							
Roof Garden	LAYER DESCRIPTION (from inside to outside)		d m	W/mK	C W/m²K	R m²K/W	U_K W/m² K
	Internal thermal resistance ($1/h_i$)					0.11	
1	Inside surface	Ceiling	0.001				
2	Structure	Precast concrete slab	0.2	1.4	7	0.14	
3	Slope layer	Light weight concrete	0.02	0.53	26.5	0.04	
4	Vapour barrier	Waterproof film	0.001				
5	Thermal insulation layer	Expanded Polystrene(EPS)	0.1	0.04	0.40	2.50	
6	Waterproof layer	SBS waterproof membrane	0.004	0.32	80.00	0.01	
7	Protective layer	Geotextile	0.001				
8	Drainage	PVC drainage board	0.05	0.048	0.96	1.04	
9	Filter	Adhesive Bonded Fabric Filter	0.004				
10	Vegetation & soil layer	Soil	0.3	0.47	1.57	0.64	
	External thermal resistance ($1/h_e$)					0.04(W)/0.05(S)	
	Gross layer and U_K		0.68			4.37	0.229

U Value Calculation (d_{roof}=0.11m)							
Internal Floor	LAYER DESCRIPTION (from inside to outside)		d m	W/mK	C W/m²K	R m²K/W	U_K W/m²K
	Internal thermal resistance ($1/h_i$)					0.11	
1	Inside surface	Wood siding	0.03	0.09	3	0.33	
2	Sound insulation layer	Expanded Polystrene(EPS)	0.03	0.04	1.33	0.75	
3	Screed coat	Plaster(light weight)	0.03	0.18	6	0.17	
4	Structure	Corrugated steel plate	0.01				
5	Surface layer	Ceiling	0.01				
	External thermal resistance ($1/h_e$)					0.04(W)/0.05(S)	
	Gross layer and U_K		0.11			1.25	0.800

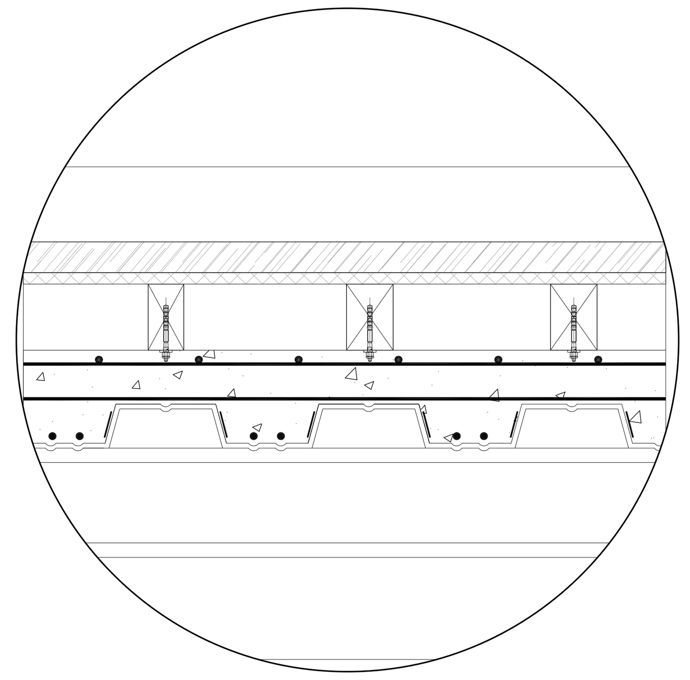
U Value Calculation (d_{wall}=0.43m)							
External wall	LAYER DESCRIPTION (from inside to outside)		d m	W/mK	C W/m²K	R m²K/W	U_K W/m²K
	Internal thermal resistance ($1/h_i$)						
1	Inside surface	Plaster(light weight)	0.02	0.18	9	0.11	
2	Structure	LW Concrete Block	0.2	0.5	2.5	0.40	
3	Screed coat	Plaster(light weight)	0.01	0.18	18	0.06	
4	Thermal insulation layer	Expanded Polystyrene(EPS)	0.15	0.04	0.27	3.75	
		Adhesive	0.0005				
5	Waterproof layer	Waterproof mortar	0.02	0.93	46.50	0.02	
6	Finishing layer	Terracotta panels	0.03	0.087	2.9	0.34	
	External thermal resistance ($1/h_e$)				0.04(W)/0.05(S)		
	Gross layer and U_K		0.43			4.68	0.214

Thickness	Solar energy		SHGC	U_K
6mm+8Argon+6mm+8Argon+6mm	Reflectance	UV-Transmitance	0.35	1.3
	22%	19		

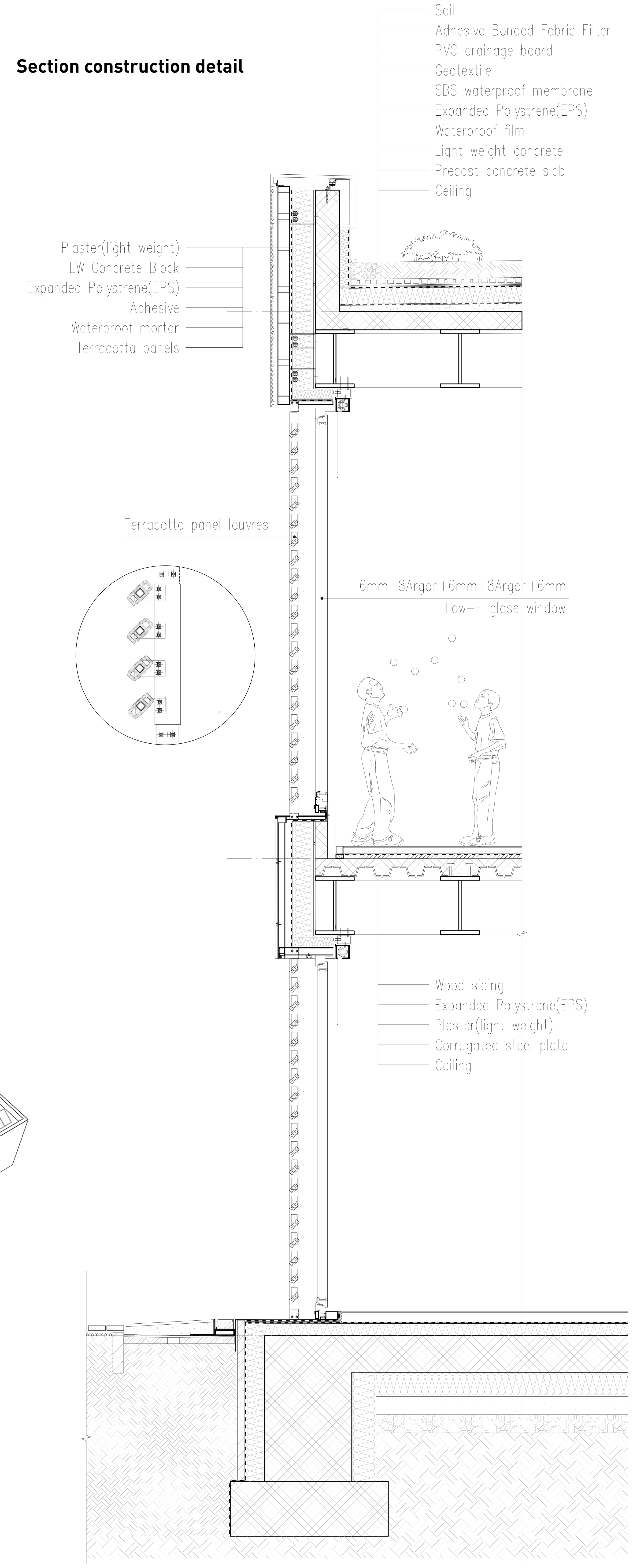
Roof Garden construction detail

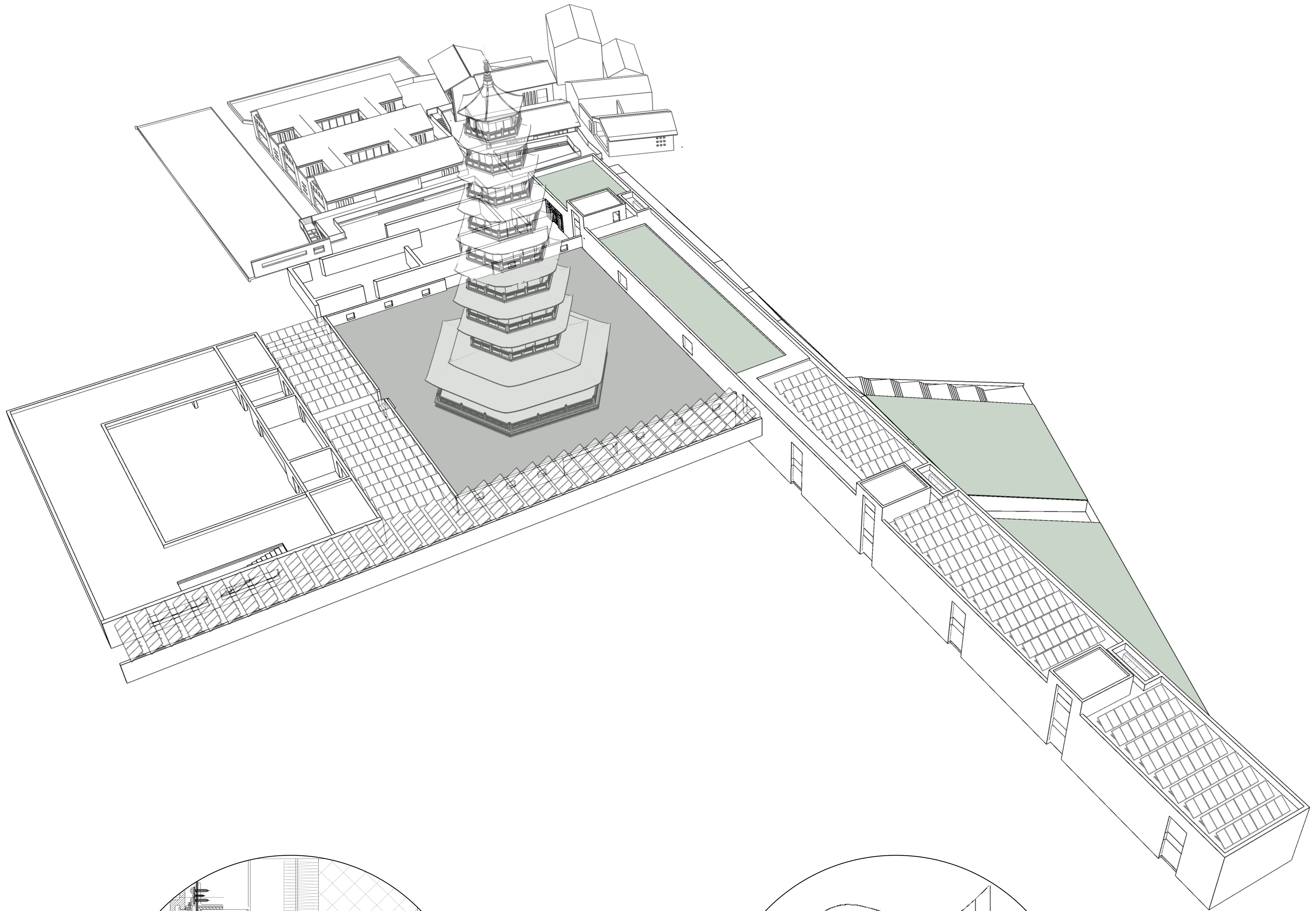


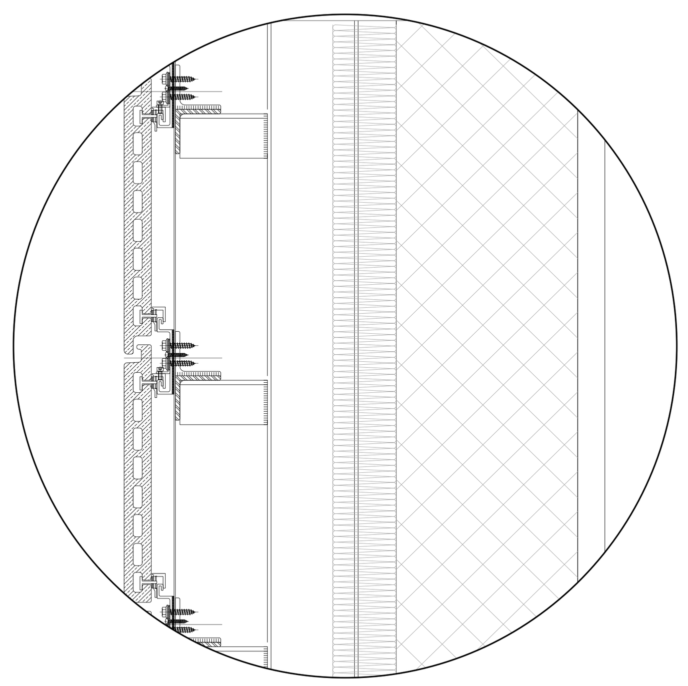
Internal floor construction detail



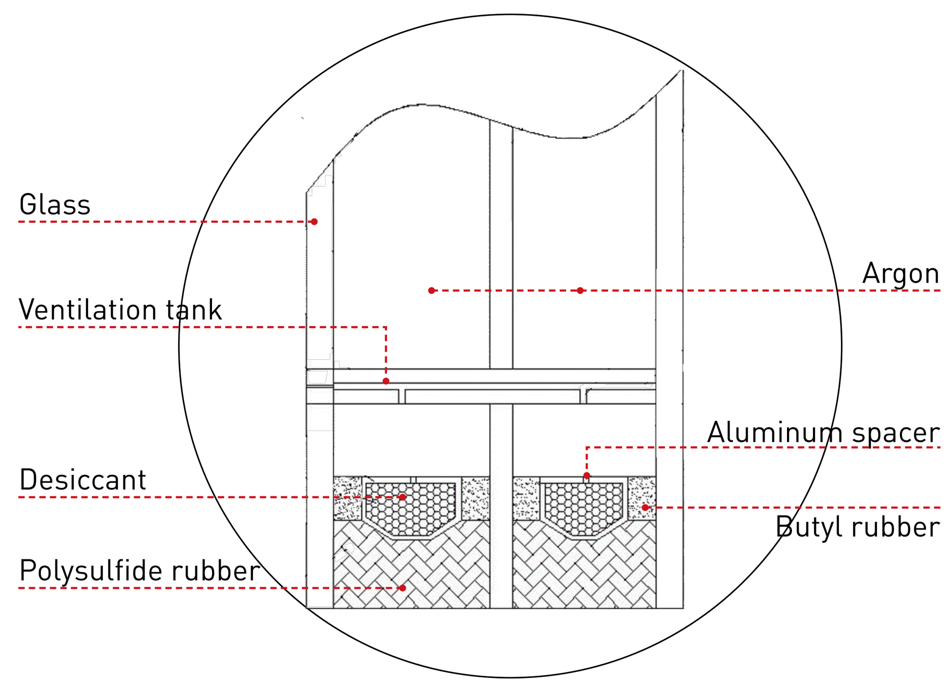
Section construction detail





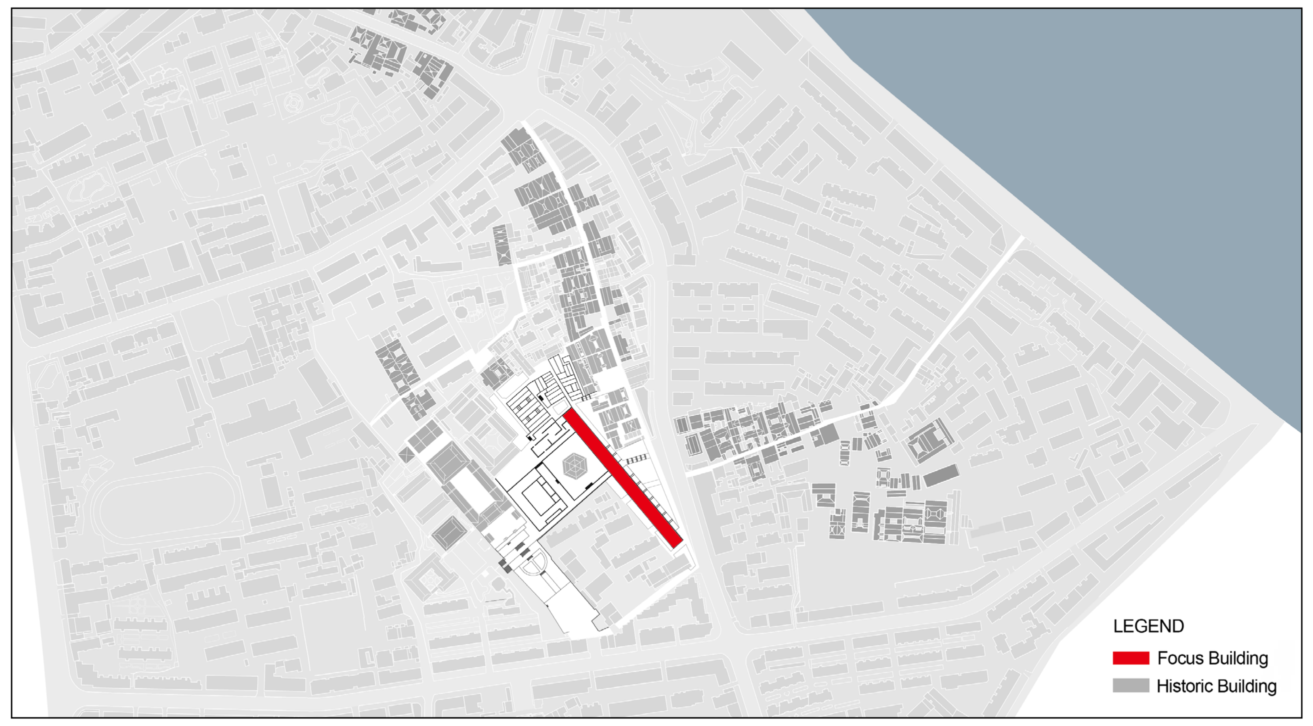


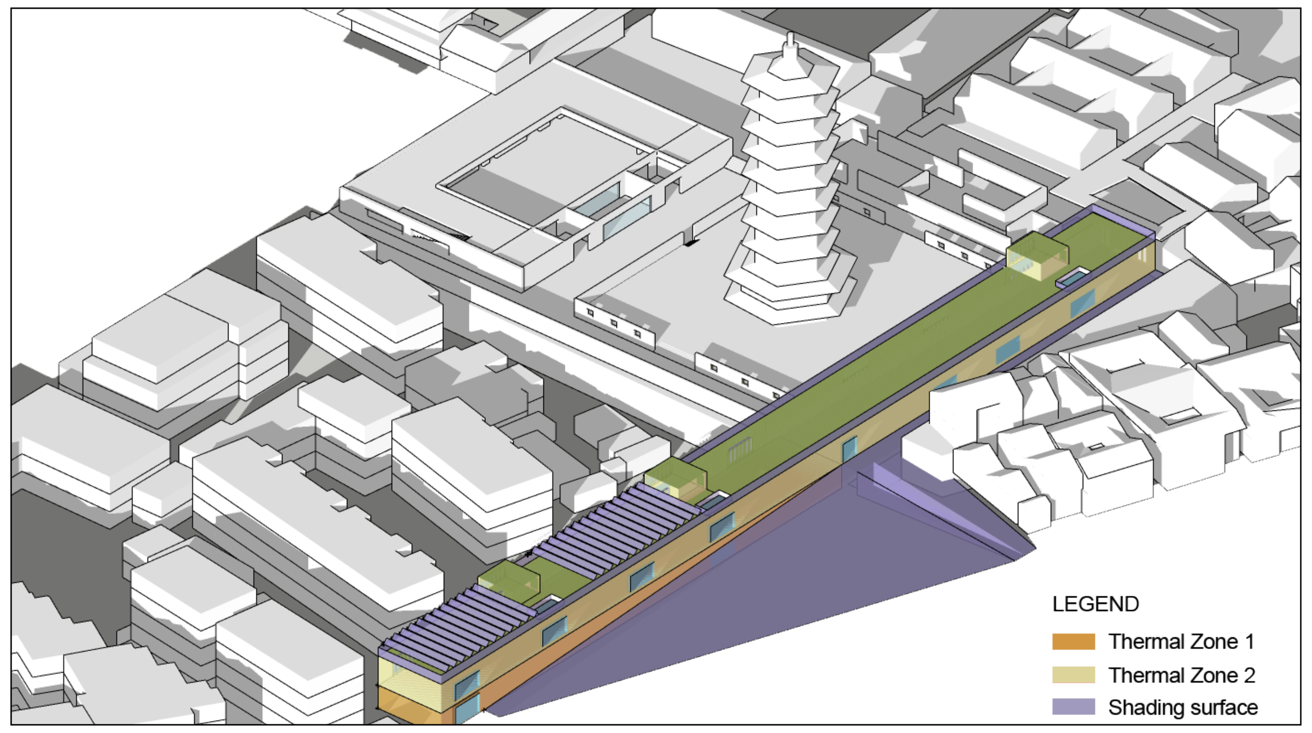
Exterior wall construction detail

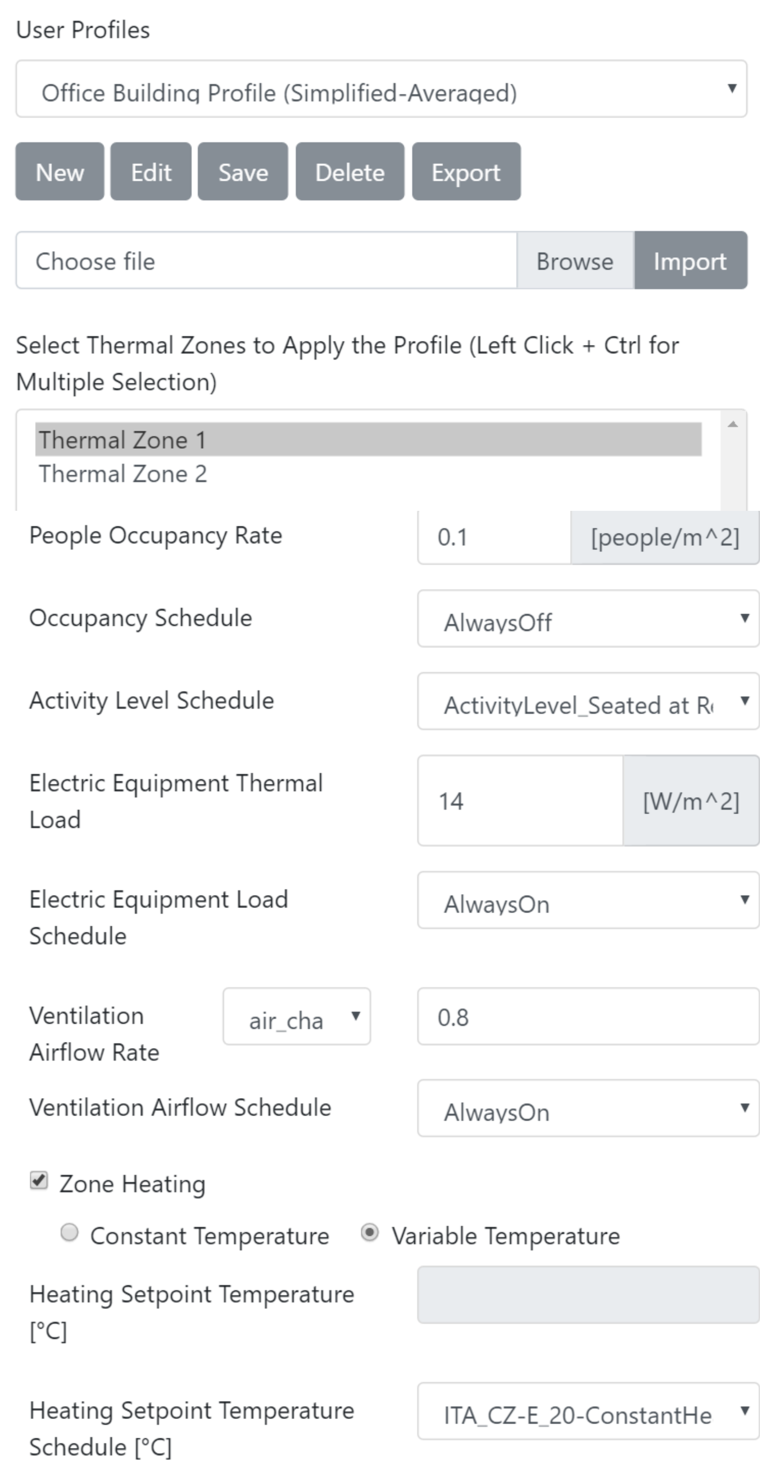


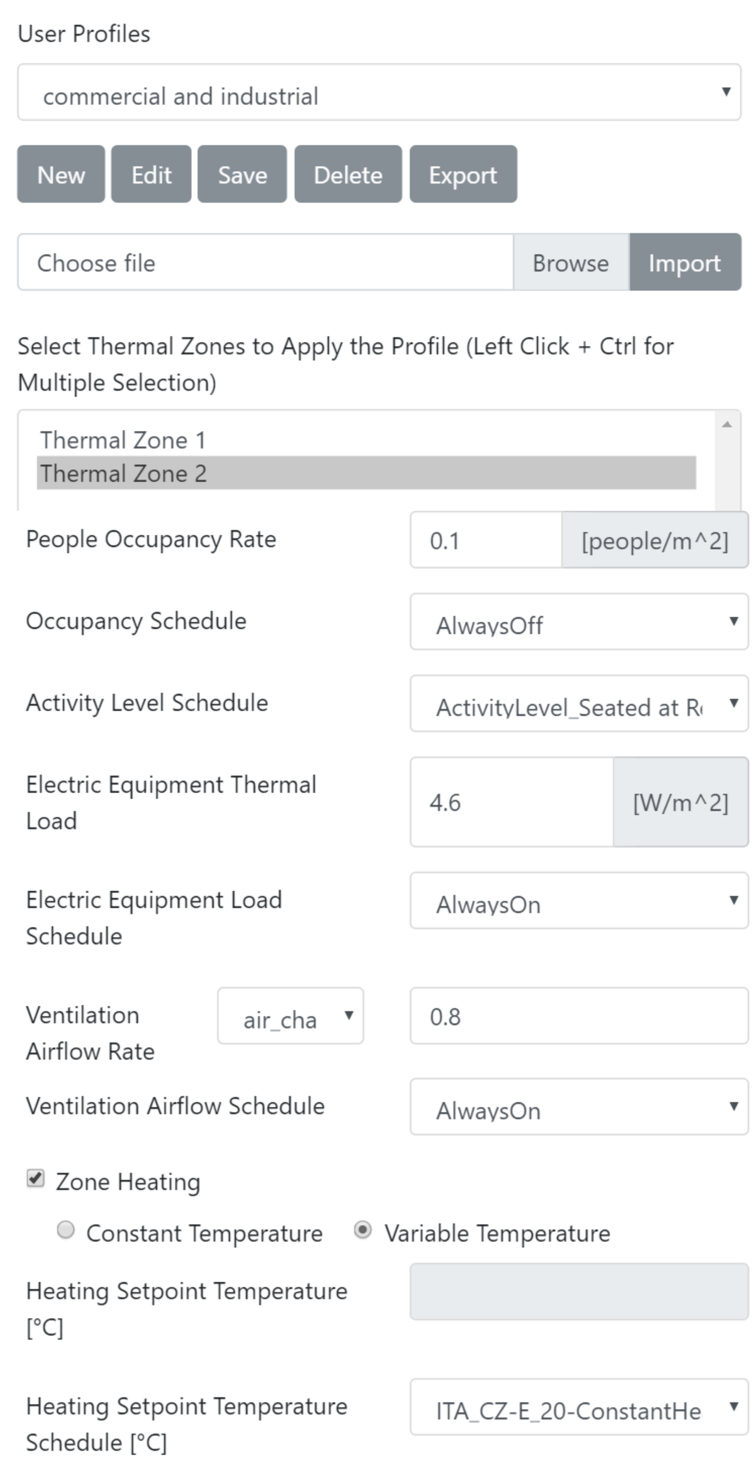
Exterior Window construction detail

Calculation of energy consumption for Cooling and Heating









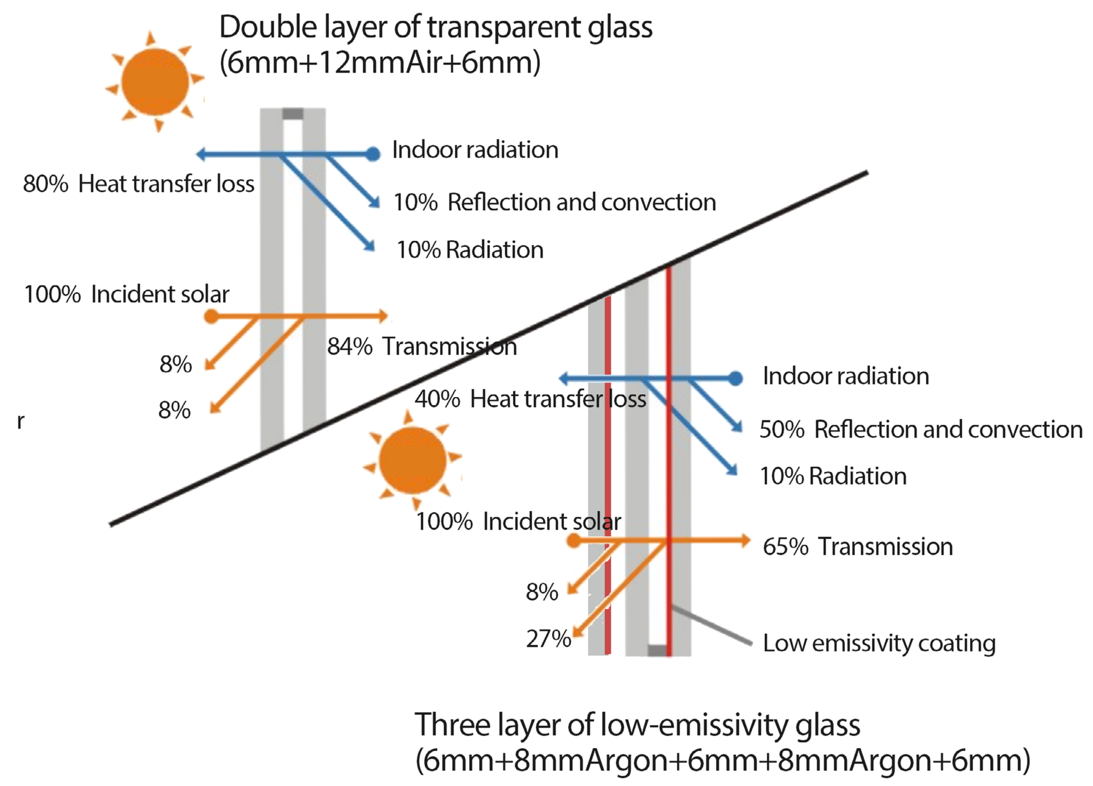
Comparison of envelope solutions

Before optimization

- Without insulation
- Without sunshade
- Ordinary double-layer LOW-E glass
- Higher solar heat gain coefficient

Heating System		
Net Sensible Heating Energy Demand	5.1	kWh/m³
Peak Sensible Heating Power	95.8	kW
Annual heating energy demand	73.9	MWh
Cooling System		
Net Sensible Cooling Energy Demand	16	kWh/m³
Peak Sensible Cooling Power	128.8	kW
Annual cooling energy demand	232	MWh

Windows before optimization



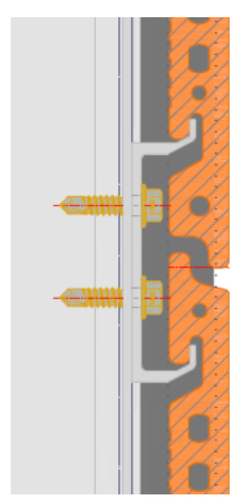
Windows after optimization

After optimization

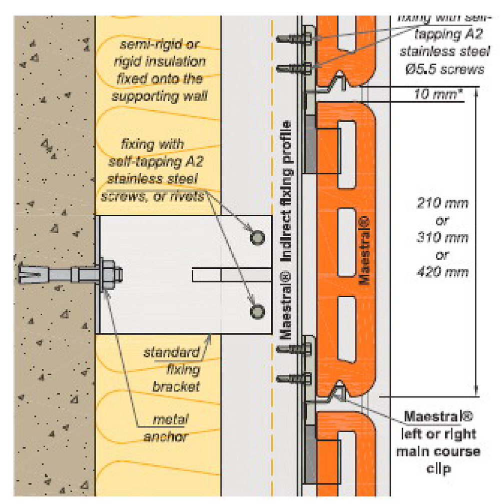
- Add insulation on exterior wall and roof
- Add sunshade louvers on southwest side and roof
- Triple Argon Low-E Glass
- Reduce the solar heat gain coefficient of exterior windows

Heating System		
Net Sensible Heating Energy Demand	4.8	kWh/m³
Peak Sensible Heating Power	83.1	kW
Annual heating energy demand	69.6	MWh
Cooling System		
Net Sensible Cooling Energy Demand	10.4	kWh/m³
Peak Sensible Cooling Power	93.2	kW
Annual cooling energy demand	150.8	MWh

External wall without insulation



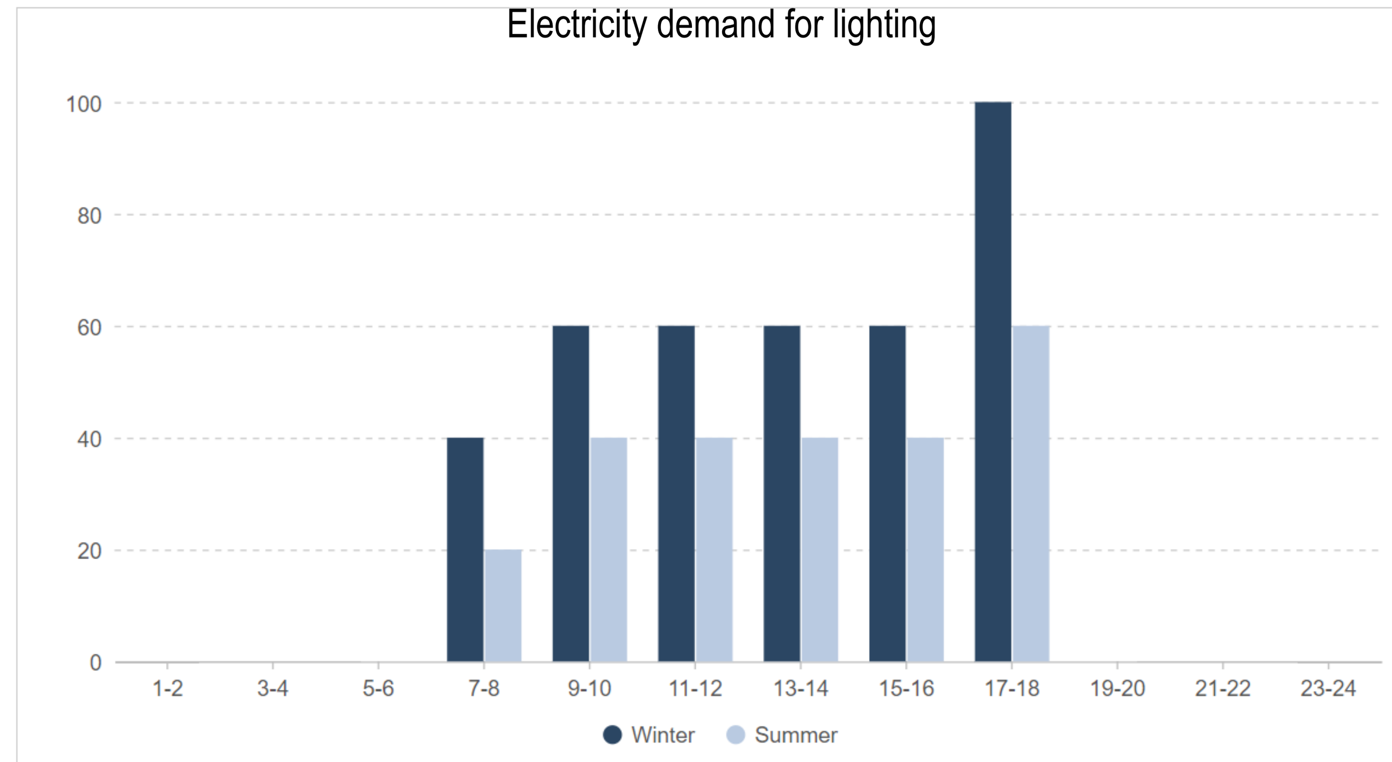
External wall with insulation



Building energy demand (Lighting,Equipment,DHW)

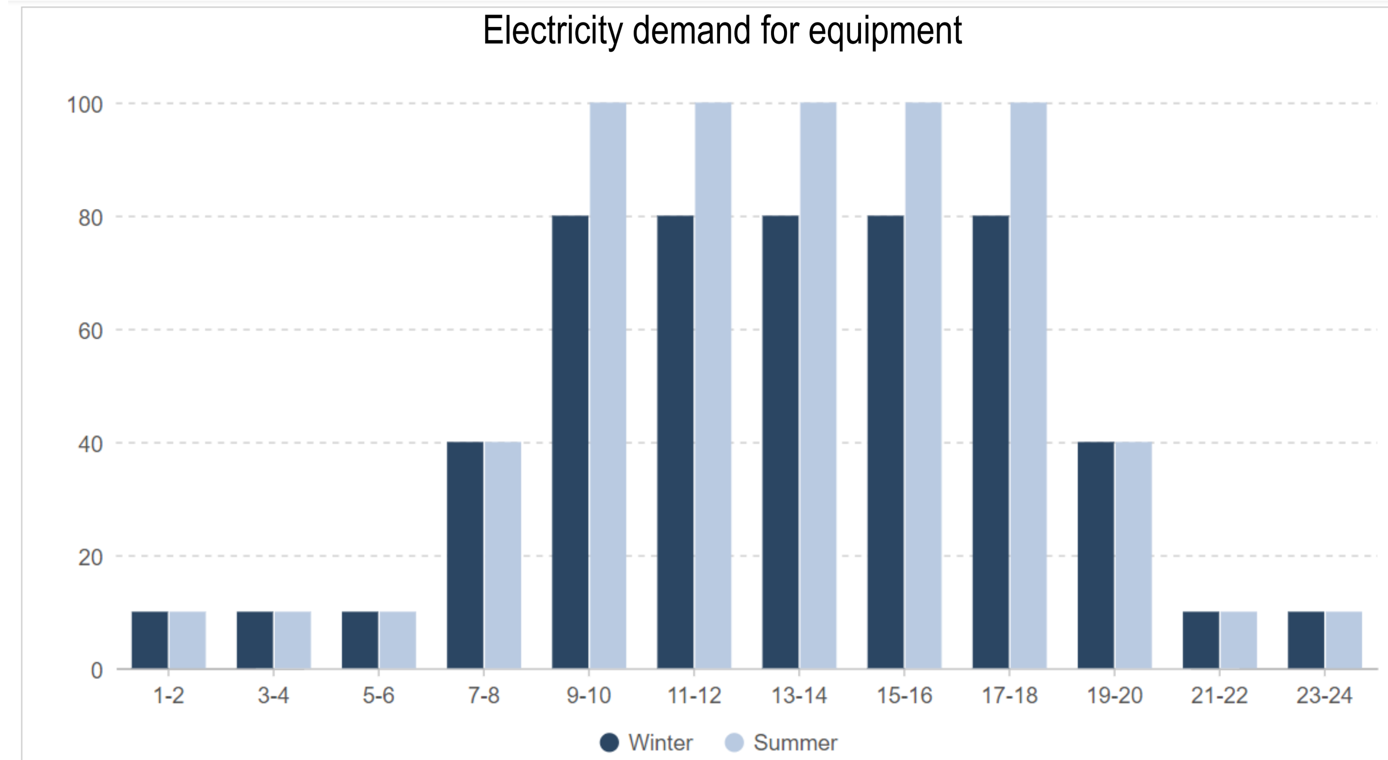
Building Function	Lighting Loads[W/m²]	Electrical Equipment[W/m²]
Commercial and industrial	6.5	4.6
Library	14	16.2
Office	9.2	14.4

Electricity demand for lighting
L=14W/ ㎡
14×20%×2h×365/2=1022wh/ ㎡
14×40%×10h×365/2=10220wh/ ㎡
14×60%×10h×365/2=15330wh/ ㎡
14×80%×2h×365/2=4088wh/ ㎡
(1022+10220+15330+4088)/1000×2994 ㎡
=91796Kwh



Electricity demand for equipment
L=16.2W/ ㎡
16.2×10%×20h×365=11826wh/ ㎡
16.2×40%×8h×365=18922wh/ ㎡
16.2×80%×10h×365/2=23652wh/ ㎡
16.2×100%×10h×365/2=29565wh/ ㎡
(11826+18922+23652+29565)/1000×2994 ㎡
=251391.21Kwh

Electricity Demand for hot water
Building demand for domestic hot water: 280wh/person/day
Estimate the number of people based on the number of seats and the area of the exhibition space:75 person
75×280×365/1000=7665kwh

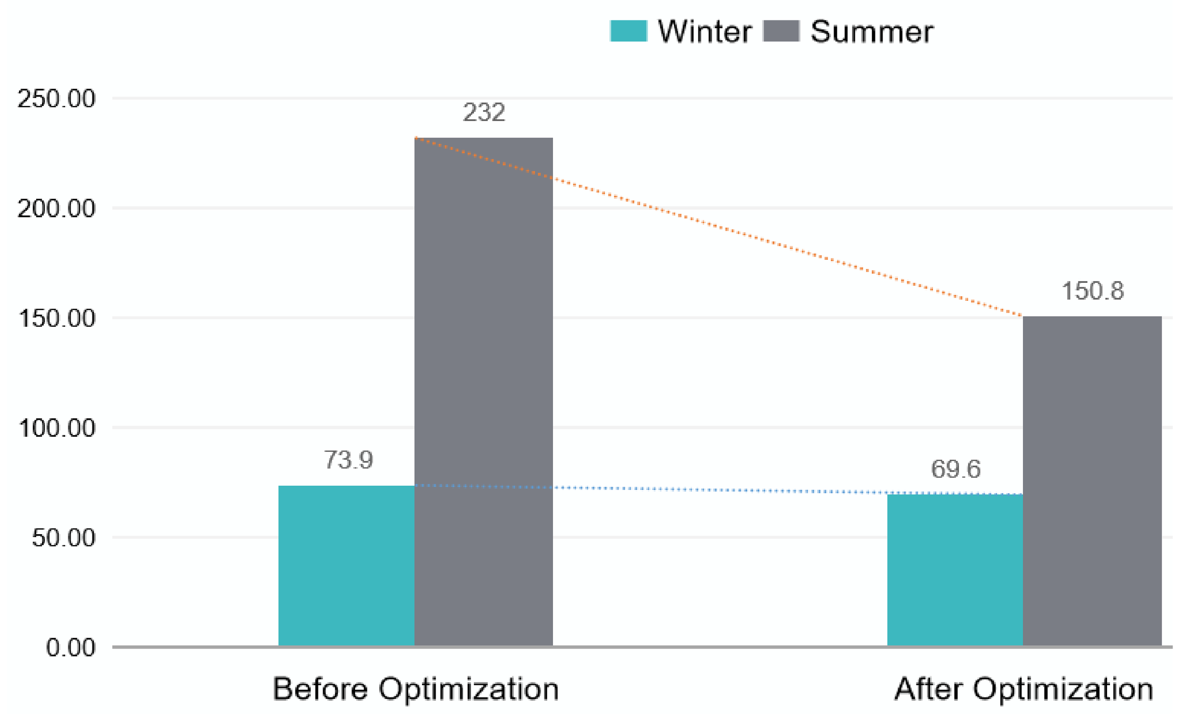


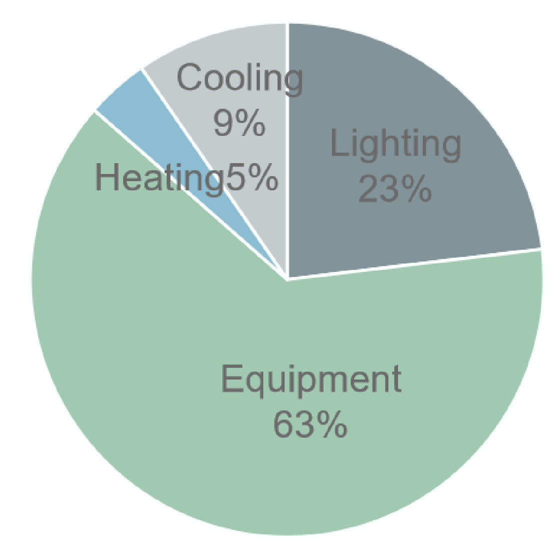
Conclusion

Energy consumption saving:
For heating in winter:
Reduced from 73.9MWh to 69.6MWh,
Saving of 6%

For cooling in summer:
Reduced from 232MWh to 150.8MWh
Saving of 35%

Total electricity energy demand:
E1=Lighting=91.8MWh
E2=Equipment=251.4MWh
E3=Heating=15.6MWh
E4=Cooling=38.2MWh
E5=Water =7.6MWh
Total=E1+E2+E3+E4+E5=404 MWh





Energy Calculation for Ground source heat pumps

-Electricity consumption for heating (MWh) :15.6
-Electricity consumption for cooling (MWh) : 38.2

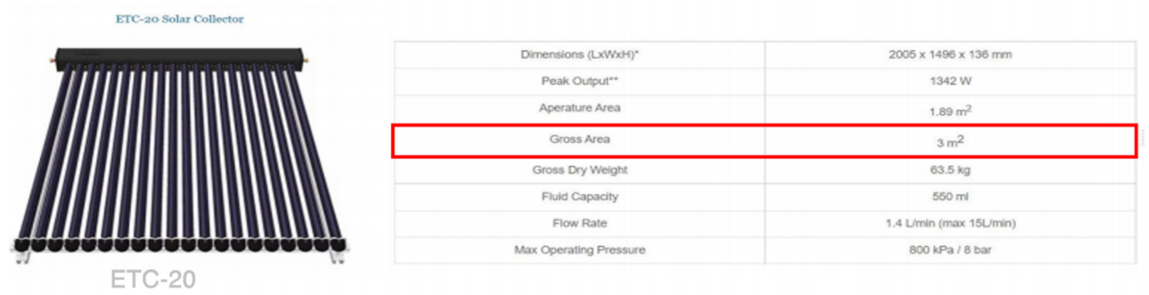
Site Conditions		Estimate	Notes/Range
Nearest location for weather data		Ganzhou	See Weather Database
Heating design temperature	°C	2.0	-40.0 to 15.0
Cooling design temperature	°C	34.8	10.0 to 40.0
Average summer daily temperature range	°C	5.7	5.0 to 15.0
Cooling humidity level	-	High	
Latitude of project location	°N	25.9	-90.0 to 90.0
Mean earth temperature	°C	18.4	Visit NASA satellite data site
Annual earth temperature amplitude	°C	15.1	5.0 to 20.0
Depth of measurement of earth temperature	m	0.0	0.0 to 3.0

Building Heating and Cooling Load		Estimate	Notes/Range
Type of building	-	Commercial	
Available information	-	Energy use data	
Design heating load	kW	83.1	
	million Btu/h	0.284	
Annual heating energy demand	MWh	69.6	
	million Btu	237.5	
Design cooling load	kW	93.2	
	ton (cooling)	26.5	
Annual cooling energy demand	MWh	150.8	
	million Btu	514.5	Return to Energy Model sheet

Site Conditions		Estimate	Notes/Range
Project name		Renovate building	See Online Manual
Project location		Ganzhou, China	
Available land area	m²	1,500	
Soil type	-	Heavy soil - damp	
Design heating load	kW	83.1	Complete H&CLC sheet
Design cooling load	kW	93.2	

System Characteristics		Estimate	Notes/Range
Base Case HVAC System			
Building has air-conditioning?	yes/no	Yes	
Heating fuel type	-	Electricity	
Heating system seasonal efficiency	%	100%	55% to 350%
Air-conditioner seasonal COP	-	5.0	2.4 to 5.0
Ground Heat Exchanger System			
System type	-	Vertical closed-loop	
Design criteria	-	Heating	
Typical land area required	m²	525	
Ground heat exchanger layout	-	Standard	
Total borehole length	m	1,847	
Heat Pump System			
Average heat pump efficiency	-	User-defined	See Product Database
Heat pump manufacturer		ABC S.A.	
Heat pump model		model XYZ	
Standard cooling COP	-	4.85	
Standard heating COP	-	5.14	
Total standard heating capacity	kW	63.6	
	million Btu/h	0.217	
Total standard cooling capacity	kW	96.8	
	ton (cooling)	27.5	
Supplemental Heating and Heat Rejection System			
Suggested supplemental heating capacity	kW	0.0	
	million Btu/h	0.000	
Suggested supplemental heat rejection	kW	41.2	
	million Btu/h	0.140	

Annual Energy Production		Estimate	Notes/Range
Heating			
Electricity used	MWh	15.6	
Supplemental energy delivered	MWh	0.0	
GSHP heating energy delivered	MWh	**69.8**	
	million Btu	238.1	
Seasonal heating COP	-	4.5	2.0 to 5.0
Cooling			
Electricity used	MWh	38.2	
GSHP cooling energy delivered	MWh	**150.8**	
	million Btu	514.5	
Seasonal cooling COP	-	4.0	2.0 to 5.5
Seasonal cooling EER	(Btu/h)/W	13.5	7.0 to 19.0
			Complete Cost Analysis sheet

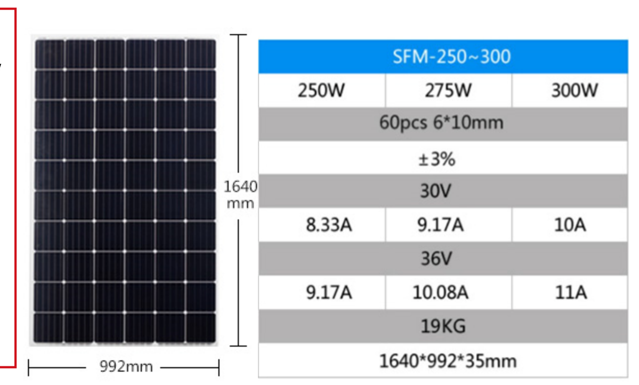


Site Conditions		Estimate	Notes/Range
Project name		Renovate building	See Online Manual
Project location		Ganzhou, China	
Nearest location for weather data		Ganzhou	Complete SR&HL sheet
Annual solar radiation (tilted surface)	MWh/m²	1.35	
Annual average temperature	°C	19.6	-20.0 to 30.0
Annual average wind speed	m/s	1.5	
Desired load temperature	°C	45	
Hot water use	L/d	1,000	
Number of months analysed	month	12.00	
Energy demand for months analysed	MWh	10.81	

Water Heating Load Calculation		Estimate	Notes/Range
Application type	-	Service hot water	
System configuration	-	With storage	
Building or load type	-	Other	
Number of units	-	-	
Rate of occupancy	%	-	50% to 100%
Estimated hot water use (at ~60 °C)	L/d	N/A	
Hot water use	L/d	1,000	
Desired water temperature	°C	45	
Days per week system is used	d	7	1 to 7
Cold water temperature	-	Auto	
Minimum	°C	15.7	1.0 to 10.0
Maximum	°C	23.1	5.0 to 15.0
Months SWH system in use	month	12.00	
Energy demand for months analysed	MWh	10.81	
	GJ	38.91	
			Return to Energy Model sheet

Energy Calculation for Solar PV

-Total available area for PV panels(m2) 1666≤ Avaliable roof area
-Total electricity generate (MWh) : 268



Site Conditions		Estimate	Notes/Range
Project name		Renovate building	See Online Manual
Project location		Ganzhou, China	
Nearest location for weather data	-	Ganzhou	Complete SR&SL sheet
Latitude of project location	°N	25.9	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.32	
Annual average temperature	°C	19.6	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	**On-grid**	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
PV Array			
PV module type	-	User-defined	
PV module manufacturer / model #		Singfosolar	See Product Database
Nominal PV module efficiency	%	15.0%	4.0% to 15.0%
NOCT	°C	48	40 to 55
PV temperature coefficient	% / °C	0.35%	0.10% to 0.50%
Miscellaneous PV array losses	%	5.0%	0.0% to 20.0%
Nominal PV array power	kWp	**250.00**	
PV array area	m²	1,666.7	
Power Conditioning			
Average inverter efficiency	%	90%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	225.0	
Inverter capacity	kW (AC)	250.0	
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	160.8	
Overall PV system efficiency	%	12.2%	
PV system capacity factor	%	12.2%	
Renewable energy collected	MWh	297.777	
Renewable energy delivered	MWh	**268.000**	
	kWh	268,000	
Excess RE available	MWh	**0.000**	
			Complete Cost Analysis sheet

Site Latitude and PV Array Orientation		Estimate	Notes/Range
Nearest location for weather data		Ganzhou	See Weather Database
Latitude of project location	°N	25.9	-90.0 to 90.0
PV array tracking mode	-	Fixed	
Slope of PV array	°	30.0	0.0 to 90.0
Azimuth of PV array	°	30.0	0.0 to 180.0

Monthly Inputs

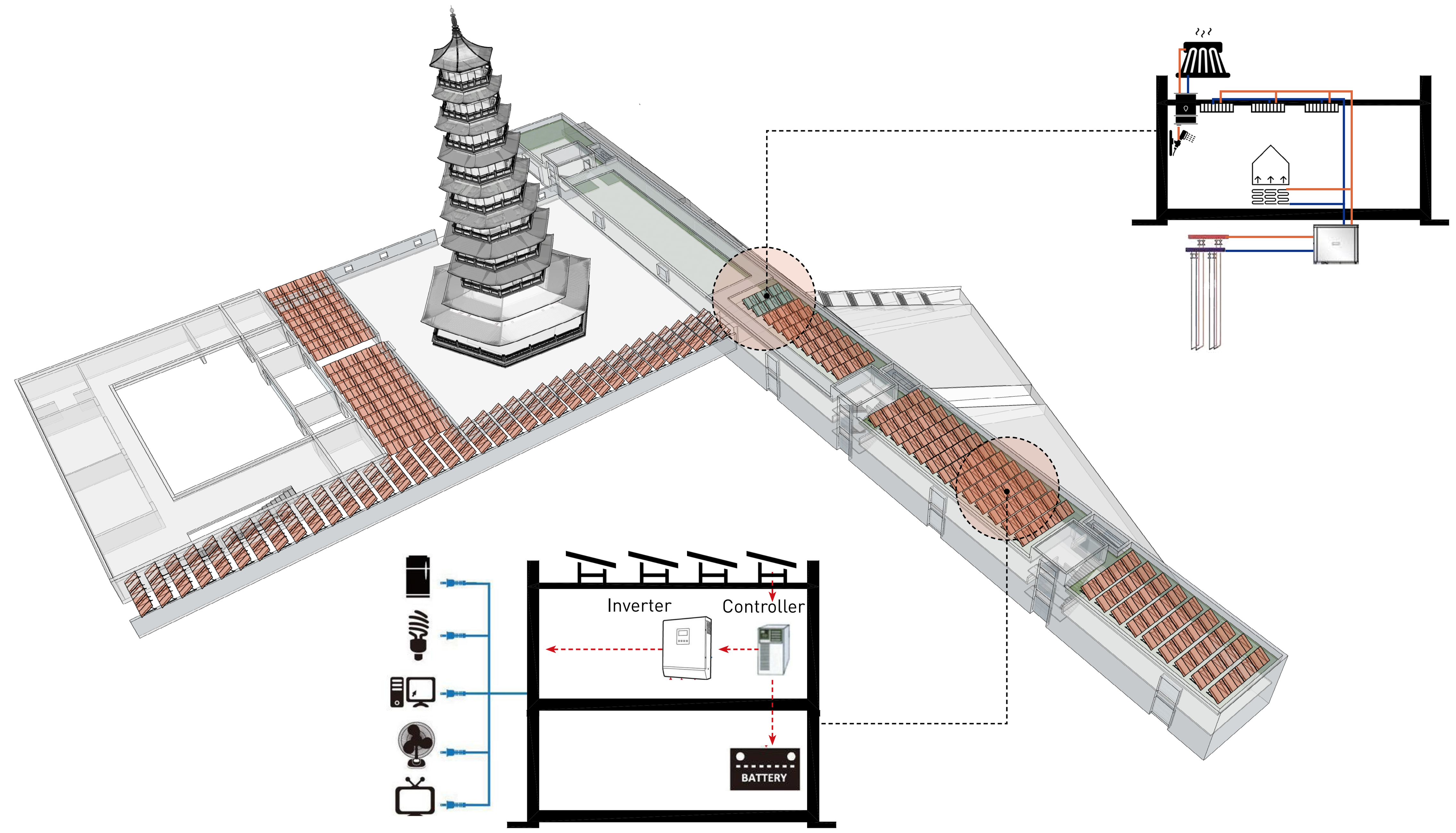
Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	1.00	2.39	8.4	2.78	-
February	1.00	2.32	10.1	2.45	-
March	1.00	2.45	13.6	2.48	-
April	1.00	3.34	20.0	3.21	-
May	1.00	3.94	24.1	3.64	-
June	1.00	4.39	27.2	3.96	-
July	1.00	5.34	29.5	4.82	-
August	1.00	4.70	28.8	4.44	-
September	1.00	3.94	25.8	3.96	-
October	1.00	3.51	21.4	3.83	-
November	1.00	3.27	15.9	3.94	-
December	1.00	3.02	10.3	3.82	-

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.30	1.30
Solar radiation (tilted surface)	MWh/m²	1.32	1.32
Average temperature	°C	19.6	19.6

System Characteristics		Estimate	Notes/Range
Application type		Service hot water (with storage)	
Base Case Water Heating System			
Heating fuel type	-	Natural gas - m³	
Water heating system seasonal efficiency	%	90%	50% to 190%
Solar Collector			
Collector type	-	Glazed	See Technical Note 1
Solar water heating collector manufacturer		Apricus	See Product Database
Solar water heating collector model		ETC-30	
Gross area of one collector	m²	4.40	1.00 to 5.00
Aperture area of one collector	m²	2.84	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.69	0.50 to 0.90
Fr UL coefficient	(W/m²)/°C	3.97	1.50 to 8.00
Temperature coefficient for Fr UL	(W/(m·°C)²)	0.00	0.000 to 0.010
Suggested number of collectors		3	
Number of collectors		5	
Total gross collector area	m²	22.0	
Storage			
Ratio of storage capacity to coll. area	L/m²	45.9	37.5 to 100.0
Storage capacity	L	652	
Balance of System			
Heat exchanger/antifreeze protection	yes/no	No	
Suggested pipe diameter	mm	13	8 to 25 or PVC 35 to 50
Pipe diameter	mm	20	8 to 25 or PVC 35 to 50
Pumping power per collector area	W/m²	0	3 to 22, or 0
Piping and solar tank losses	%	1%	1% to 10%
Losses due to snow and/or dirt	%	3%	2% to 10%
Horz. dist. from mech. room to collector	m	5	5 to 20
# of floors from mech. room to collector	-	2	0 to 20

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
SWH system capacity	kW_{th}	10	
	MWth	0.010	
Pumping energy (electricity)	MWh	**0.00**	
Specific yield	kWh/m²	365	
System efficiency	%	27%	
Solar fraction	%	74%	
Renewable energy delivered	MWh	**8.03**	
	GJ	28.92	
			Complete Cost Analysis sheet

-Total energy demand (MWh) : 8.03
-Total gross collector area (m2) :22
-Solar fraction (%) : 74



CONCLUSION:

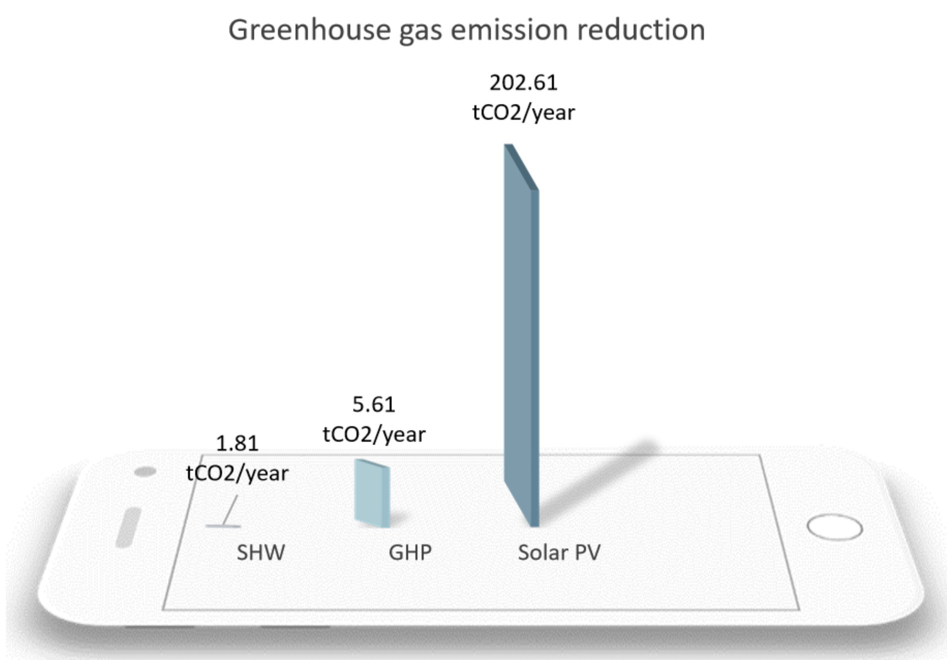
Energy Calculation for Ground source heat pumps
-Electricity consumption for heating (MWh) :15.6
-Electricity consumption for cooling (MWh) : 38.2

Energy Calculation for Solar PV
-Total available area for PV panels(m2)1666≤ Avaliable roof area
-Total electricity generate (MWh) : 268

Energy Calculation for Solar Heating Water
-Total energy demand (MWh) : 8.03
-Total gross collector area (m2) :22
-Solar fraction (%) : 74

Total green houses gases (CO2) emission reduction:
Solar Heating Water:1.81 tCO2/year
Ground Source Heat Pump:36.36tCO2/year
Solar PV: 202.61tCO2/year

Total:
1.81 (SH)+ 36.36(Heat pump)+ 202.61(Solar PV)
=240.78 tCO2/year



Background Information

Project Information		Global Warming Potential of GHG	
Project name	Renovate building	1 tonne CH_4 = 21 tonnes CO_2	(IPCC 1996)
Project location	Ganzhou, China	1 tonne N_2O = 310 tonnes CO_2	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Natural gas	2.0%	56.1	0.0030	0.0010	45.0%	8.0%	0.491
Coal	72.6%	94.6	0.0020	0.0030	35.0%	8.0%	1.069
Large hydro	18.6%	0.0	0.0000	0.0000	100.0%	8.0%	0.000
Diesel (#2 oil)	0.2%	74.1	0.0020	0.0020	30.0%	8.0%	0.975
Nuclear	2.3%	0.0	0.0000	0.0000	30.0%	8.0%	0.000
Electricity mix	96%	216.6	0.0047	0.0068		7.7%	0.788

Fuel mix should total 100%

Base Case Heating and Cooling System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Electricity	100.0%	216.6	0.0047	0.0068	100.0%	0.788
Cooling system						
Electricity	100.0%	216.6	0.0047	0.0068	500.0%	0.158

Proposed Case Heating and Cooling System (Ground-Source Heat Pump Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Electricity	100.0%	216.6	0.0047	0.0068	446.5%	0.176
Cooling system						
Electricity	100.0%	216.6	0.0047	0.0068	395.1%	0.199

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)		Annual GHG emission reduction (t_{CO2})
Heating system	0.788	0.176	69.8		42.66
Cooling system	0.158	0.199	150.8		-6.30
			Net GHG emission reduction	t_{CO2}/yr	**36.36**

Complete Financial Summary sheet

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)		Annual GHG emission reduction (t_{CO2})
Heating system	0.226	0.000	8.03		1.81
			Net GHG emission reduction	t_{CO2}/yr	**1.81**

Complete Financial Summary sheet

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)		Annual GHG emission reduction (t_{CO2})
Electricity system	0.788	0.000	257.280		202.61
			Net GHG emission reduction	t_{CO2}/yr	**202.61**

Complete Financial Summary sheet