BEAT THE HEAT

V1 DRAFT

DESIGN COOL OUTDOOR SPACES IN PUBLIC HOUSING

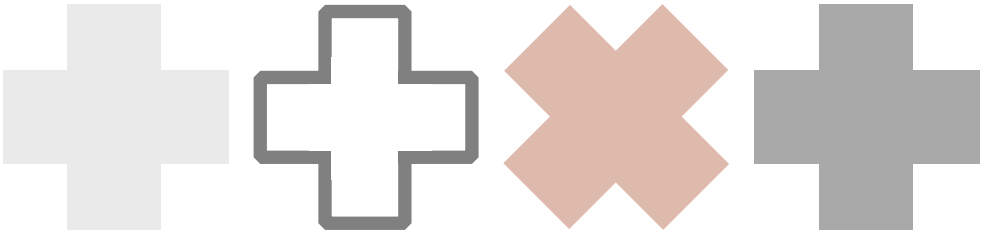
[PREFACE]

The global warming trend is unimpeachable. For two consecutive years, scientists have announced that the world has experienced the warmest temperatures on record. As urban areas continue to face intensifying heat challenges, the need for climate-responsive design solutions becomes increasingly urgent. Hong Kong, with its dense urban environment and subtropical climate, is particularly vulnerable to extreme heat events, making the development of heat-resilient public spaces a critical priority.

Design future-heat-resilient public spaces

The creation of thermally comfortable outdoor spaces requires a nuanced understanding of local climate conditions, urban morphology, and human comfort needs. As climate projections indicate continuing temperature rises and the new-normal of heatwaves, designing public spaces that can provide high-quality experience under future heat stress becomes paramount, i.e., future-heat-resilient public spaces.

To reach such a goal, adopting innovative design approaches that are scientific-evidence-based are essential to ensure the effectiveness and practicality of these approaches, considering the constraints of existing infrastructure and available resources. However, due to the vast number of available studies, adopting suitable strategies for a specific background climate and urban context is challenging for non-experts, emphasizing the significance to provide context-specific suggestions to support evidence-based climate-responsive design.



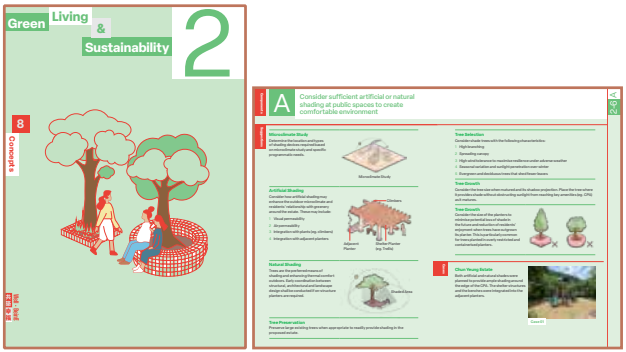
Public housing estates, accommodating over 40% of Hong Kong's population, play a crucial role in the city's climate adaptation efforts. These estates serve not just as residential spaces but as communities where the impacts of urban heat are experienced daily. The provision of future-heat-resilient public spaces in Hong Kong's public housing through design and management can significantly influence residents' comfort, health, and overall quality of life.

Fostering well-being in Hong Kong's public housing

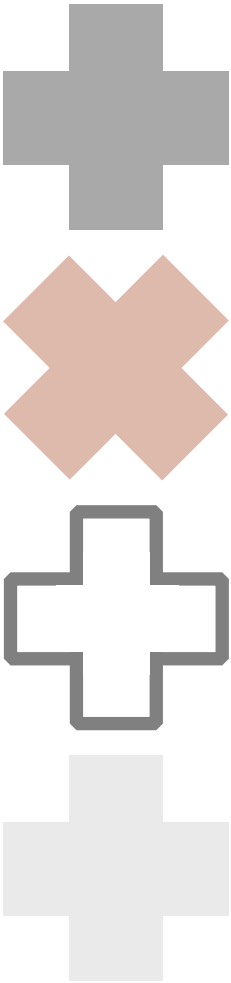
Advancing societal well-being is advocated by WHO as a universal target. According to the WHO Health Promotion Glossary 2021, well-being is defined as

> *a positive state experienced by individuals and societies. Similar to health, it is a resource for daily life and is determined by social, economic and environmental conditions.*

Well-being encompasses quality of life, as well as the ability of people and societies to contribute to the world in accordance with a sense of meaning and purpose. Focusing on well-being supports the tracking of the equitable distribution of resources, overall thriving, and sustainability. A society's well-being can be observed by the extent to which they are resilient, build capacity for action, and are prepared to transcend challenges.



↑ Snapshots from **Well·Being 共築幸福 (2024)**. https://housingwellbeing.hk/en/design-guide/



Advancing well-being in Hong Kong's public housing also gains attention from the local authorities. Led by Hong Kong Housing Authority, design guide to promote well-being is advocated in the design and renovation of Hong Kong's public housing estates. Eight key concepts, covering health & vitality, green living and sustainability, urban integration, etc., provide a holistic framework enhancing human well-being.

Among these concepts, considerations of microclimate and outdoor thermal comfort are aggregated in Strategy 2-6 Optimization of outdoor microclimate, and mentioned in several strategies as key considerations. In addition to these generalized guidelines, we find that more detailed information could assist practitioners who are less familiar with the nuanced technical details to make easier decisions in practice.

These considerations bring us to the development of this design guidebook focusing on feasible cooling strategies in public spaces in Hong Kong's public housing estates. Based on credible scientific evidence, we aim to provide tailored suggestions of feasible design elements that are locally applicable, cost effective, and context specific, illustrated in a way that is layman-friendly and visually interpretable. We expect this guidebook to serve the local community, including the policy makers, local administrators, and planners and designers, with credible information and as a useful tool in their work.

The development of this guidebook is supported by a Theme-based Research Scheme project (T22-504/21-R), named "Healthy and Resilient City with Pervasive LoCHs", funded by Hong Kong University Grants Committee, to which we express our sincere gratitude.

CONTENTS

1 URBAN OVERHEATING
under climate change

Climate change is leading to an increase in extreme heat events worldwide, posing a challenge to landscape designers to create outdoor spaces that are both functional and comfortable for users. As temperatures continue to rise, it is crucial to adopt innovative strategies that mitigate the effects of urban overheating, promoting the well-being of residents and fostering a more sustainable and livable environment.

CLIMATE CHANGE AND EXTREME HEAT

Climate change is causing more frequent and severe heatwaves, which have various implications for human health and urban life. Heat-related health risks, such as heat exhaustion, heatstroke, and dehydration, become more common as temperatures soar. These conditions can significantly reduce productivity and overall quality of life, making it increasingly important for landscape designers to consider ways to mitigate these challenges.

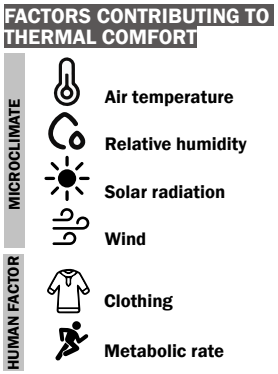
Extreme heat also places stress on infrastructure and urban services, such as energy and water supply systems, which can be exacerbated by increased demand for cooling. Furthermore, the impacts of extreme heat are often felt most acutely by vulnerable populations, including the elderly and low-income communities, who may have limited access to resources and cooling options. Designing outdoor spaces that effectively combat heat is essential to promote social equity and create more inclusive urban environments.

MICROCLIMATE AND THERMAL COMFORT

Microclimate refers to the localized atmospheric conditions within a specific area, which can be significantly influenced by factors such as solar radiation, air temperature, humidity, and wind speed. These factors play a crucial role in determining the thermal comfort of a space, which is the subjective satisfaction that individuals experience with their thermal environment.

Understanding and addressing microclimate and thermal comfort is vital for landscape designers, as it can help them create outdoor spaces that are more enjoyable and usable for residents, even during periods of extreme heat. By incorporating elements such as shade, water features, and windbreaks, designers can effectively manipulate microclimates to improve thermal comfort and promote a more pleasant experience for users of the space.

Landscape designers must be increasingly aware of the challenges posed by climate change and extreme heat when designing outdoor spaces for public housing. By considering factors such as microclimate and thermal comfort, they can create environments that are both functional and comfortable, promoting well-being and social equity in the face of a changing climate.



II OVERSEA CASES of cool residential public spaces

Cities worldwide are facing the identical daunting challenge of climate change and extreme heat. To adapt to these challenges, many cities are adopting innovative designs that prioritize sustainable living environments for their citizens. In particular, providing sustainable and high-quality living environments in mass housing is crucial to achieving sustainable goals and benefiting the wider public. The oversea cases of cool residential public spaces presented here provide valuable references for building similar spaces in Hong Kong.

Punggol Waterway Terraces

| **Location** Singapore | **Architects** Aedas, G8A |
| **Area** 258, 000 m^2 | **Year** 2015 |

Public Housing | Tropical | Mass Housing

Looking to the future whilst looking back to the past, the Punggol Waterway Terraces form a blueprint for 21st century sustainable mass housing and mark a return to Singapore's original ethos of community pride and identity.

In the face of global warming and the loss of community identity, the pendulum has swung back to the principles and the spirit of tropical-modernist design, especially in the field of public housing. The sheer mass and the fundamental design elements of the Waterway Terraces are not hidden, they instead are presented to the public and the residents as an unequivocal response to the 21st century requirements for a sustainable, yet enjoyable, high-density urban lifestyle.

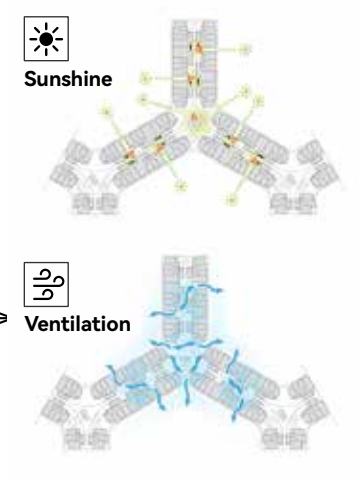
Waterway Terraces is a genuine precursor to the zero-energy mass housing that will be essential for the continued growth of Asia's cities.

The original SIT public housing blocks were tropical adaptations of contemporary clean-lined odernism. As they were designed well before the advent of airconditioning,the apartments required cross- entilation, they were shaded by overhangs, and were orientated to avoid the heat of the afternoon sun. When the first large-scale HDB blocks were built in Queenstown in the early 1970s, that 'tropical-necessity modernist-design' architectural hybrid symbolised a newly independent Singapore.

As Singapore grew more affluent and as global architectural fashions changed, those heroic tropical-modernist forms were to quietly disappear. They were replaced by an architecture that itched to assert Singapore's worldliness, but the designs became increasingly generic, many of the developments were implicitly anti-social,and the structures were unsustainably non-tropical.

A continuous no-dead-end corridor runs the length of every floor in each of the two sectors, and by virtue of an ingenious planning manoeuvre, the double-loaded corridors actually facilitate cross-ventilation and vertical cooling, instead of blocking the airflow to the apartments. Due to the hexagonal block plans, three corridors are angled at 120 degrees from the lift cores to serve apartments grouped in threes. Each apartment is directly ventilated by the lift-core breezeways and by voids inserted between the groupings.

Looking to the future whilst looking back to the past, the Punggol Waterway Terraces form a blueprint for 21st century sustainable mass housing and mark a return to Singapore's original ethos of community pride and identity.



Source
https://g8a-architects.com/project/punggol-waterway-terraces/
https://www.archdaily.com/787479/punggol-waterway-terraces-group8asia/
https://mooool.com/en/punggol-waterway-terraces-by-g8a-architecture-urban-planning-aedas.html/

Baiziwan Social Housing

| **Location** Beijing, China | **Architects** MAD, EADG |
| **Area** 93,900 m^2 | **Year** 2019 |

Public Housing | Landscape Design | Rooftop Garden

Baiziwan Social Housing is located next to Guanghua Street, Chaoyang District, Beijing, and the Chemical Station of Metro Line 7. The project covers an area of 93,900 square meters, with a total construction area of 473,300 square meters. It consists of 12 residential buildings ranging from 6 to 27 floors. It consists of six small blocks, with a total of 4,000 households.

While the ground level opens the site to a wider urban audience, the second level, only access to the residents, offers a communal outdoor landscape for residents. A pedestrian circuit weaves around all six blocks, forming a large above-ground park with a variety of communal functions including a gym, community gardens, badminton court, children's playground, ecological sanctuary, and communal support services.

In addition to the main residents' park on the second floor, MAD's scheme incorporates staggered half-floors and semi-opened gray spaces of various scales throughout the design. Despite the rigid green coverage ratio of residential design specifications and the high density required for city center living, the scheme strives to provide green coverage on ground level, the second-level park, and the rooftop, ensuring residents enjoy a holistic setting with strong connections to nature and the outdoors and achieving a green coverage of 47%. The standardized green coverage of the commercial residential compounds is 30%.

MAD's strategy strives to integrate the community into the urban fabric and connect the neighborhood with the city. MAD divided the plot into six blocks, anchored by the main avenue cutting through the center of the site. The large site is fragmented into a much smaller human scale. At the street level, the scheme's central avenue is home to a range of commercial and convenience spaces, such as shops, cafes, restaurants, kindergartens, pharmacies, bookstores, and elder care facilities. The arterial route through the center of the scheme fosters connections between the neighborhood and the city. With the human-scaled site planning and diversity of spaces, the design creates a vibrant and open urban life across the new neighborhood.

The greenery in this project incorporates a combination of trees, shrubs, and grasses, with a significant emphasis on shrubs alongside some trees. It is widely recognized that a thicker layer of mulch yields greater benefits for the growth of woody plants and enhances the overall ecological advantages, such as humidification, cooling, energy conservation, and rainwater storage. Among various mulch depths, a 1.5-meter layer stands out as offering the most optimal ecological benefits. In this project, the mulch depth ranges from 1.2 to 1.5 meters, ensuring compliance with overall load requirements and providing optimal conditions for plant growth.

Source
https://mooool.com/baiziwan-social-housing-landscape-design-by-eadg.html
https://www.archdaily.com/984014/baiziwan-social-housing-mad-architects

Green Cloud Rooftop Garden

| **Location** Shenzhen, China | **Architects** ZHUBO |
| **Area** 90 m^2 | **Year** 2018 |

Rooftop Garden | Urban Farming | Urban Renewal

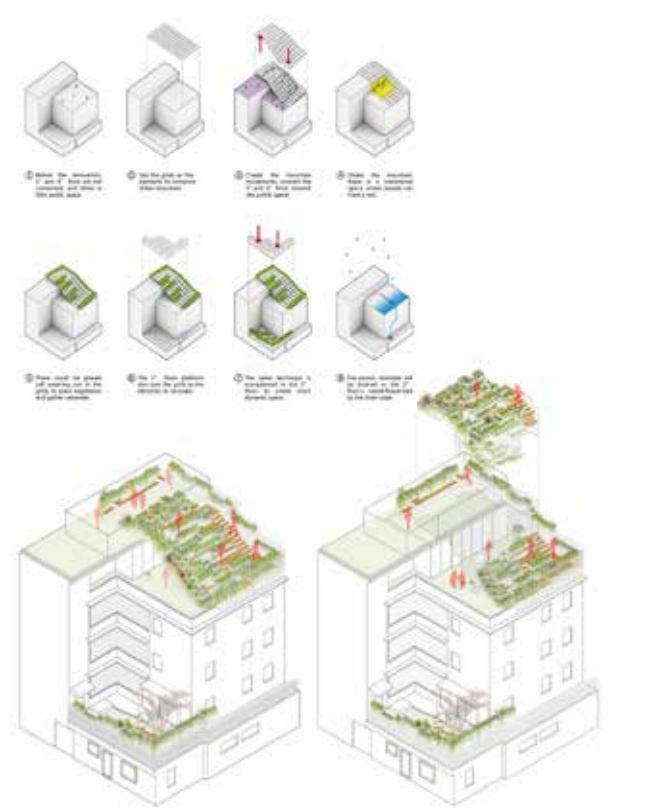
Along with the expansion of modern city, original villages located in the edge of city have been turning into isolated islands in flourishing city. Urban village, resulting from population boom in modern China, exists in major cities as common case.

However, there is no mountain or river in the so called urban 'village' as in imagination, but the concrete land which is hard and impermeable. Moreover, due to the poor condition of lighting and narrow space,The first impression of most people for urban village is messy and unsafe. Architects in AAO has made a practice seeking for a solution to problems in urban village.

Architects propose a tentative idea of Green Cloud, aiming to improve rainwater management ability as well as providing green and comfort common place for residents, from which the current living states of residents could be improved.'Green Cloud' is a low-technique required renovation method which can be copied easily.To make use of large quantity of roofs in urban village, architects build Urban Mountain on the roof which have potential to be reconstructed.

Architects set up Urban Mountain on dwelling roofs to make up for this kind of Green Cloud practice be as demonstration. We hope adjacent residents could be impacted to master the construction skill of Urban Mountain idiopathically and after that,copy them to their own roofs.As Urban Mountains being built in urban village one after another and connecting in the sky,a new landscape full of fun, joy and greening that we planned is coming out -- the Green Cloud.

Urban Mountain has gradually been a culture activity zone in urban village. Recently(June 2018), a mid-summer concert was held on Urban Mountain, 9 little musicians aged 4-11 made neighbors open the windows that had been closed for so long. After big success of the concert, other residential community activities that comes later are expected.



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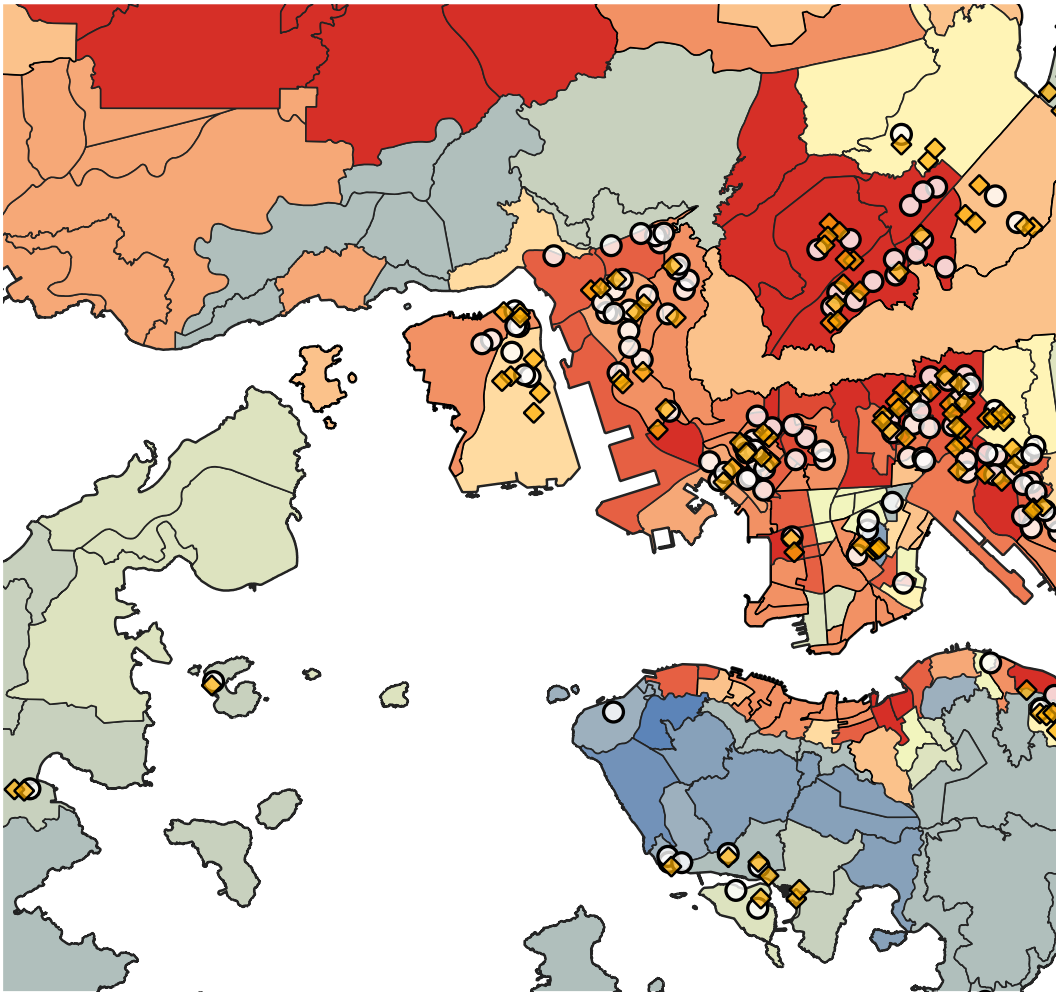
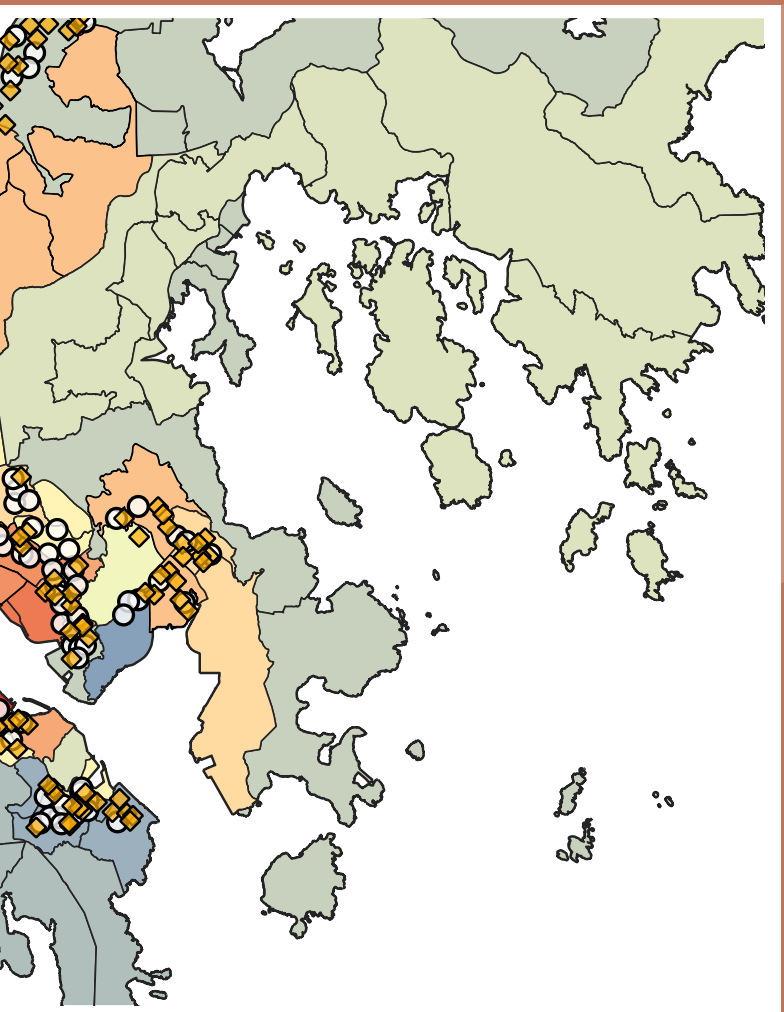


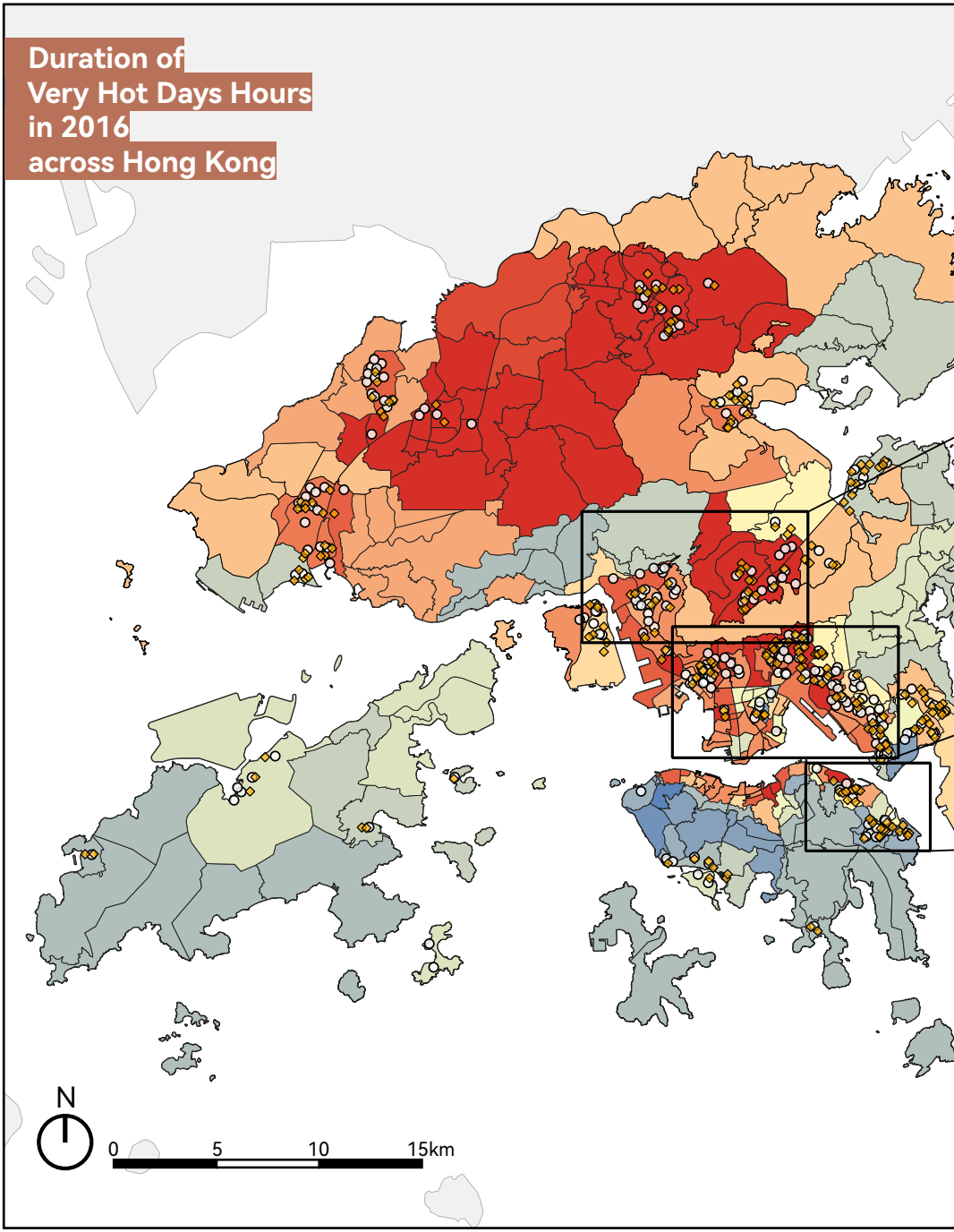
III HEAT RISKS in Hong Kong Public Housing

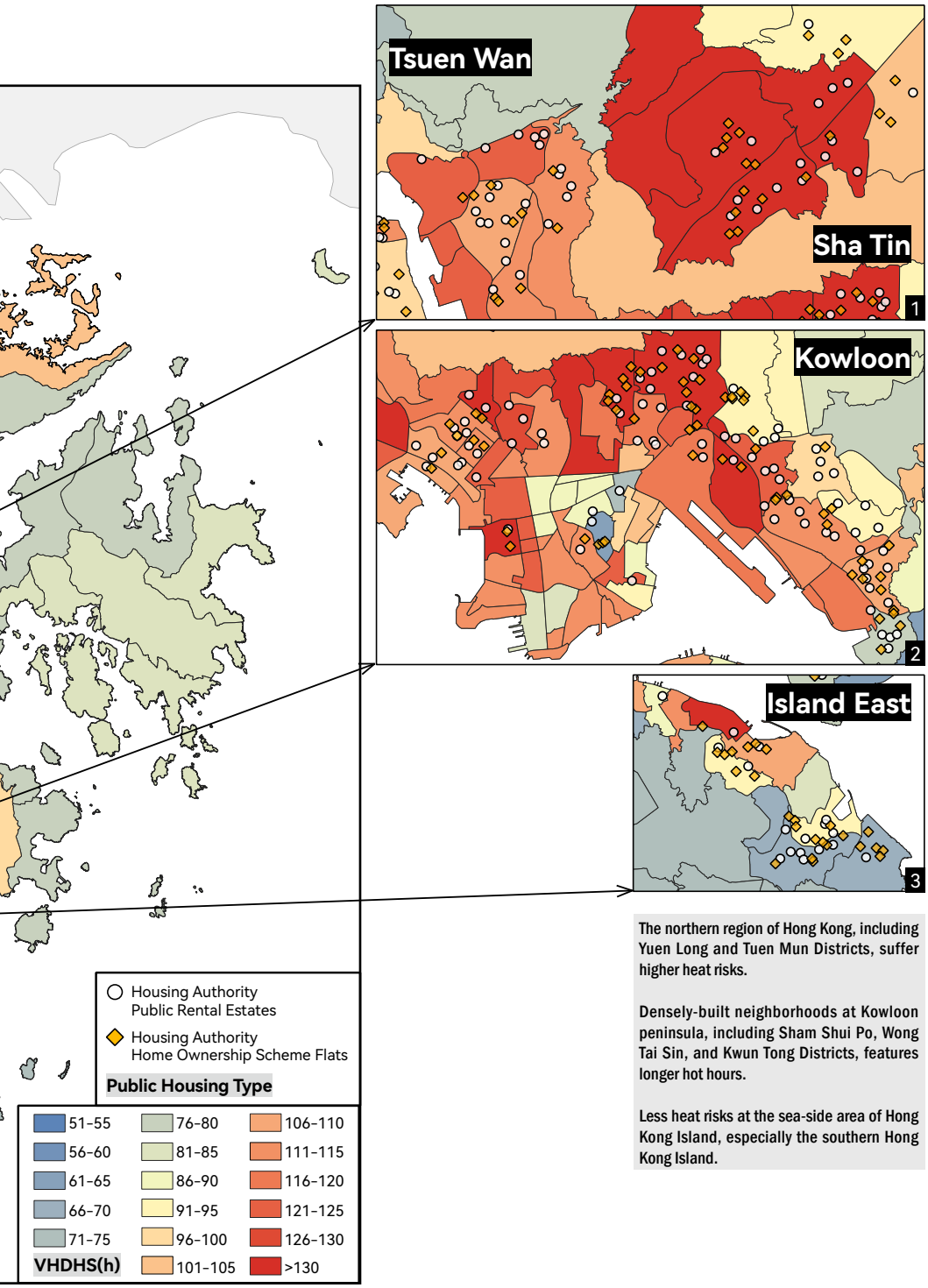
Covering 17 km^2 of its land, Public Housings in Hong Kong accommodate >40% of Hong Kong's population, and are located throughout the territory. By overlapping the locations of Public Housings and the heat hazard map assessing the duration of very hot days hours in 2016, it gives an overview of the stress experienced by the public housing residents.

Hua, J., Zhang, X., Ren, C., Shi, Y., & Lee, T.-C. (2021). Spatiotemporal assessment of extreme heat risk for high-density cities: A case study of Hong Kong from 2006 to 2016. *Sustainable Cities and Society*, 64, 102507. https://doi.org/10.1016/j.scs.2020.102507



Duration of Very Hot Days Hours in 2016 across Hong Kong





The northern region of Hong Kong, including Yuen Long and Tuen Mun Districts, suffer higher heat risks.

Densely-built neighborhoods at Kowloon peninsula, including Sham Shui Po, Wong Tai Sin, and Kwun Tong Districts, features longer hot hours.

Less heat risks at the sea-side area of Hong Kong Island, especially the southern Hong Kong Island.

IV EFFECTIVE COOLING MEASURES for typological public spaces

Open, vegetated, and semi-outdoor spaces are typological spaces in public housing estates. They feature different functions, usage, characteristics, and microclimate conditions. These typical characteristics are introduced below, followed by feasible strategies to beat the heat in these types of spaces.


SEMI-OUTDOOR SPACES

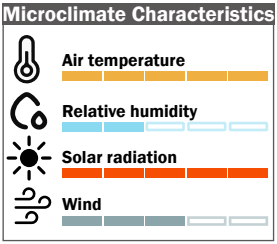
Instagram, @hk_estate_centres, "Tai Yuen Estate", posted on May 16, 2022.

01

Feasible cooling measures in **OPEN SPACES**

Large, open spaces with few or no obstructions. Typical examples of open spaces in public housings are squares and playgrounds, which serves for community gatherings, public activities, and all kinds of light to intense outdoor exercise.

Due to the openness of these spaces, they are most likely to be exposed to strong solar radiation, and feature high air temperature radiant temperature. Cooling strategies are needed especially under extremely hot summer days.



Measure 1	Utilize building shade
Measure 2	Covered walkway
Measure 3	High-reflectance Pavement material
Measure 4	Temporary shading device
Measure 5	Water feature
Measure 6	Mist spraying

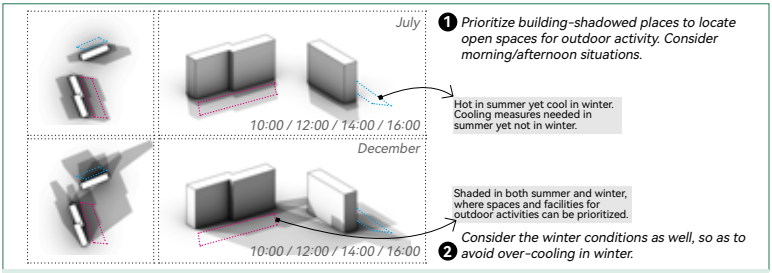
IV EFFECTIVE COOLING MEASURES for typological public spaces

Measure 1 Utilize building shade

Consider the building orientation in relation to the sun to maximize the utilization of building shade. Both summer and winter shading conditions should be considered, so as to maximize to usage of shade in summer and avoid over-cooling in winter. Open spaces located in summertime building shade but out of wintertime building shade tend to be mutually thermally comfortable.

[SCIENTIFIC EVIDENCE]

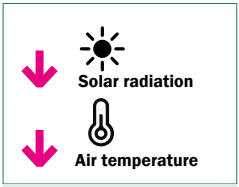
The seasonal variation of building shade was observed to have an impact on long-term thermal comfort [1]. Over-cooling due to the shading in winter may cause discomfort in subtropical climate, yet building shade is preferable in hot summers.



❶ *Prioritize building-shadowed places to locate open spaces for outdoor activity. Consider morning/afternoon situations.*

❷ *Consider the winter conditions as well, so as to avoid over-cooling in winter.*

[PRACTICAL GUIDE]



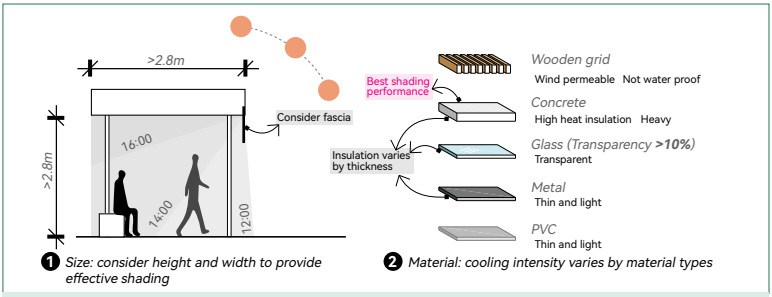
[EFFECTS]

Measure 2 Covered walkway

Allocate covered walkway along routine trajectories to connect buildings and infrastructures. This can provide shade and reduce direct sunlight exposure during hot seasons. It is necessary to consider the solar angle to ensure effective shading during the hottest hours. Co-benefits of protection from rain and other weather elements can also be guaranteed.

[SCIENTIFIC EVIDENCE]

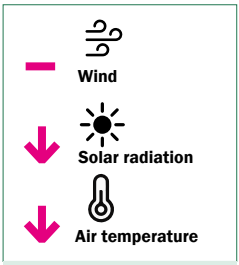
Covered walkway may provide effective shading to pedestrians and reduce heat stress in hot summer. The existing covered walkway in a Public Housing Estate were observed to effectively reduce mean radiant temperature by over 20°C [2]. Different roof materials may also influence the cooling performance. Opaque materials (concrete, aluminum, and PVC) and glass transparency over 10% can be prioritized to achieve better cooling intensity [3].



❶ *Size: consider height and width to provide effective shading*

❷ *Material: cooling intensity varies by material types*

[PRACTICAL GUIDE]



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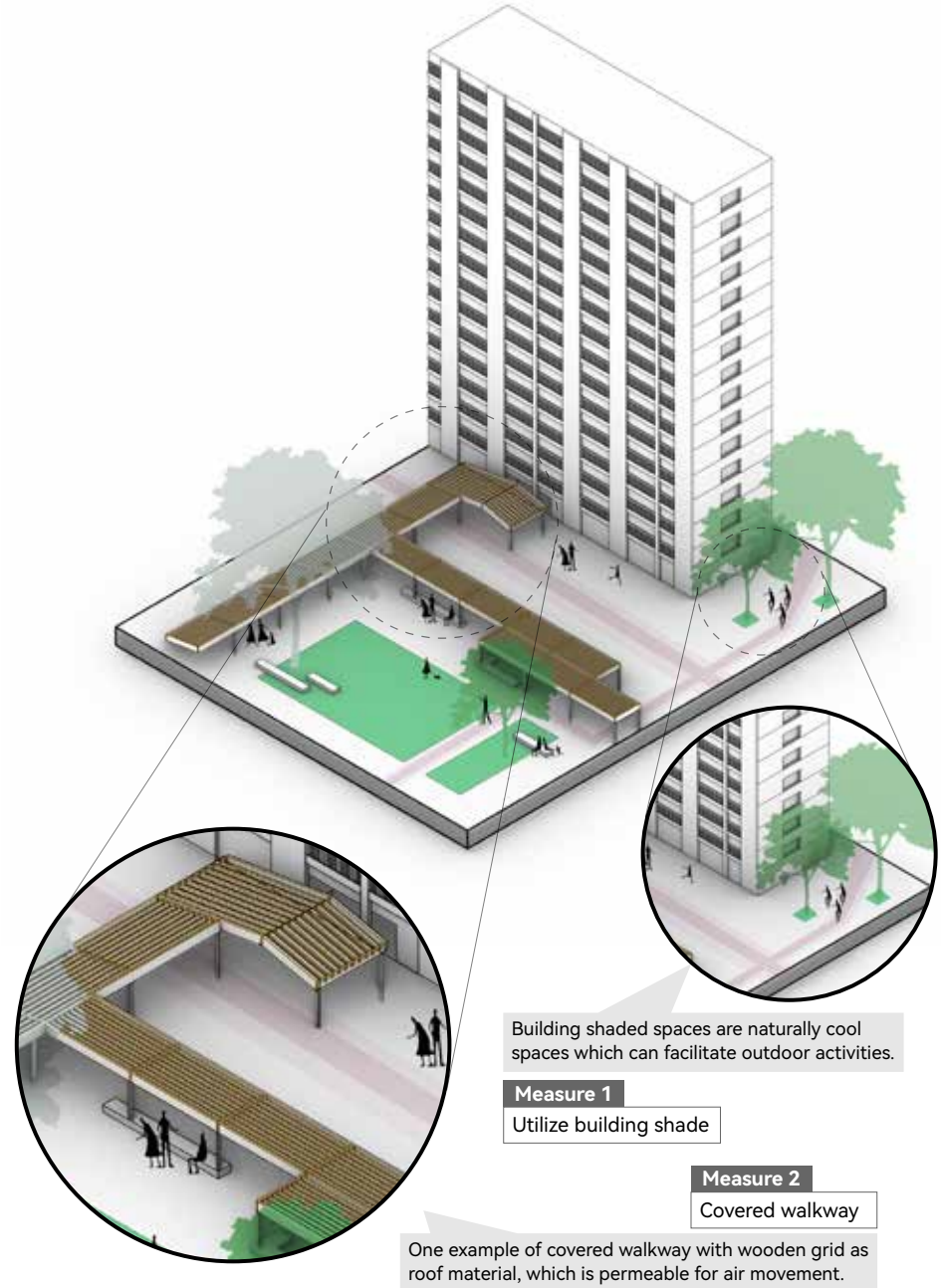


Building shaded spaces are naturally cool spaces which can facilitate outdoor activities.

Measure 1

Utilize building shade

Measure 2

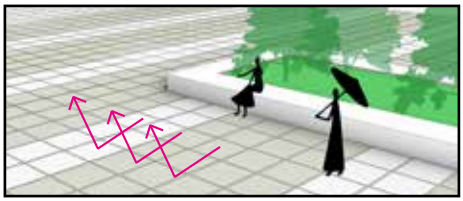
Covered walkway

One example of covered walkway with wooden grid as roof material, which is permeable for air movement.

[MEASURES COMBINATION]

IV EFFECTIVE COOLING MEASURES for typological public spaces

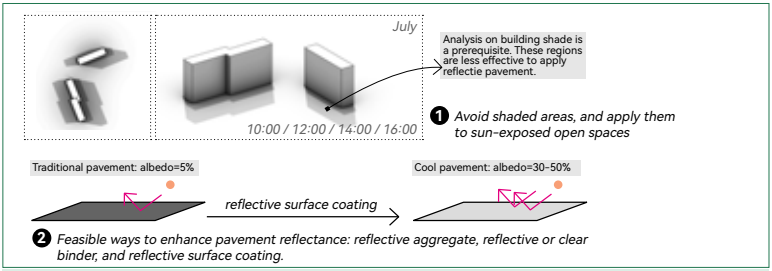
Measure 3 High-reflectance pavement material



Prioritize high-reflectance pavement material at places that are highly exposed to sunlight, which may minimize the absorption of solar radiation and reflect a significant portion of the sun's energy. Such specialized pavement has a high solar reflectance index, which helps to reduce the surface temperature of outdoor spaces. By reflecting sunlight instead of absorbing it, it helps to keep the sunlight-exposed outdoor areas cooler.

[SCIENTIFIC EVIDENCE]

Reflective pavements used in residential areas has been proved as effective mitigation on extreme heat. High reflectance of these materials may reflect the radiation and reduce the surface temperature of and the radiant temperature above the pavement, especially at noon [4]. Different pavement materials can also influence subject's local skin temperatures, which further determine the perceived thermal comfort of individuals [5].



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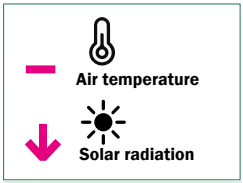
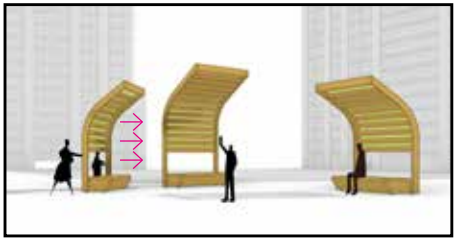


[EFFECTS]

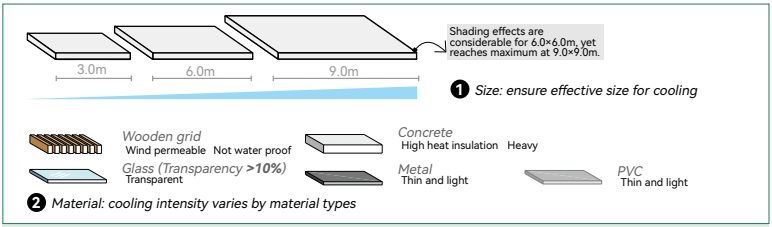
Measure 4 Temporary shading device



Designate landscape structures, such as pergolas, arbors, etc., as temporary shading device. They feature manually adjustable elements, allowing users to control the amount of shade they need. Such flexibility ensures optimal comfort in extremely hot weather conditions, and at the same time offer multifunctional usage, serving as attractive architectural features that enhance outdoor spaces. By incorporating temporary shading devices, individuals can create comfortable and versatile environments that protect against excessive sun exposure while adding aesthetic value to their surroundings.

[SCIENTIFIC EVIDENCE]

By simulation, shading provided by opaque materials, such as concrete, aluminum, and PVC, can reduce mean radiant temperature by up to 24 °C. Comparatively, the cooling effect of transparent materials is reduced to 1.4° C. In terms of the size of the shading devices, maximum thermal stress reduction can be reached by devices larger than 9.0×9.0m, compared to 3.0×3.0m and 6.0×6.0m [3].



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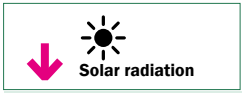

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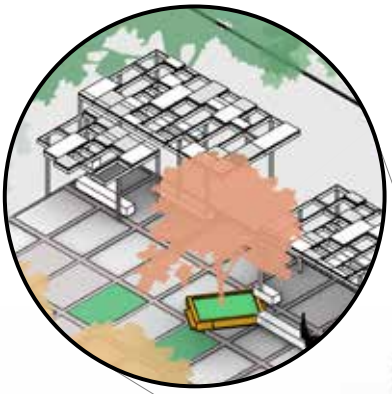
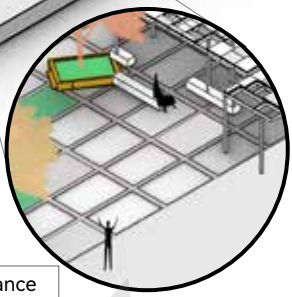


Measure 3

High-reflectance pavement material

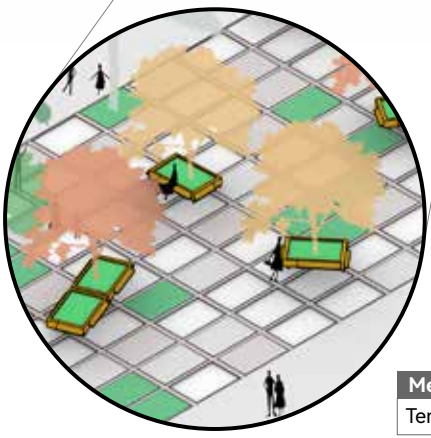
Such high-reflectance material can also be used as rooftop materials.



Measure 3

High-reflectance pavement material

Suitable for open squares that are free from buildings or trees' shade.



Temporary shading devices are flexible cooling measures and up to users' need. It also enhances the interaction between users and the landscape.

Measure 4

Temporary shading device

[MEASURES COMBINATION]

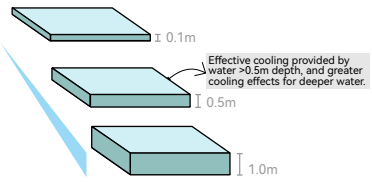
IV EFFECTIVE COOLING MEASURES for typological public spaces

Measure 5 Water feature

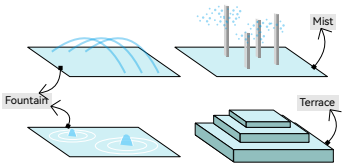
Consider allocating water features on open squares, e.g., fountains, ponds, and other water elements, to cool the surrounding air. Heat can be stored in water due to its large heat capacity, yet effective cooling requires certain amount of water. Evaporation also cools the air, yet the enhancement on thermal comfort is hampered by its humidifying effect.

[SCIENTIFIC EVIDENCE]

The high heat capacity of water determines its strong cooling effect during summer daytime but heating at night. In Hong Kong, significantly lower air temperature was observed on a lawn near a small pond [6]. The morphology of water features also casts an impact. Parametric studies reveal that deeper [7] and more dispersed [8] water bodies are more effective in enhancing thermal comfort.

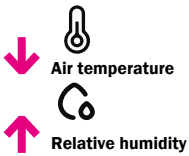


❶ *Ensure depth and volume of water for effective cooling*



❷ *Incorporate different types of water feature*

[PRACTICAL GUIDE]



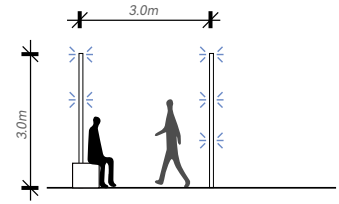
[EFFECTS]

Measure 6 Mist spraying

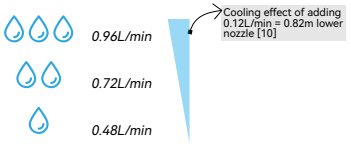
Combine mist spraying landscape structures or standalone devices at particular hot spots to provide active cooling. Mist spraying may effectively reduce human skin temperature and enhance thermal comfort under extreme heat condition. It can also be combined with interactive landscape. By incorporating mist spraying technology, more enjoyable and comfortable environments can be created, providing relief from the heat and promoting a pleasant outdoor experience.

[SCIENTIFIC EVIDENCE]

As a heat mitigation strategy, mist spraying has been proved effective in reducing ambient heat and improve thermal comfort. It can reduce human skin temperature by as short as a 5 minute exposure [9]. Denser mist located closer to the subjects [10], and synergistic effect with wind [11] and shade [12] may induce greater thermal comfort enhancement.

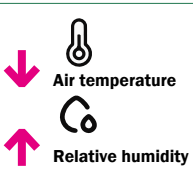


❶ *Size: construct a misting system of the size of human subjects walking or sitting*



❷ *Mist density: denser mist leads to better cooling, yet too dense the mist leads to undesirable wetedness*

[PRACTICAL GUIDE]

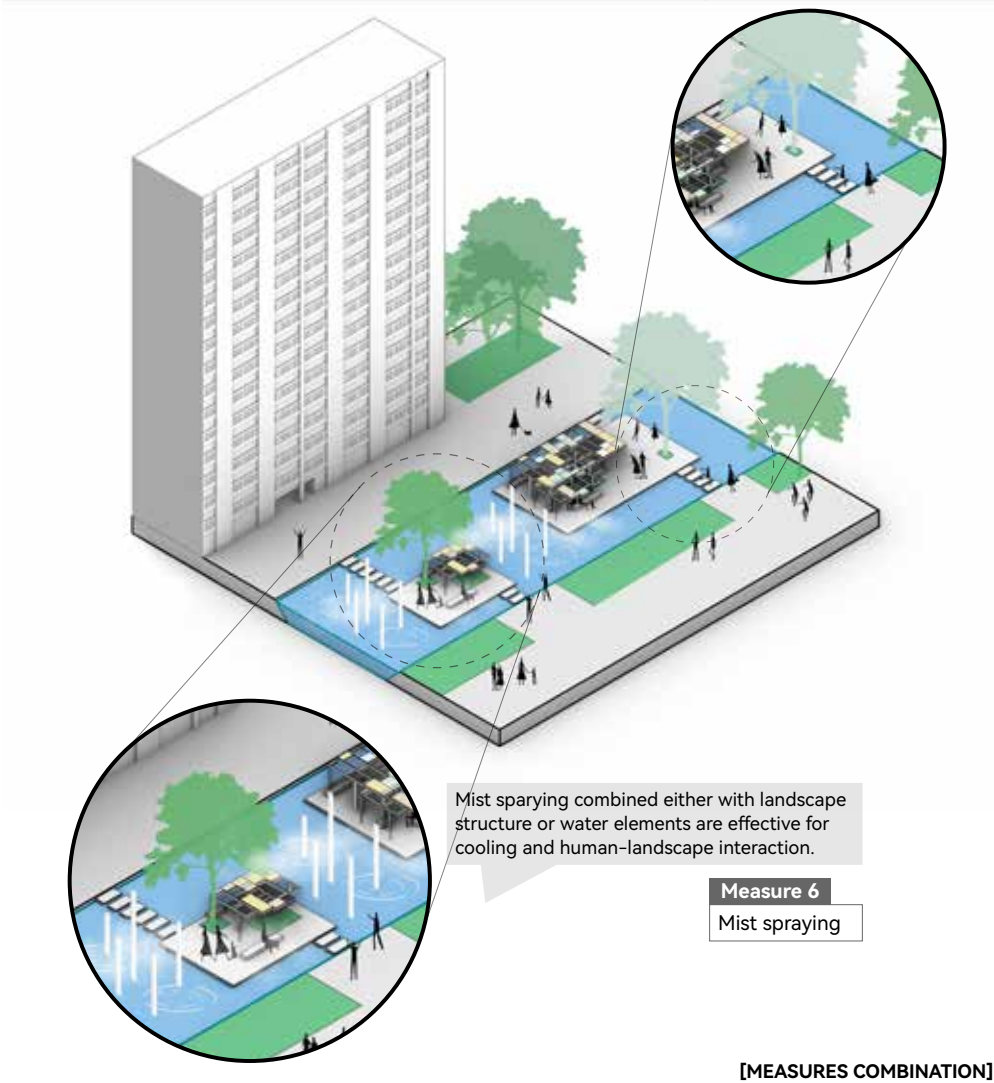


[EFFECTS]

Measure 5

Water feature

Water features not only are effective to cool environment, but also are popular elements favored by the public.



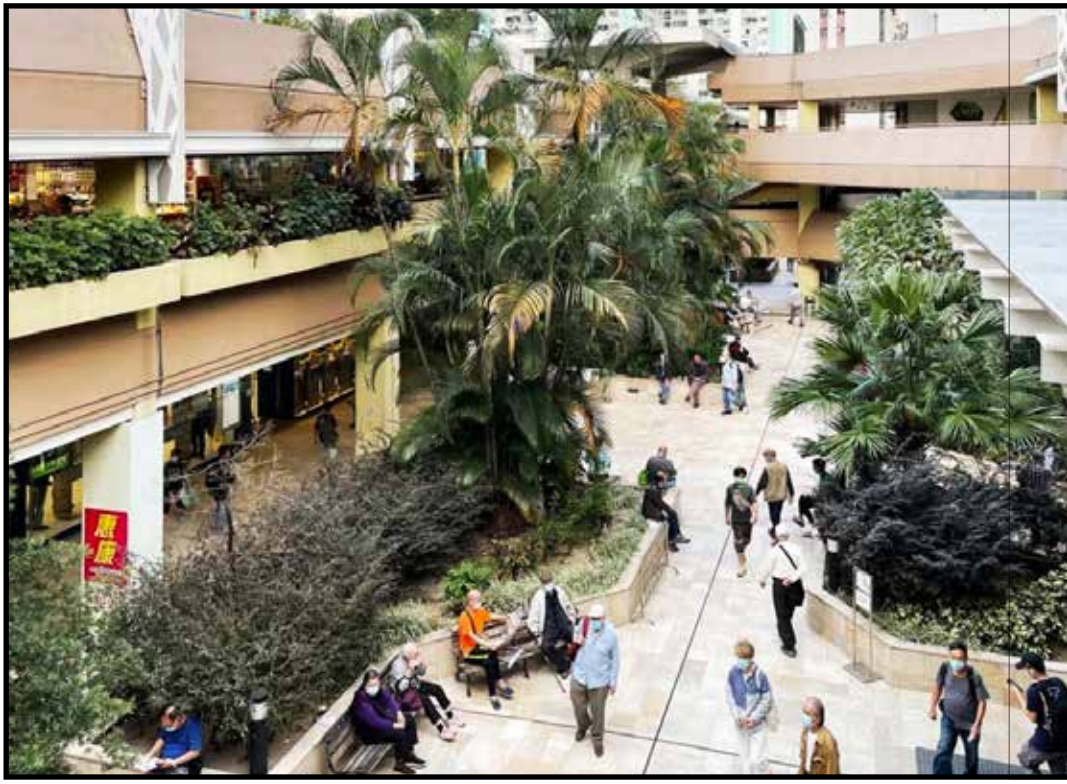
Mist sparying combined either with landscape structure or water elements are effective for cooling and human-landscape interaction.

Measure 6

Mist spraying

[MEASURES COMBINATION]

IV EFFECTIVE COOLING MEASURES for typological public spaces



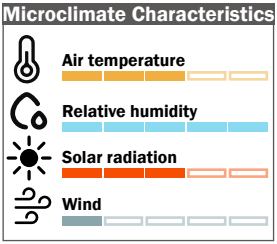
Instagram, @hk_estate_centres, "Choi Wan Estate", posted on May 2, 2022.

02

Feasible cooling measures in **VEGETATED SPACES**

Spaces with various types of vegetation consists of pocket gardens, tree-shaded squares and walkways, which are spaces for daily resting, recreation, as well as community gathering and public activities.

Due to the shading and evapotranspiration effects of vegetation, these spaces face less heat stress compared to open spaces, but still feature relatively strong solar radiation, high air temperature and relative humidity.



Measure 1	Proper plant type and species
Measure 2	Combined Shading
Measure 3	Optimize tree and building

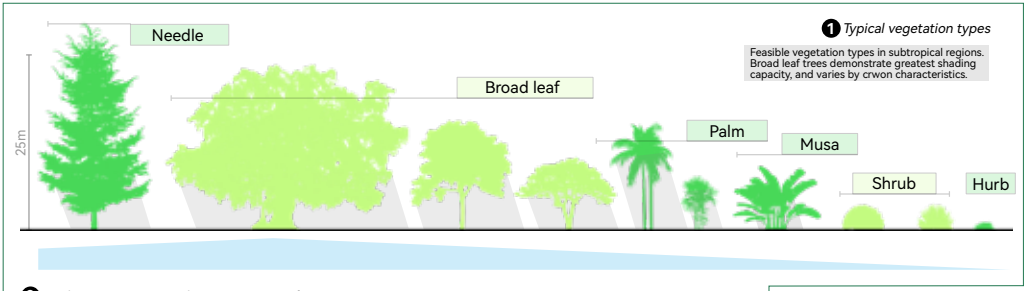
IV EFFECTIVE COOLING MEASURES for typological public spaces

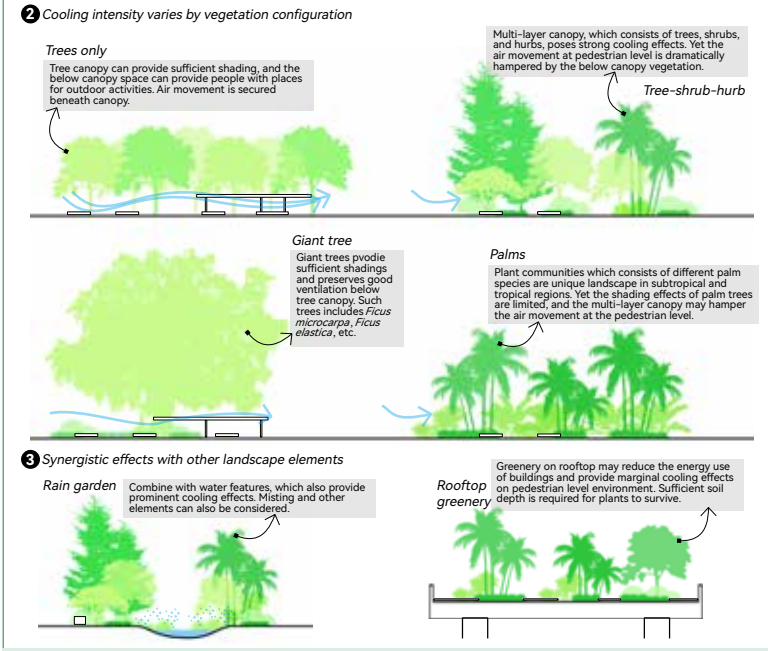
Measure 1 Proper plant type and species

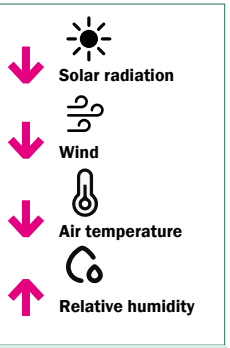
Select proper plant types and species for planting, as trees, shrubs, and herbs feature different microclimate effects. Trees with large crown are most effective for cooling as they provide the most prominent shades, which are more suitable for spots inaccessible to building shades. Shrubs and herbs are less effective in providing shades, yet can provide evapotranspiration for cooling. Vines are suitable materials to combine with landscape structures.

[SCIENTIFIC EVIDENCE]

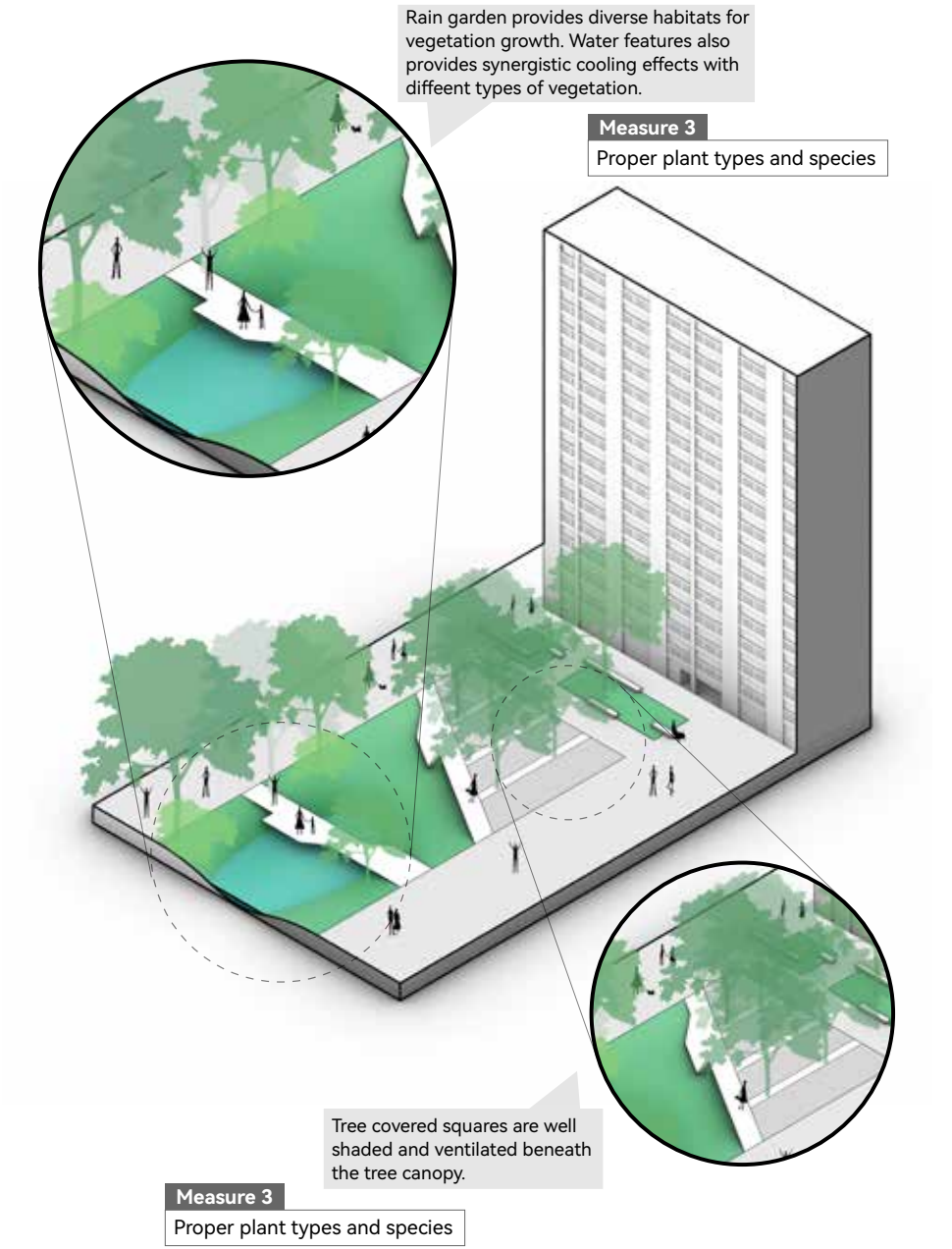
Optimizing trees and buildings for better cooling was found to provide twice cooling benefits in subtropical Hong Kong [16]. Study in Hong Kong's public housings reveals that sky view factor (SVF) can be used as a key indicator for building and greenery configuration in outdoor spaces. Effective cooling can be achieved by reducing SVF to below 0.4 by optimizing buildings and greenery, which jointly shape the sky openness [17].







[PRACTICAL GUIDE] **[EFFECTS]**



[MEASURES COMBINATION]

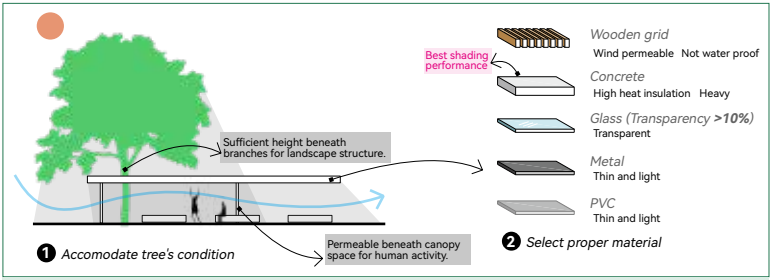
IV EFFECTIVE COOLING MEASURES for typological public spaces

Measure 2 Combined Shading

Combine structures and infrastructures with trees may provide both effective shading and recreational infrastructures, such as pavilions. It is feasible in cases where the planting of large trees is constrained, such as limited soil depth. By merging vegetation with other landscape elements, we can generate cool spaces that offer both functional benefits and opportunities for leisure, all while ensuring favorable thermal comfort conditions. It not only enhances the aesthetic appeal of the environment but also promotes sustainability by creating comfortable and inviting spaces for people to enjoy.

[SCIENTIFIC EVIDENCE]

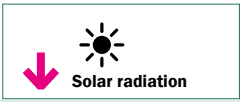
Field measurement in public housings in Hong Kong reveals that the cooling intensity of tree's shading and artificial structure's shading are comparable [2]. Nevertheless, the uncontrollable tree's crown size and trunk height can be supplemented by artificial structures. Especially for situations that can restrict the growth of trees, such as insufficient soil depth on podiums or roof-top.



❶ *Accomodate tree's condition*

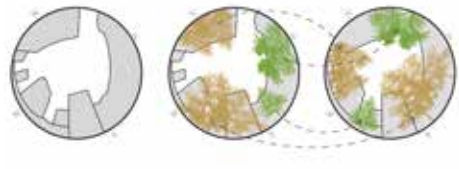
❷ *Select proper material*

[PRACTICAL GUIDE]



[EFFECTS]

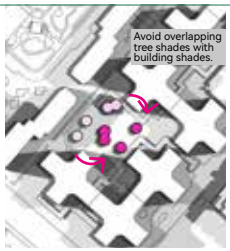
Measure 3 Optimize tree and building



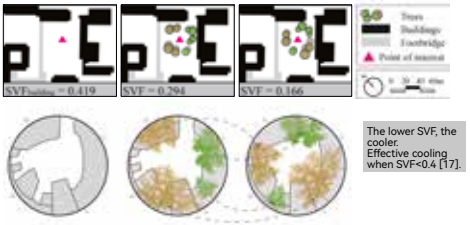
Optimize trees and buildings to make good use of different types of shading. Prioritizing the planting of trees in areas that are free from building shadows can enhance overall cooling effects. Conversely, overlapping the shades of trees and buildings is a less effective approach. By strategically positioning trees and buildings, it is likely to achieve optimal shading and create a more thermally comfortable outdoor environment.

[SCIENTIFIC EVIDENCE]

Optimizing trees and buildings for better cooling was found to provide twice cooling benefits in subtropical Hong Kong [16]. Study in Hong Kong's public housings reveals that sky view factor (SVF) can be used as a key indicator for building and greenery configuration in outdoor spaces. Effective cooling can be achieved by reducing SVF to below 0.4 by optimizing buildings and greenery, which jointly shape the sky openness [17].

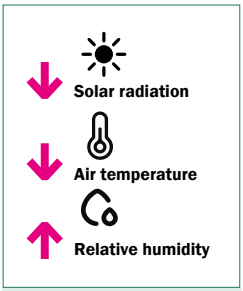


❶ *Avoid building shaded areas*

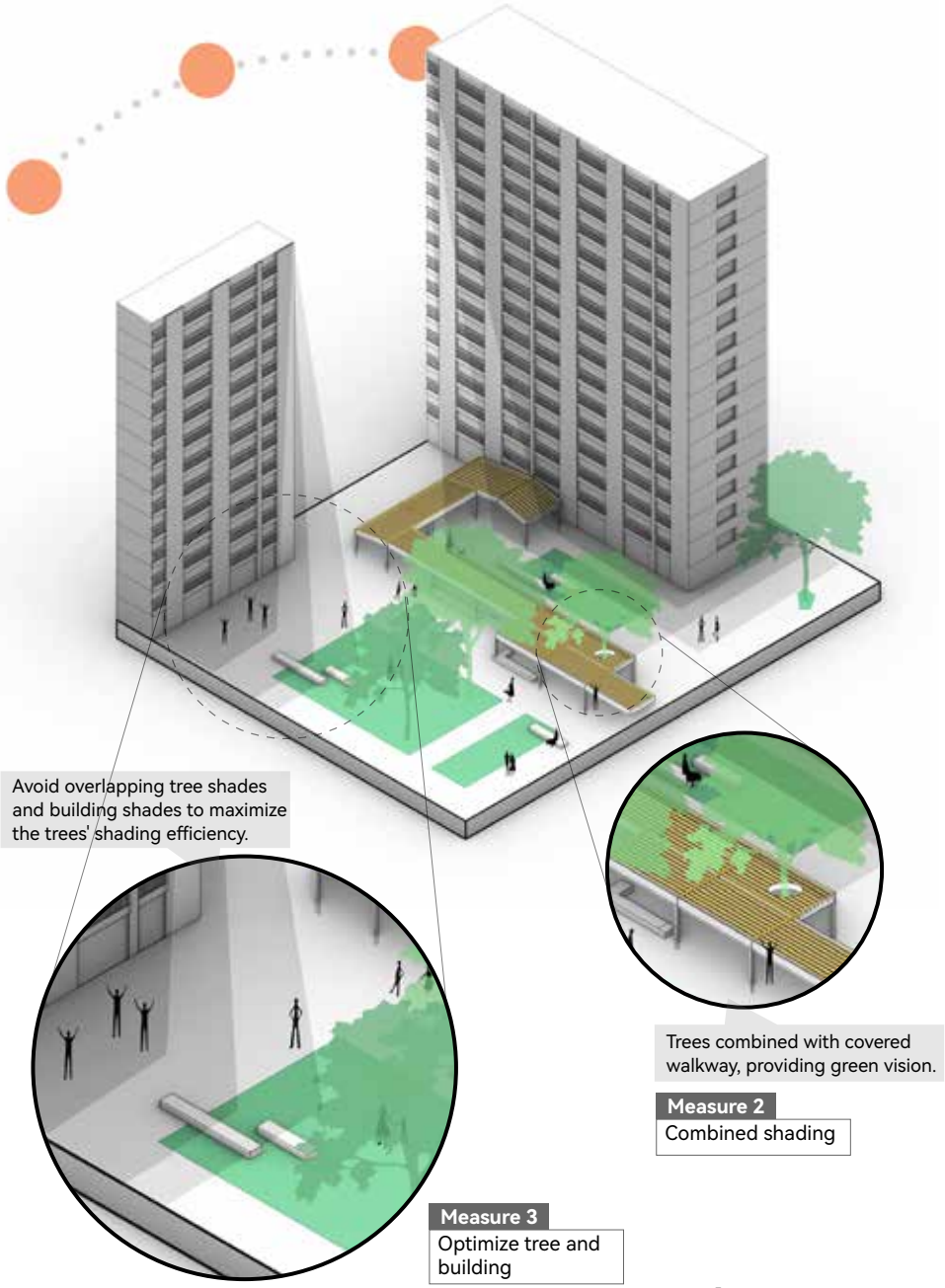


❷ *Reduce SVF to <0.4 for effective cooling by tree configuration*

[PRACTICAL GUIDE]



[EFFECTS]



[MEASURES COMBINATION]

IV EFFECTIVE COOLING MEASURES
for typological public spaces

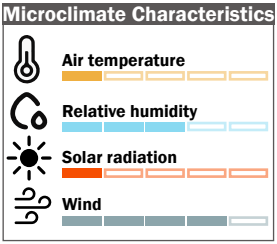
Instagram, @hk_estate_centres, "Kai Yip Estate", posted on July 13, 2022.

03

Feasible cooling measures in **SEMI-OUTDOOR SPACES**

Spaces enclosed by buildings or structures, such as pilotis, corridors, shelters, and shaded terraces. These spaces included daily communal spaces, and are frequently designed as spaces for resting and light sporting activities.

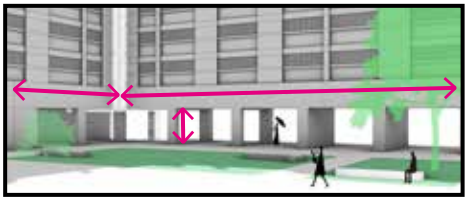
As Semi-outdoor spaces are mostly shaded and free from solar radiation, occupants face less heat stress, yet the ventilation and visual quality in these spaces are crucial considerations.



Measure 1	Enhance porosity, connectivity, and volume
Measure 2	Combine shade-tolerance greenery

IV EFFECTIVE COOLING MEASURES for typological public spaces

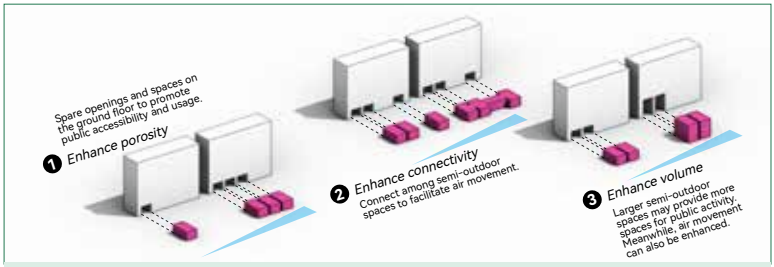
Measure 1 Enhance porosity, connectivity, and volume



Enhance the porosity, connectivity, and volume of the semi-outdoor spaces. It may dramatically improve natural ventilation and improve the thermal comfort condition in these shaded spaces. It is crucial to consider the solar angle to determine which areas receive sunlight. By enhancing the functionality and versatility of these spaces, individuals can encourage increased activity and engagement, further improving the overall experience.

[SCIENTIFIC EVIDENCE]

Previous studies observed that the morphology of semi-outdoor spaces is associated with the microclimate conditions. The height-to-depth radio of semi-outdoor spaces as found a crucial indicator, and the higher the ratio, the higher the mean radiant temperature and the wind velocity [18]. And enhancing wind velocity in semi-outdoor spaces by creating horizontal and vertical breezeways should be prioritized to enhance thermal comfort condition [19].



[PRACTICAL GUIDE]

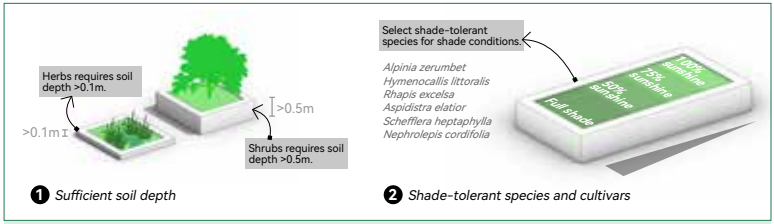
[EFFECTS]

Measure 2 Combine shade-tolerance greenery

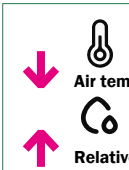
Incorporate vegetation planting in semi-outdoor spaces to enhance cooling and visual quality. Green walls, planters, and potteries are feasible options for introducing plants in semi-outdoor spaces. The plants not only provide evaporative cooling, but they also add aesthetic appeal to the space. It is advisable to prioritize shade-tolerant plants that can adapt well to the shaded environment, ensuring their optimal growth and longevity. By incorporating vegetation, semi-outdoor spaces can benefit from both the cooling effects and the visual beauty of lush greenery.

[SCIENTIFIC EVIDENCE]

Greenery elements in semi-outdoor spaces are found effective in enhancing relative humidity and reducing mean radiant temperature [18], nevertheless, the suitable species shall be dependent on the solar radiation condition in the semi-outdoor spaces. Moreover, the psychological benefits of greenery may also enhance the subjective thermal comfort, as visions of green elements also enhance perceived thermal comfort [20].



[PRACTICAL GUIDE]

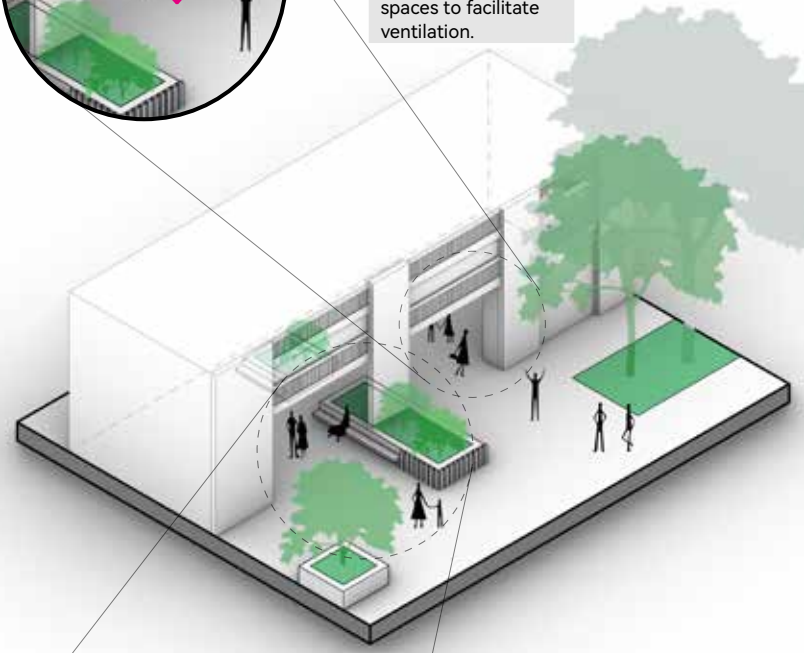


[EFFECTS]

Measure 1

Enhance porosity, connectivity, and volume

Enlarge the openings of the semi-outdoor spaces to facilitate ventilation.



Some shade-tolerent species that can be used in semi-outdoor spaces.

Measure 2

Combine shade-tolerance greenery

[MEASURES COMBINATION]

IV EFFECTIVE COOLING MEASURES for typological public spaces

Considering the heat risk level of the site, proportion of different types of outdoor spaces should be considered. Cooler types of spaces are advised to be prioritized. Additionally, the intensity of different cooling measures in corresponding space types should also be tactically considered.

HIGH HEAT-RISK REGION

OPEN SPACES — 50%

Measure 1	Utilize building shade	+ + + + + +
Measure 2	Covered walkway	+ + + + + +
Measure 3	High-reflectance Pavement material	+ +
Measure 4	Temporary shading device	+ + + + + +
Measure 5	Water feature	+ + + +
Measure 6	Mist spraying	+ + +

VEGETATED SPACES — 35%

Measure 1	Proper plant type and species	
	Tree (broad-leaf)	+ + + + + +
	Shrub	+
Measure 2	Combined Shading	+ + + + +
Measure 3	Optimize tree and building	+ + + + + +

SEMI-OUTDOOR SPACES — 15%

Measure 1	Enhance porosity, connectivity, and volume	+ + + + +
Measure 2	Combine shade-tolerance greenery	+ + + +

MEDIUM
HEAT-RISK
REGION

LOW
HEAT-RISK
REGION

50%

+ + + + +
+ + + + + +
+ +
+ + + + +
+ + +
+ +

60%

+ + + + +
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35%

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30%

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15%

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10%

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EXTENDED READING
of relevent guidelines

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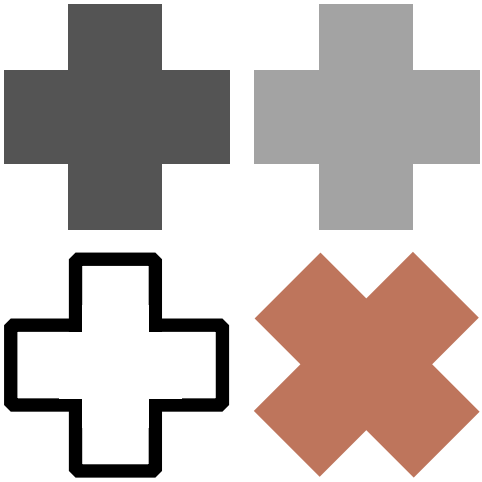

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