HKGBC Guidebook on Urban Microclimate Study

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Guidebook on Urban Microclimate Study

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About HKGBC

The Hong Kong Green Building Council Limited (HKGBC) is a non-profit, member led organisation established in 2009 with the vision to help save the planet and improve the wellbeing of the people of Hong Kong by transforming the city into a greener built environment. The Founding Members of HKGBC include the Construction Industry Council (CIC), the Business Environment Council (BEC), the BEAM Society Limited (BSL) and the Professional Green Building Council (PGBC). Its mission is to lead market transformation by advocating green policies to the Government; introducing green building practices to all stakeholders; setting design, construction and management standards for the building profession; and promoting green living to the people of Hong Kong.

To learn more about the HKGBC, please visit www.hkgbc.org.hk.

Our Vision

To help save the planet and improve the wellbeing of the people of Hong Kong by transforming the city into a greener built environment.

Our Mission

To lead market transformation by advocating green policies to the Government; introducing green building practices to all stakeholders; setting design, construction and management standards for the building profession; and promoting green living to the people of Hong Kong.

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Message from

Secretary for the Environment

Climate change is a critical global issue and extreme weather events are expected to increase. To mitigate the impact to Hong Kong brought about by climate change such as extreme hot weather, adoption of urban and building designs with consideration of urban climate will be essential to improve the liveability of local built environment.

Over the years, the government has implemented a range of policies to encourage district cooling, urban greening, energy conservation, and improvement in air quality. The Climate Action Plan 2030+ launched by the Government further pointed to the importance of consideration of the urban climate in adapting to climate change. Specifically, the strategies provided in the Hong Kong Urban Climatic Planning Recommendation Map will help improve urban thermal comfort and the wind environment through optimising the planning and design of the city.

The Guidebook on Urban Microclimate Study, introduced by the Hong Kong Green Building Council (HKGBC), puts forward guidelines and strategies to further help industry practitioners implement measures beneficial to both their own projects and the wider public. It provides a good summary of feasible approaches to good urban microclimatic designs.

I wish to express my appreciation to the HKGBC for its efforts in promoting the sustainable built environment in Hong Kong. The Guidebook on Urban Microclimate Study is a valuable contribution to the environmental awareness and efforts in both the public and private sectors.

Mr WONG Kam-sing, GBS, JP
Secretary for the Environment

Foreword from

Chairman of HKGBC

On behalf of the Hong Kong Green Building Council (HKGBC), we take great pleasure in presenting the Guidebook on Urban Microclimate Study (the Guidebook) for designing a more sustainable, resilient and comfortable city.

Founded in 2009, the HKGBC is committed to introducing and promoting green building practices to construction industry practitioners, developers, owners, operators and occupants of schools, shops, hotels, offices and the general public. A number of guidebooks have been published over the years for different types of buildings to foster the concept of green building and living. To further enhance the awareness of the impact of the built environment on city dwellers, HKGBC now presents its fifth guidebook to provide easy-to-understand microclimatic knowledge and good design practice to practitioners and the general public.

The Guidebook provides the inspiration and the necessary knowledge for urban microclimate designs through introducing four key parameters namely wind, thermal radiation, temperature, and precipitation. Thirty one strategies are introduced to optimise microclimate conditions.

We would like to take this opportunity to thank the Steering Committee on HKGBC Guidebook on Urban Microclimate Study for their contribution in the development of the Guidebook. We are also grateful for the assistance provided by professional bodies, universities and green organisations in compiling the case studies featured in the Guidebook. Finally, we would like to express our gratitude to the Construction Industry Council (CIC) for its funding support for this project.

We trust the Guidebook provides useful information and inspiration for the building industry in the creation of a healthier and more comfortable urban environment. The engagement of a wide range of stakeholders is essential in building a sustainable city for both our current and future generations. Let's work together to make Hong Kong greener.

Mr CHEUNG Hau-wai, SBS
Chairman, Hong Kong Green Building Council

Executive Summary

The HKGBC Guidebook on Urban Microclimate Study provides the knowledge of and inspiration for urban microclimate design. In the Guidebook's easy-to-understand chapters, the science and principles of urban microclimate studies are introduced, strategies to optimise the microclimate conditions are stipulated, and good practices—both local and overseas— are reflected on. Recommendations for further studies and policy adjustments are made at the end of the Guidebook.

The Guidebook's introduction chapter defines the audience, scope and need of urban microclimate studies. Urban microclimate design is taken as a set of practices aiming at improving the outdoor environment where people spend their everyday lives. Only the outdoor environment and physical aspects of wellbeing and comfort are considered in the Guidebook. Indoor environment, and the social and psychological aspects are excluded. The scientific understanding of urban microclimate, its link to climate change and the benefits of good urban microclimate design are spelt out in the chapter. The idea of thermal comfort and the context of Hong Kong are also introduced.

The second chapter lays the ground work for the case analyses in subsequent chapters by introducing the key parameters and strategies in urban microclimate design. The four key parameters are wind, thermal radiation, temperature, and precipitation, under which 31 strategies are introduced. Linkage to the BEAM Plus rating system is also investigated.

The third chapter then studies good practices in other areas that share similar climatic characteristics with Hong Kong and explores the feasibility to adopt their strategies in the city. The chosen cases are Japan, Singapore, Australia and Macau. Their policies, guidelines and featured building projects are reviewed in this chapter.

Development projects with good microclimate considerations in Hong Kong are subsequently presented. The cases are selected from the shortlisted projects of Green Building Award 2012, 2014 and 2016, and BEAM Plus Platinum (Final Assessment). They represent good practices under different construction scenarios in Hong Kong in terms of density and the plot size. The form of urban microclimate studies and strategies employed in the projects are analysed.

The final chapter concludes the study by making suggestions in the areas of science and technology development, policy, practice and design, and public awareness and education. The Guidebook in general calls for concerted efforts among the Government, industry and public in improving the city's urban microclimate.

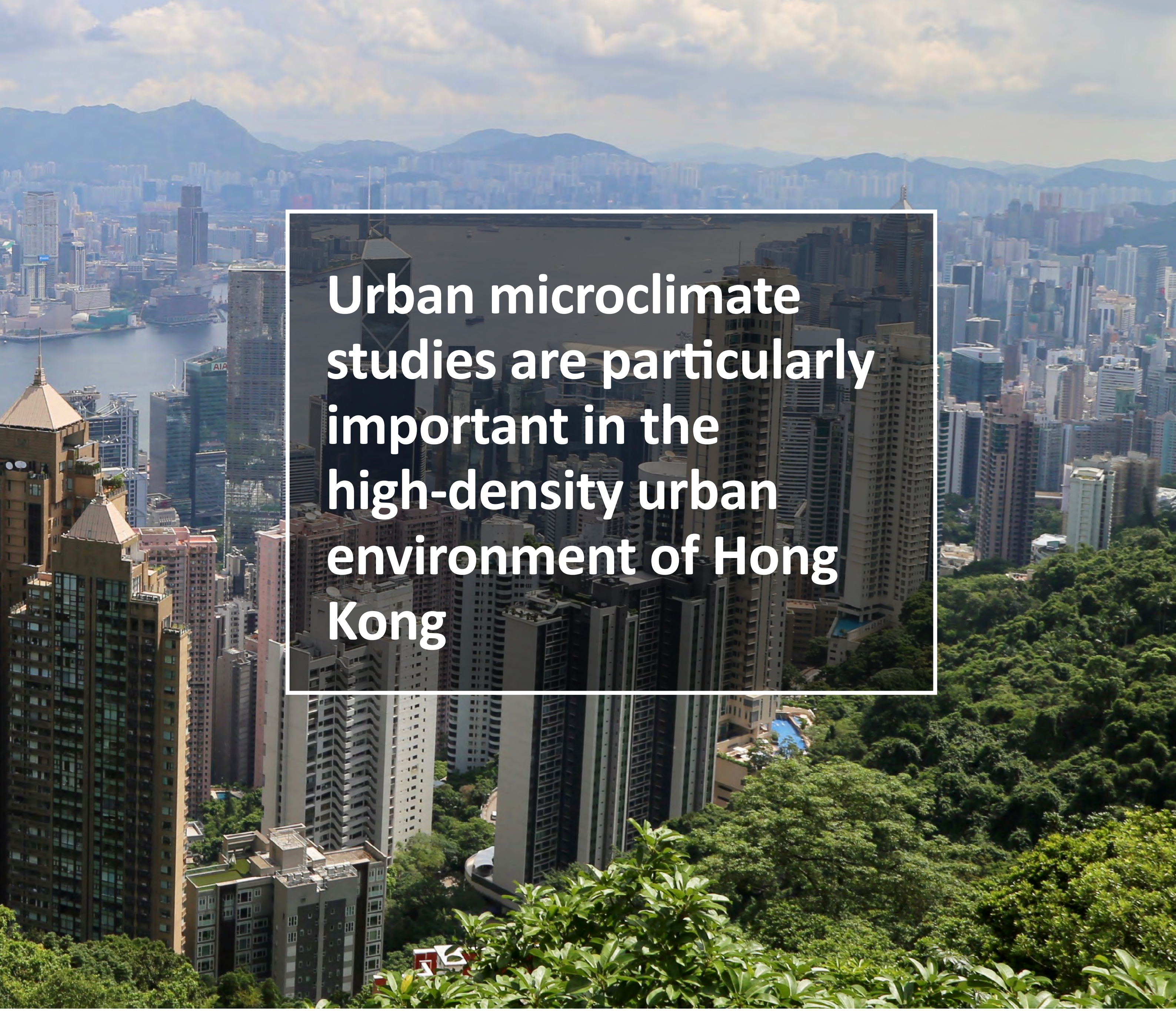
CHAPTER 1

Introduction

In Hong Kong's high-density and sub-tropical environment, comfort is an important factor in people's use of the outdoor space. The intense Urban Heat Island (UHI) effect in Hong Kong means high temperature in built-up areas and uncomfortable urban living. It leads to heat stress and other related health problems. The issues of health and comfort in the outdoor space become even more complicated in face of the challenges brought about by climate change.

The building industry plays an important role in the improvement of the urban microclimate, for example, by using lighter colours in façades, providing shading, and incorporating greenery. The improved and more pleasant outdoor environment will in turn attract more visitors, reduce energy use in buildings and enhance the enjoyment of natural ventilation indoors.

It is the goal of the Guidebook to give the industry's professionals and practitioners the inspiration and knowledge to consider projects' impacts on the urban microclimate. The ideas introduced in the Guidebook will facilitate their communication with specialists.



Urban microclimate studies are particularly important in the high-density urban environment of Hong Kong

In the Guidebook, the science and principles of urban microclimate studies will be introduced. Strategies to optimise the microclimate conditions will be stipulated and reflected on with both local and overseas case studies and good practices. Recommendations for further studies and policy adjustments will also be made.

In the Guidebook, we take urban microclimate design as a set of practices aiming to optimise the climate variables of a small-scale area within the urban canopy layer to achieve better human physical wellbeing and comfort. The technical terms involved in this definition will be duly explained in the next section.

The rest of the Guidebook takes readers through guidelines and examples that are particularly relevant to Hong Kong's hot and humid sub-tropical climate. With better understanding of the dynamics between the built environment and the microclimate, and improved awareness in the building industry, Hong Kong's urban living will become more comfortable and healthier.

Scientific Background - Key ideas

Climate is a generic term covering a wide range of spatial scales—from macro to micro (Figure 1). While climate at the macro scale is determined by a range of global factors, urban microclimate is more about the interactions between the local built environment, human activities and climates at larger scales.

However complicated it may sound and can get, the basic idea of urban microclimate can be summarised with the five elements below:

Scale	The urban climate consists of the urban canopy layer (UCL) and the urban boundary layer (UBL) (Figure 2). Urban microclimate happens within the UCL, where people live and work. Thus, urban microclimate affects people's quality of life significantly in terms of both comfort and health. With regards to physical scales, the urban microclimate scale of 1m to 10m covers indoor climate and street canyon, while that of 10m to 1000m covers the neighbourhood and the climatic variation within[1].
Components	Urban microclimate is determined by (a) local air velocity, temperature and humidity; (b) solar radiation and reflection; (c) surface temperatures of buildings and ground, and (d) long-wave radiation exchange[2]. The forms of urban development and human activities can change the energy balance, and thus climate, of an urban area.
Factors/Influences	A city's location, metabolism, urban setting, time and weather all affect its urban microclimate, as explained in Figure 3. For example, compact urban development reduces urban air flow and results in poor ventilation. Urban heat and air pollutants will be trapped, and residents' health will consequently be jeopardised.
Well-known phenomenon	Urban Heat Island (UHI) is an extensively studied microclimate phenomenon in dense urban areas. It refers to the relatively higher temperature in built-up areas compared to the surrounding rural parts. High UHI leads to higher energy consumption, thermal discomfort and higher heat-related mortality in the summer.
Benefits	The cumulative effect of localised measures over time will eventually benefit the whole city and people from all walks of life. In general, the outdoor environment will become more pleasant. Thermal comfort, especially under hot and humid conditions in summer, will be improved, and energy consumption will be reduced.

1. Mayor of London. London's Urban Heat Island: A Summary for Decision Makers. London: Greater London Authority, 2006.
2. Dorer, Viktor, et al. "Modelling the urban microclimate and its impact on the energy demand of buildings and building clusters." Proceedings of BS 2013 (2013): 3483-3489.

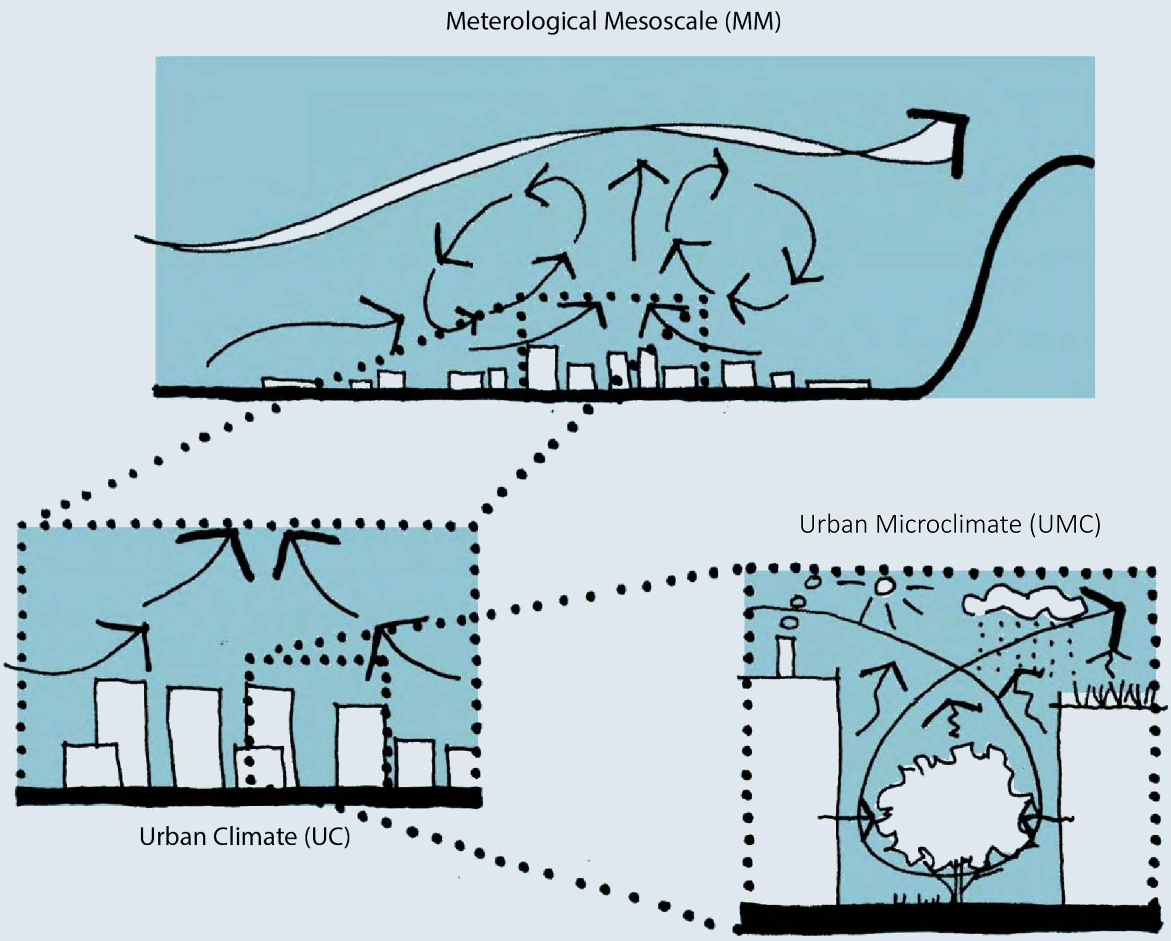


Figure 1 Different scales in climatic studies [3].

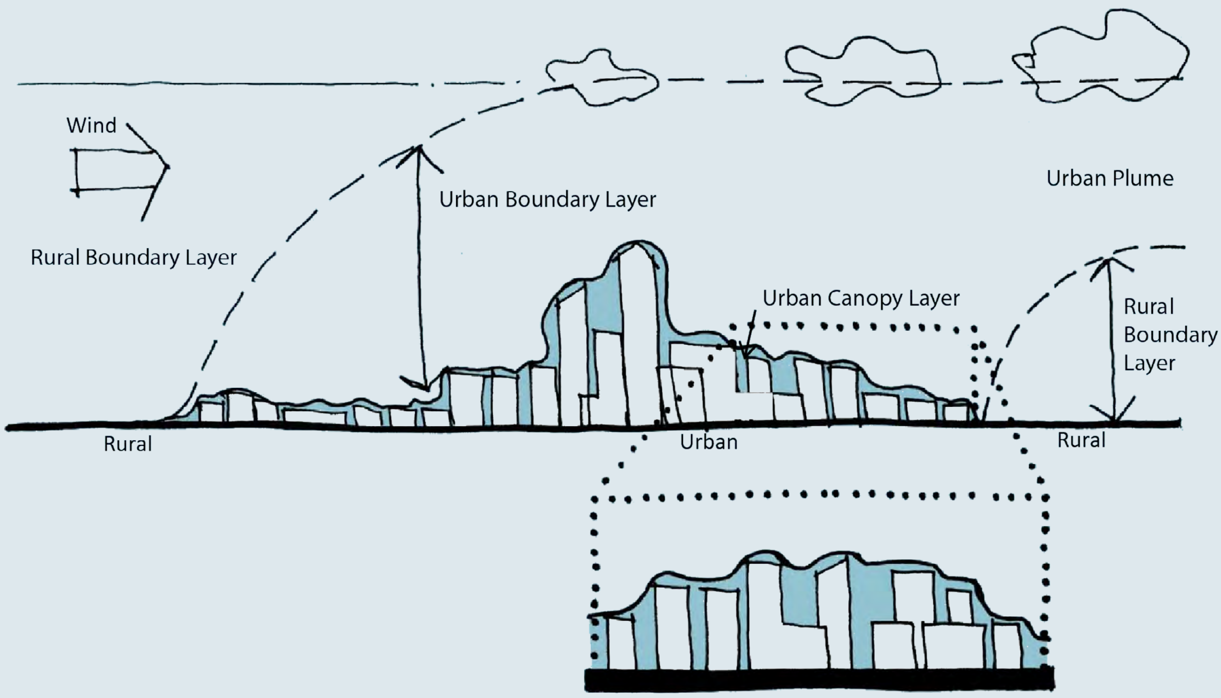


Figure 2 Urban boundary layer and urban canopy layer.

3. Dorer, Viktor, et al.

Why Climate Change Matters

Climate change is mainly driven by the increased concentration of greenhouse gases in the atmosphere. It is extremely likely that greenhouse gas emissions by human activities are the main contributor of the warming trend[4]. Climate change can bring serious threats to both the natural environment and human settlements. Key risks include heatwave and heat-related mortality, flooding, food and water security and urban poverty, as summarised in Table 1.

Cities are vulnerable to climate risks. In Hong Kong, extreme weather events such as heatwaves could become more frequent, leading to rising electricity bills and health costs for both residents and businesses[5]. Although climate change is often spoken of or projected at a broader scale, considerations at the local scale are equally important as that is where the impacts are most felt.

Cities present great opportunities for both adaptation and mitigation, particularly as the majority of the world population now lives in urban areas[6]. When it comes to urban climate strategies, the focus is on adaptation. Through land use planning, building design and the use of urban greenery, heatwaves and heat-related mortality can be duly managed. At the same time, if the urban climate is well taken care of, energy use and carbon emissions in cities can be reduced, and the adverse impact of climate change can be minimised.

Key Risks	Urban Climate Strategy
Heatwave and heat-related mortality	Urban Land Use Building Design Urban Vegetation
Flooding and related deaths, injuries, diseases	Urban Infrastructure Seawall and Drainage Water Supply Network
Food and water security	Urban Planning Population Control
Urbanisation and urban poverty	Urban Governance City Planning and Design

Global Climate → **Urban Climate**

Table 1 Climate change and urban climate.

4. Hong Kong Observatory. Hong Kong in a Warming World. Hong Kong: HKSAR Government, 2015.
5. Environment Bureau. Hong Kong Climate Change Report. Hong Kong: HKSAR Government, 2015.
6. Intergovernmental Panel on Climate Change . Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects. Cambridge University Press, 2014.

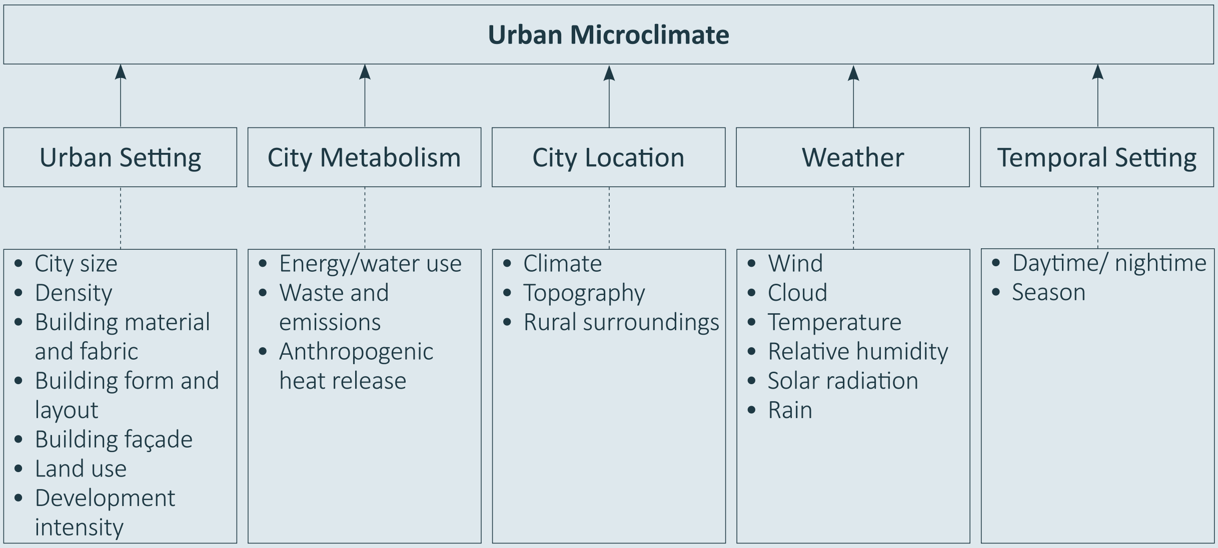


Figure 3 Factors influencing the urban microclimate[7].

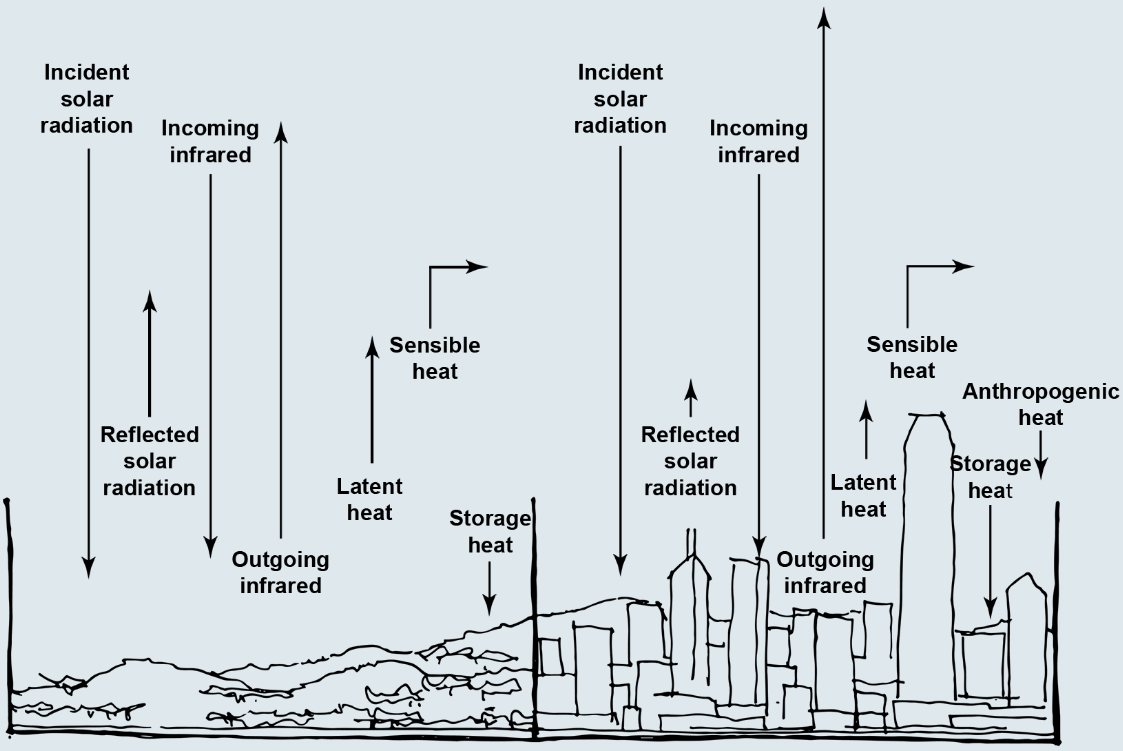


Figure 4 A comparison of energy balances in typical rural and urban settings.

7. Oke, T. R.,. Boundary Layer Climates. London; New York: Routledge, 1987.

What is Outdoor Human Thermal Comfort?

A major objective of urban microclimate design is to enhance the outdoor environmental quality and to provide a thermally comfortable environment for pedestrians. To evaluate the urban microclimate of an outdoor space, human thermal comfort is commonly referred to. It describes the perception of the surrounding thermal environment in relation to the subject's satisfaction. It is determined by personal preferences and external climatic factors that interact with the human body, such as wind, solar radiation, humidity, temperature, clothing, metabolic rate, etc. Several scientific methods have been developed to estimate the level of human thermal comfort at an outdoor space at any given time. With the assumption of similar personal preferences, the evaluation of human thermal comfort can be simplified to consider only the climatic factors. A thermally comfortable outdoor space can be achieved through careful architectural and landscape considerations for the urban microclimate.

There are several widely accepted methodologies to measure outdoor human thermal comfort. Two commonly used methods in Hong Kong are Thermal Sensation Index (TSI)[8] and Physiological Equivalent Temperature (PET)[9]. Both methodologies are used in the evaluation of outdoor thermal comfort in BEAM Plus Neighbourhood Version 1.0 under Outdoor Environmental Quality (OEQ) credit 1.

8. Givoni, B., M. Noguchi, H. Saaroni, O. Pocher, Y., Yaacov, N. Feller and S. Becker.,. Outdoor comfort research issues. Energy and Buildings vol. 33, pp. 77-86, 2003.
9. Hoppe, P.,. The physiological equivalent temperature—A universal index for the biometeorological assessment of the thermal environment. International Journal of Biometeorology, vol. 43, pp. 71-75, 1999.

Thermal Sensation Index (TSI)

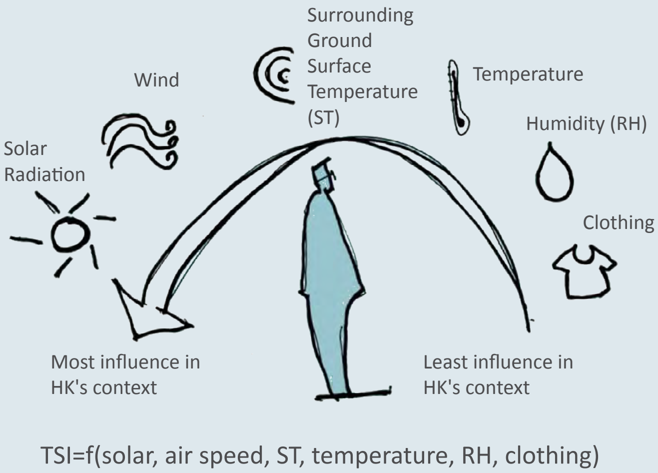
TSI is an empirical model developed by studies conducted in the context of Japan. It considers five climatic factors— air temperature, horizontal solar radiation, wind speed, relative humidity and mean radiant temperature— at a given location and time. TSI's prevalence in Hong Kong can be explained by its user-friendly nature. Particularly, it is the index that public housing projects in Hong Kong adopt.

TSI is subdivided into a scale of seven levels, where level 1 is cold, and level 7 is hot. While level 4 is considered neutral, a TSI between 3 and 5 is deemed thermally acceptable, where no major discomfort is expected.
TSI can be calculated by the following formula:

$$TSI = 1.7 + 0.1118Ta + 0.0019SR - 0.322WS - 0.0073RH + 0.0054ST$$

Where,
Ta = air temperature (°C)
SR = horizontal solar radiation (W/m2)
WS = wind speed (m/s)
RH = relatively humidity (%)
ST = surrounding ground surface temperature (°C), assumed to be Ta+3°C for TSI calculation

Figure 5 shows the various climatic factors TSI considers in the order of importance in a sub-tropical region.



TSI	Thermal sensation	
1	Cold	Too cold
2	Slightly cold	
3	Acceptably cool	Thermally acceptable range
4	Neutral	
5	Acceptably warm	
6	Slight hot	Too hot
7	Hot	

Figure 5 Thermal sensation index.

Physiological Equivalent Temperature (PET)

PET is another widely used index for assessing the thermal environment. The analytical model is derived from the Munich Energy-balance Model for Individuals (MEMI), which models the thermal conditions of the human body in a physiologically relevant way. PET is applicable to any given place (both outdoor and indoor) and represents the equivalent air temperature at which, in a typical indoor setting, the heat balance of the human body is maintained with core and skin temperatures equal to those under the conditions being assessed.

PET thermal perceptions classifications are defined for both sub-tropical and temperate regions. In Hong Kong, the classification for sub-tropical region is used, where a PET between 22°C and 34°C is considered comfortable.

In a high-rise high-density context, PET under "light air" urban ventilation conditions (0.5<v<1.5m/s) can be obtained by the following formula[10]:

$$\mathbf{PET = 1.2Ta - 2.2v + 0.52(Tmrt - Ta)}$$

Where,
Ta =air temperature (°C)
v =wind speed (m/s)
Tmrt = mean radiant temperature (°C), assumed 0-3°C under shade, 10°C under cloudy sky and 40-60°C under direct sun

Thermal Perception	TPC for sub-tropical region	Range of thermal comfort
Very cold	<14	Too cold
Cold	≥14 to <18	
Cool	≥18 to <22	
Slightly cool	≥22 to <26	Range of thermal comfort
Neutral	≥26 to <30	
Slightly warm	≥30 to <34	
Warm	≥34 to <38	Too hot
Hot	≥38 to <42	
Very hot	≥42	

Table 2 Thermal perception classification (TPC) and range of thermal comfort according to PET[11].

10. Planning Department. Urban Climatic Map and Standards for Wind Environment - Feasibility Study, Hong Kong: HKSAR Government, 2012.
11. Lin, T. P., Matzarakis, A. 'Tourism climate and thermal comfort in Sun Moon Lake, Taiwan', International Journal of Biometeorology, vol. 52, pp. 281-290, 2008.

Hong Kong Context

Residents in Hong Kong are no stranger to its hot and humid summers. The sub-tropical heat is further magnified by the city's high-density development which causes UHI. Research carried out by the Hong Kong Observatory attributed the city's warming trend mainly to global climate change and local urbanisation effect, with the latter estimated to have contributed to up to half of the observed warming[12,13]. As temperature rises, urban living has become more uncomfortable, with heat stress and related health problems becoming a major concern. Energy use in cooling is also on the rise.

The numbers of very hot days (daily maximum air temperature greater than or equal to 33°C) and hot nights (daily minimum air temperature greater than or equal to 28°C) in Hong Kong have increased dramatically over the years as a result of UHI[14].

Decade	Number of very hot days[15] (decadal average)	Number of hot nights[16] (decadal average)
1950-59	10.2	1.1
1960-69	20.3	4.9
1970-79	11.8	5.3
1980-89	8.6	13.7
1990-99	8.9	18.3
2000-09	13.4	20.1
2010-16 (7 years)	24.1 (avg of 7 years)	26.4 (avg of 7 years)

Table 3 Number of very hot days and hot nights in the past seven decades.

12. Hong Kong Observatory. Hong Kong in a Warming World.
13. Chan, H.S., Kok, M.H. & Lee, T.C. Temperature trends in Hong Kong from a seasonal perspective, Clim Res, vol. 55, no. 1, pp. 53-63, 2012.
14. Hong Kong Observatory, Statistics of special weather events, accessed 2017, http://www.hko.gov.hk/cis/statistic_e.htm.
15. Hong Kong Observatory. Number of very hot days observed at the Hong Kong Observatory since 1884, exclude 1940-1946, accessed 2017, http://www.hko.gov.hk/cis/statistic/hngtday_statistic_e.htm.
16. Hong Kong Observatory. Number of hot nights observed at the Hong Kong Observatory since 1884, exclude 1940-1946, accessed 2017, http://www.hko.gov.hk/cis/statistic/hngtday_statistic_e.htm.

Review of Planning and Design Guidelines in Hong Kong

The quality of the urban environment can be improved with better planning and design. More wind can be channelled through the city fabric and heat stress can be relieved with a range of measures to be introduced in Chapter 2. In Hong Kong, various consultancy studies have been conducted by the Government on the urban climate. Many of them became actual guidelines and policies, as summarised in Table 4.

Time and respective department	Studies	Guidelines and policies	Levels of implementation
2003-2005 Planning Department	Feasibility Study for Establishment of Air Ventilation Assessment System	In 2005, the Housing, Planning and Lands Bureau and Environment, Transport and Works Bureau jointly issued a Technical Circular No. 1/06 on Air Ventilation Assessment.	• Building design • Master Layout Planning • District planning
		In 2006, Hong Kong Planning Standards and Guidelines (HKPSG) incorporated guidelines on air ventilation as Chapter 11.	• Urban design
2006-2009 Buildings Department	Building Design that Supports Sustainable Urban Living Space in Hong Kong	In 2009, the Council for Sustainable Development launched a public engagement process entitled "Building Design to Foster a Quality and Sustainable Built Environment" in collaboration with the Government.	• Building design • Master Layout Planning
		In 2011, the SBD Guidelines were developed to promote building separation, building set back and site coverage of greenery. They were promulgated in the Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers (PNAP) APP-152.	• Building design • Master Layout Planning
2006-2012 Planning Department	Urban Climatic Map and Standards for. Wind Environment - Feasibility Study	A review of Outline Zoning Plans (OZPs) was launched in 2007. It was carried out in phases and amendments have been made to the development parameters of the reviewed OZPs. Building height and other development restrictions were added to some of the amended OZPs.	• Master Layout Planning • District planning • Urban planning and design
			• Urban planning and design
2010-2013 Planning Department	Consultancy Study on Establishment of Simulated Site Wind Availability Data for Air Ventilation Assessment	Site Wind Availability Data for Hong Kong were made available online in 2013.	• Building design • Master Layout Planning • District planning

Table 4 Summary of consultancy studies conducted by the Hong Kong Government on urban climate.

The two main sets of guidelines on urban climate are *Air Ventilation Assessment (AVA)* and *Sustainable Building Design (SBD) Guidelines*. The AVA system was first introduced in 2006 based on the scientific understanding that thermal comfort can be achieved through enhancing natural ventilation[17]. AVA was subsequently incorporated as Chapter 11 in *Hong Kong Planning Standards and Guidelines (HKPSG)* in 2011[18]. Several qualitative guidelines on air ventilation at district and site level were recommended, as stipulated in Table 5.

In 2011, the Buildings Department (BD) of Hong Kong promulgated *Sustainable Building Design (SBD) Guidelines* to establish three key building design elements—"building separation", "building set-back" and "site coverage of greenery"[19]. The *SBD Guidelines* were refined in 2016 in the light of the experience gained.

The requirements for the three key building design elements are:

1) 20% to 33.3% permeability (Figure 6) is required for buildings in large site or buildings with a long façade, depending on their planes and height;
2) buildings abutting a street narrower than 15m wide shall be set back;
3) 20% to 30% site coverage of greenery is required depending on the size of the site.

Hong Kong has lately further looked into its future development vision in "*Hong Kong 2030+: Towards a Planning Vision and Strategy Transcending 2030*". Planning for a healthy city is one of its focuses, with microclimate considerations being a part of it. Suggestions to strengthen urban climatic and air ventilation considerations and to update the current AVA technical circular are made.

The dense built-up environment in Hong Kong leads to strong UHI effect.

17. Ng E., Cheng V. Urban Human Thermal Comfort in Hot and Humid Hong Kong, Energy and Buildings 55: 51-65, 2012. DOI: 10.1016/j.enbuild.2011.09.025
18. Planning Department. Hong Kong Planning Standards and Guidelines (HKPSG), Hong Kong: HKSAR Government, 2011.
19. Buildings Department. Sustainable Building Design Guidelines, Hong Kong: HKSAR Government, 2016.

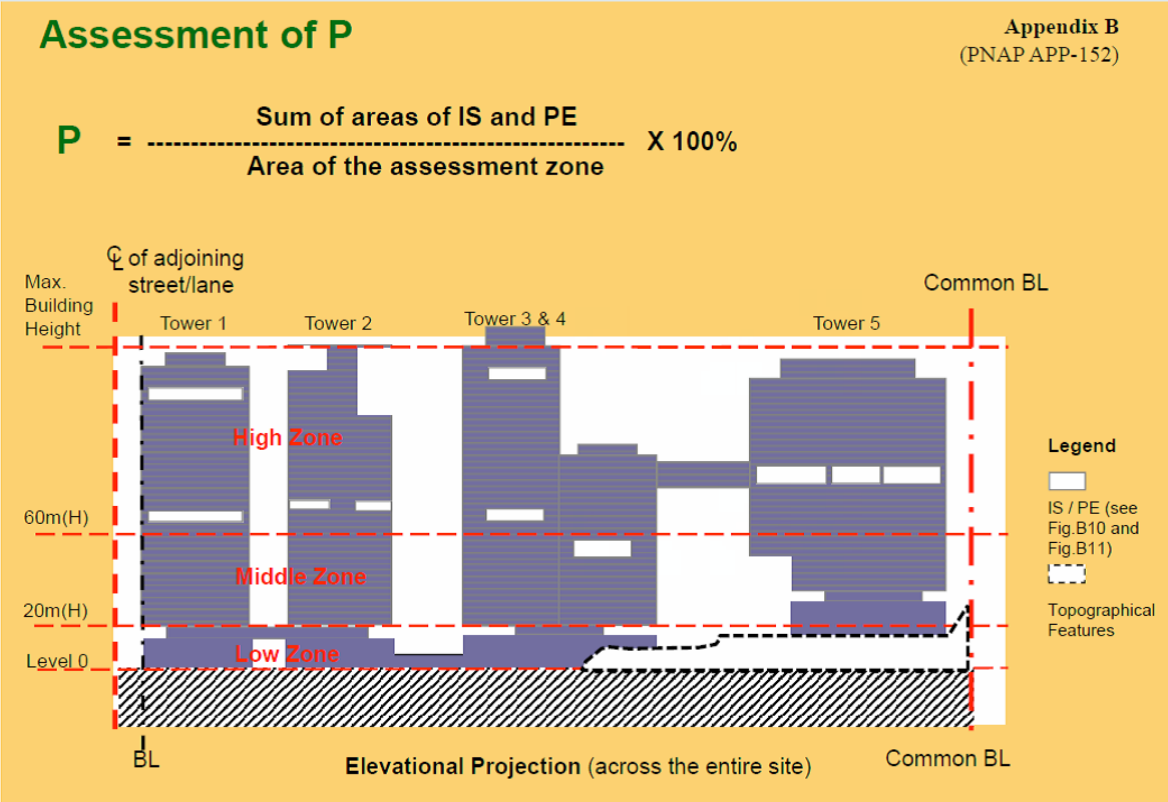


Figure 6 An illustration of the assessment of building permeability (P) in the SBD guidelines. IS in the graph refers to intervening space, PE is permeable element, and BL is boundary line.

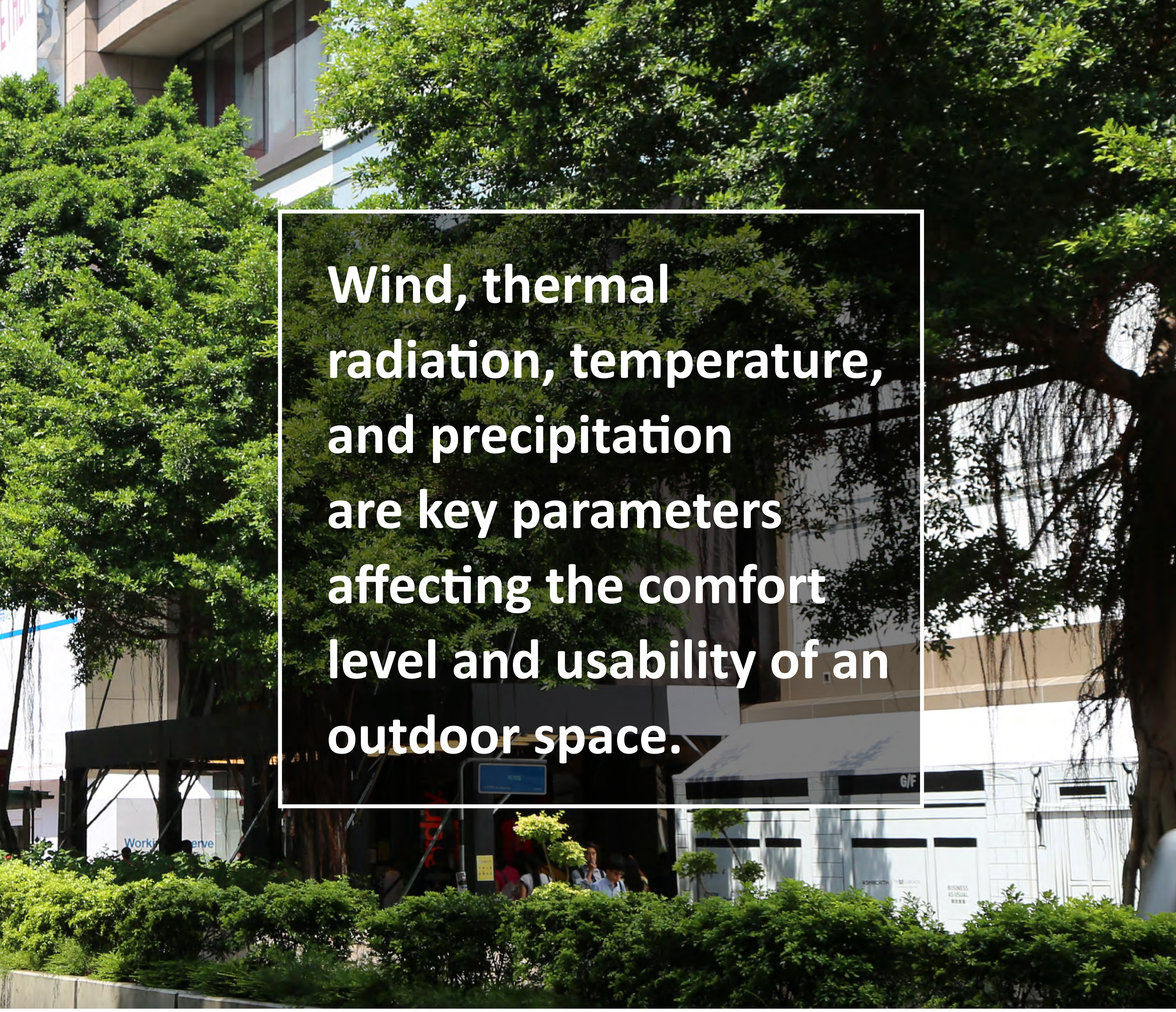
Level	**Qualitative guidelines**
District Level	(1) Site disposition
	(2) Breezeways/Air Paths
	(3) Street Orientation, Pattern and Widening
	(4) Waterfront Sites
	(5) Height Profile
	(6) Greening and Disposition of Open Space and Pedestrian Area
Site Level	(1) Podium Structure
	(2) Building Disposition
	(3) Building Permeability
	(4) Building Height and Form
	(5) Landscaping
	(6) Projecting Obstructions
	(7) Cool Materials

Table 5 Qualitative Guidelines on Air Ventilation in Chapter 11 of HKPSG.

CHAPTER 2

Guidelines for Urban Microclimate Design

Man's pursuit for a thermally comfortable environment through architecture dates back to ancient times. Over the years, valuable experience has been accumulated and the understanding of architecture and the environment has evolved. A set of factors has been found to have profound impact on urban microclimate and people's enjoyment of the outdoor environment. Considerations of these factors are becoming more important in the building industry not only because of its relation to the environment but also the added advantages of increased pedestrian activities and reduced energy use. This chapter provides a comprehensive tool set for designers to adopt microclimate friendly designs with concrete strategies and easy-to-understand illustrations. It also reminds practitioners of the importance of considering these measures at an early stage of design.



Wind, thermal radiation, temperature, and precipitation are key parameters affecting the comfort level and usability of an outdoor space.

31 urban microclimate design strategies categorised into 8 approaches

2.1 Wind
- Increase ventilation with site planning [01-07]
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2.2 Thermal Radiation
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2.3 Temperature
- Increase evaporative cooling [22-25]
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WIND

Increase ventilation with site planning

Major Breezeways

01 Manipulate layout massing to increase wind flow

02 Wind corridor to align with the prevailing wind

03 Connect open spaces

04 Arrange buildings to channel wind

Minor Breezeways

05 Building setback

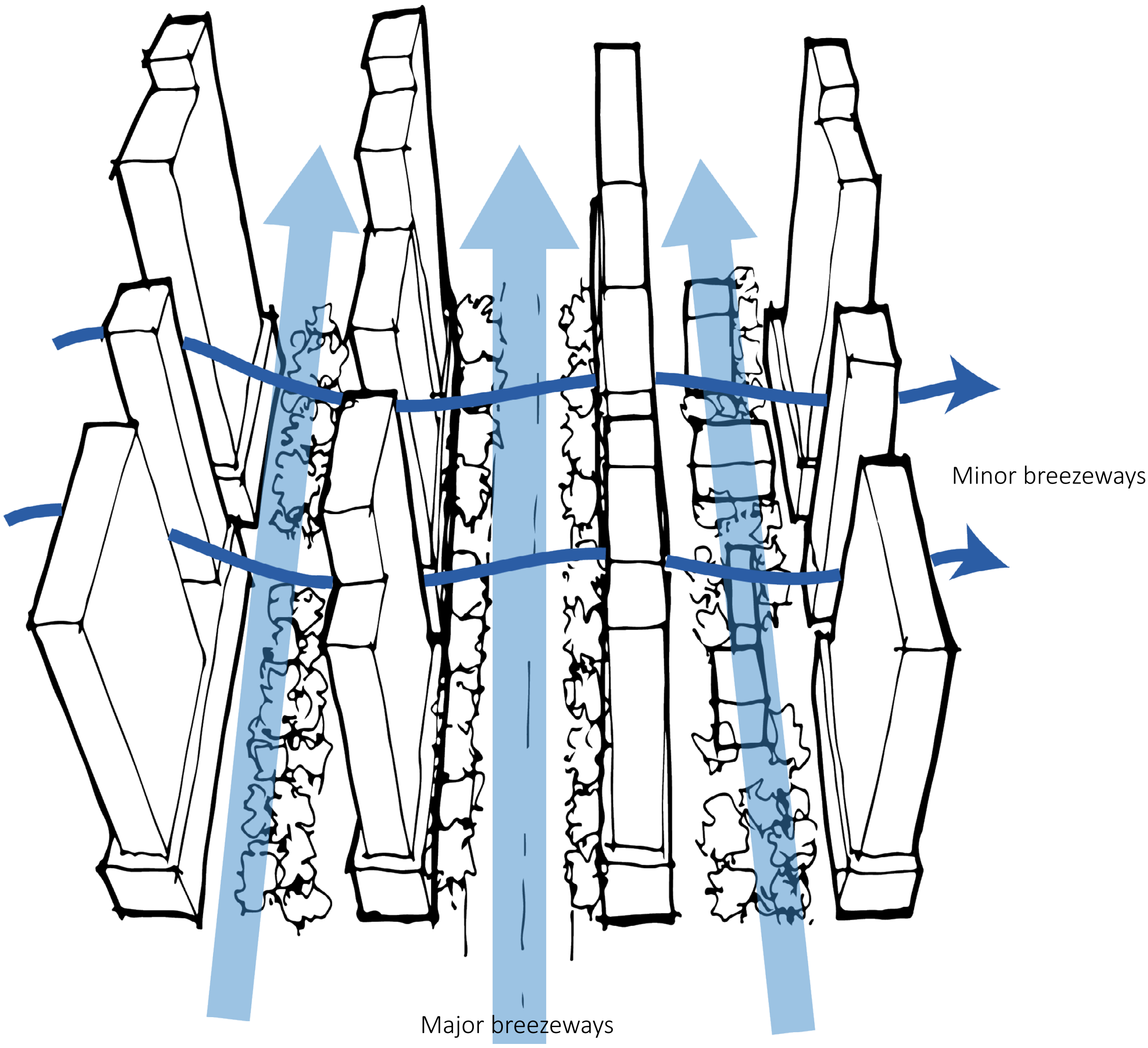
06 Increase permeability of building blocks / No wall building

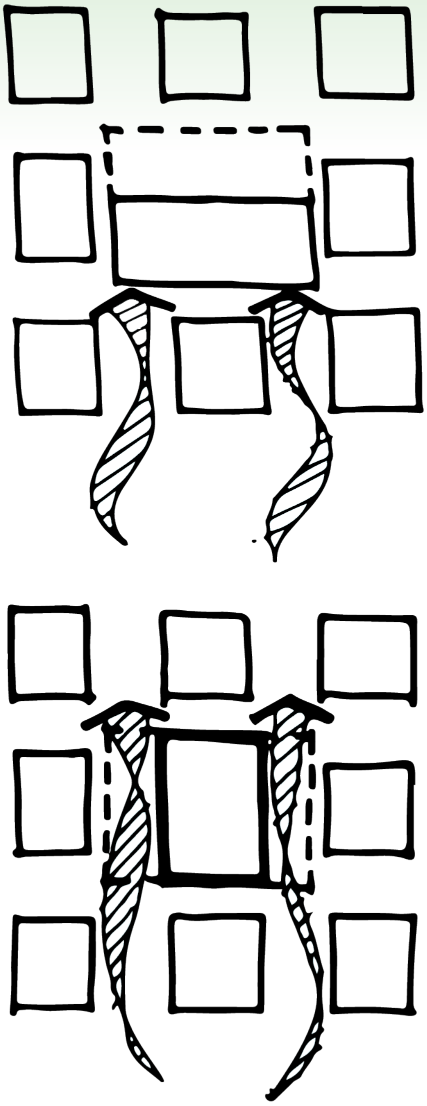
07 Stepped building height profile

Increase ventilation with site planning

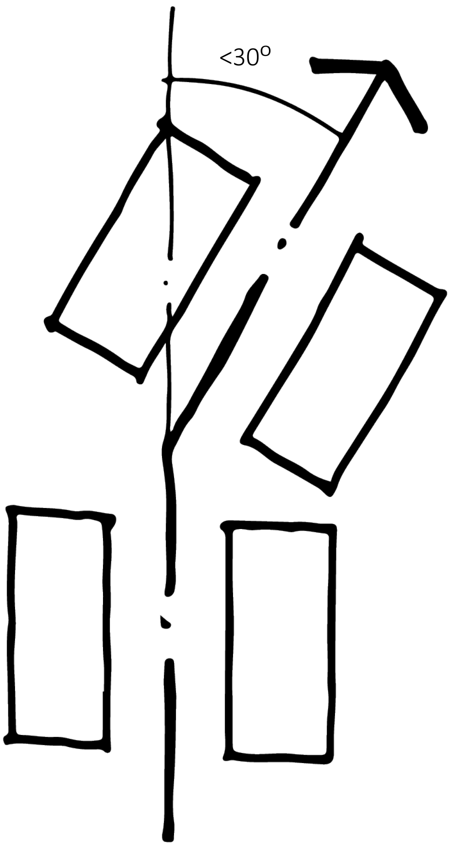
Heat accumulation within the urban canopy, and thus air temperature, can be reduced by improving ventilation. The increased air speed around a person will also accelerate sweat evaporation and therefore induce a cooler sensation.

Breezeways are a crucial element of ventilation in dense urban areas. Major breezeways are typically formed by linear roadways and open spaces where the prevailing wind flows along. Minor breezeways are formed by building separation that allows wind to penetrate through the development. During site planning, careful consideration of the building layout is important to maintain major breezeways and leave sufficient gaps between buildings to facilitate wind penetration.

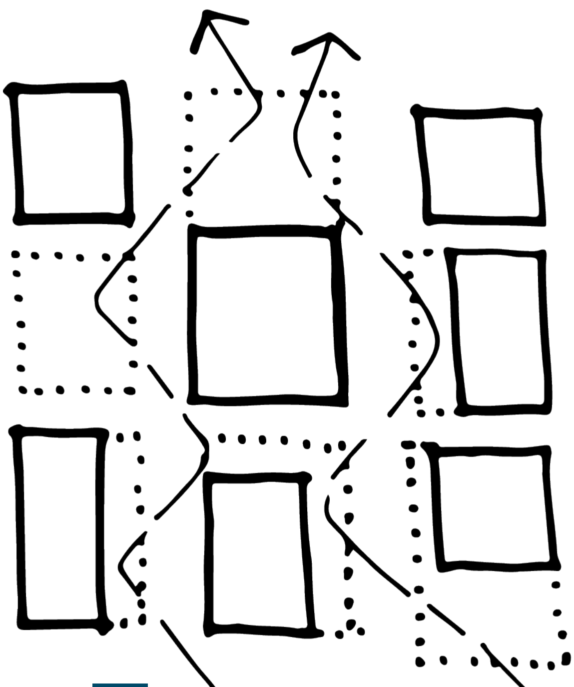




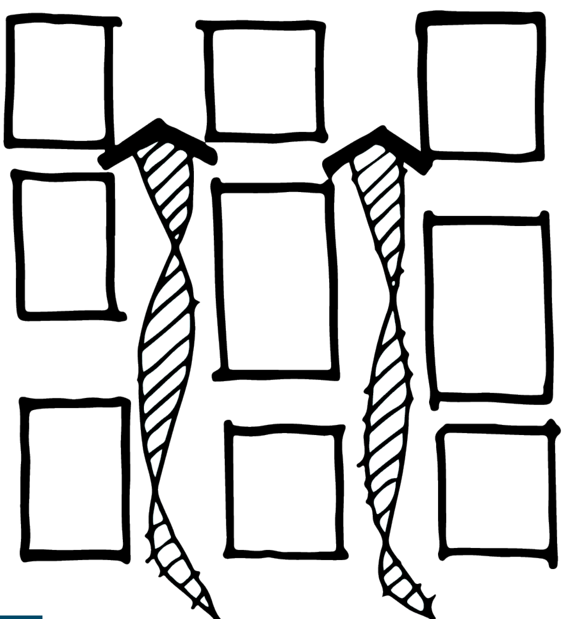
01 Manipulate layout massing to increase wind flow



02 Wind corridor to align with the prevailing wind



03 Connect open spaces



04 Arrange buildings to channel wind

Major breezeways

01 Manipulate layout massing to increase wind flow

Intent

Building disposition in a high-density high-rise urban environment often restricts wind flow. During site planning, layout massing should be considered and manipulated to enhance wind flow. (Cross reference: HKPSG Ch.11- Air Paths)

Implementation

When a development site covers a breezeway or wind corridor, avoid placing any building massing there, so the prevailing wind can flow through the urban district.

02 Wind corridor to align with the prevailing wind

Intent

Breezeways and air paths are commonly created as wind corridors in district planning in the forms of major roadways, inter-linked open spaces, non-building areas etc. Where applicable, building disposition in new developments should be designed to preserve these air paths. (Cross reference: HKPSG Ch.11- Orientation of Street Grids)

Implementation

Provide open spaces and building gaps within the site to enhance wind penetration through the development. Align these features with existing or planned breezeways and air paths to maintain good ventilation in the urban environment. They should be parallel to the incoming wind, or at an angle of no more than 30 degrees to the prevailing wind direction. There should not be more than one turning point.

03 Connect open spaces

Intent

Open spaces are often scattered across an urban area. These spaces consist typically of low-rise structures which can form part of the area's breezeway. When the open spaces are connected, the microclimate, particularly in terms of ventilation, of these areas will be improved. (Cross reference: HKPSG Ch.11- Linkage of Roads, Open Spaces and Low-rise Buildings to Form Breezeways)

Implementation

When there are open spaces adjacent to the project site, connect them by providing a wind corridor of at least 15m wide within the site.

04 Arrange buildings to channel wind

Intent

Wind velocity is often low on the leeward side of a building, forming a wake zone. It can be minimised by arranging the longitudinal side of the building block parallel to the prevailing wind direction. (Cross reference: HKPSG Ch.11- Pattern of Street Grids)

Implementation

Orientate and arrange building blocks so the longitudinal axis is parallel to the prevailing wind direction to channel or direct wind across the site. This can effectively reduce stagnant zones and at the same time enhance wind permeability through the development. A building separation for wind flow should measure at least 15m to be effective.

Recommended steps for good site planning in air ventilation

1 Understand the site context and wind availability.

"Site Wind Availability Data" published by PlanD
http://www.pland.gov.hk/pland_en/info_serv/site_wind/site_wind

Meteorological data published by Hong Kong Observatory
http://www.hko.gov.hk/publica/pubsmo.htm

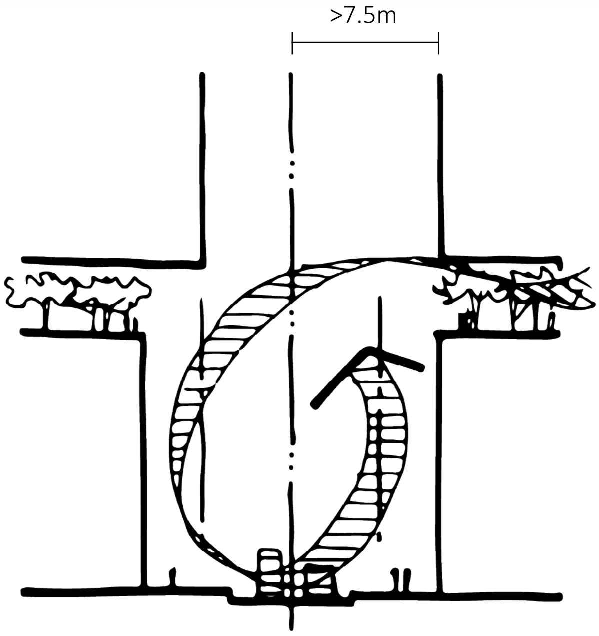
2 Identify wind paths and breezeways in the development and its surroundings.

AVA reports published on PlanD's Air Ventilation Assessment (AVA) Register
The information regarding major air-paths or breezeways at selected areas can be found in the reports of the Planning Department's Air Ventilation Assessment (AVA) Register.
http://www.pland.gov.hk/pland_en/info_serv/ava_register/index.html

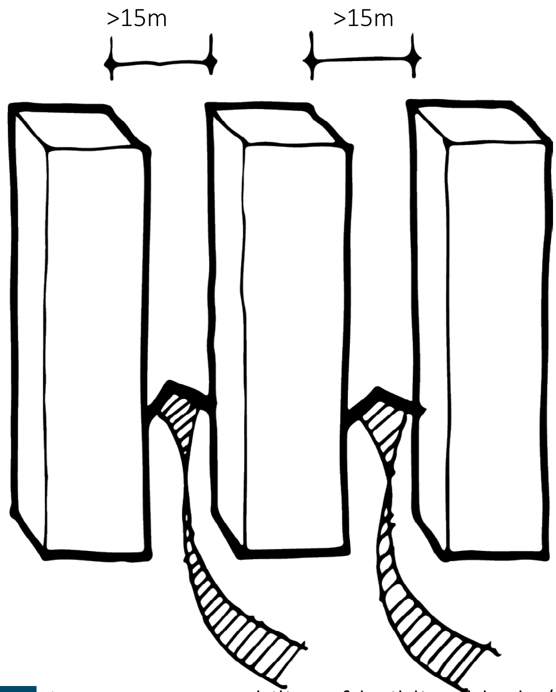
3 Implement design features to maintain wind paths and breezeways.

PNAP APP-152
Sustainable building design guidelines
http://www.bd.gov.hk/english/documents/pnap/APP/APP152.pdf

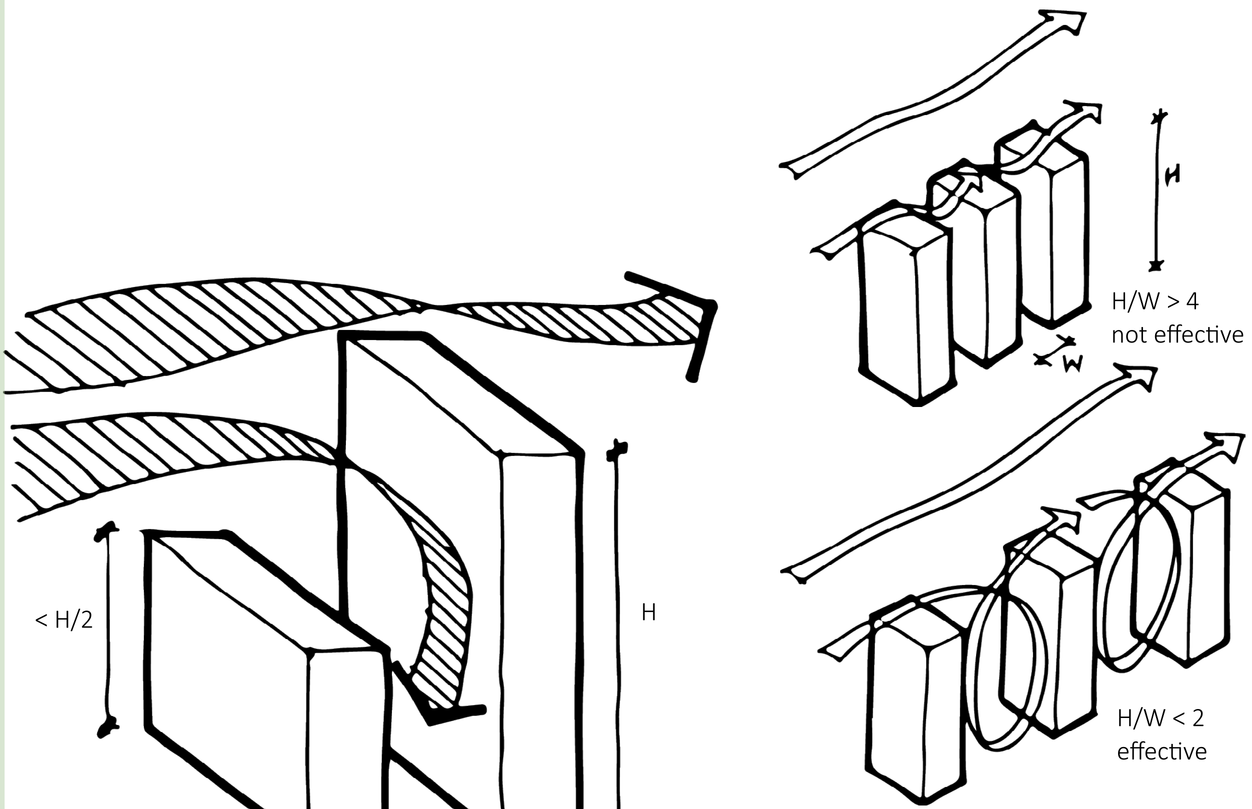
HKPSG Chapter 11
Urban Design Principles
http://www.pland.gov.hk/pland_en/tech_doc/hkpsg/full/ch11/ch11_text.htm



05 Building setback



06 Increase permeability of building blocks/ No wall building



07 Stepped building height profile

When buildings cannot be arranged to channel wind flow and a stepped building height profile cannot be adopted, a height-width ratio of less than 2 is recommended.

Minor breezeways

05 Building setback

Intent

Prevailing winds often flow along wind corridors and breezeways at major roadways or through building gaps. Building setback increases the distances between buildings and enables a larger volume of prevailing wind flow, thereby enhancing the wind environment of a development and its surrounding areas. (Cross reference: HKPSG Ch.11- Widening/Building Setback)

Implementation

Set back buildings at existing major wind paths by leaving clear an area of least 7.5m wide from the centreline of the adjacent roadway. When building setback is widely adopted, the total additional space along the roadway will result in better ventilation.

06 Increase permeability of building blocks / No wall building

Intent

Wall buildings are characterised by long continuous façade blocking ventilation. Impermeable building blocks reduce prevailing wind flow through the development. Building separation enables air flow towards the downwind areas, improving the wind environment for the outdoor space on the downwind side. (Cross reference: HKPSG Ch.11- Gaps between Building Blocks to Enhance Air Permeability)

Implementation

Separate buildings by at least 15m to create minor breezeways. The continuous length of a particular façade should be less than five times the width of the street canyon along it to avoid wall building effect.

07 Stepped building height profile

Intent

In a high-density urban environment, closely clustered buildings give rise to a generally weak wind environment in the streets. However, if the building heights are varied, mid-to-high-level prevailing wind can be captured and diverted downwards to the pedestrian area by the downwash effect. Thus, the appropriate use of a stepped building height profile can potentially improve ventilation in an urban area. This is an alternative strategy when buildings cannot be arranged to channel or direct wind due to site constraints. (Cross reference: HKPSG Ch.11- Stepping Height Profile to Divert Winds to Lower Levels)

Implementation

For a multi-building development, adopt a stepped building height profile by placing lower buildings on the windward side. For a single-building development, consider the heights of the adjacent buildings in the design. For effective application, the taller building should at least double the height of the shorter one. The façade of the taller building should abut the podium edge so the downwash wind can reach the street below.

Tips:
Downwash wind can at times become too strong and cause safety and comfort concerns. Wind environment at the pedestrian area should be carefully studied with detailed analysis beforehand to minimise possible issues.

Further reading:
Planning Department, Urban Climatic Map and Standards for Wind Environment-- Feasibility Study (Stakeholders Engagement Digest). Hong Kong: HKSAR Government, 2011.

WIND

Increase ventilation with building design

Permeable Tower Design

08 Increase building permeability

09 Permeable sky garden

10 Reduce building frontage

Minor Breezeway

11 Ventilation bay / Permeable podium

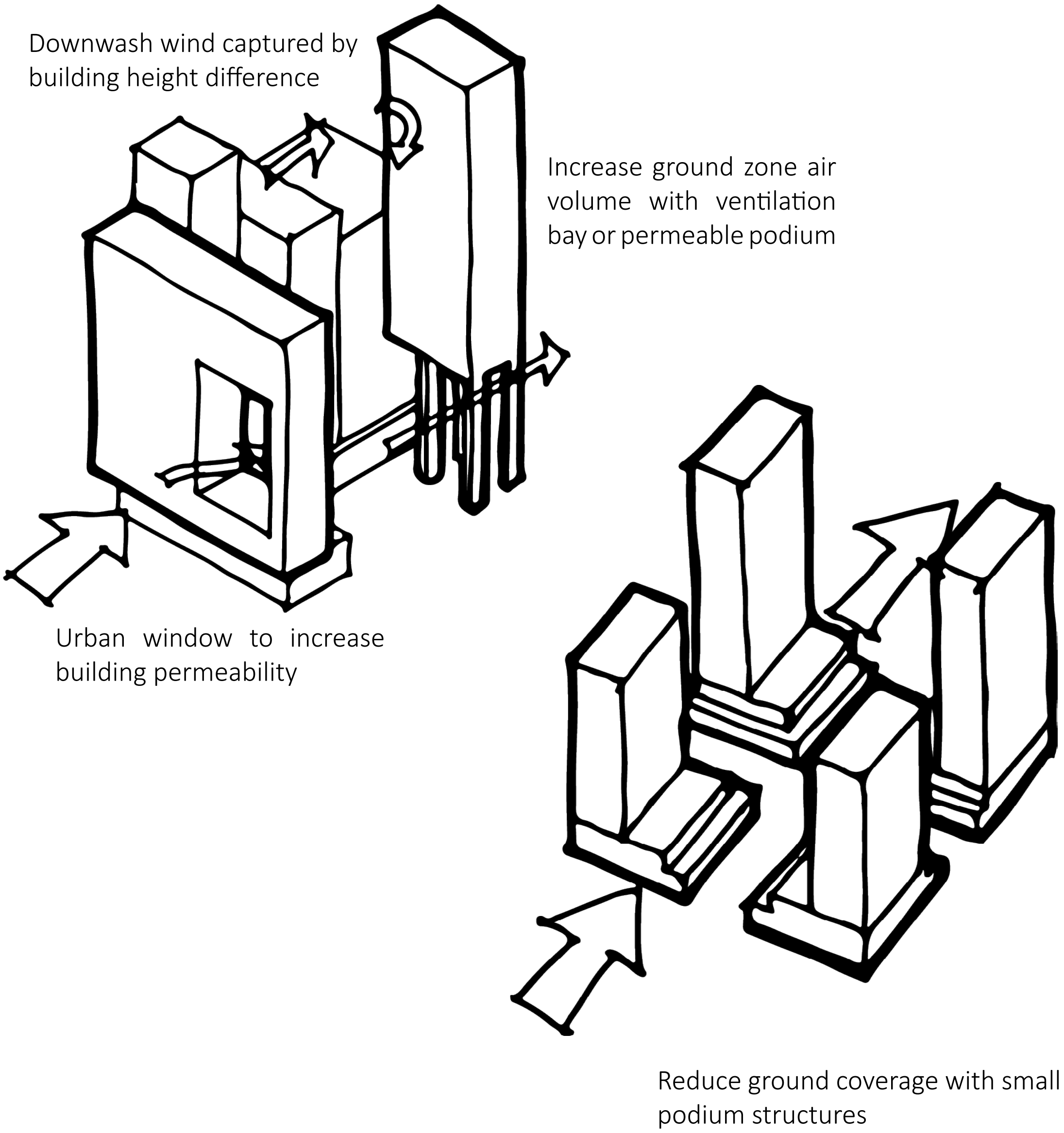
12 Reduce ground coverage

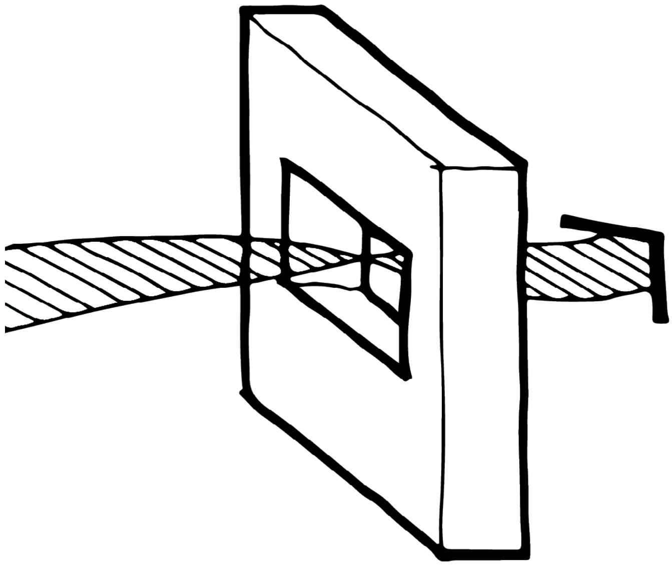
13 Increase ground zone air volume

Increase ventilation with building design

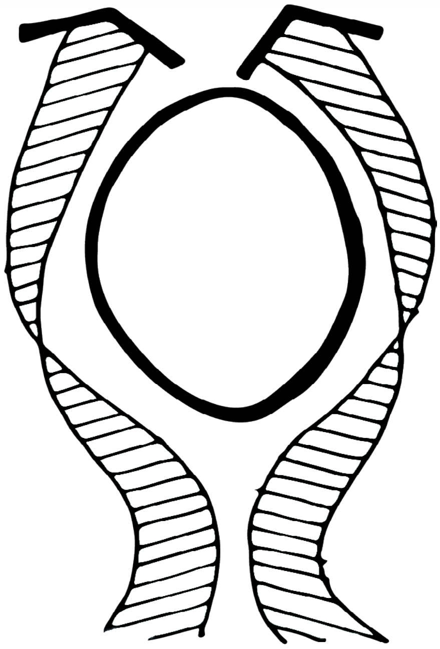
In addition to site planning and master layout, the building design stage also offers many opportunities to improve wind penetration through the development by increasing building blocks' permeability. In this section, strategies aiming to increase ventilation with podium and tower designs are discussed.

This section is particularly relevant to compact sites, where size constraints make ventilation enhancement through site planning difficult. Nonetheless, they are also applicable to large sites in the improvement of ventilation.

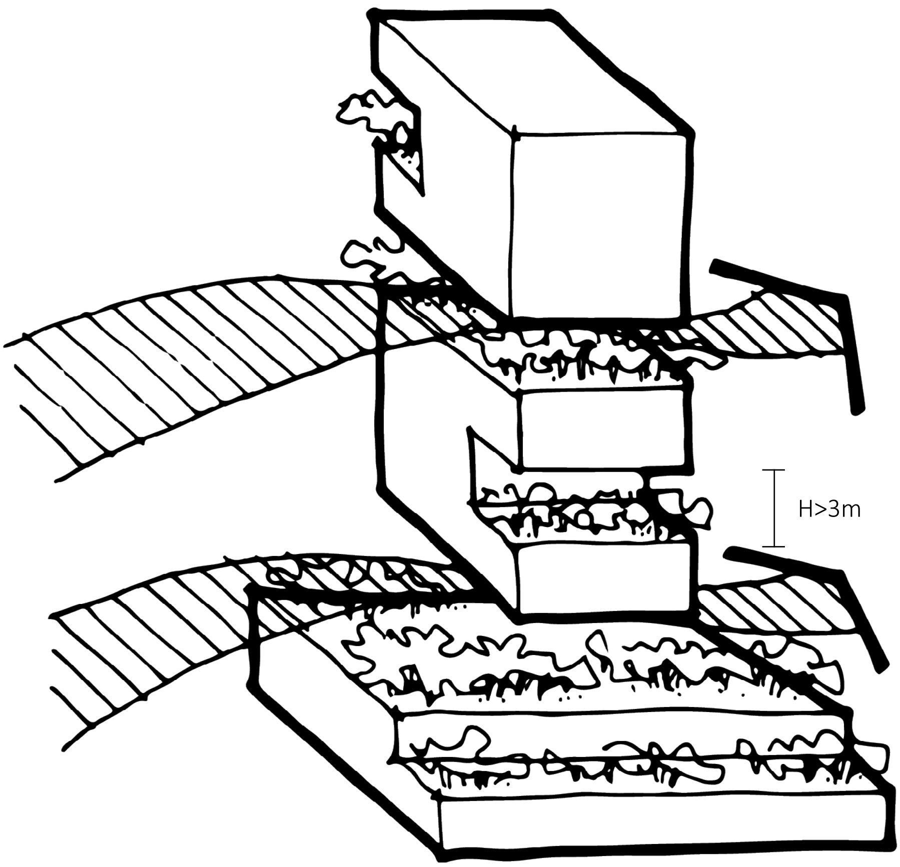




08 Increase building permeability



10 Reduce building frontage



09 Permeable sky gardens

Permeable tower design

08 Increase building permeability

Intent

Building structures are becoming taller and bulkier in response to the increasing demand for space on limited urban land. The resulting impaired ventilation, especially at higher altitudes, can be mitigated by increasing a tower's permeability. (Cross reference: HKPSG Ch.11- Creating Voids in Façades Facing Wind Direction)

Implementation

Create openings such as urban windows in building façades to increase wind penetration high up from the ground through the building. The size of any opening for ventilation purpose should have a minimum clear width and height of 3m.

Building permeability calculation methodology and requirements in Hong Kong:
PNAP APP-152 Sustainable Building Design Guidelines sets out a permeability calculation methodology and the recommended requirements. This could be taken as the minimum requirement for building permeability. http://www.bd.gov.hk/english/documents/pnap/APP/APP152.pdf.

09 Permeable sky garden

Intent

The limited ground area in a compact site means open spaces are commonly placed in the middle of the building. Apart from providing a communal area for tenants to enjoy, these spaces improve the building's permeability and enhance ventilation. (Cross reference: HKPSG Ch.11- Gaps between the Podium and Building Blocks to Enhance Air Permeability)

Implementation

Sky gardens should contain as few building structures as possible to facilitate wind penetration. They should be of at least 3m tall. Apart from their ventilation benefits, sky gardens are shaded by the tower itself, so users of the space will enjoy an even more thermally comfortable environment.

10 Reduce building frontage

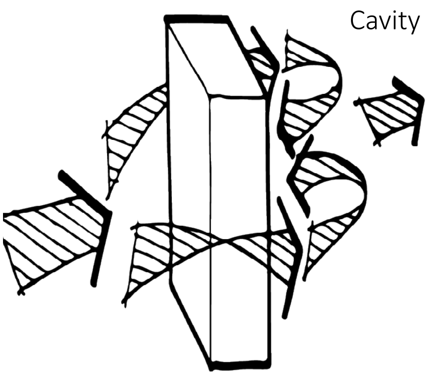
Intent

Large building frontage facing the prevailing wind direction reduces wind penetration and affects the wind environment at downwind locations.

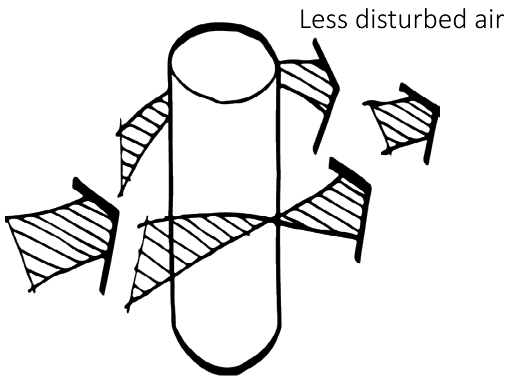
Implementation

Wind penetration can be enhanced by reducing the building frontage area. The adoption of aerodynamically shaped frontage can also facilitate wind flow around the building structure.

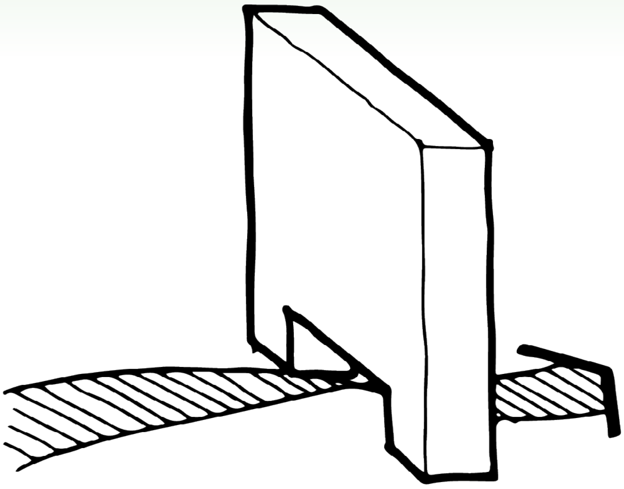
Further reading:
Planning Department, Urban Climatic Map and Standards for Wind Environment - Feasibility Study
http://www.pland.gov.hk/pland_en/p_study/prog_s/ucmapweb/ucmap_project/content/reports/final_report.pdf.



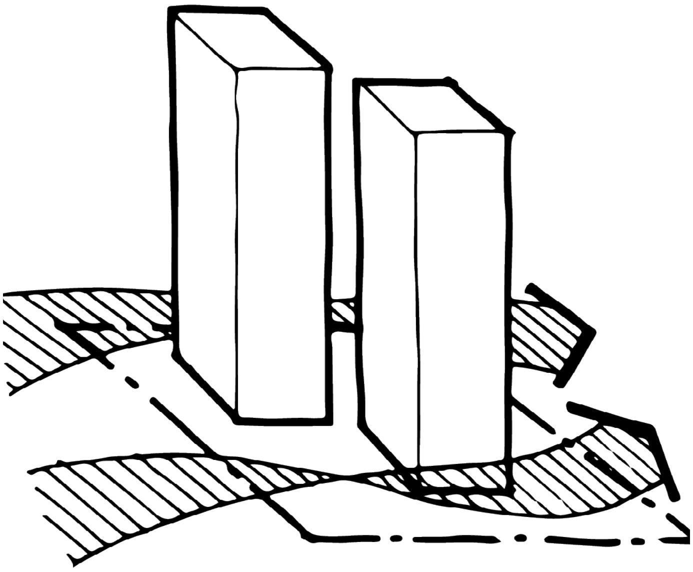
Square shape



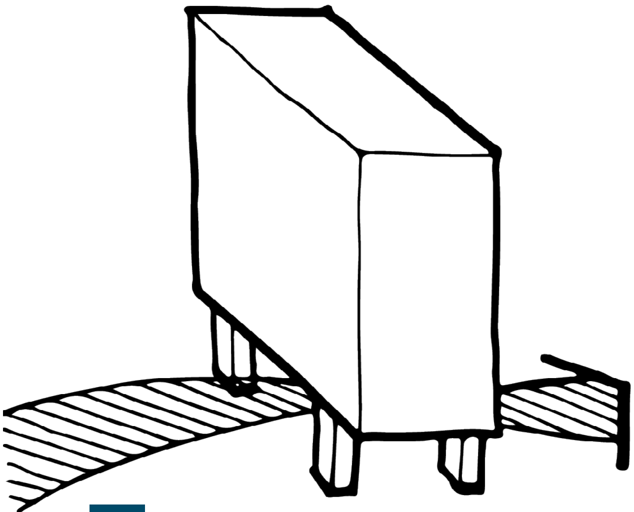
Aerodynamic shape



11 Ventilation bay/ permeable podium



12 Reduce ground coverage



13 Increase ground zone air volume

Example:
Hong Kong Design Institute

Permeable podium design

11 Ventilation bay / permeable podium

Intent
Ventilation bay at the ground level enables wind to flow through and provides thermally comfortable shaded open spaces for communal use.

Implementation
Provide ventilation bay at the ground level of the building blocks. It will be more effective if the ventilation bay aligns with the wind paths. The size of any opening should have a minimum clear width and height of 3m for effective ventilation.

12 Reduce ground coverage

Intent
Building developments with large ground coverage, such as those with podium design, restrict wind flow at near-ground levels and weaken the wind environment at ground-level open spaces. In contrast, podium-free designs increase the air volume at the ground level and contribute to a more thermally comfortable environment. (Cross reference: HKPSG Ch.11- Reducing Site Coverage of the Podia to Allow More Open Space at Grade)

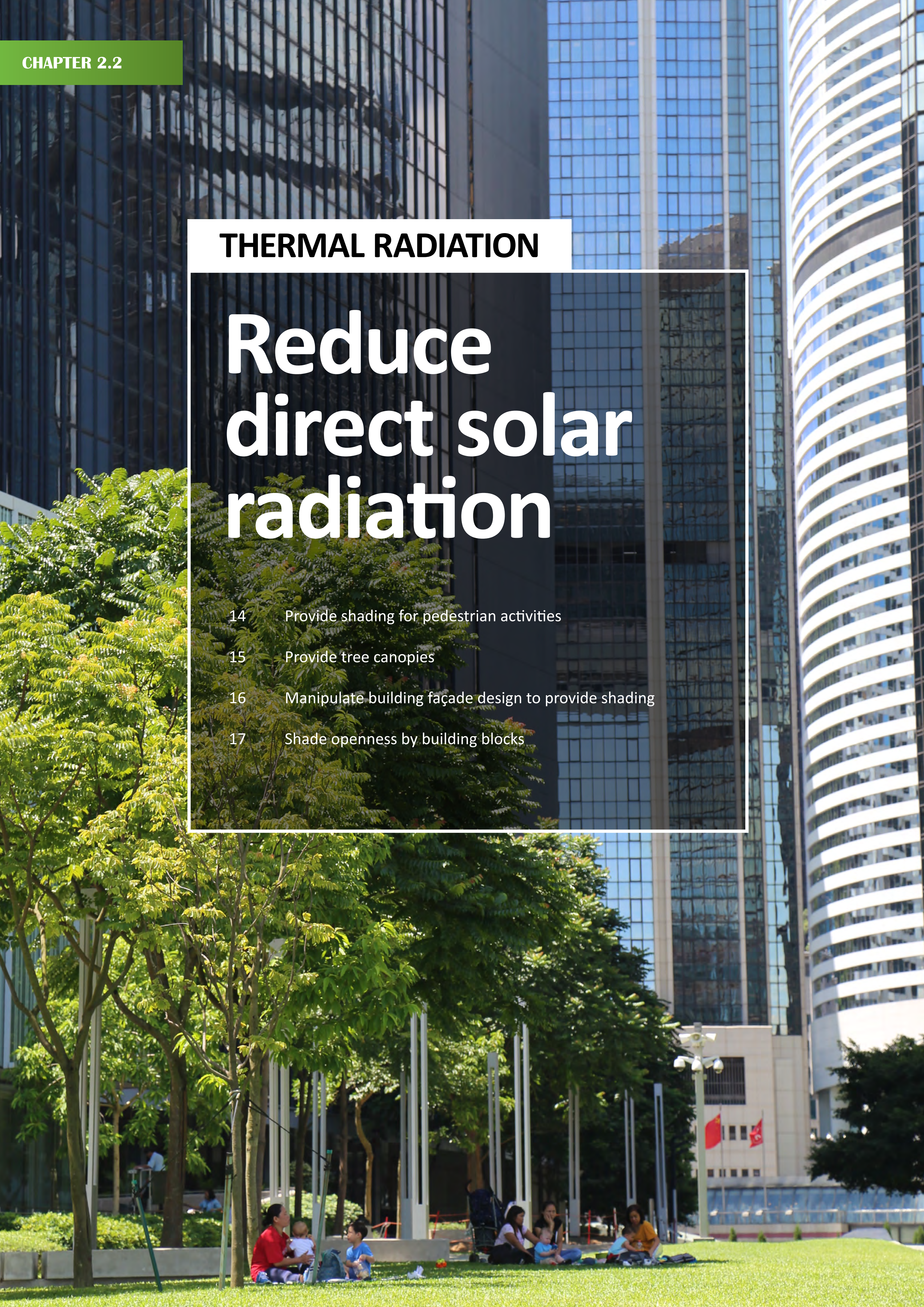
Implementation
Minimise ground coverage and avoid large podium designs to enhance wind penetration. The space between any two podia should measure at least 15m and align with the prevailing wind direction.

13 Increase ground zone air volume

Intent
The wind environment of urban pedestrian areas is often impaired by the surrounding densely constructed buildings. This can be mitigated by reducing building massing on the ground level to increase the ground zone volume.

Implementation
Place semi-outdoor spaces with large permeability at the ground level and locate enclosed spaces higher up. The elevated building structure will increase air volume at the ground zone.

Tips:
An elevated building structure may impact the localised air flow pattern and cause concerns. Detailed studies are recommended to ensure negative impacts to the surrounding wind environment are mitigated.



THERMAL RADIATION

Reduce direct solar radiation

14 Provide shading for pedestrian activities

15 Provide tree canopies

16 Manipulate building façade design to provide shading

17 Shade openness by building blocks

Reduce direct solar radiation

Direct solar radiation in the form of short-wave radiation plays an important role in outdoor thermal comfort. Pedestrians' direct exposure to solar radiation can be effectively reduced by making use of opaque shading devices. They can come in many forms, such as covers, tree canopies and building shade.

14 Provide shading for pedestrian activities

Intent

Shade offers the most effective remedy to thermal discomfort caused by direct solar radiation.

Implementation

Install opaque shading devices at open areas with frequent pedestrian access. The reduction in solar radiation can be up to almost 100% on a typical summer day. The reduction in solar radiation and impact on thermal comfort at different times of the year can be studied through computational analysis.

PET thermal comfort calculation-Mean radiant temperature (Tmrt) under various conditions:
- Direct sun: 40-60°C
- Cloudy sky/ tree canopy/ translucent shade: 10°C
- Opaque shade/ building shadow: 0-3°C

15 Provide tree canopies

Intent

Another way to reduce pedestrians' direct exposure to solar radiation is to shade them with tree canopies.

Implementation

Plant trees with large canopies in frequently used open spaces. Select plant species with high leaf density to maximise the shading effect. For large sites, provide tree coverage for over 25% of the total site area. For compact and single building sites, provide tree canopies in all frequently accessed outdoor spaces. The effectiveness depends on the crown size and leaf density.

Tips:
In landscape design and plant selection, carefully consider the species' need for direct sunlight exposure as some locations may have little or no exposure to direct sunlight in winter.

16 Manipulate building façade design to provide shading

Intent

Pedestrian walkways are often located near or along the edge of a building. These walkways are often uncovered and exposed to direct solar radiation.

Implementation

Locate pedestrian walkways and open spaces adjacent to the building façade, which can act as a shading structure. Colonnade and cantilever structures are some examples of the design. The reduction in solar radiation and impact on thermal comfort at different times of the year can be studied through computational analysis.

17 Shade openness by building blocks

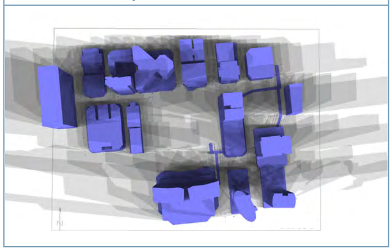
Intent

In a high-density high-rise urban environment, the shadows of building blocks often shade the surrounding ground space during different times of the day.

Implementation

Place outdoor open spaces at locations shaded by building blocks during certain periods of time in summer. Sun shadow analysis can be performed to determine the appropriate location of an open space.

Example:
This sun shadow analysis shows the project site is shaded by the surrounding building blocks on a summer day.



THERMAL RADIATION

Reduce surface temperature

18 Use cool material for ground surface

19 Green wall to reduce façade surface temperature

20 Increase albedo in buildings

21 Increase sky view factor to improve night cooling

Reduce surface temperature

The rate of radiative heat transfer is proportional to the surface temperature of the heat source. Thus, strategies to reduce the surface temperature of the ground and surrounding building structures can help reduce heat stress on the pedestrians.

18 Use cool material for ground surface

Intent

Ground surface material absorbs solar heat and re-radiates it to the surrounding environment. Conventional pavements such as impervious concrete and asphalt can reach a surface temperature of 48-67°C. Cool materials with high solar reflectance (albedo) can help reduce the ground surface temperature.

Implementation

Use cool materials with an albedo index of at least 0.4, such as those of lighter colours, for outdoor ground surfaces. Researchers have estimated that a 10% increase in solar reflectance for ground surface pavement can reduce surface temperature by 3-6°C. Albedo can be increased from 0.1 to 0.5 by replacing asphalt with concrete, and that can reduce the surface temperature by 10-20°C.

Examples of cool surface paving:
For roadways
- Asphalt pavements covered with high albedo material
- Concrete pavements mixed with Portland cement

For low-traffic areas
- Resin based pavement

Further reading on cool pavements:
United States Environmental Protection Agency, Heat Island Compendium Chapter 5: Cool Pavements, 2012: https://www.epa.gov/sites/production/files/2017-05/documents/reducing_urban_heat_islands_ch_5.pdf.

19 Green wall to reduce façade surface temperature

Intent

Green walls can help lower façade surface temperature as the leaves and substrates reduce solar heat transfer to the building surface.

Implementation

Install green walls on building façades near open spaces that are exposed to a substantial amount of solar radiation in summer. Solar radiation analysis can be conducted to identify or confirm the façade receiving the most solar radiation. The thermal performance of a green wall depends significantly on leaf coverage. With a 100% leaf coverage, a green wall can reduce the façade's surface temperature by 3-6°C.

Experimental study on vertical greenery:
F.M. Zhang, Experimental study to the thermal performance of Vertical greenery system -A case study in Hong Kong, Chinese University of Hong Kong.

20 Increase albedo in buildings

Intent

'Albedo', means whiteness in Latin. In modern use, the albedo of a surface is defined as the fraction of the incident sunlight reflected from it. A high-albedo material demonstrates high reflectivity in both light and heat. Using such material will reduce thermal absorption by the building material.

Implementation

A variety of measures, such as using light-coloured surface paint or thermally treated surface material, can be adopted. Select high-albedo building surface material of at least 0.4 to effectively lower the surface temperature and reduce radiative heat transfer to the surrounding environment. A light grey material with an albedo index of 0.5 will be 5-10°C cooler than a dark grey material of 0.2.

21 Increase sky view factor to improve night cooling

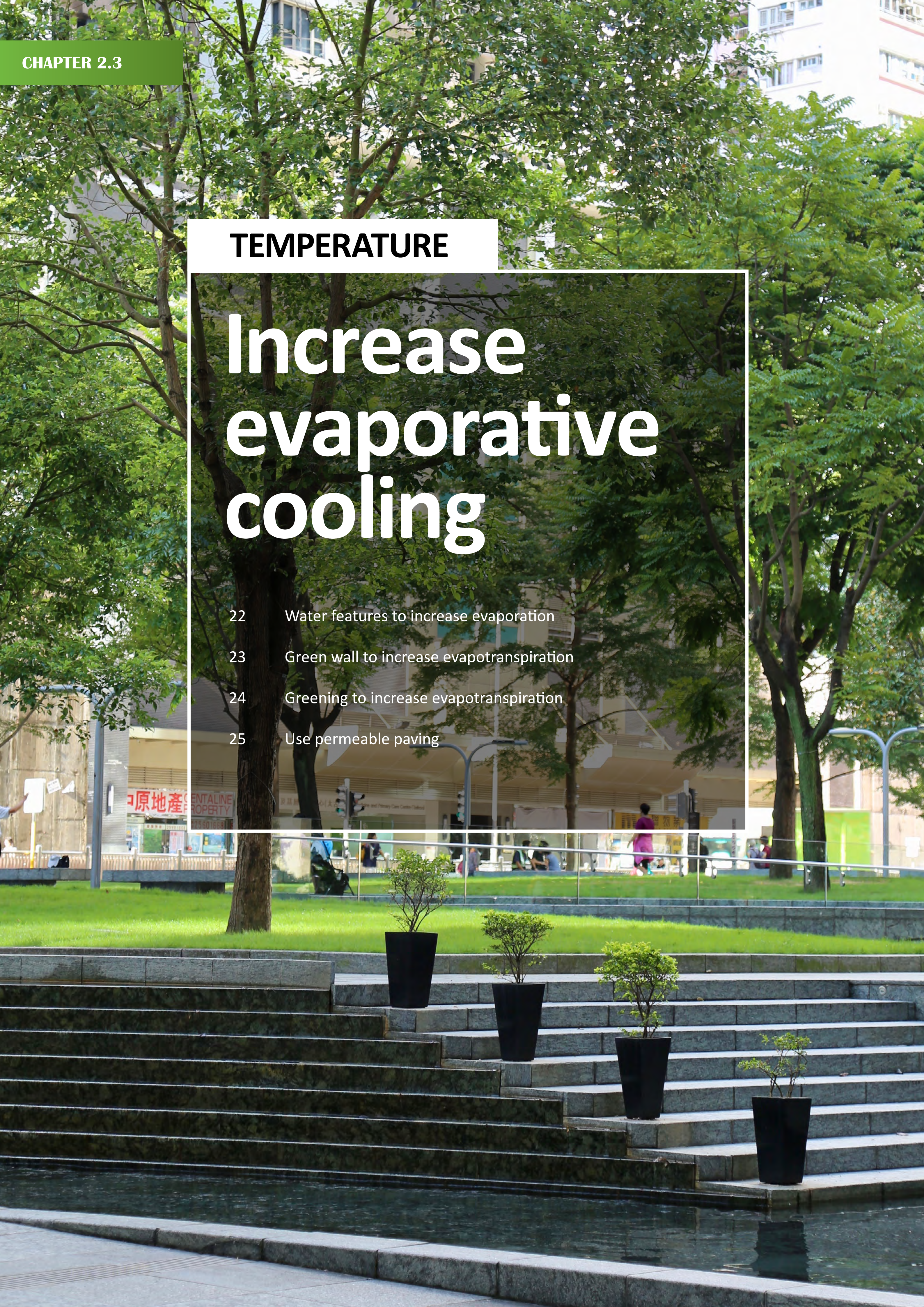
Intent

Sky view factor (SVF) is the percentage of the sky visible from the ground up. An SVF of 1 means the entire sky is visible, whereas an SVF of 0 implies the sky is completely obstructed from the view point. On a clear night, heat is radiated to the sky from the earth surface. The higher the SVF, the greater is the heat transfer rate, and the faster the earth surface is cooled down by the night cooling effect during the hot summer season.

Implementation

During site planning, arrange building blocks to increase the SVF at the open space, such as by varying building heights of the development or widening the gap between building blocks. SVF can be obtained via analysis with simulation tools.

SVF analytical model:
L. Chen, Sky view factor analysis of street canyons and its implications for daytime intra-urban air temperature differentials in high-rise, high-density urban areas of Hong Kong: a GIS-based simulation approach, International Journal of Climatology 32: 121–136 (2012), 2010.



TEMPERATURE

Increase evaporative cooling

22 Water features to increase evaporation

23 Green wall to increase evapotranspiration

24 Greening to increase evapotranspiration

25 Use permeable paving

Increase evaporative cooling

A direct way to improve thermal comfort is to reduce the ambient temperature. The large latent heat of vaporisation (2,260kJ per litre of water) makes evaporation an effective way to extract and carry away heat from the environment. Carefully designed features can take full advantage of evaporation.

22 Water features to increase evaporation

Intent

Water features help maintain a lower surrounding ambient temperature as water evaporation extracts heat from the surrounding environment.

Implementation

Provide water features in open spaces or landscape areas. Some effective examples are fountains, waterfalls and mist sprays. The water droplets they produce enhance the evaporation rate because of the increased surface area in contact with air. Static water features can reduce the ambient air temperature of the surrounding area within 3m by 0.2°C. For fountains and mist sprays, the ambient air temperature can be reduce by 3-5°C within the same distance.

Tips:
The cooling effect of water features will be impaired by humid or cloudy weather conditions. The high level of water content in humid air makes it difficult for water to evaporate.

23 Green wall to increase evapotranspiration

Intent

Evapotranspiration refers to the process of moisture transferring from land and soil to the atmosphere by evaporation and transpiration. Green walls in general have a lower surface temperature than other materials on a building façade thanks to the effect. The rise in ambient air temperature from solar exposure near the green wall can also be reduced.

Implementation

Install green walls and covers on trellis panels at open spaces for communal use. There are broadly two types of plants commonly used in green walls: climbing and substrate-based. Their cooling effect depends more on leaf coverage than plant types. With full leaf coverage, air temperature near the green wall can go down by 1°C.

Further reading:
United States Environmental Protection Agency, Heat Island Compendium Chapter 2: Trees and Vegetation, 2008
https://www.epa.gov/sites/production/files/2017-05/documents/reducing_urban_heat_island s_ch_2.pdf.

Greenery coverage calculation methodology and requirements in Hong Kong
A greenery coverage calculation methodology and the recommended requirements is set out in PNAP APP-152 Sustainable Building Design Guidelines.
http://www.bd.gov.hk/english/documents/pnap/APP/APP152.pdf.

24 Greening to increase evapotranspiration

Intent

Vegetation offers an effective way to reduce the ambient air temperature by evapotranspiration.

Implementation

Provide vegetation at all outdoor spaces, especially those for communal use. Large trees are more effective than grass and smaller planters as the total leaf surface area is larger. A tree coverage of 30% will reduce air temperature by approximately 1°C.

Further reading:
Planning Department, Urban Climatic Map and Standards for Wind Environment - Feasibility Study
http://www.pland.gov.hk/pland_en/p_study/prog_s/ucmapweb/ucmap_project/content/reports/final_report.pdf.

25 Use permeable paving

Intent

Permeable paving was originally designed for stormwater control. It allows air and water to enter the void of the material. The moisture content in the void reduces the ground surface temperature through evaporation and helps create a cooler near-ground environment.

Implementation

Use permeable paving in walkways and open spaces for communal use. Attention should be paid to the structural needs for the expected traffic loads. A permeable pavement saturated with water will reduce the air temperature 1m above it by 0.2°C.

Examples of permeable paving
- Porous asphalt
- Pervious concrete
- Permeable pavers
- Vegetated permeable pavement such as grass pavers and concrete grid pavers with vegetation in the interstices
- Concrete grid pavements
- Grass paver

TEMPERATURE

Reduce heat accumulation

26 Increase ventilation to carry away heat energy

27 Allow downhill wind flow

28 Allow sea breezes

Reduce heat accumulation

Poorly designed outdoor spaces can trap heat from nearby air conditioners and traffic, whilst improved ventilation can help increase the rate of heat dissipation. The introduction of cooler air from nearby mountains and water bodies is also helpful in the reduction of the ambient temperature.

26 Increase ventilation to carry away heat energy

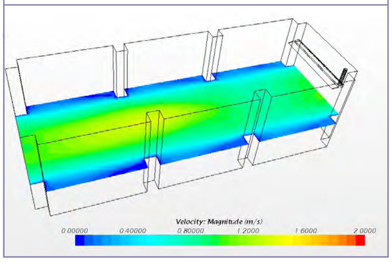
Intent

Solar heat in the outdoor environment tends to be trapped in built-up areas, especially at open spaces surrounded by building blocks with weak ventilation. Localised ventilation can carry away the heated air and introduce cooler fresh air from the surroundings.

Implementation

Increase ventilation at open spaces frequently accessed by pedestrians. Locate them at wind paths. Avoid air stagnation under prevailing wind condition and ideally also under windless condition, such as by using mechanical ventilation. A minimum wind speed of 1m/s is recommended for a comfortable environment under shade during summer.

Example:
CFD simulation to verify air speed distribution for covered open space by mechanical ventilation under windless condition.



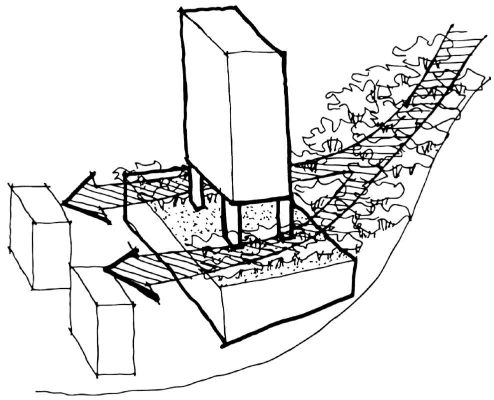
27 Allow downhill wind flow

Intent

During calm wind conditions, the temperature difference between the city fabric and vegetated slopes will induce a local air flow, known as katabatic wind. This air flow under tree canopies is approximately 1-2°C lower than the ambient air temperature. The slightly cooler and denser air on the vegetated slopes flows down the slope towards the urban area, permeating and cooling the streets. This strategy is not commonly adopted at the moment. However, as the Government plans to build at the urban fringes, considerations about the downhill wind flow will become more important in the future.

Implementation

For developments facing vegetated slopes, make sure the buildings do not obstruct the katabatic wind flow from uphill. Maintain adequate gaps between buildings and increase permeability in podium design to enhance the flow through the site. The wind path through the development must be shaded or vegetated to avoid heating up the air.



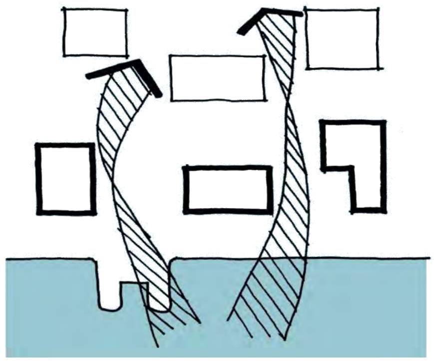
28 Allow sea breezes

Intent

Sea breezes are generated by the contrast in air pressure induced by the different heat capacities of the land and sea. The fresh air from the sea can be 2-4°C cooler than the ambient air temperature in an urban area. The cool sea breezes can ventilate hot air trapped in the urban area effectively at night.

Implementation

For project sites near the waterfront, facilitate sea breezes through the development by placing low-rise and highly permeable building blocks on the shore and providing wind corridors perpendicular to it. The wind corridor should be at least 15m wide and preferably aligned with the wind corridor at the downwind location.



(Cross reference: HKPSG ch 11: Waterfront Sites)

TEMPERATURE

Reduce heat release

29 Reduce anthropogenic heat dissipation near pedestrian area

30 Reduce thermal mass heat storage of building materials

Reduce heat dissipation

Sources that release heat to the surroundings are prevalent on urban streets. They include vehicles on major roadways, exhaust outlets and the thermal mass of building materials. To mitigate their effect on human thermal comfort, these sources should be located away from open spaces.

29 Reduce anthropogenic heat discharge near pedestrian area

Intent

Air conditioning units, cooling towers and motor vehicles are some major sources of anthropogenic heat dissipations in the urban environment. Their effect on thermal comfort in nearby areas can be minimised by locating them away from pedestrian open spaces. By removing these anthropogenic heat sources, the ambient air temperature can be lowered by 0.5-1°C.

Implementation

The most effective way to reduce anthropogenic heat dissipation by motor vehicles is to limit their access to the development. Also, the number of private vehicles can be reduced by not providing any parking facilities. Another way to reduce the effect of anthropogenic heat is to locate open spaces away from major roadways. Heat rejection equipment (e.g. A/C, cooling tower, exhaust outlet etc.) should be installed away from outdoor pedestrian areas.

Example:
Discovery Bay, Hong Kong
Private vehicles are restricted to enter the large scale development of Discovery Bay on Lantau Island.

30 Reduce thermal mass heat storage of building materials

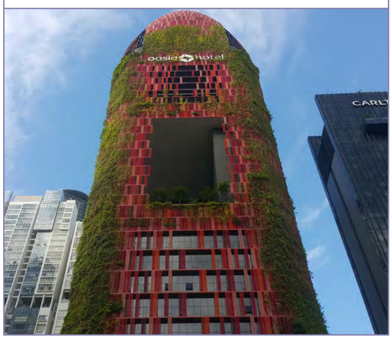
Intent

Thermal mass is the material property of absorbing and storing heat energy. Building materials such as concrete and bricks typically have high thermal mass. These materials store heat energy under sun exposure during the day, and release it to the surrounding area at night. By reducing the thermal storage of the building materials, heat dissipation to the outdoor environment and ambient temperature can be reduced.

Implementation

Reduce solar exposure of building materials with a heavy thermal weight. Shade the building mass from the sun with light-weight external shades, such as aluminium louvres or green walls. Materials with low thermal mass are those with low specific heat capacity and density.

Example:
Osaia Downtown Hotel, Singapore
Building envelope covered by metal louvres and greenery.



PRECIPITATION

Provide rain protection

31 Provide cover for rain protection

Provide rain protection

Sub-tropical Hong Kong sees heavy and frequent rainfall and thunderstorms during the summer months of May to September. Protecting pedestrians from precipitation will improve the microclimate and usability of open spaces.

31 Provide cover for rain protection

Intent

Relative humidity is close to 100% on rainy days. Covered structures keep pedestrians dry and speed up the heat dissipation process for better thermal comfort.

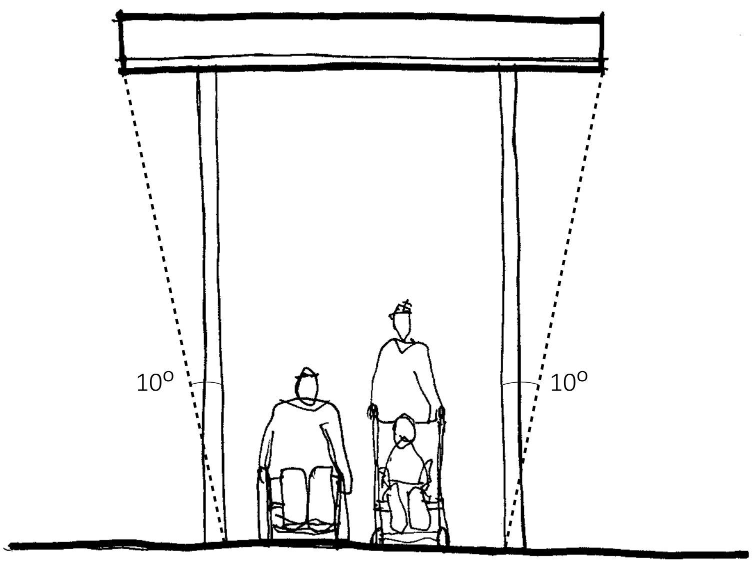
Implementation

Provide rain cover along major pedestrian walkways. The angle of deflection from the driving rain effect should be taken into consideration. The estimated angle of deflection of driving rain under the typical heavy rain condition in Hong Kong is approximately 10 degrees. This should be taken into account in the design of covered walkways for effective rain protection.

Further reading on wind driven rain effect:

Chand, Bhargava, Estimation of Angle of Deflection of Rain at Driving Rain Prone Stations in India, 2005.

Sagadashvili, Methods of Processing Meteorological Observational Data for Assessment of Driving Rain Parameters, Proceedings of the Symposium on Building Climatology, Moscow, 619 – 629, 1982.



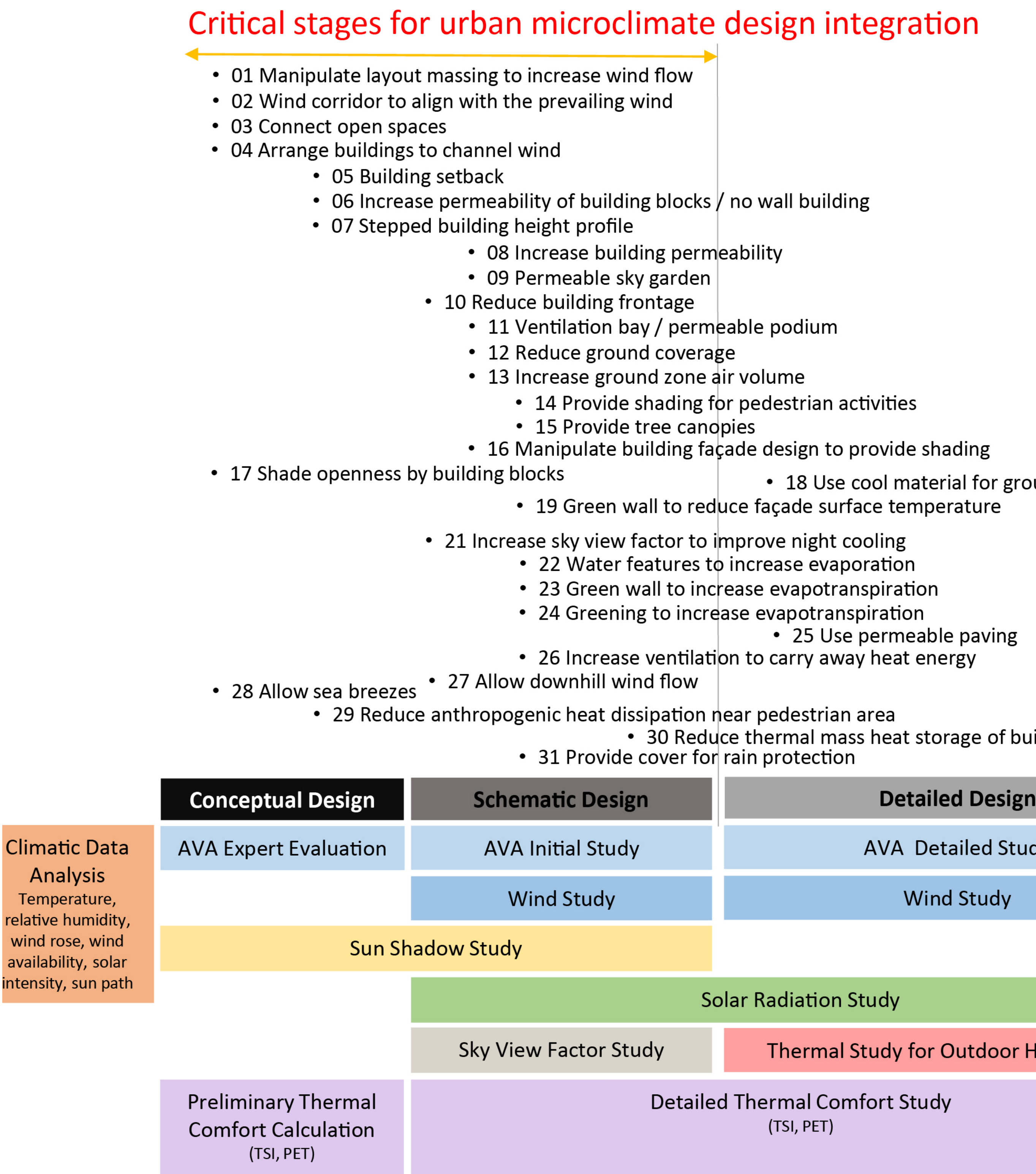
In designing a covered walkway, the angle of deflection from the driving rain effect should be considered. With an hourly rainfall intensity of 30mm/hr and hourly mean wind speed of 1.145m/s, an angle of deflection of 10° will be formed as illustrated.

Additional information:

In the event of extreme rainfall, the municipal drainage system will funnel rainwater run-off to the sea. Together with the rise of sea level, the risk of localised flooding in the community will increase. The concept of 'Blue-Green Infrastructure' promoted by the Drainage Services Department aims to improve flood control through rain capture and stormwater reuse. Although this is a city scale initiative, some of the strategies in the concept can be adopted at the building development level, such as the use of retention tank, porous pavement, wetland, retention lake and rain garden etc.

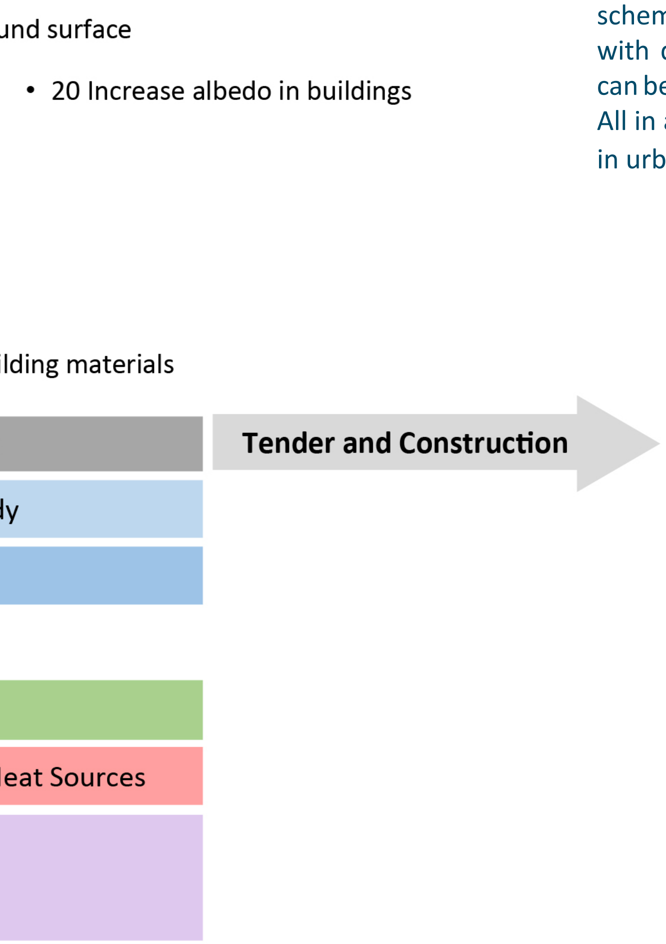
Hong Kong Environment Bureau, Hong Kong's Climate Action Plan 2030+, Chapter 7. https://www.climateready.gov.hk/files/report/en/7.pdf.

Integrated Design Process



The timing of implementation of the urban microclimate design strategies introduced in the Guidebook is critical. Very often, beneficial features cannot be applied properly because considerations were made too late. Strategies related to site planning and layout massing should be planned and applied at the early conceptual design stage. Those related to building design, building permeability and landscape design can be considered at the subsequent schematic design stage. Finally, strategies on building material selection can be implemented at the detailed design stage. As such, the majority of urban microclimate design strategies should be implemented before the detailed design stage and hence the most critical stages occur early in new development projects (i.e. conceptual design and schematic design stages).

Additionally, technical studies and analyses will facilitate the concrete design of urban microclimate strategies. Desktop climatic data analysis should be conducted at the very beginning of any design works, so the project team can understand the environment of the site. Qualitative analysis should be carried out at the conceptual design stage for site planning. At the schematic design stage, the building design should be fine tuned with detailed quantitative analysis. Computational calculations can be used to optimise and verify the microclimate performance. All in all, design for thermal comfort should be the ultimate goal in urban microclimate design.

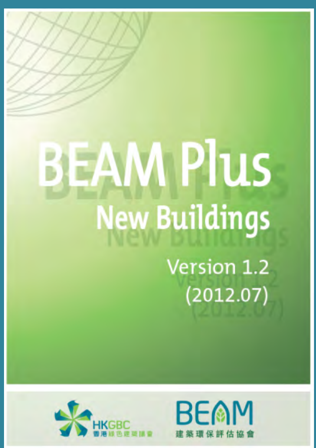


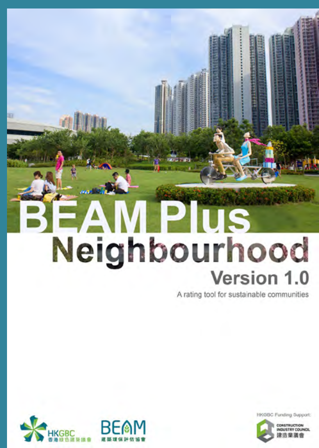
Linkage to BEAM Plus

BUILDING ENVIRONMENTAL ASSESSMENT METHOD (BEAM) provides building users with a single performance label that demonstrates the overall quality of a building, either new or refurbished, or one that is already in use. A building certified by BEAM Plus is safer, healthier, more comfortable, more functional and more efficient than a similar building that does not achieve the level of performance prescribed in BEAM.

BEAM Plus embraces a range of good practices in planning, design, construction, management, operation and maintenance of buildings, and is aligned with local regulations, standards and codes of practice. Urban microclimate design is addressed in several credits under different BEAM Plus rating schemes.

The following table summarises the linkage between the urban microclimate design strategies in the Guidebook and the BEAM Plus rating system, specifically BEAM Plus New Buildings Version 1.2, its newer Version 2.0[20] and Neighbourhood Version 1.0. Details of the linkage are further described in Section 4.3.1 and 4.3.2. Credit information such as credit intent, background and requirements will not be stipulated in the Guidebook. Please refer to the BEAM Plus New Buildings Version 1.2 Manual, BEAM Plus New Buildings Version 2.0 Manual and BEAM Plus Neighbourhood Version 1.0 Manual for details.





20. Disclaimer: The BEAM Plus NB V2.0 credits and summary presented in this chapter are based on the BEAM Plus NB V2.0 Upgrade Training Course held in July 2017. Please refer to the official release of NB V2.0 manual for any discrepancy.

		BEAM Plus New Buildings Version 1.2						BEAM Plus New Buildings Version 2.0								BEAM Plus Neighbourhood Version 1.0						
		SA P1	SA7a	SA7b	SA8a	SA8b	SA8c	SA P1	SA1	SA7	SA8	SA9	SA10	SA11	HWB3	CA3d	SA2a	SA2b	SA2c	SA7	OEQ1	OEQ2
Wind																						
Increase ventilation with site planning																						
1	Manipulate layout massing to increase wind flow				●		●				●	●	●								●	●
2	Wind corridor to align with the prevailing wind				●		●				●	●	●								●	●
3	Connect open spaces				●		●				●	●	●								●	●
4	Arrange buildings to channel wind				●		●				●	●	●								●	●
5	Building setback				●		●				●	●	●			●			●	●	●	●
6	Increase permeability of building blocks / no wall building				●		●				●	●	●								●	●
7	Stepped building height profile				●		●				●	●	●								●	●
Increase ventilation with building design																						
8	Increase building permeability				●		●				●	●	●								●	●
9	Permeable sky garden				●		●				●	●	●								●	●
10	Reduce building frontage				●		●				●	●	●								●	●
11	Ventilation bay / permeable podium				●		●				●	●	●								●	●
12	Reduce ground coverage				●		●				●	●	●				●	●			●	●
13	Increase ground zone air volume				●		●				●	●	●								●	●
Thermal Radiation																						
Reduce direct solar radiation																						
14	Provide shading for pedestrian activities					●					●		●			●			●	●	●	
15	Provide tree canopies	●		●				●	●	●	●		●			●			●	●	●	●
16	Manipulate building façade design to provide shading					●					●		●			●			●	●	●	●
17	Shade openness by building blocks										●		●								●	●
Reduce surface temperature																						
18	Use cool material for ground surface										●											●
19	Green wall to reduce façade surface temperature	●		●				●	●		●									●		●
20	Increase albedo in buildings					●					●	·										●
21	Increase sky view factor to improve night cooling										●									●		●
Temperature																						
Increase evaporative cooling																						
22	Water features to increase evaporation	●		●				●			●			●			●	●		●		●
23	Green wall to increase evapotranspiration	●		●				●	●		●									●		●
24	Greening to increase evapotranspiration	●		●				●	●		●			●			●	●		●		●
25	Use permeable paving		●								●			●								●
Reduce heat accumulation																						
26	Increase ventilation to carry away heat energy																					
27	Allow downhill wind flow																					
28	Allow sea breezes																					
Reduce heat release																						
29	Reduce anthropogenic heat discharge near pedestrian area								●													
30	Reduce thermal mass heat storage of building materials																					
Precipitation																						
Provide rain protection																						
31	Provide cover for rain protection					●					●		●		●	●			●	●	●	

Table 6 Summary of the linkage between the urban microclimate strategies and BEAM Plus rating system.

BEAM Plus New Buildings Version 1.2

BEAM Plus New Buildings aims to reduce the environmental impacts of new buildings. The following credits in BEAM Plus New Buildings Version 1.2 address microclimate design. Their linkage to the urban microclimate design strategies is described.

SA P1
SA 7b

Minimum Landscaping Area/ Soft Landscaping

The requirements for minimum landscape area increase the amount of greenery in urban developments. Greenery can take the different forms of green walls, large trees, shrubs, etc. They help improve the microclimate of outdoor spaces by providing shading for pedestrian activities, reducing the surface temperature of building façade and lowering ambient temperature through evaporation. The related urban microclimate design strategies include:

15	Provide tree canopies	23	Green wall to increase evapotranspiration
19	Green wall to reduce façade surface temperature	24	Provide greening to increase evapotranspiration
22	Provide water features to increase evaporation		

SA 7a

Hard Landscaping

The use of pervious materials in hard landscaped areas helps reduce the ambient air temperature through evaporation and thus improve the microclimate of outdoor open spaces. The related urban microclimate design strategy:

25	Use permeable paving

SA 8a
SA 8c

Wind Amplification/ Air Ventilation Assessment

These credits encourage building designs that help enhance the wind environment in the surrounding outdoor pedestrian areas. A good wind environment is a key factor in the provision of thermally comfortable open spaces. The related urban microclimate design strategies include:

1	Manipulate layout massing to increase wind flow	8	Increase building permeability
2	Wind corridor to align with the prevailing wind	9	Permeable sky garden
3	Connect open spaces	10	Reduce building frontage
4	Arrange buildings to channel wind	11	Ventilation bay / permeable podium
5	Building setback	12	Reduce ground coverage
6	Increase permeability of building blocks / no wall building	13	Increase ground zone air volume
7	Stepped building height profile		

SA 8b

Elevated Temperatures

Shading provided at parking, walkways and plazas reduces direct solar radiation on pedestrians, while light-coloured high-albedo materials reduce the surface temperature of the shading structure. Both reduce the amount of solar radiation reaching open spaces and thus improve an area's microclimate. The related urban microclimate design strategies include:

22	Water features to increase evaporation	25	Use permeable paving
24	Greening to increase evapotranspiration		

BEAM Plus New Buildings Version 2.0

This version succeeds Version 1.2 when released. The credits and summary presented below are based on the BEAM Plus New Buildings Version 2.0 Upgrade Training Course held in July 2017. Please refer to the official release of BEAM Plus New Buildings Version 2.0 manual for any discrepancy.

SA P1 Minimum Landscaping Requirements

The requirements for minimum landscape area increase the amount of greenery in urban developments. Greenery can take the different forms of green walls, large trees, shrubs, etc. They help improve the microclimate of outdoor spaces by providing shading for pedestrian activities, reducing the surface temperature of building façade and lowering ambient temperature through evaporation. The related urban microclimate design strategies include:

15	Provide tree canopies	23	Green wall to increase evapotranspiration
19	Green wall to reduce façade surface temperature	24	Greening to increase evapotranspiration
22	Water features to increase evaporation		

SA 1 Pedestrian-oriented and Low Carbon Transport

Microclimate design can help create a pleasant environment for pedestrians in the outdoor space. The related urban microclimate design strategies include:

15	Provide tree canopies	24	Greening to increase evapotranspiration
19	Green wall to reduce façade surface temperature	29	Reduce anthropogenic heat discharge near pedestrian area
23	Green wall to increase evapotranspiration		

SA 7 Ecological Preservation/ Enhancement

This credit encourages tree retention to enhance the ecological value in terms of habitat and biodiversity. The preserved trees are typically mature with relatively large tree crowns. They provide effective shading to reduce direct solar radiation on pedestrians. The related urban microclimate design strategy:

15	Provide tree canopies

SA 8 Urban Heat Island Mitigation

UHI is a major environmental issue in urban areas. The provision of extensive tree coverage helps reduce the ambient temperature and shade the outdoor space. The UHI study under BEAM Plus is an assessment considering various design parameters and environmental factors related to UHI, such as water bodies, greenery ratio, thermal effect of building material and air ventilation etc. The urban microclimate design strategies in the Guidebook address some of the above design parameters and environmental factors that help reduce the UHI effect. The related urban microclimate design strategies include:

1	Manipulate layout massing to increase wind flow	15	Provide tree canopies
2	Wind corridor to align with the prevailing wind	16	Manipulate building façade design to provide shading
3	Connect open spaces	17	Shade openness by building blocks
4	Arrange buildings to channel wind	18	Use cool material for ground surface
5	Building setback	19	Green wall to reduce façade surface temperature
6	Increase permeability of building blocks / no wall building	20	Increase albedo in buildings
7	Stepped building height profile	21	Increase sky view factor to improve night cooling
8	Increase building permeability	22	Water features to increase evaporation
9	Permeable sky garden	23	Green wall to increase evapotranspiration
10	Reduce building frontage	24	Greening to increase evapotranspiration
11	Ventilation bay / permeable podium	25	Use permeable paving
12	Reduce ground coverage	31	Provide cover for rain protection
13	Increase ground zone air volume		

SA 9 Immediate Neighbourhood Wind Environment

This credit encourages building designs that help enhance the wind environment in the surrounding outdoor pedestrian areas. A good wind environment is a key factor in the provision of thermally comfortable open spaces. The related urban microclimate design strategies include:

1	Manipulate layout massing to increase wind flow	8	Increase building permeability
2	Wind corridor to align with the prevailing wind	9	Permeable sky garden
3	Connect open spaces	10	Reduce building frontage
4	Arrange buildings to channel wind	11	Ventilation bay / permeable podium
5	Building setback	12	Reduce ground coverage
6	Increase permeability of building blocks / No wall building	13	Increase ground zone air volume
7	Stepped building height profile		

SA 10

Outdoor Thermal Comfort

The intent of this credit is similar to OEQ1 under BEAM Plus Neighbourhood Version 1.0, which aims to improve human thermal comfort in the outdoor space. The related urban microclimate design strategies include:

1	Manipulate layout massing to increase wind flow	10	Reduce building frontage
2	Wind corridor to align with the prevailing wind	11	Ventilation bay/ permeable podium
3	Connect open spaces	12	Reduce ground coverage
4	Arrange buildings to channel wind	13	Increase ground zone air volume
5	Building setback	14	Provide shading for pedestrian activities
6	Increase permeability of building blocks / no wall building	15	Provide tree canopies
7	Stepped building height profile	16	Manipulate building façade design to provide shading
8	Increase building permeability	17	Shade openness by building blocks
9	Permeable sky garden	31	Provide cover for rain protection

SA 11

Stormwater Management

Some of the microclimate design strategies promote on-site water retention to reduce ambient temperature through evaporative cooling. The water retention capability in these features also helps manage stormwater. The related urban microclimate design strategies include:

22	Water features to increase evaporation	25	Use permeable paving
24	Greening to increase evapotranspiration		

HWB 3

Inclusive Design

Rainfall reduces the usage of outdoor space. Weather protection features against wind-driven rain is an effective application of inclusive design that improves the user-friendliness of an outdoor space. The related urban microclimate design strategy:

31	Provide cover for rain protection

BEAM Plus Neighbourhood Version 1.0

BEAM Plus Neighbourhood is developed by the HKGBC. It is designed to assess the performance of a development project and help owners incorporate a broader framework of urban sustainability principles at the early planning stage for subsequent project implementation.

The following credits in BEAM Plus Neighbourhood Version 1.0 address microclimate design and the linkage to the urban microclimate design strategies is described.

CA 3d
SA 2c

Shaded or Covered Pedestrian Routes to Basic Services or Recreational Facilities / Shaded or Covered Pedestrian Routes to Open Space, Green Space and Blue Assets

Strategies to reduce direct solar radiation, including shading and tree canopies, help shade pedestrian routes to basic services or recreational facilities. The related urban microclimate design strategies include:

5	Building setback	16	Manipulate building façade design to provide shading
14	Provide shading for pedestrian activities	31	Provide cover for rain protection
15	Provide tree canopies		

SA 2a
SA 2b

Neighbourhood Open Space, Green Space and Blue Assets / Provision of Open Space, Green Space and Blue Assets

The incorporation of natural woodland, shrub land, grassland, wetland and water bodies in the project site helps reduce the ambient air temperature through evaporation. The provision of open space by reducing the ground coverage of a building structure helps increase ventilation. The related urban microclimate design strategies include:

12	Reduce ground coverage	24	Greening to increase evapotranspiration
22	Water features to increase evaporation		

SA 7

Quality Open Space

The "Public Open Space in Private Developments Design and Management Guidelines" published by the Development Bureau provides a framework to improve the quality of public open spaces. The open-to-sky design element helps increase sky view factor to improve night cooling, which in turn reduces surface temperature. The considerations in landscape planning and planting encourage the use of water features, greenery, shading, tree canopies etc. to improve the microclimate of public open spaces. The related urban microclimate design strategies include:

14	Provide shading for pedestrian activities	22	Water features to increase evaporation
15	Provide tree canopies	23	Green wall to increase evapotranspiration
16	Manipulate building façade design to provide shading	24	Greening to increase evapotranspiration
19	Green wall to reduce façade surface temperature	31	Provide cover for rain protection
21	Increase sky view factor to improve night cooling		

OEQ 1 Outdoor Thermal Comfort

Outdoor thermal comfort is a common criterion in the assessment of the microclimate of outdoor spaces in BEAM Plus. The urban microclimate design strategies in the Guidebook under the radiation and wind categories aim to reduce direct solar radiation and increase ventilation at the project site—two major factors in the improvement of outdoor thermal comfort. The related urban microclimate design strategies include:

1	Manipulate layout massing to increase wind flow	10	Reduce building frontage
2	Wind corridor to align with the prevailing wind	11	Ventilation bay/ permeable podium
3	Connect open spaces	12	Reduce ground coverage
4	Arrange buildings to channel wind	13	Increase ground zone air volume
5	Building setback	14	Provide shading for pedestrian activities
6	Increase permeability of building blocks / no wall building	15	Provide tree canopies
7	Stepped building height profile	16	Manipulate building façade design to provide shading
8	Increase building permeability	17	Shade openness by building blocks
9	Permeable sky garden	31	Provide cover for rain protection

OEQ 2 Intra-urban Temperature and Urban Heat Island Effect

UHI is a major environmental issue in built- up areas. The provision of extensive tree coverage helps reduce ambient temperature and shade the outdoor space. The UHI study under BEAM Plus is an assessment considering various design parameters and environmental factors related to UHI, such as water bodies, greenery ratio, thermal effect of building material, air ventilation etc. The urban microclimate design strategies in the Guidebook address some of the above design parameters and environmental factors that help reduce the UHI effect. The related urban microclimate design strategies include:

1	Manipulate layout massing to increase wind flow	15	Provide tree canopies
2	Wind corridor to align with the prevailing wind	16	Manipulate building façade design to provide shading
3	Connect open spaces	17	Shade openness by building blocks
4	Arrange buildings to channel wind	18	Use cool material for ground surface
5	Building setback	19	Green wall to reduce façade surface temperature
6	Increase permeability of building blocks / no wall building	20	Increase albedo in buildings
7	Stepped building height profile	21	Increase sky view factor to improve night cooling
8	Increase building permeability	22	Water features to increase evaporation
9	Permeable sky garden	23	Green wall to increase evapotranspiration
10	Reduce building frontage	24	Greening to increase evapotranspiration
11	Ventilation bay / permeable podium	25	Use permeable paving
12	Reduce ground coverage	31	Provide cover for rain protection
13	Increase ground zone air volume		

Overseas Urban Microclimate Design

Urban microclimate strategies must cater for the specific environment a place is in. Hong Kong's sub-tropical climate is characterised by its hot and humid summers, and the same features are shared by some other places in the world. This chapter reviews the strategies employed in four places that share similar climatic characteristics with Hong Kong— Singapore, Japan, Macau and Brisbane (Australia). Selected projects and cases are also illustrated.

The overseas cases indicate the need for strong initiatives and efforts from both the Government and industry to address issues concerning the urban microclimate. It is also important to have long-term strategic plans, given the complexities involved and the long life-span of the building stock. To achieve the healthy city vision in Hong Kong 2030+, concerted efforts from the Government and industry are much required.

Singapore	Guidelines	• Sensitive Design and Development: An Industry Guide of Good Practices to Minimise Wall-Like Development • Building, Planning and Massing
	Case Study	• South Beach
Japan	Guidelines	• CASBEE-HI
	Case Studies	• Osaki Urban Renaissance Vision • ACROS Fukuoka Prefectural International Hall
Brisbane, Australia	Guidelines	• Buildings that Breathe
Macau	Case Study	• New Reclamation Areas

Singapore

There are two main guides in Singapore on better urban microclimate designs. They are ***Sensitive Design and Development: An Industry Guide of Good Practices to Minimise Wall-Like Development,*** and ***Building, Planning and Massing.***

Tall buildings with long continuous façade are the focus in *Sensitive Design and Development*. The guide takes lessons both locally and from Hong Kong. It serves as a framework to address the environmental concerns brought about by wall-like developments.

The study team examined the relationship between building length and height to establish a comfortable scale and massing for developments with three ranges—acceptable, intervention and undesirable. On top of that, standards of spacing between buildings according to their heights and numbers of buildings are set.

For buildings falling into the intervention zone, their developments are reviewed against a set of performance criteria:

a. Whether the development enhances the streetscape;
b. Whether the surrounding developments can view major green and blue public spaces;
c. Whether effective mitigating measures have been adopted to break down building massing.

The guide focuses heavily on view and psychological issues, but wall buildings also affect a place's urban microclimate.

Building, Planning and Massing gives building owners, architects, engineering consultants and other parties in a building project information on sustainable building design, attributes of green buildings, the latest green building technologies, and design strategies and approaches.

A majority of the guide's content is related to urban microclimate, such as the chapters of Building Siting, Massing and Orientation, Natural Ventilation, and Building Greenery and Landscaping. It encourages an integrated approach in the design process, which requires early in-depth understanding of the interactions between the building systems and the environment, early and closer communication of project team members, iterative processes and design analysis tools.

In Building Siting, Massing and Orientation, the issues of UHI and storm water generation are introduced. Later in the chapter of Natural Ventilation, designers are encouraged to consider the wind flow by various strategies, such as manipulating differences in building heights and arrangement of blocks, and the use of sky gardens and void decks. In Building Greenery and Landscaping, ground greenery, green roofs and vertical green walls are suggested as possible ways to mitigate the UHI effect and to generate other benefits for the environment.

Singapore's two guides provide a holistic overview for practitioners to design for better urban microclimate and offers practical strategies for them to follow.

Related strategies:

- **Wind corridor to align with the prevailing wind**
- **Stepped building height profile**
- **Increase building permeability**
- **Ventilation bay / permeable podium**
- **Reduce ground coverage**
- **Green wall to reduce façade surface temperature**
- **Increase albedo in buildings**
- **Greening to increase evapotranspiration**

A 280m long canopy covers the pedestrian outdoor space at South Beach, Singapore. It provides shading and rain protection, and captures the prevailing wind for natural ventilation at the pedestrian walkway.

Case Study: **South Beach, Singapore**

South Beach is a mixed-use development with two high-rise towers on a site with four historical buildings. Alongside with office, retail, residential and hotel space, the project has large semi-outdoor public spaces and a wide pedestrian avenue at the ground level with sunken courtyards and tiered gardens routing people through the site.

In the project, microclimate considerations were adopted at the design development stage to enhance environmental and energy performance. A parametric environmental design analysis was conducted to optimise thermal comfort, daylight and natural ventilation, and to harvest renewable energy and rainwater.

During the design stage, a large canopy was planned at the landscaped pedestrian avenue weaving through the elongated site, providing a naturally conditioned semi-outdoor pathway. The canopy consists of steel and aluminium louvres that flex above the primary walkway near the site boundary. It forms a series of horizontal sun shading louvres carefully angled to facilitate natural ventilation. Particular concerns were given to the following:

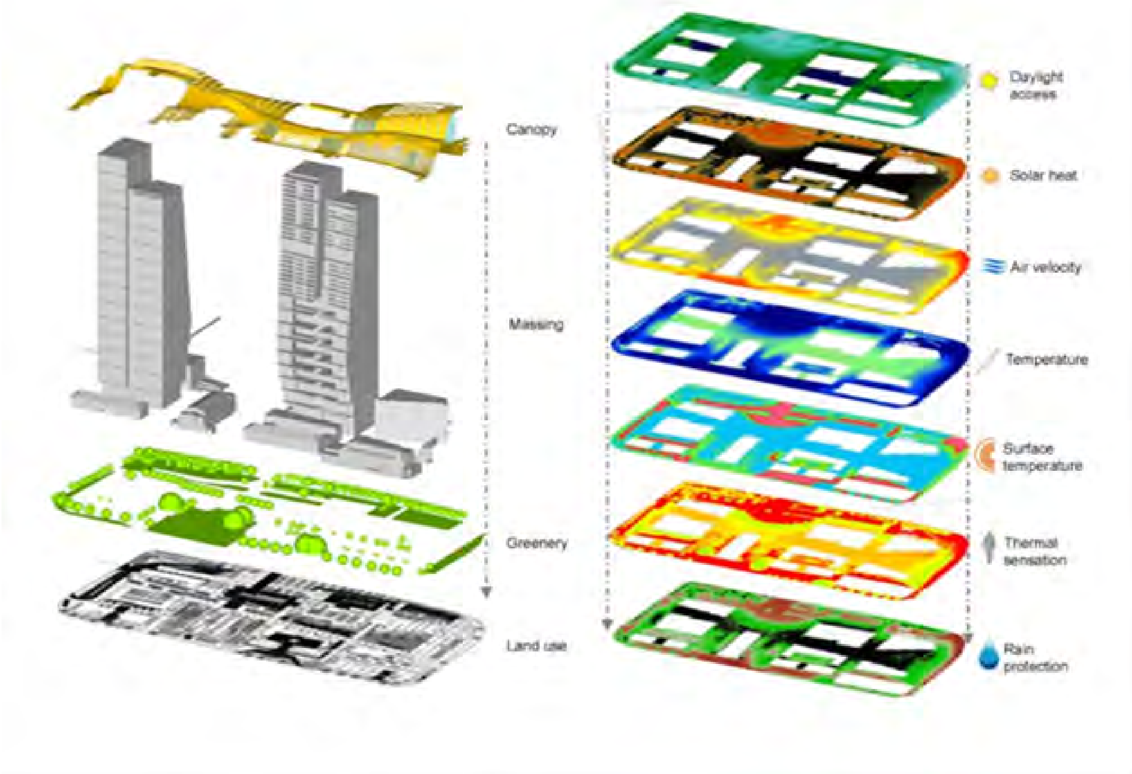
a. Daylight access
b. Solar heat
c. Air velocity
d. Temperature
e. Surface temperature
f. Thermal sensation
g. Rain protection

The undulating form of the canopy was evolved through an iterative process of parametric environmental design analysis to simulate the environmental performance. Accordingly, each aluminium louvre on the canopy was carefully adjusted to fulfil the design intent.

Furthermore, extensive greenery was integrated into the design of the public spaces and building envelope at South Beach. This helps mitigate the urban heat island effect and improve the thermal comfort of pedestrians in the development.

Related strategies:

- **Wind corridor to align with the prevailing wind**
- **Connect open spaces**
- **Building setback**
- **Ventilation bay / permeable podium**
- **Reduce ground coverage**
- **Provide shading for pedestrian activities**
- **Manipulate building façade design to provide shading**
- **Greening to increase evapotranspiration**



Project name: South Beach
Location: Singapore
Completion: 2016
Site area: 34,950m^2
Gross floor area: 146,827 m^2
Building type: Mixed-use

Japan

In Japan, urban microclimate efforts at the policy level are best reflected in its guidelines, assessment system, and the setup of 'model areas' to mitigate the urban heat island effect.

Guidelines for Architectural Design to Mitigate the Urban Heat Island Effect were issued by the Ministry of Land Infrastructure and Transport in 2004, followed by ***the Comprehensive Assessment System for Built Environmental Efficiency on Heat Island Relaxation (CASBEE-HI)*** in 2006.

They encourage owners, professionals and designers in the building industry to adopt mitigation measures. The Guidelines give recommendations on shading, surface cover, exterior construction materials, open and airy space and heat release from the building.

Related strategies:

- **Wind corridor to align with the prevailing wind**
- **Connect open spaces**
- **Building setback**
- **Ventilation bay / permeable podium**
- **Reduce ground coverage**
- **Provide shading for pedestrian activities**
- **Manipulate building façade design to provide shading**
- **Greening to increase evapotranspiration**

CASBEE-HI addresses the quality of the outdoor environment of a building site, the load of the surrounding environment and the planet as a whole. It evaluates building designs by their effects on urban ventilation, shadows, the choice of ground cover materials, the choice of wall materials, and building and anthropogenic heat emissions. The assessment of each item is conducted according to the building type (residential or non-residential), site conditions, and plot ratios.

Concrete implementation examples can be seen in the model areas established under the policy *Development of Measures against Global Warming and Heat Islands through Urban Renaissance Projects*. Thirteen areas in 10 cities were designated in 2005, where environmental and energy-saving measures were implemented to mitigate the UHI effect. The **Osaki/ Meguro** district in Tokyo is one such area.

The plan to transform the Osaki Station district dates back to July 2002, when it was designated an urban emergency redevelopment area under the Urban Renaissance Special Measures Law. The overall aim was to make the iconic Meguro River part of the area's environmental resources with emphases on UHI mitigation measures, creation of space for the area's community, development of guidelines, and their application to reduce the environmental loads from building projects.

Related strategies:

- **Greening to increase evapotranspiration**
- **Use permeable paving**

In the project, space was created along the Meguro river for residents to interact with water and enjoy Osaki's environmental attributes; wind paths were set aside by positioning buildings at a 45 degree angle to the river; water-retentive pavement was used to lower the temperature of the surface; trees and plants were erected along the road; green spaces were extended to the adjacent land to develop cool spots.

Following that, the *Osaki Station District Environmental-conscious Guidelines* were set forth in July 2005 to encourage developers to undertake environmental measures to mitigate UHI. An *Environmental-conscious Manual* was also developed to present examples to aid practitioners in the implementation of the guidelines.

Read more:

Yamamoto, Yoshika. "Measures to Mitigate Urban Heat Islands." Science and Technology Trends Quarterly Review 18.1 (2006): 65-83.


ODAKYU

Case Study: **ACROS Fukuoka Prefectural International Hall, Fukuoka, Japan**

The ACROS Fukuoka Prefectural International Hall features 15 stepped green terraces. The project presents itself as a powerful solution to reconcile a developer's desire for profitable use of a site with the public's need for open green space.

Before the hall's construction, the city-owned site was originally a park and the last large undeveloped plot in central Fukuoka. It was eventually designated to be developed under a joint-venture scheme, where part of the building's space would be devoted to public and municipal operations, and the remaining revenue-producing. As concerns were raised about the effect of the development on the adjacent Tenjin Central Park, the architect decided to design the space in a way that the same area of land taken up by the building will be given back to the public.

Hence, the building's green terraces are made assessable to the public as gardens for meditation and relaxation, while the top floor offers a panorama of the bay of Fukuoka and the surrounding mountains. Apart from plants, a stepped series of reflecting pools are set up on the terraces, connected by upwardly spraying jets of water. The resulting ladder-like climbing waterfall helps mask the ambient noise of the city beyond. Moreover, the façade of the building rakes outwardly and acts as an awning over the sidewalk to shade pedestrians.

The plant-covered building is proved to be effective in alleviating UHI in a study in 2000 by the Takenaka Corporation, Kyushu University, and Nippon Institute of Technology, which found a difference of 15°C between the surface temperatures of the concrete and the greenery.

The ambient air temperature of the surrounding is reduced due to evapotranspiration of vegetation.

Related strategies:

- **Wind corridor to align with the prevailing wind**
- **Provide shading for pedestrian activities**
- **Green wall to reduce façade surface temperature**
- **Water features to increase evaporation**
- **Greening to increase evapotranspiration**

Read more:

Greenroofs. "ACROS Fukuoka Prefectural International Hall." 2015. Web. <http://www.greenroofs.com/projects/pview.php?id=476>.

Project name: ACROS Fukuoka Prefectural International Hall
Location: Japan
Completion: 1994
Site area: 97,493m^2
Gross floor area: 97,252 m^2
Building type: Commercial

Brisbane, Australia

Brisbane's ***Buildings that Breathe*** guide is part of the ***Brisbane City Plan 2014*** and aims to provide an inspirational design benchmark for practitioners, developers and professionals to design buildings that respond to the city's sub-tropical climate, urban character and outdoor lifestyle. The 2016 guide consists of eight elements, four of which concern urban microclimate. They are "Orientate Yourself", "Natural Air and Ventilation", "Shade and Protection", and "Living Greenery".

In Orientate Yourself, the importance of location and orientation is stipulated. The location and orientation should consider solar access, prevailing breezes, natural features and topography, the guide advises.

The importance of bringing in natural ventilation, installing operable windows, using doors and openings at the ground level, and employing layered façades is emphasised in Natural Air and Ventilation. The guide highlights the benefits on health, costs, the environment and street activities of better natural ventilation.

Shade and Protection addresses the hot and rainy summer circumstances in sub-tropical Brisbane. It encourages the use of shade structures, external shading devices, awnings and operable blinds to shade and protect pedestrians from torrential rainfall. The sense of sheltered openness and occupants' ability to control shade according to the sun's position and strength are stressed.

The benefits of urban vegetation in the reduction of the UHI effect and cooling public spaces are addressed in Living Greenery. The strategies it introduces include internal planting, elevated gardens, ground plane gardens and vertical greenery. The guide envisages a city as an urban garden to enrich inhabitants' urban experience and create a distinct city profile.

All in all, the non-statutory guide provides clear and simple guidance for the industry to create a city that is of character and comfortable to live in.

Related strategies:

- **Arrange buildings to channel wind**
- **Building setback**
- **Increase building permeability**
- **Provide shading for pedestrian activities**
- **Provide tree canopies**
- **Manipulate building façade design to provide shading**
- **Shade openness by building blocks**
- **Green wall to reduce façade surface temperature**
- **Increase albedo in buildings**
- **Greening to increase evapotranspiration**
- **Provide cover for rain protection**

Shade structures, external shading devices, awnings and operable blinds can help shade and protect pedestrians from torrential rainfall.

> “Vision: Our city is a sub-tropical urban garden occupied by buildings that breathe – open to our climate and adorned with greenery.
>
> Building walls and windows open up to natural light and air, capturing ambient daylight and cooling breezes, reducing our energy needs.
>
> Shaded outdoor spaces with panoramic views create memorable places to meet and relax.
>
> Generous planting grows on our streets, rooftop and walls, embedding green into our city and enriching our urban biodiversity.
>
> In Brisbane, our buildings celebrate our sub-tropical climate.”
>
> —— ***Buildings that Breathe***

Macau New Reclamation Areas

Macau has planned to create six reclamation areas around its present coasts. As they are situated at the wind gap, concerns were raised about the possible impact on the microclimate of the existing neighbourhoods in the Old Town of Macau and northern Taipa.

Against this background, the city commissioned The Chinese University of Hong Kong to conduct a study on the possible impact, so constructions that may adversely affect the urban climate can be avoided by preserving wind paths, using open areas and designating green areas. It follows the city's strategy to study its urban climate, establish a database, build an urban climate map and draw up planning guidelines.

In the study, the turbulent wind field in Macau is simulated and analysed, and situations with and without the new reclamation areas are compared.

The study reveals that ventilation in the existing districts of the Peninsula of Macau is extremely spatially varied. It confirms some well-known facts of the urban canopy layer:

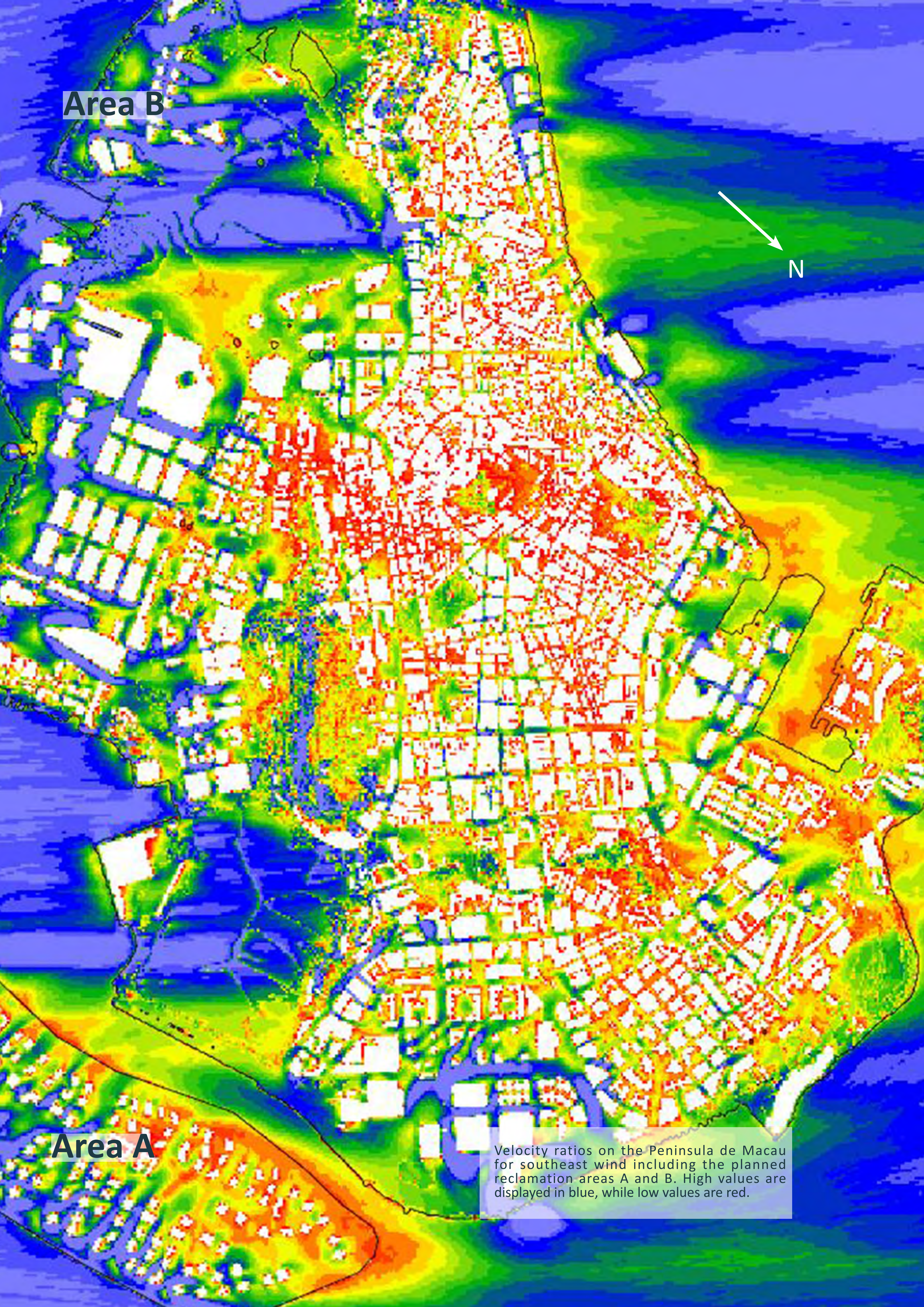
a. Wide streets are better ventilated than narrow ones;
b. Isolated high-rise buildings can improve the ventilation of the surrounding area;
c. Districts with very uniform building heights are worse ventilated than those with greater building height variability.

Moreover, it finds that two areas of the planned reclamation may adversely affect ventilation in some existing districts. It suggests building arrangements in the planned reclamation areas be further optimised to minimise the effect.

Related strategies:

- **Manipulate layout massing to increase wind flow**
- **Provide shading for pedestrian activities**
- **Provide tree canopies**
- **Manipulate building façade design to provide shading**
- **Shade openness by building blocks**

Map of the Peninsula de Macau and Taipa. Displayed in orange are the six planned reclamation areas.



Velocity ratios on the Peninsula de Macau for southeast wind including the planned reclamation areas A and B. High values are displayed in blue, while low values are red.

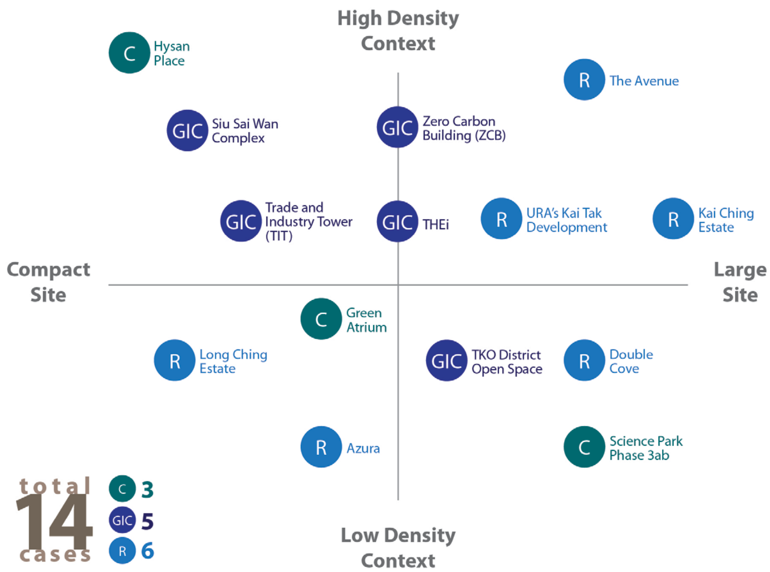
Local Good Practice – Case Studies

In Hong Kong, many projects have taken measures to minimise their effect on or even improve the microclimate of their areas. They provide good, practicable and concrete examples to practitioners in future designs. Here, 14 cases of different site contexts are selected from the shortlisted projects in Green Building Award 2012, 2014 and 2016, and BEAM Plus Platinum (Final Assessment). In determining which strategies to employ in a project, site context is of paramount importance. Therefore, practitioners are encouraged to see from this chapter which strategies are the most relevant to them.

In elaborating each case, six questions are asked and answered. They are:

- Where is the project site?
- What are the key microclimate features?
- Why is it important to care for the microclimate there?
- How were the microclimate conditions studied and improved?
- When were the microclimate conditions and potential strategies taken into account in the process?
- What are the expected achievements?


POAD


High Density Context
Low Density Context
Compact Site
Large Site
C Hysan Place
R The Avenue
GIC Siu Sai Wan Complex
GIC Zero Carbon Building (ZCB)
GIC Trade and Industry Tower (TIT)
GIC THEi
R URA's Kai Tak Development
R Kai Ching Estate
C Green Atrium
R Long Ching Estate
GIC TKO District Open Space
R Double Cove
R Azura
C Science Park Phase 3ab
total 14 cases
C 3
GIC 5
R 6

		1. Kai Ching Estate	2. Double Cove	3. HK Science Park Phase 3ab	4. The Avenue	5. Long Ching Estate	6. URA's Kai Tak Development	7. VTC THEi Chai Wan Campus	8. Trade and Industry Tower	9. Siu Sai Wan Complex	10. CIC Zero Carbon Building	11. District Open Space in TKO	12. The Green Atrium	13. Hysan Place	14. Azura
Site Context		Larger Site				Compact Site				Low-rise Development				Single Building	
Wind															
Increase ventilation with site planning															
01	Manipulate layout massing to increase wind flow	●		●	●		●	●			●	●			
02	Wind corridor to align with the prevailing wind	●		●		●	●	●		●	●				
03	Connect open spaces	●								●					
04	Arrange buildings to channel wind	●	●	●		●		●		●					
05	Building setback				●	●				●	●	●			
06	Increase permeability of building blocks / no wall buildings	●	●	●	●	●	●	●				●			
07	Stepped building height profile					●	●								
Increase ventilation with building design															
08	Increase building permeability						●						●	●	
09	Permeable sky garden				●								●	●	
10	Reduce building frontage										●	●			
11	Ventilation bay / permeable podium	●	●			●		●			●			●	●
12	Reduce ground coverage			●			●								
13	Increase ground zone air volume			●	●	●			●	●					●
Thermal Radiation															
Reduce direct solar radiation															
14	Provide shading for pedestrian activities	●	●	●		●		●	●	●	●	●	●		●
15	Provide tree canopies	●	●	●	●	●	●	●	●	●	●	●			●
16	Manipulate building façade design to provide shading	●				●				●	●				
17	Shade open space by building blocks	●	●		●	●		●						●	
Reduce surface temperature															
18	Use cool material for ground surface	●									●				
19	Green wall to reduce façade surface temperature	●	●					●	●		●		●		
20	Increase albedo in buildings	●			●	●		●			●	●		●	●
21	Increase sky view to improve night cooling		●								●	●			
Temperature															
Increase evaporative cooling															
22	Water features to increase evaporation		●		●								●		●
23	Green wall to increase evapotranspiration	●	●					●	●		●		●		
24	Greening to increase evapotranspiration	●	●	●	●	●	●	●	●	●	●	●	●	●	●
25	Use permeable paving	●	●	●		●	●	●		●	●	●		●	
Reduce heat accumulation															
26	Increase ventilation to carry away heat energy										●		●		
27	Allow downhill wind flow														
28	Allow sea breezes		●	●				●							
Reduce heat release															
29	Reduce anthropogenic heat discharge near pedestrian area	●	●	●	●		●				●	●			
30	Reduce thermal mass heat storage of building materials										●		●		
Precipitation															
Provide rain protection															
31	Provide cover for rain protection	●	●	●		●			●						

Table 7 Strategies each project has employed.

Kai Ching Estate

Increase ventilation with site planning

Location: Kai Tak
Completion: 2013
Site area: 34,700m^2
Gross floor area: 224,750m^2
Building type: Public housing
Recognition: GBA2014 Merit

Where

The large new-development site in Kai Tak faces the Victoria Harbour on one side and the old and dense districts of San Po Kong, Choi Hung and Kowloon Bay on the other.

What

Prevailing wind and sea breezes.

Why

The high density of its neighbouring districts means its master layout plan and building design must be carefully developed to minimise or even eliminate the impact not only on its own microclimatic conditions, but also its vicinity's. The wind environment is of particular concern.

How

A microclimate study was conducted by the Housing Authority. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Two features are of particular emphasis here:

Improving the wind environment:
- Manipulate layout massing to increase wind flow (Strategy 01);
- Increase permeability of building blocks/ no wall buildings (Strategy 06).

When

The wind environment at the site and the surrounding neighbourhoods was considered at both the planning and design stages. At the planning stage, the layout massing was arranged to align with the wind corridors. At the design stage, the wind environment was further optimised with building design strategies. For example, openings were provided at the ground level and wings of domestic blocks were rotated to widen building separation. Thermal comfort at the open spaces with pedestrian activities was analysed and recommendations were made for areas of concern.

Achieve-ments

- Capturing the incoming south-easterly prevailing wind and sea breezes;
- Improvement in the wind environment, maximisation of natural ventilation at the site, and increase in wind penetration;
- Improvement in residents' outdoor thermal comfort condition in summer.

Domestic blocks were positioned to capture the prevailing south-easterly and south-westerly wind for most of the year to maximise its ventilation performance.

Blocks were designed to have no bulky podium structures to reduce ground coverage and increase permeability for better ventilation at open spaces. The provision of large ventilation bays further improves the building permeability.

The site has a greening ratio of 30%, cooling the open space with evapotranspiration. Large trees were planted at the pedestrian areas to improve thermal comfort.

Double Cove

Increase evaporative cooling

Location: Ma On Shan
Completion: 2015
Site area: 96,841m^2
Gross floor area: 274,123m^2
Building type: Residential/ Commercial
Recognition: GBA2012 Merit

Where

The large new-development project is located on a natural twin-cove peninsula in Wu Kai Sha, facing Tolo Harbour. There are small villages and a few other relatively open sites nearby.

What

Prevailing wind, sea breezes, and provision of extensive greenery.

Why

Its large site and seafront position mean its master layout and building design do not only have an effect on the project's own microclimate, but also that of the future developments in its vicinity.

How

In this project, AVA and microclimate studies were conducted. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Three features are of particular emphasis here:

Mitigating the UHI effect:

- Install water features to increase evaporation (Strategy 22);
- Provide landscaped area for more than 40% of the site. It comprises preserved woodlands, recreated woodland and landscaped decks with extensive green roofs, walls and water features (Strategies 19, 22, 23 and 24);
- Increase sky view factor by leaving large open spaces between building blocks (Strategy 21).

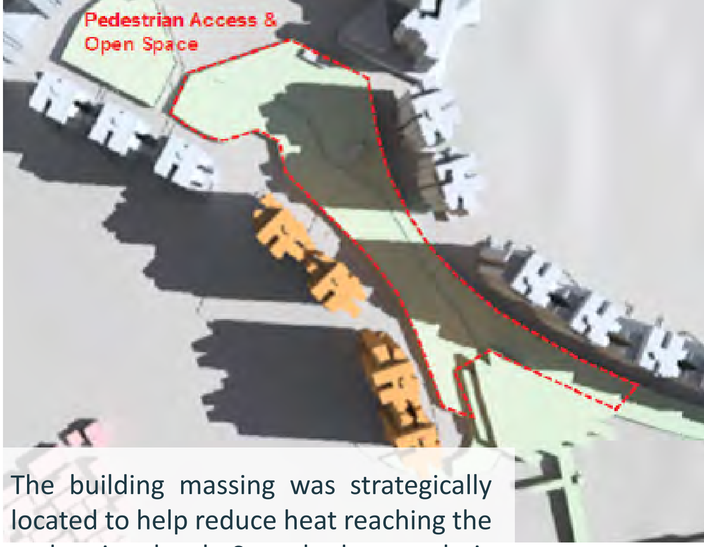
When

A heat island index assessment based on a scientific model was conducted at the early schematic design stage. Microclimate factors, including the wind environment, sun shadow of building blocks, landscape design, and sky view of the open space, were considered. Each of these factors was analysed and optimised to ensure the heat island effect is within the desired range.

Achievements

- Capturing the incoming prevailing wind and sea breezes;
- Mitigation of the UHI effect;
- Improvement in residents' outdoor thermal comfort in summer.

Building blocks were arranged to enhance wind penetration.



The building massing was strategically located to help reduce heat reaching the pedestrian level. Sun shadow analysis was conducted to evaluate the level of direct sun penetration at each hour. By optimising the climatic factors of wind, sun shadow and sky view, and the design parameters of greenery, water features, etc., the daily averaged heat island temperature was limited to 1.5°C.

Over 40% of the site is landscaped area comprising preserved woodlands, recreated woodland and landscaped decks with extensive green roofs, green walls and water features to lower heat accumulation. The large size of the project site means it can effectively reduce the ambient temperature and improve the microclimate of the site itself and the surrounding neighbourhoods.

Hong Kong Science Park Phase 3ab

Increase ventilation with site planning

Location: Taipo
Completion: 2013
Site area: 62,487m^2
Gross floor area: 73,742m^2
Building type: Commercial
Recognitions: GBA2012 Finalist
GBA2014 Grand
BEAM Plus NB V1.1 Platinum

Where

The project is on a large site in Taipo on the shore of Tolo Harbour. There are some small villages and a few other relatively open sites nearby.

What

Prevailing wind, sea breezes, and lush greenery surrounding the site.

Why

The large new-development site occupies a seafront area. Its master layout and building design do not only affect its own microclimatic conditions, but also those of the potential development areas in the surroundings.

How

In this project, AVA and microclimate studies were conducted with CFD and other simulations. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Two features are of particular emphasis here:

Improving the wind environment:

- Align wind corridors with the prevailing wind (Strategy 02);
- Arrange building blocks to channel wind flow (Strategy 04);

When

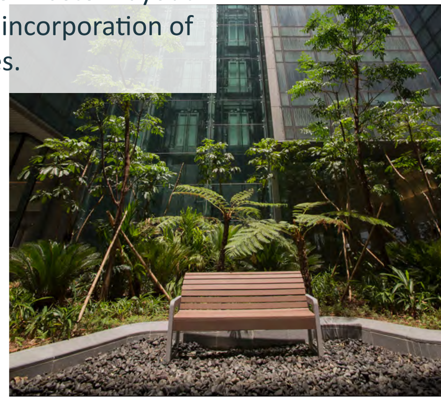
A sustainable master plan was developed at the concept design stage. Climate-sensitive features were identified and design guidelines on matters such as building orientation, building separation and layout massing, were formulated.

Achievements

- Capturing the prevailing wind and sea breezes;
- Improvement in people’s outdoor thermal comfort in summer.

The master layout plan was designed to make the best use of the site and its natural resources (sun, wind and rain). Buildings were positioned and orientated in a way to promote natural site ventilation. Solar footprint was minimised to reduce heat gain.

The consideration for the microclimate in the master layout plan was a critical step. It paved the way for the incorporation of microclimate design strategies at the later stages.



The extensive green coverage of approximately 40% of the site area helps minimise solar heat absorption and reduce the UHI effect. The related design elements are:

- Soft landscape area with local and adaptive species to minimise irrigation needs;
- Cool roof;
- Hardscape with high solar reflective index.

The Avenue

Reduce direct solar radiation

Location: Wan Chai
Completion: 2014
Site area: 8,200m^2
Gross floor area: 133,700m^2
Building type: Mixed use
Recognition: GBA2014 Finalist

Where

The redevelopment project is located on a large site in the densely populated district of Wan Chai.

What

Limited urban ventilation.

Why

The enhancement of urban ventilation at the development and the provision of shading at the pedestrian-only walkway create a comfortable outdoor environment both within and outside the site.

How

An AVA study was conducted to evaluate the wind environment at the pedestrian area. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Five features are of particular emphasis here:

Reducing direct solar radiation:

- Provide tree canopies at the pedestrian-only walkway for shading (Strategies 15);
- Shade open space by building blocks (Strategy 17).

Reducing heat accumulation

- Designate a pedestrian-only walkway to reduce anthropogenic heat discharge in the open space (Strategy 29).

Improving the wind environment:

- Building setback (Strategy 05);
- Increase air volume at the ground zone (Strategy 13).

When

At the schematic design stage, an AVA was conducted to identify options to enhance ventilation at both the development and its surroundings. In the study, the improvement in the wind environment was quantified by comparing the different design schemes.

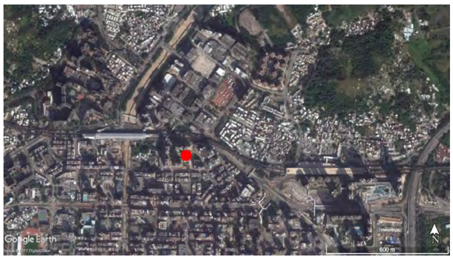
Achievements

- Improvement in the wind environment, maximisation of ventilation, and increase in wind penetration;
- Improvement in pedestrians' outdoor thermal comfort in summer.

The pre-existing street in the large project site has been designated a pedestrian-only walkway. Building blocks and podia on the two sides shade the walkway during daytime, while trees with large canopies provide localised shading from direct solar radiation. The restriction on vehicle access to the walkway effectively reduces anthropogenic heat discharge from motor vehicles, while ventilation is facilitated through the careful design of the podium blocks.

Long Ching Estate

Increase ventilation with building design



Location: Yuen Long
Completion: 2015
Site area: 4,300m^2
Gross floor area: approx. 21,000m^2(dom.)
approx. 850m^2(non-dom.)
Building type: Mixed use
Recognition: GBA2014 Grand

Where

The small redevelopment site in Yuen Long is surrounded by dense neighbourhoods in a compact urban setting. The project consists of two public housing blocks and two podium structures.

What

Limited urban ventilation.

Why

The high-density context makes microclimate considerations in site planning essential for the enhancement of ventilation and residents' enjoyment of the outdoor space.

How

An AVA study was conducted with CFD simulation. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Two features are of particular emphasis here:

Improving the wind environment:

- Increase permeability of building blocks to improve ventilation for the pedestrian area and low zone by adopting a permeable podium design (Strategy 11);
- Adopt permeable building design elements, such as ventilation bay and void deck (Strategy 11).

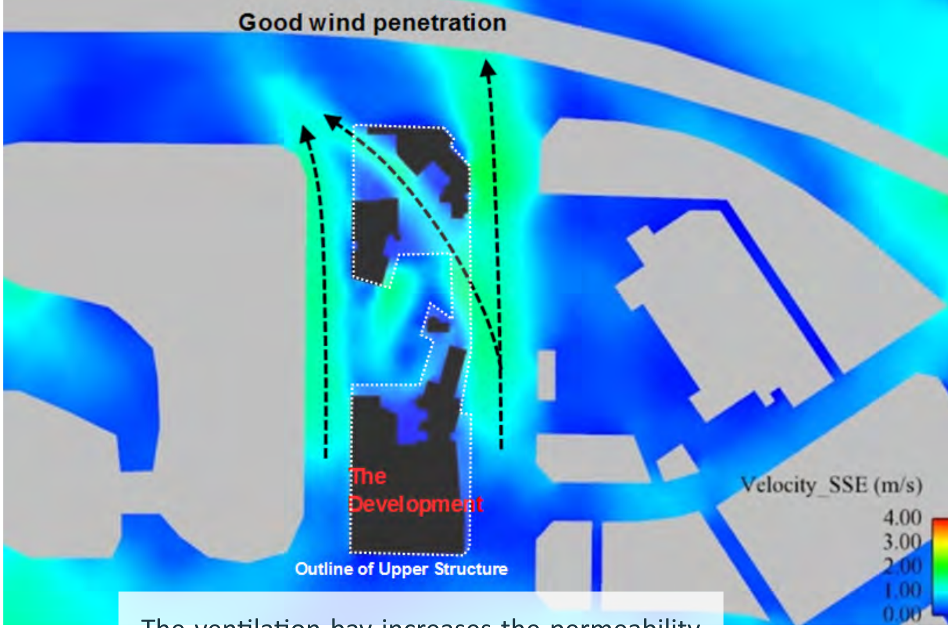
When

Microclimate studies were conducted during the schematic design stage. The wind environment was assessed and openings were provided at the podium to improve wind penetration. Pedestrians' thermal comfort in the open space was also evaluated by the microclimate factors of temperature, solar radiation and wind environment.

Achievements

- Improvement in urban ventilation;
- Reduction in pedestrians' exposure to direct solar radiation exposure;
- Improvement in outdoor thermal comfort in summer.

Building permeability of over 40% was achieved with reference to the SBD Guidelines by leaving large gaps between buildings and setting them back from the from the site boundary.



The ventilation bay increases the permeability of the podium, allowing good wind penetration through the development. CFD simulation was used to assess its ventilation performance, along with other comprehensive microclimate studies at the planning and design stages.

Large building gaps and the permeable podium design facilitate the penetration of the prevailing wind and improve ventilation at the pedestrian zones at the ground level.

URA's Kai Tak Development

Reduce heat release

Location: Kai Tak
Completion: 2015
Site area: 5,700m^2
Gross floor area: 28,470m^2
Building type: Residential
Recognitions: GBA2014 Merit
GBA2016 Grand

Where

The compact new-development site in Kai Tak is situated between the Victoria Harbour and the old and dense districts of San Po Kong, Choi Hung and Kowloon Bay.

What

Prevailing wind and sea breezes.

Why

The large population in the site's neighbouring districts mean the project's master layout and building design do not only have an effect on its own microclimate, but also the vicinity's. The wind environment is of particular concern.

How

An AVA study was conducted by the URA and different design proposals were compared to look for the best option in terms of ventilation. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Three features are of particular emphasis here:

Improving the wind environment:
- Increase building permeability by providing openings in building structure (Strategy 08);
- Adopt stepped building height profile (Strategy 07).

Reducing heat release:
- Reduce anthropogenic heat discharge near the pedestrian area by limiting vehicular access to the development (Strategy 29).

When

At the early concept design stage, the wind performance of three different design schemes was compared with CFD simulation, where the effectiveness of the openings on the building block was quantified. Negotiation with corresponding governmental bodies on parking provision issues was initiated at the early design stage.

Achievements

- Capturing the incoming south-easterly prevailing wind and sea breezes;
- Improvement in the wind environment and maximisation of ventilation across the site;
- Increase in wind penetration;
- Reduction in heat generation from motor vehicles.

The prevailing wind directions were identified early in the concept design stage with wind rose data. Wind corridors and minor breezeways were located after an assessment of the surrounding context found the prevailing south-easterly wind in summer would reach the site through a nearby wind corridor.

In all projects, this can be carried out through qualitative means, such as climatic data analysis and AVA expert evaluation.

A large opening wider than 3m was constructed from the ground up to the middle of the building to increase building permeability. It was aligned with the summer prevailing wind to enhance ventilation in summer.

VTC THEi Chai Wan Complex

Increase ventilation with site planning

Location: Chai Wan
Completion: 2017
Site area: 9,800m^2
Gross floor area: 39,000m^2
Building type: Educational
Recognitions: GBA2014 Grand BEAM Plus NB V1.2 Platinum (Provisional)

Where

The project is on a compact site in Chai Wan, close to a built-up seafront area.

What

Urban ventilation and sea breezes.

Why

The preservation of wind corridor in this project is not only beneficial to the site's own microclimate but also the environment of the nearby built-up areas.

How

A microclimate assessment was conducted with CFD analysis to examine the building permeability level and achieve the best ventilation effect at the pedestrian level. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Three features are of particular emphasis here:

Improving the wind environment:

- Manipulate layout massing to increase wind flow (Strategy 01);
- Align wind corridor with the prevailing wind (Strategy 02);
- Allow sea breezes (Strategy 28).

When

At the early concept design stage, the building orientation was optimised to align with the prevailing wind and seashore to facilitate wind penetration through the development. A CFD simulation was carried out to assess the ventilation performance.

Achievements

- Improvement in the wind environment and maximisation of natural ventilation for the site itself and adjoining areas;
- Increase in sea breeze penetration.

Sustainability was actively considered at the site planning stage. Particularly, a parametric study to maximise permeability of the building design was carried out. In the first step, the summer prevailing wind was identified to be coming from the southeast. Secondly, a twin-tower design was adopted to increase building permeability and improve ventilation. Next, the towers were rotated to align with the south-easterly wind. Lastly, one of the towers was angled to increase windward exposure and strengthen air flow under summer prevailing wind condition.

Trade and Industry Tower

Increase ventilation with site planning

Location: Kai Tak
Completion: 2015
Site area: 8,300m^2
Gross floor area: approx. 53,760m^2
Building type: Office & community hall
Recognitions: GBA2014 Grand
BEAM Plus NB V1.1 Platinum (Provisional)

Where	The project is located on a relatively open site of the Kai Tak development area. The building project consists of 22 storeys above ground and a basement. It accommodates offices, a community hall and car parking facilities.
What	The provision of shading for pedestrians.
Why	Considerations for the pedestrians' comfort under rain and sun will improve usage of the landscaped area.
How	The project has taken particular care over pedestrians' exposure to sun and rain. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Two features are of particular emphasis here: Reducing direct solar radiation: • Provide shading for walkway with frequent pedestrian access (Strategy 14). Rain protection: • Provide cover for rain protection at major pedestrian walkway (Strategy 31).
When	At the design stage, covers were planned at the main entrance drop-off area.
Achieve-ments	• Reduction in direct solar radiation exposure; • Increased usage of the landscaped area on rainy days.

The project's covered walkway shades pedestrians from direct solar radiation on sunny days and provides shelter under rainy conditions. This effectively improves pedestrians' thermal comfort and increases the usability of the space.

Siu Sai Wan Complex

Increase ventilation with site planning

Location: Chai Wan
Completion: 2010
Site area: 4,400m^2
Gross floor area: 25,932m^2
Building type: Institution
Recognition: GBA2012 Grand

Where

The project on a compact site in Chai Wan has two schools at its back and high-rise buildings nearby.

What

Urban ventilation.

Why

The project is located on a wind corridor, the preservation of which is important for ventilation at the neighbouring schools and the district as a whole.

How

An AVA study was conducted and a CFD simulation was employed to examine the building permeability level and ventilation effect at the pedestrian area. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Two features are of particular emphasis here:

Improving the wind environment:
- Connect open spaces for wind penetration by separating the blocks (Strategy 03).

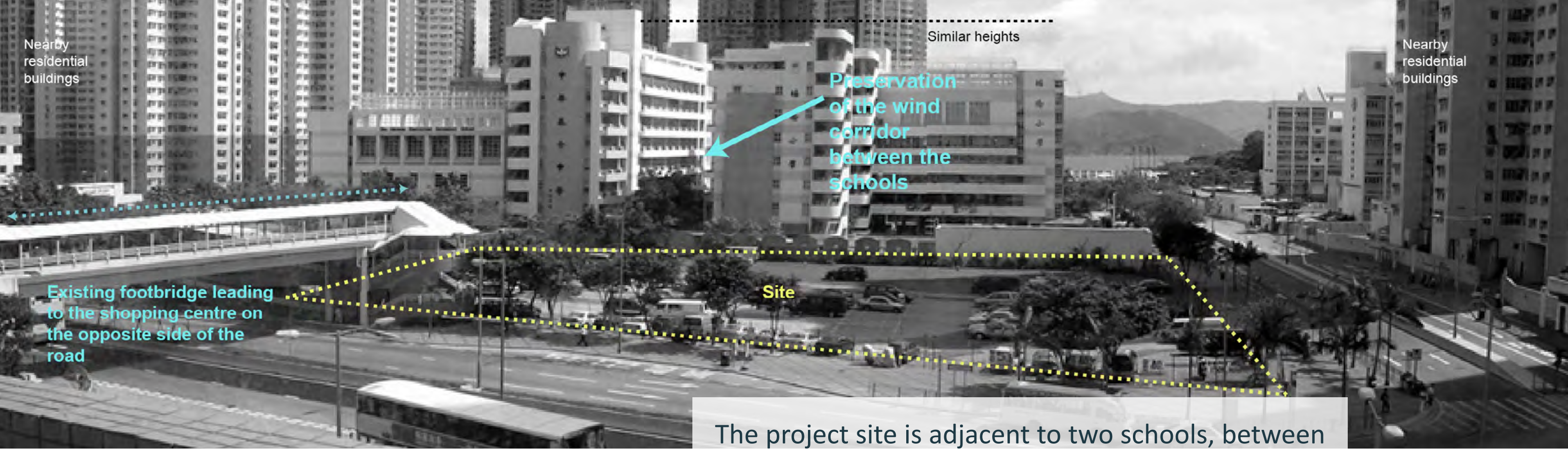
Reducing direct solar radiation:
- Manipulate the building façade and roof design to provide shading for the open space (Strategy 16).

When

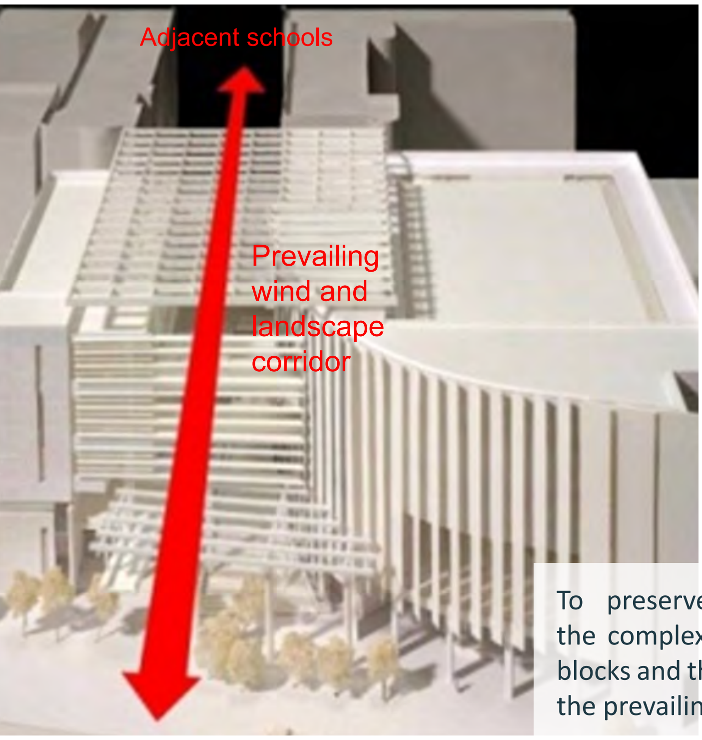
At the concept design stage, a covered open space through the development was planned to preserve the local wind path. A wind study was carried out to evaluate the ventilation performance and effectiveness of the design.

Achievements

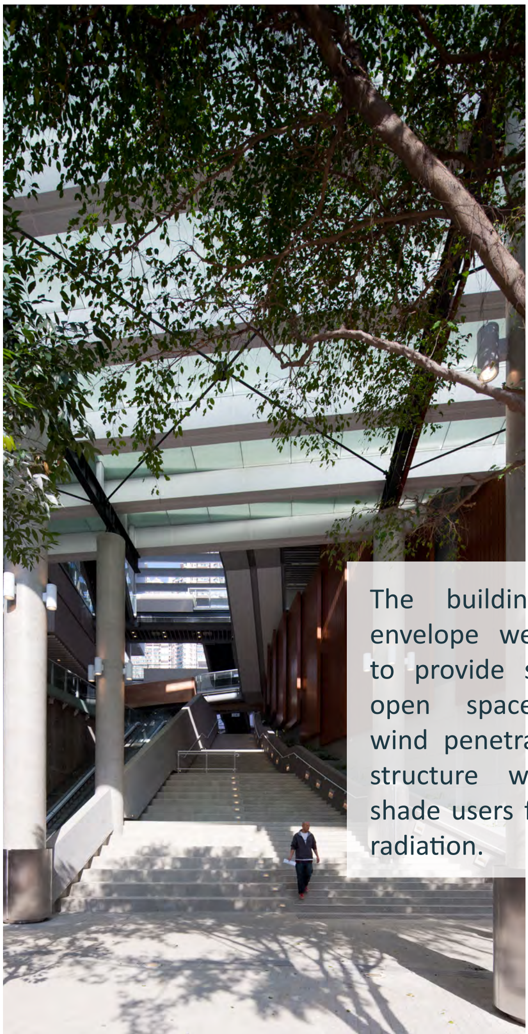
- Improvement in the wind environment and maximisation of natural ventilation at its own site and the neighbouring schools;
- Increase in wind penetration;
- Reduction in pedestrians' direct solar exposure at the open space.



The project site is adjacent to two schools, between which a wind corridor runs through. The design goal was to preserve the existing wind corridor.



To preserve the wind corridor, the complex was divided into two blocks and the gap was aligned with the prevailing wind direction.



The building façade and envelope were manipulated to provide shading for the open space created for wind penetration. A louvred structure was erected to shade users from direct solar radiation.

CIC Zero Carbon Building

Reduce surface temperature

Location: Kowloon Bay
Completion: 2012
Site area: 14,800m^2
Gross floor area: 3,305m^2
Building type: Institutional
Recognitions: GBA2012 Grand
BEAM Plus NB V1.1 Platinum

Where

The project is in the built–up area of Kowloon Bay. It showcases state-of-the-art zero/low carbon building design strategies and technologies in the unique context of Hong Kong.

What

Good urban ventilation by embracing the prevailing wind and the provision of extensive greenery to improve thermal comfort of the open space.

Why

The importance of the project's considerations for urban ventilation and outdoor thermal comfort extends beyond the site itself to its adjoining areas. These considerations drive its master plan and building design.

How

A comprehensive microclimate assessment and thermal comfort analysis were conducted for the evaluation of the conditions at the pedestrian area. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Three features are of particular emphasis here:

Improving thermal comfort of open space:

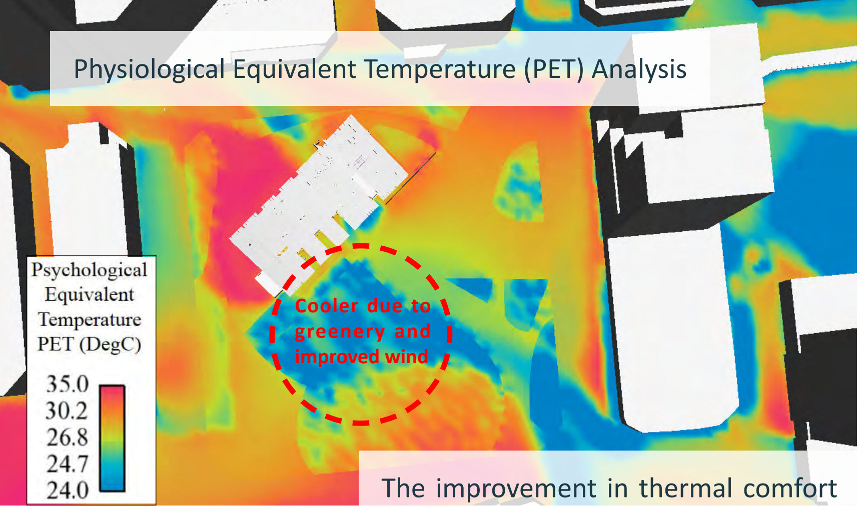
- Use permeable paving to reduce ground surface temperature (Strategy 25);
- Reduce thermal mass heat storage of building materials by shading the building structure with light-weight materials (Strategy 30);
- Provide greenery to lower surface temperature (Strategy 19).

When

At the beginning of the concept design stage, the building was planned to be placed at the area with the highest exposure to direct solar radiation, leaving the open space shaded. Also, the building shape was designed to facilitate prevailing wind flow. The wind environment, solar radiation and landscape design were taken into account in assessing the thermal comfort of the outdoor space. In the analysis process, wind CFD simulation, sun shadow and solar radiation analysis were conducted to support the thermal comfort calculation.

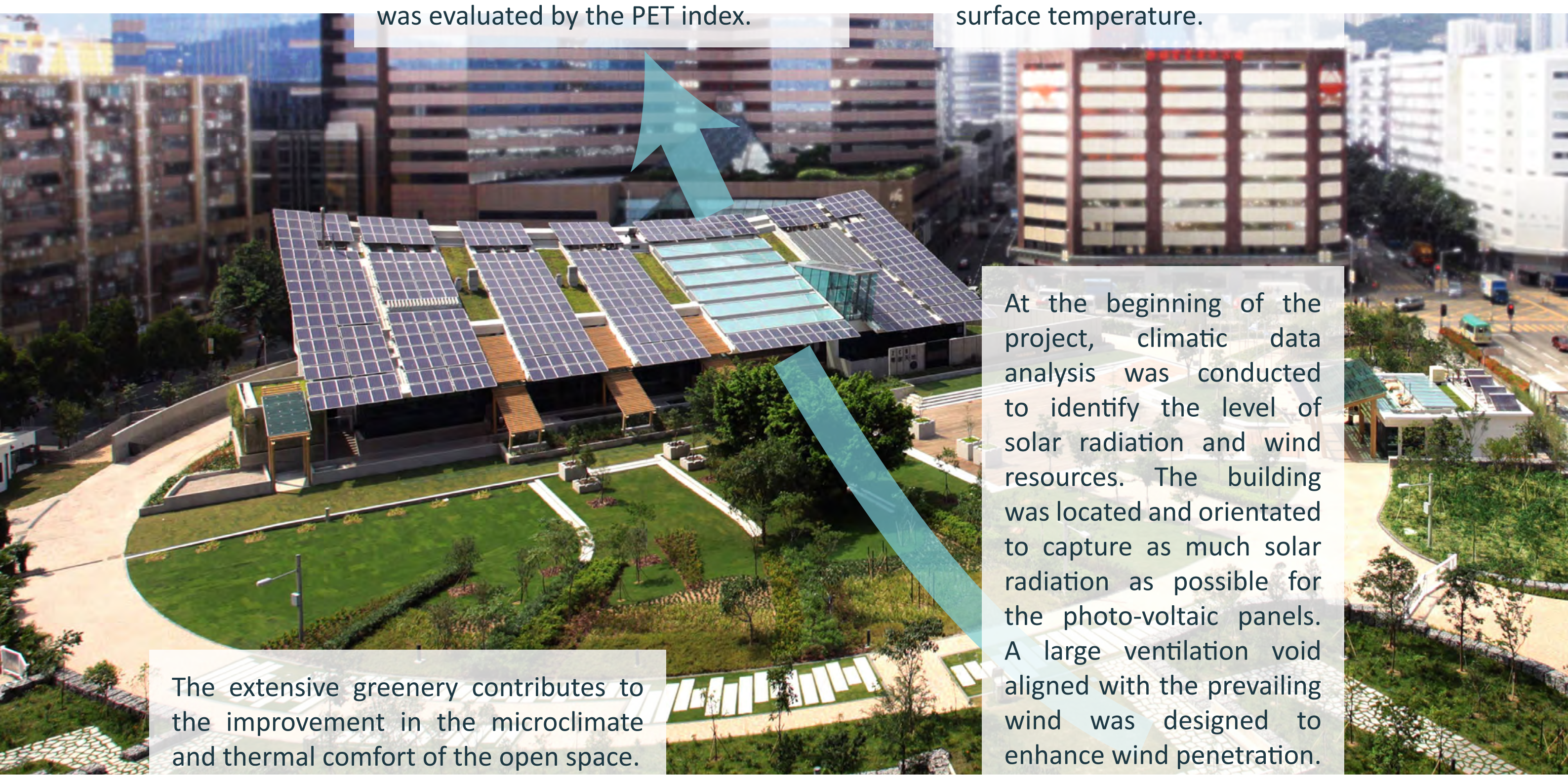
Achievements

- Improvement in the wind environment at the pedestrian level;
- Reduction in the UHI effect;
- Reduction in the ground surface temperature;
- Improvement in pedestrian's outdoor thermal comfort.



The improvement in thermal comfort was evaluated by the PET index.

Permeable paving helps lower surface temperature.



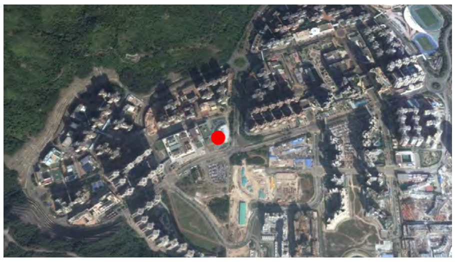
At the beginning of the project, climatic data analysis was conducted to identify the level of solar radiation and wind resources. The building was located and orientated to capture as much solar radiation as possible for the photo-voltaic panels. A large ventilation void aligned with the prevailing wind was designed to enhance wind penetration.

The extensive greenery contributes to the improvement in the microclimate and thermal comfort of the open space.

High-albedo material in white on the building façade reduces heat absorption by the building structure.

District Open Space, Sports Centre & Library in Tseung Kwan O

Increase ventilation with building design



Location: Tsueng Kwan O
Completion: 2015
Site area: 18,000m2
Gross floor area: 17,153m2
Building type: Institutional
Recognitions: GBA2014 Finalist
HK-BEAM 4/04 NB Platinum

Where

The twin-building project is in the Tseung Kwan O new town.

What

Good urban ventilation by embracing the prevailing wind.

Why

The improvement in urban ventilation and considerations for outdoor thermal comfort benefit both users of the space and the site's neighbouring areas.

How

AVA and microclimate studies were conducted to evaluate the conditions at the pedestrian area. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Two features are of particular emphasis here:

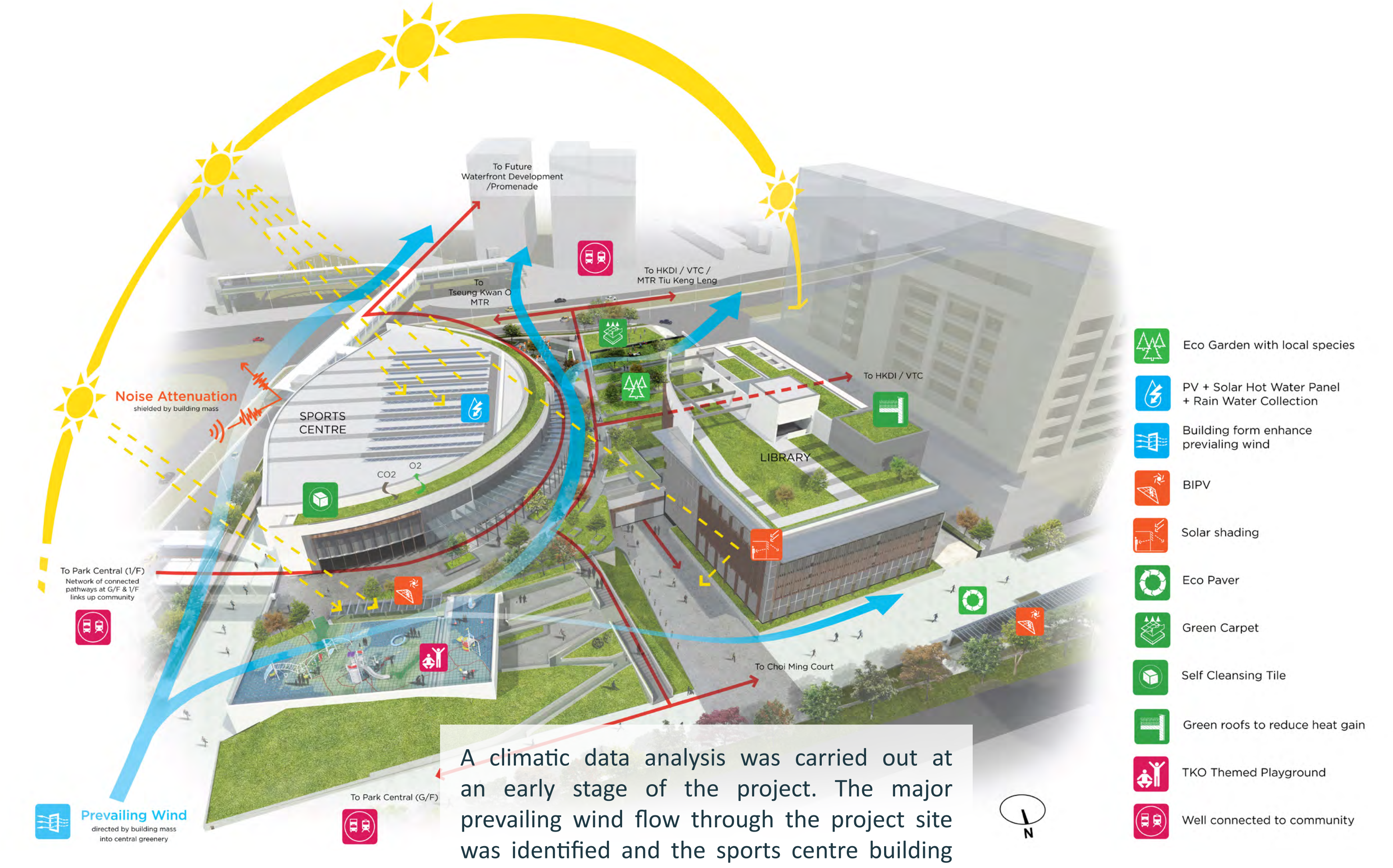
Improving the wind environment:
- Manipulate layout massing to increase wind flow (Strategy 01);
- Reduce building frontage with aerodynamically shaped design (Strategy 10).

When

At the early design stage, an AVA expert evaluation was carried out to obtain an idea of the wind availability at the project site. A large gap between the two buildings was reserved as wind corridor. To further facilitate wind penetration through the development, the building massing was aerodynamically shaped to reduce the building frontage.

Achievements

- Improvement in the wind environment at the pedestrian level;
- Reduction in ground surface temperature.



A climatic data analysis was carried out at an early stage of the project. The major prevailing wind flow through the project site was identified and the sports centre building adopted an aerodynamic shape to reduce the building frontage. As a result, a better wind environment was achieved.

The two blocks are separated and the gap is aligned with the prevailing wind for better wind penetration.

The Green Atrium

Reduce heat accumulation

Location: Yuen Long
Completion: 2015
Site area: 800m2
Gross floor area: 2,200m2
Building type: Commercial
Recognition: GBA2014 Finalist
GBA2016 Finalist

Where

The low-rise project with three storeys only is located on a compact site in Yuen Long.

What

Natural ventilation and the extensive green wall on the building envelope.

Why

Considerations for urban ventilation and outdoor thermal comfort do not only benefit the site itself, but also the neighbouring areas.

How

A CFD simulation was conducted to evaluate its natural ventilation and wind environment at the pedestrian area. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. Three features are of particular emphasis here:

Improving the wind environment:
- Increase building permeability with permeable building structure and atrium design (Strategy 08).

Reducing heat accumulation:
- Employ innovative ventilation to carry away heat energy in semi-open space (Strategy 26).

Reducing surface temperature:
- Provide extensive green wall to reduce façade surface temperature (Strategy 19).

When

From the concept design stage, the building was designed with a climate responsive approach. Large openings were planned for the semi-open space and an atrium was located at the centre to facilitate natural ventilation. An extensive green wall was constructed for envelope shading. An innovative ventilation device was used to improve thermal comfort in the semi-open space during summer.

Achievements

- Improvement in the wind environment at the pedestrian area;
- Reduction in the façade surface temperature;
- Increase in ventilation at semi-open space.

Innovative ventilation is used to introduce cooler fresh air from the outside to the semi-open space for dining use.

An extensive green wall with a leaf coverage of almost 100% helps reduce the façade surface and ambient air temperatures.

The atrium at the centre of the building structure facilitates natural ventilation through the building structure.

Hysan Place

Increase ventilation with building design

Location: Causeway Bay
Completion: 2012
Site area: 4,435m2
Gross floor area: 65,960m2
Building type: Shopping mall/ office
Recognition: GBA2012 Merit
BEAM Plus NB V1.1 Platinum

Where

The single-tower redevelopment project stands amid a cluster of high-rise buildings project in the densely populated district of Causeway Bay.

What

Limited ventilation.

Why

Although the project itself is a single office and retail-mall tower, the microclimatic conditions of the crowded district could be adversely affected if considerations were not duly given to the design. The wind environment is of particular concern.

How

An AVA study was conducted by the developer and different design proposals were compared with CFD simulations to look for the best permeability and ventilation effect. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. A feature is of particular emphasis here:

Improving the wind environment:

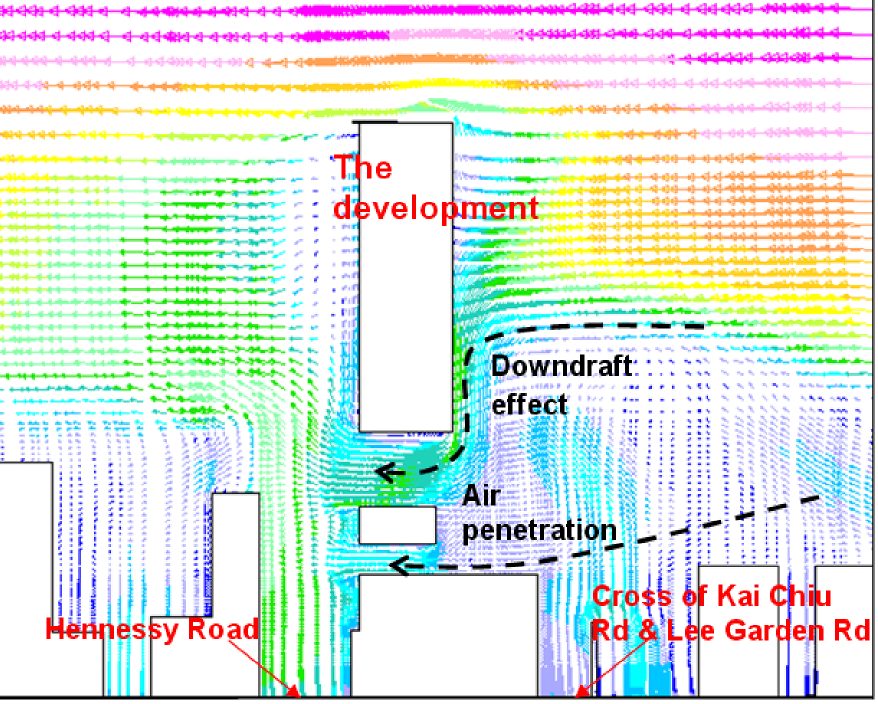
- Increase building permeability at above-ground levels by constructing large openings in the building structure (Strategy 08).

When

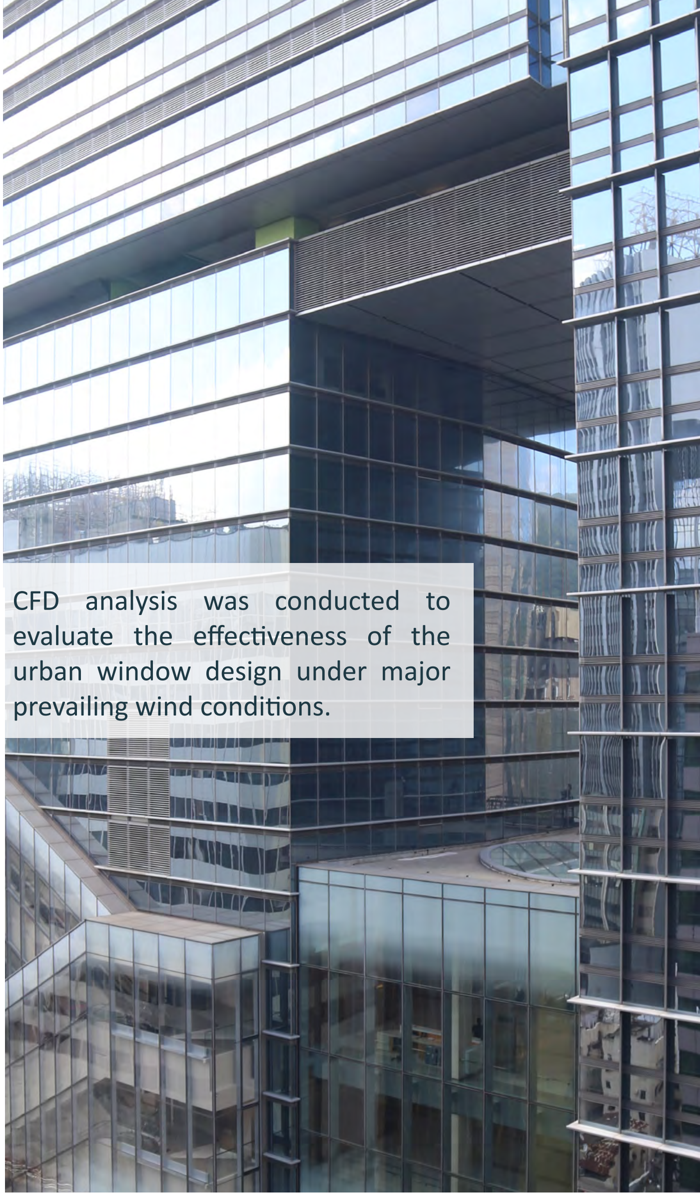
A CFD simulation was conducted during the schematic design stage to evaluate the wind environment at the development and its surroundings. The study assisted the project team in the quantification of the wind penetration effect of the urban windows.

Achievements

- Improvement in the wind environment and maximisation of natural ventilation;
- Increase in wind penetration;
- Greenery coverage at different heights.



The three openings in the building structure act as urban windows for wind to penetrate high up from the ground.



CFD analysis was conducted to evaluate the effectiveness of the urban window design under major prevailing wind conditions.

Sky gardens are elevated from the ground to avoid heat from the roadway. They are shaded by the building profile for better comfort.

Azura

Increase ventilation with building design

Location: Mid-levels
Completion: 2012
Site area: 2,100m2
Gross floor area: 19,166m2
Building type: Residential
Recognition: GBA2014 Finalist
HK-BEAM 4/04 NB Platinum

Where

The individual residential skyscraper is in the Mid-Levels.

What

Good urban ventilation design for a single building.

Why

Even for a new single-building development, the initiative to enhance ventilation is important for the general good of both the site itself and its vicinity. The project's master plan and building design were driven by ventilation concerns.

How

A microclimate assessment was conducted to evaluate the wind environment at the pedestrian area. The project has employed a range of urban microclimate strategies, which can be referred to on p. 68. A feature is of particular emphasis here:

Improving the wind environment:
- Permeable podium design to enhance wind penetration at the pedestrian zone near ground (Strategy 11).

When

At the design stage, an opening was planned at the podium to enhance wind penetration through the building according to the wind environment assessment.

Achievements

- Improvement in the wind environment at the pedestrian area.

A permeable podium design was adopted to improve ventilation. The podium was set back from the building edge to facilitate the penetration of a larger volume of air, enhancing the wind environment at the podium and the area near the building entrance on the ground level.

Way Forward

At the beginning of the Guidebook, Hong Kong's efforts to improve the urban climate and microclimate designs were introduced. Towards the end, local good practices were showcased. The city has clearly walked a long way down the path towards a healthier and more comfortable environment, but there is always another step that can be taken in the way forward.

There are three areas where advancement must be made to improve the city's microclimate—Science and Technology Development, Policy, Practice and Design, and Public Awareness and Education. The potentials in each area are identified, and the suggestions made here are not only attainable but also crucial to the improvement of the city's environment.

Science and Technology Development

Local institutions have been actively carrying out research to both develop new methods to assess and evaluate the microclimatic condition of a place, and suggest new ways to foster a more thermally comfortable environment.

One recent example is an ongoing study by The Hong Kong Polytechnic University on design methodologies to improve the wind environment and thermal comfort in the urban context[21]. The University of Hong Kong has a long track record of research on greening, and its Healthy High Density Cities Lab[22] and Sustainable High Density Cities Lab[23] investigate issues particularly relevant to the city's context. At The Chinese University of Hong Kong, researchers have contributed to the development of new methodologies to obtain urban data, implementation of scientific findings in urban policies, and research on urban climate, planning and outdoor thermal comfort[24].

Hong Kong University of Science and Technology and City University of Hong Kong are also key players in urban microclimate research, while other universities—Hong Kong Baptist University, Open University of Hong Kong, Education University of Hong Kong and Lingnan University—as well produce a wide range of research to further our knowledge of the environment.

These efforts to advance knowledge and technology must be encouraged and further deepened for the development of strategies and measurements that take the city's unique context into consideration. Adequate funding is essential. Only in this way can the next step forward be solid and grounded.

Policy, Practice and Design

Over the past decade, the Government has introduced a range of measures and commissioned a variety of studies to improve the urban climate. Guidelines such as the *Technical Circular on Air Ventilation Assessments* are very much appreciated, but these efforts must be continuous and concerted. The Development Bureau, Environment Bureau, Transport and Housing Bureau, and the

21. See Niu, Jianlei, et al. A New Method to Assess Spatial Variations of Outdoor Thermal Comfort: Onsite Monitoring Results and Implications for Precinct Planning. 91 Vol. , 2015.; Du, Yaxing, et al. New Criteria for Assessing Low Wind Environment at Pedestrian Level in Hong Kong. 123 Vol. , 2017.
22. See the website of Healthy High Density Cities Lab: http://www.arch.hku.hk/researchcentre/centre-for-healthy-high-density-cities/
23. See the website of Healthy High Density Cities Lab: http://www.arch.hku.hk/researchcentre/centre-for-healthy-high-density-cities/
24. See the Institute of Future Cities: http://www.iofc.cuhk.edu.hk/; And Edward's Laboratory: http://web5.arch.cuhk.edu.hk/server1/staff1/edward/www/team/Index.html

departments under them must work together to create a synergy. Particularly, microclimate-related data and information should be readily shared among different governmental parties.

Further policy encouragement may be needed to motivate developers to employ urban microclimate strategies. Three particular areas have been identified in the development of the Guidebook— the installation of covered walkway and canopies, adoption of non-building areas, and setting up of green walls. Developers often find it difficult to adopt strategies in these areas because of commercial or statutory constraints. The Government and developers must come together to look for a way out. It will take some negotiation and the result may be of a carrot-and-stick approach, but the main message here is that communication with the industry is just as important as between different governmental bureaus and departments.

Industry practitioners should take the initiative to learn about urban microclimate and implement the strategies introduced the Guidebook in their projects. A better outdoor environment is for the benefit of both the general public and the development itself. BEAM Plus as an assessment system has played a key role in promoting microclimate designs in the industry. However, its site aspect may need ongoing update to cope with the growing public aspiration and changing needs. The recent introduction of BEAM Plus ND is a positive step forward, but continuous monitoring and fine-tuning is required for it to remain relevant in the years to come.

To tackle climate change challenges and realise the vision outlined in *Hong Kong 2030+: Towards a Planning Vision and Strategy Transcending 2030*, the Government must demonstrate leadership in the improvement of the city's microclimate.

Public Awareness and Education

Since the first Government initiatives over a decade ago, the concept of microclimate has become less remote to the architectural profession. The local good practices highlighted in the Guidebook is a testimony to effective promotion and education. However, public and professional awareness can still be further enhanced and the gap in professional education and knowledge transfer must be filled.

The Guidebook attempts to be simple and easy to understand. It speaks to practitioners as well as interested laymen in a language stripped of professional jargon. Future efforts similar to this are essential to the spread of knowledge and increase in awareness. The architectural profession as a whole—not just those focusing on green buildings—and the wider population must be engaged in building a better city.

At the same time, there is a gap in the professional education of urban climatology between brief courses and extremely in-depth knowledge pursuit, such as in the form of a PhD. A better ladder of professional training must be provided to engage a bigger number of practitioners and encourage wider application. Academic institutions are in a good position to take the lead.

Conclusion

Considerations for the urban climate are becoming more important and urgent in the face of climate change, and the above areas are key to the Hong Kong's further development into a sustainable city. The way forward may be a long one, but continuous and concerted efforts will make the walk smoother and easier.

Bibliography

Buildings Department. Sustainable Building Design Guidelines, Hong Kong: HKSAR Government, 2016.

Chan, H.S., Kok, M.H. & Lee, T.C. Temperature trends in Hong Kong from a seasonal perspective, Clim Res, vol. 55, no. 1, pp. 53-63, 2012.

Dorer, Viktor, et al. "Modelling the urban microclimate and its impact on the energy demand of buildings and building clusters." Proceedings of BS 2013, pp3483-3489, 2013.

Environment Bureau. Hong Kong Climate Change Report, Hong Kong: HKSAR Government, 2015.

Givoni, B., M. Noguchi, H. Saaroni, O. Pocher, Y., Yaacov, N. Feller and S. Becker.,. Outdoor comfort research issues. Energy and Buildings vol. 33, pp. 77-86, 2003.

Greenroofs. "ACROS Fukuoka Prefectural International Hall." 2015. Web. <http://www.greenroofs.com/projects/pview.php?id=476>.

Hong Kong Observatory, Statistics of Special Weather Events, accessed 2017, http://www.hko.gov.hk/cis/statistic_e.htm

Hong Kong Observatory. Hong Kong in a Warming World. Hong Kong: HKSAR Government, 2015.

Hong Kong Observatory. Number of Hot nights observed at the Hong Kong Observatory since 1884, exclude 1940-1946, accessed 2017, http://www.hko.gov.hk/cis/statistic/hngtday_statistic_e.htm.

Hong Kong Observatory. Number of Very Hot days observed at the Hong Kong Observatory since1884, exclude 1940-1946, accessed 2017, http://www.hko.gov.hk/cis/statistic/hngtday_statistic_e.htm.

Hoppe, P.,. The physiological equivalent temperature—A universal index for the biometeorological assessment of the thermal environment. International Journal of Biometeorology, vol. 43, pp. 71-75, 1999.

Intergovernmental Panel on Climate Change . Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects. Cambridge University Press, 2014.

Lin, T. P., Matzarakis, A. 'Tourism climate and thermal comfort in Sun Moon Lake, Taiwan', International Journal of Biometeorology, vol. 52, pp. 281-290, 2008.

Mayor of London. London's Urban Heat Island: A Summary for Decision Makers. London: Greater London Authority, 2006. Print.

Ng E., Cheng V. Urban Human Thermal Comfort in Hot and Humid Hong Kong, Energy and Buildings 55: 51-65, 2012. DOI: 10.1016/j.enbuild.2011.09.025

Oke, T. R.,. Boundary Layer Climates. London; New York: Routledge, 1987.

Planning Department. Urban Climatic Map and Standards for Wind Environment - Feasibility Study, Hong Kong: HKSAR Government, 2012.

Planning Department. Hong Kong Planning Standards and Guidelines (HKPSG), Hong Kong: HKSAR Government, 2011.

Yamamoto, Yoshika. "Measures to Mitigate Urban Heat Islands." Science and Technology Trends Quarterly Review 18.1 (2006): 65-83.

Further Reading

Microclimate guides from other places:

China:
Guide for Environmental Performance Evaluation of Urban Ecological Construction (Pilot), published by the Ministry of Housing and Urban-Rural Development of PRC, 2015. (In Chinese)
(城市生態建設環境績效評估導則（試行）< 中華人民共和國住房和城鄉建設部 > 2015)

Design Standard for Thermal Environment of Urban Residential Areas <JGJ 286-2013>, released by MOHURD PRC, published by the China Building Industry Press, 2013. (In Chinese)
(城市居住區熱環境設計標準 (JGJ 286-2013) < 中華人民共和國住房和城鄉建設部 > 中國建築工業出版社 , 2013)

Standard of Climatic Regionalization for Architecture (GB 50178-93), released by the State Bureau of Technical Supervision and the Ministry of Construction PRC, published by the China Building Industry Press, 1993. (In Chinese)
(建築氣候區劃標準 (GB 50178-93) < 國家技術監督局 中華人民共和國建設部 聯合發布 > 中國建築工業出版社 , 1993)

Singapore:
Building Planning and Massing, published by the Building and Construction Authority, 2010.

Vertical Greenery for the Tropics, edited by Kelly Chiang and Alex Tan, published by National Parks Board and National Parks Board Headquarters, 2009.

Australia:
New World City Design Guide: Buildings that Breathe, published by Brisbane City Council, 2016.

AILA Statement: Liveable Cities, published by Australian Institute of Landscape Architects, 2015.

Cool Communities: Urban Trees, Climate and Health, by Helen Brown, Dianne Katscherian, May Carter and Jeff Spickett, 2013.

Responding to the Urban Heat Island: A Review of the Potential of Green Infrastructure, by Annie Hunter Block, Stephen J. Livesley, and Nicholas S.G. Williams, published by Victorian Centre for Climate Change Adaptation Research, 2012.

Subtropical Design in South East Queensland: A Handbook for Planners, Developers and Decision Makers, published by the Centre for Subtropical design, QUT, 2010.

United Kingdom:
National Meteorological Library and Archive Fact Sheet 14—Microclimates, published by Met Office, 2011.

Climate Change Projections for Greater Manchester, by G. Cavan, EcoCities project, University of Manchester, 2010.

Climate Change Adaptation by Design: a Guide for Sustainable Communities, by R. Shaw, M. Colley and R. Connell, published by Town and Country Planning Association.

Canada:
Urban Heat Island Mitigation Strategies, by Mellisa Giguere, published by Institut National de Sante Publique du Quebec.

United States:
Cooling Our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing, published by the Environmental Protection Agency, 1992.

General guides and academic readings:
Brown, R. D. Design with Microclimate: The Secret to Comfortable Outdoor Space. Island Press, 2010.

DeKay M, Brown GZ. Sun, Wind, and Light: Architectural Design Strategies, 3rd Edition. Wiley, 2014.
Emmanuel, M. Rohinton,. Urban Climate Challenges in the Tropics : Rethinking Planning and Design Opportunities., 2016.

Erell, Evyatar, David Pearlmutter, and Terry Williamson. Urban Microclimate: Designing the Spaces between Buildings. London; Washington, DC: Earthscan, 2012.
Givoni B. Climate Considerations in Building and Urban Design. New York: Van Nostrand Reinhold; 1998.

Esch, Marjolein Pijpers-van. "Designing the Urban Microclimate. A Framework for a Design-Decision Support Tool for the Dissemination of Knowledge on the Urban Microclimate to the Urban Design Process." A+BE | Architecture and the Built Environment 5.6 (2015): 1-308.

Landsberg, Helmut Erich. The Urban Climate. New York: Academic Press, 1981.

Lenzholzer, Sandra. Weather in the City: How Design Shapes the Urban Climate. Nai010 Publishers, 2015.

Ng E, and Ren C, eds. The Urban Climatic Map : A Methodology for Sustainable Urban Planning. Abingdon, Oxon; New York, NY: Routledge; 2015.

Oke, T. R.,. Boundary Layer Climates. London; New York: Routledge, 1987.

任超 , 城市風環境評估與風道規劃 -- 打造呼吸城市 , 中國建築工業出版社 , 2016.

任超及吳恩融 . 編 .《城市環境氣候圖 - 可持續城市規劃輔助訊息系統工具》 . 中國北京 : 中國建築工業出版社 , 2012.

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Checklist

Practitioners are encouraged to use the checklist below to identify potential urban microclimate strategies that can be implemented in a project.

Wind		
Increase ventilation with site planning		
1	Manipulate layout massing to increase wind flow	
2	Wind corridor to align with the prevailing wind	
3	Connect open spaces	
4	Arrange buildings to channel wind	
5	Building setback	
6	Increase permeability of building blocks / no wall building	
7	Stepped building height profile	
Increase ventilation with building design		
8	Increase building permeability	
9	Permeable sky garden	
10	Reduce building frontage	
11	Ventilation bay / permeable podium	
12	Reduce ground coverage	
13	Increase ground zone air volume	
Thermal Radiation		
Reduce direct solar radiation		
14	Provide shading for pedestrian activities	
15	Provide tree canopies	
16	Manipulate building façade design to provide shading	
17	Shade openness by building blocks	
Reduce surface temperature		
18	Use cool material for ground surface	
19	Green wall to reduce façade surface temperature	
20	Increase albedo in buildings	
21	Increase sky view factor to improve night cooling	
Temperature		
Increase evaporative cooling		
22	Water features to increase evaporation	
23	Green wall to increase evapotranspiration	
24	Greening to increase evapotranspiration	
25	Use permeable paving	
Reduce heat accumulation		
26	Increase ventilation to carry away heat energy	
27	Allow downhill wind flow	
28	Allow sea breezes	
Reduce heat release		
29	Reduce anthropogenic heat discharge near pedestrian area	
30	Reduce thermal mass heat storage of building materials	
Precipitation		
Provide rain protection		
31	Provide cover for rain protection	

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