COOL IT DOWN!

TACKLING URBAN HEAT ISLAND EFFECT IN SINGAPORE

MASTER THESIS | MARCIN ŻEBROWSKI
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Sustainable Urban Design

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ACKNOWLEDGEMENTS

Working on this was a long and challenging process. It would also not be the same without important people that I would like to show my gratitude to.

I would like to thank my thesis supervisor *Andreas Olsson* for his whole support along the way, many conversations that we had, but also his trust in my skills. He assisted me while looking for a good concept of the development of such an enormous site and, along the way, he made sure that my vision was not shredded.

I wanted to thank my dear friend *Marek Grochowicz* who inspired me to go 10 000 km and visit him in a distant Singapore and became my personal guide showing me the hidden corners of this fascinating city.

I want to express my gratitude to my girlfriend *Dominika Misterka* for her involvement in my working process and all the support she had given me both in the good and hard moments.

I am grateful for my ***family's*** support as well and that they have been believing in me and accepting my choices about first moving out to Sweden and then travelling to the other side of the world to Singapore all alone.

Last but not least, I want to express my gratitude to the best ***SUDes team*** and friends from the studio that I learned a lot from and who inspired me during the whole master programme.

PROJECT SUMMARY

Contemporary Singapore is a unique metropolis that will disappear under bulldozers paving the way to „urbanization".

In consequence, the residents live here in the shadow of skyscrapers. And this is just a metaphorical shadow. The shadow of concrete is different from the shadow of a tree - hides from the sun but it cannot be from the omnipresent humidity, stuffiness and swelter.

According to Channel News Asia (sixth-widest reach among television news channels in Asia), **Singapore gets warmer twice faster than the rest of the world.** It is not only due to its tropical location but also the rapid urbanisation over the past decades. Many scientists even predict that before 2100 it can be even too warm to run outdoors.

The project **COOL IT DOWN** proposes solutions to this challenge, which are presented as a **toolbox**.

The toolbox uses Singapore as a reference point, but its content is universal. The rapid warming of the cities is a global phenomenon that needs to be addressed. The toolbox is presented in **three different design scales: LARGE, MEDIUM** and **SMALL.**

The **LARGE** scale comprises master planning and a set of guidelines on the areal scale to influence air temperature or ventilation.

The **MEDIUM** scale includes building typologies that can effectively provide wind and protect from heat and solar radiation.

The **SMALL** scale focuses on the design on a street level that can positively influence the microclimate.

The master plan is a proposal for an enormous **166 ha site** that is a central area in the bustling metropolis. It is a fully artificial land that has a key role in the future development of the city.

Having in mind the possible negative consequences of concrete the design site emphasizes the importance of greenery in overcoming the given challenge.

CONTENTS

PREFACE

Singapore A rare scene of people playing in an opened park during the day despite the lack of shadow

AIM

This master thesis aims to propose **sustainable solutions** to influence **the microclimate,** tackle the **urban heat island effect** and provide **a climate-sensitive design** for **Marina Bay in Singapore.**

Proposed guidelines and typologies will be presented as **a toolbox** and will base on the analysis of the microclimate in Singapore.

The toolbox provides solutions in three scales: **large, medium** and **small.**

The solutions from the toolbox will be applied in the Singapore context to tackle the urban heat island effect and enable the citizens to use the city public spaces during the daytime.

BACKGROUND

I started my master thesis preparations with a handful of the necessary research to use my time on the site as effectively as possible.

Going to Singapore was my second time in Asia. Before the whole SUDes course group went to China during the Urban Dynamics Studio which inspired me a lot.

When I was thinking Downtown Singapore I portrayed **the Vancouver model skyscrapers** with the podium as my main typology. Or maybe we should call it the **Singapore model**, as there is a huge amount of buildings with podiums already there.

Having the first walk in Singapore a saw numerous skyscrapers, some of which had green facades. I could even argue that skyscraper is a sustainable solution. As Scandinavian sustainable urban design students, we might have rather negative associations with skyscrapers. But given the land scarcity in Singapore, the high rise that can accommodate hundreds of families seem to be a proper answer. Adding the omnipresent green facades and podiums with services we have a **sustainable typology.**

I realized that a sustainable approach to urban design can be completely different from what I got used to before. I wondered: what was the **phenomenon** I would like to analyse and address?

From the beginning of my study trip, I was using numerous underground corridors, passages and escalators. From my experience, the people living in Singapore **celebrate indoor life.** They meet at the food court to get something to eat, to drink something cold and meet people. Long corridors between metro stations have many varied services which are tempting the residents to stop, sit for a while a buy a cake, tea, fruit shake or a bowl of food.

Why are indoors so attractive? The tropical rainforest climate is ruthless. There is one game-changer: **air conditioning**. The tropical rainforest climate, equator sun and temperatures of +30 celsius are successfully discouraging people from using the open public spaces.

It is just a part of the lifestyle - my friend told me. So I adjusted myself to the Singaporean lifestyle for almost three weeks. But outdoor streets, places, or buildings were very green and well designed that I wished I could have spent more time around them.

This led me to my main **reflection:**

How can we design so that, people living in Singapore will spend their time in the public realm - in open outdoor public spaces, instead of crowded, air-conditioned shopping malls?

Hence, my research questions became:

How can design attract people to use the outdoor public space and tackle the urban heat island effect and unfavourable tropical climate?

01

CLIMATE RESEARCH

URBAN CLIMATE

The urban climate is a set of climatic conditions that prevails in a large metropolitan area and that differs from the climate of its rural surroundings.

Urban climates are distinguished from those of less built-up areas by differences in air temperature, humidity, wind speed and direction, and amount of precipitation.

These differences often occur as an effect of human activity and change of the natural terrain through the construction of artificial structures and surfaces.

For example, tall buildings, paved streets, and parking lots affect wind flow, precipitation runoff, and the energy balance of a city.

The centre of a city is warmer than are outlying areas. Daily minimum temperature readings at related urban and rural sites frequently show that the urban site is 6° to 11° C warmer than the rural site. It leads to an occurrence of the **"heat island."**

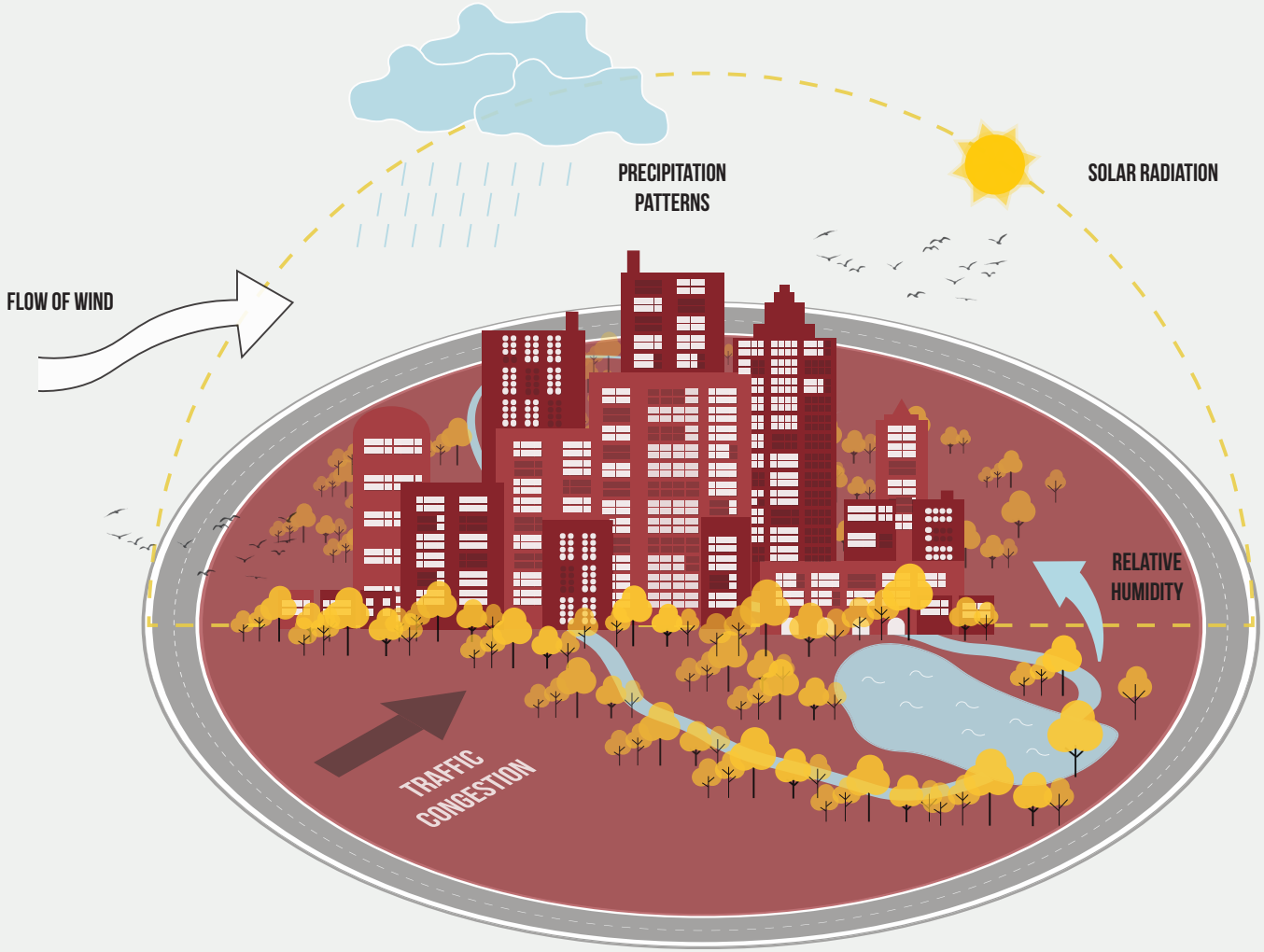
Urban structures and asphalt absorb, store, and reradiate more solar energy than do the vegetation and soil typical of rural areas. At night, radiative losses from urban building and street materials keep the city's air warmer than that of rural areas.

The average **relative humidity** in cities is usually several % lower than that of adjacent rural areas, primarily because of increased runoff of precipitation and the lack of evapotranspiration from vegetation in urban areas.

The **flow of wind** through a city is characterized by mean speeds that are 20 to 30 % lower than those of winds blowing across the adjacent countryside. This difference occurs as a result of the increased frictional drag on air flowing over built-up urban terrain, which is rougher than rural areas.

The amount of **solar radiation** received by cities is reduced by some of the particulates in the overlying atmosphere. The higher particulate concentrations in urban atmospheres reduce visibility by both scattering and absorbing light.

A city also influences **precipitation patterns** in urban areas. Such city-generated or city-modified weather factors as wind turbulence, thermal convection, and high concentrations of condensation nuclei might be expected to increase precipitation. The data suggests that the amount of precipitation over many large cities is about 5 to 10 % greater than that over nearby rural areas.


PRECIPITATION
PATTERNS
SOLAR RADIATION
FLOW OF WIND
RELATIVE
HUMIDITY
TRAFFIC
CONGESTION

MICROCLIMATE

In one sentence, **microclimate means that the temperature, humidity and other weather elements can be very different even within the same area.** (LAU Po-wing, 2018). Obviously, the whole concept is way more complex and detailed.

In other words, microclimate is a local set of atmospheric conditions that differ from those in the surrounding areas, often with a slight difference but sometimes with a substantial one. The term may refer to areas as small as a few square meters (for example a garden, pocket park or a cave) or as large as many square kilometers or square miles.

The strongest gradients of temperature and humidity occur just above and below the Earth's surface. Complexities of microclimate are necessary for the existence of a variety of life forms because, although any single species may tolerate only a limited range of climate, strongly contrasting microclimates in proximity provide a total environment in which many species of flora and fauna can coexist and interact.

Because the climate is statistical, which implies a spatial and temporal variation of the mean values of the describing parameters, within a region there can occur and persist over time sets of statistically distinct conditions, that is, microclimates.

Due to the influence of the surrounding terrain, orientation and density of buildings, weather conditions during the time as well as other factors, the climatic characteristics of an area may differ from those prevailing over the surrounding large region. Therefore, the weather elements at different points of location can somehow be rather different even though they are within the same area (LAU Po-wing, 2018).

Microclimatic conditions depend on such factors as **radiation, temperature, the albedo of materials, humidity, precipitation** or **wind**.

In the next pages, I will **present the factors** and introduce the ubiquitous urban microclimate phenomenon called **the urban heat island effect.**

MICROCLIMATE EXPERIENCE

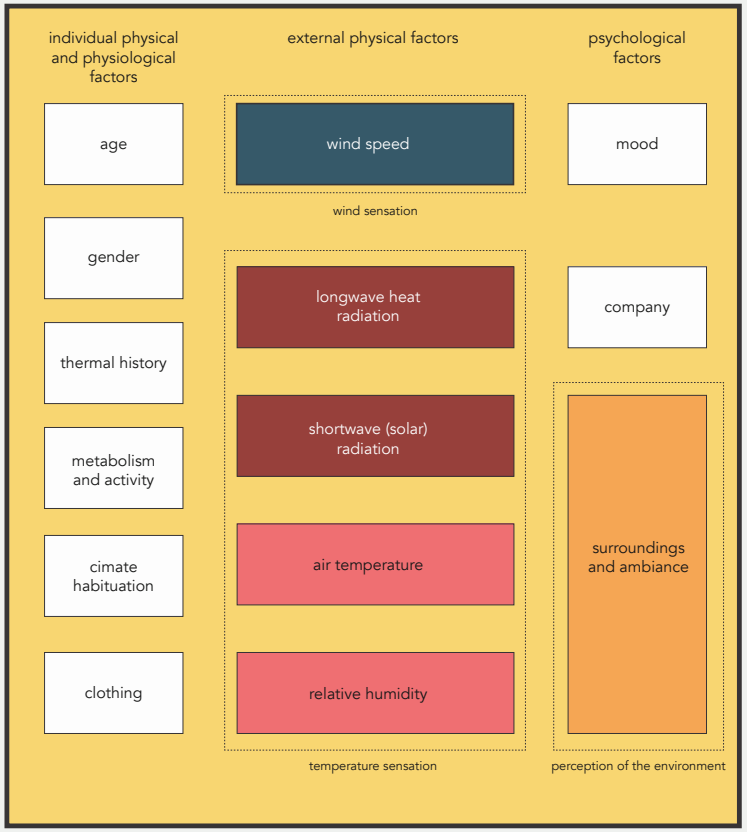
Many factors are determining how people experience the microclimate. It is important to underline that because of these different factors we, **people, experience the climate differently** and our perception of temperature and thermal comfort might vary.

There are **three main clusters of factors** influencing how people experience microclimate:

1) the individual physical and physiological factors include age, gender, thermal history, metabolism and activity, climate habituation and clothing. These cannot be influenced through design and are different for every human being. A middle-aged active man, eating healthy and wearing light clothes will perceive the climate different than an old woman, who is not active nor eats healthy and wears warm clothes. We as designers cannot influence these factors through design and even people themselves have a limited influence on these aspects.

2) external physical factors include wind and temperature sensation. A combination of factors has an effect on the temperature sensation. Air temperature and the influence of long and shortwave radiation determine it to a large extent. Wind sensation is also very important for the physical microclimate experience. Both wind and temperature sensation can be influenced well through large or small-scale design. Longwave heat radiation, as well as shortwave radiation, can be influenced on a small-scale with a good effect on the microclimate. Air temperature and humidity are more difficult to influence but it is possible to make with greater interventions.

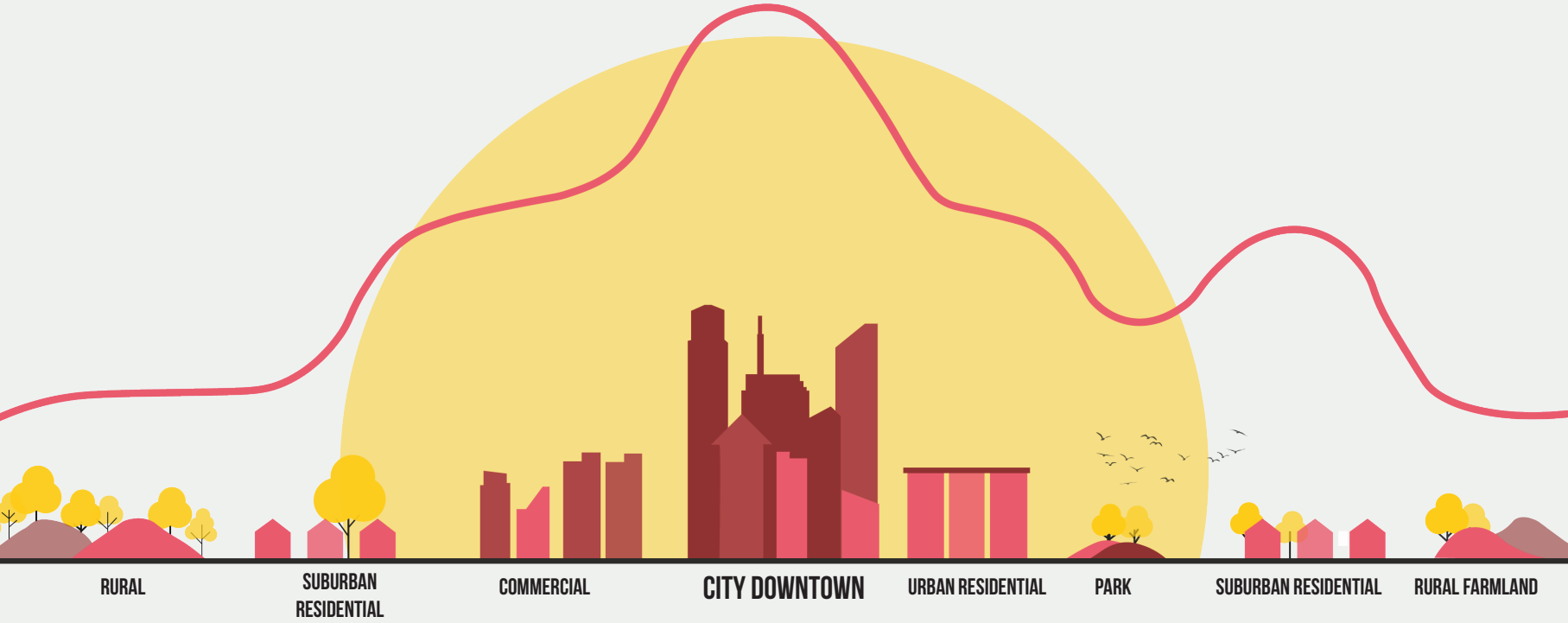
3) psychological factors include mood, company and surroundings and ambience. In part, these can be manipulated through the design of the city. The mood of a person can be positively influenced by the presence of greenery, trees, attractive design of spaces or the presence of other people using the space. A lively space with people, neighbours or acquaintances can influence how we feel. The thermal comfort also varies because of that. The microclimate perception and ambience of space can be determined by size, colours, materials or even sounds. This shows that we perceive microclimate due to different incentives in our heads.

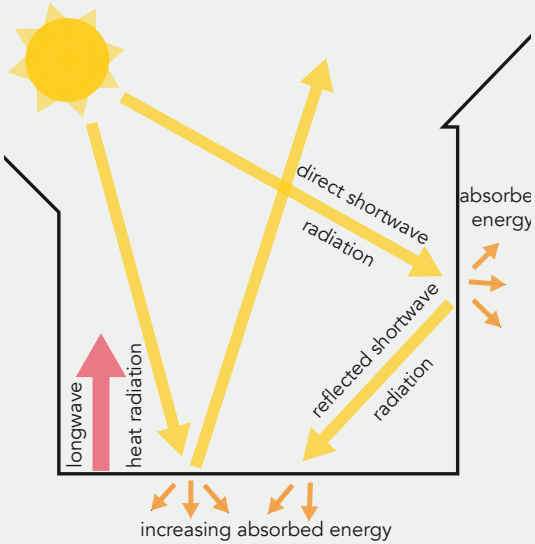


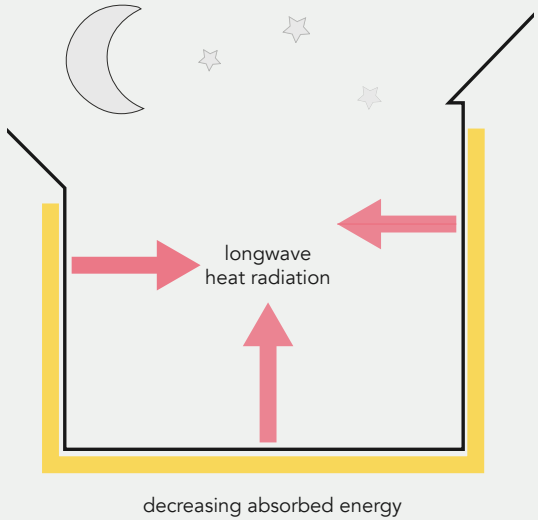
URBAN HEAT ISLAND EFFECT

There tend to be a different climate in cities than in most natural landscapes, and the densely built-up city is usually warmer than the surroundings. This is the result of retained longwave thermal radiation, anthropogenic heat and reduced evaporation. It is mostly due to a lack of open soil surfaces, water or greenery. This heat phenomenon is called an **urban heat island.**

However, even within a city, there are areas with different density, green structure or the presence of wind corridors and consequently with different air temperatures. This is why the term heat archipelago is also used in literature and refers to the fact that cities have various heat areas and one should not consider only the whole city scale.







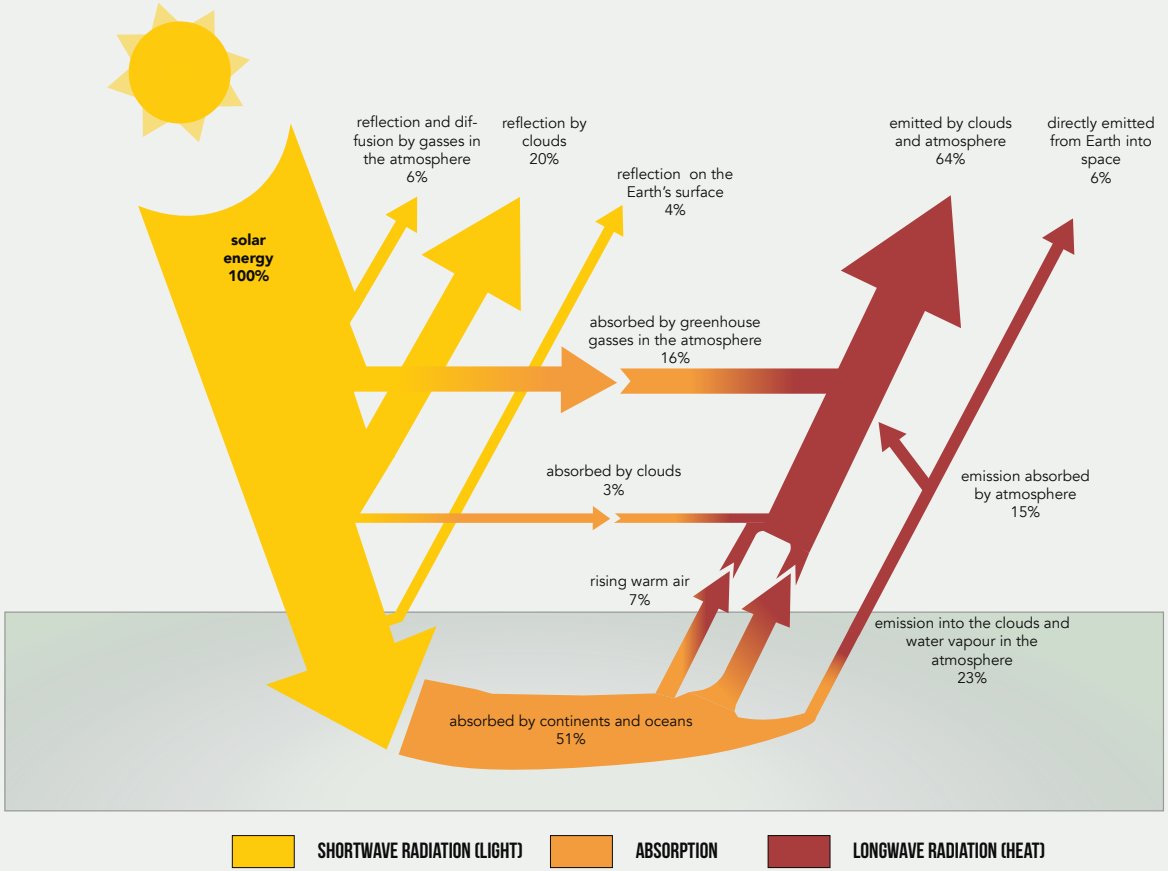
During the **summer season, radiation itself is mostly responsible for the urban heat island effect**. It is mostly received and stored during the day and it is released as longwave radiation at night. During the daytime, urban heat islands are a little warmer than the countryside. The heat island effect is strongest on hot, cloudless days with little wind as the radiations hit directly the surfaces.

People often believe that warmer cities are much better and there are no troubles in a warmer climate, that does not provide any snow. Actually, the problems connected to urban heat are way bigger. **Heat stress** leads to inevitable health issues, food spoils quicker, there can be mosquitos plagues and people dehydrate faster.

Moreover, overheating leads to infrastructural challenges, asphalt wears out and deforms, train tracks can bend, the usage of power to provide air conditioning skyrockets and street furniture can be too warm to even use them. Concluding, these problems lead to enormous costs both in money and human capital.

The urban heat island can occur **both during summer and winter**. During the latter, it is mostly created by the anthropogenic heat coming from residential heating, transportation or industry. However, due to the location of Singapore and lack of winter, I will focus on the summer season.

RADIATION IN THE ATMOSPHERE

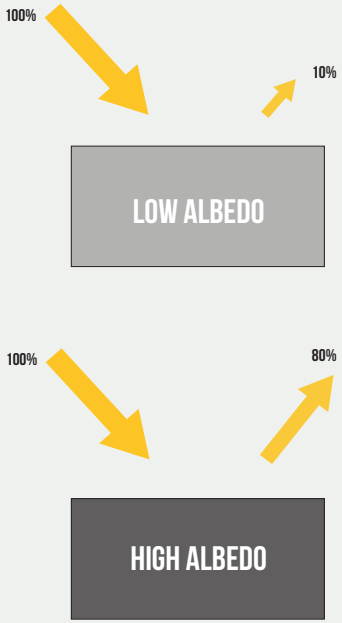


ALBEDO OF MATERIALS

What is albedo?

Albedo is **a measurement of reflectivity which is expressed in a percentage of the total of the incoming radiation**. Part of the incoming radiation is absorbed and part is reflected. How much radiations surfaces reflect depends on how light and smooth they are. The lighter and smoother the surface, the more reflection. With those objects, the radiation does not reach the mass underneath, so the material warms up slower.

The knowledge of materials' reflectivity can help regulate incoming solar radiation. All materials have different heat storage and release characteristics. The important term emissivity describes the ability of materials to release stored heat in the form of longwave radiation.



TYPES OF SURFACES/MATERIALS	ALBEDO OF SHORT WAVE RADIATION	EMISSIVITY	THERMAL CONDUCTIVITY
Asphalt	5-20%	95%	higher
Grey concrete	10-35%	71-95%	higher
Wood	40%	90%	higher
Glass	10-50%	90%	higher
White wall	70-95%	90%	higher
Black wall	2-15%	90%	higher
Open soil, dark	7-10%	90-98%	low
Grass/lawn	15-25%	90-95%	low
Water (high sun angle)	3-10%	98%	intermediate

TEMPERATURE EXPERIENCE

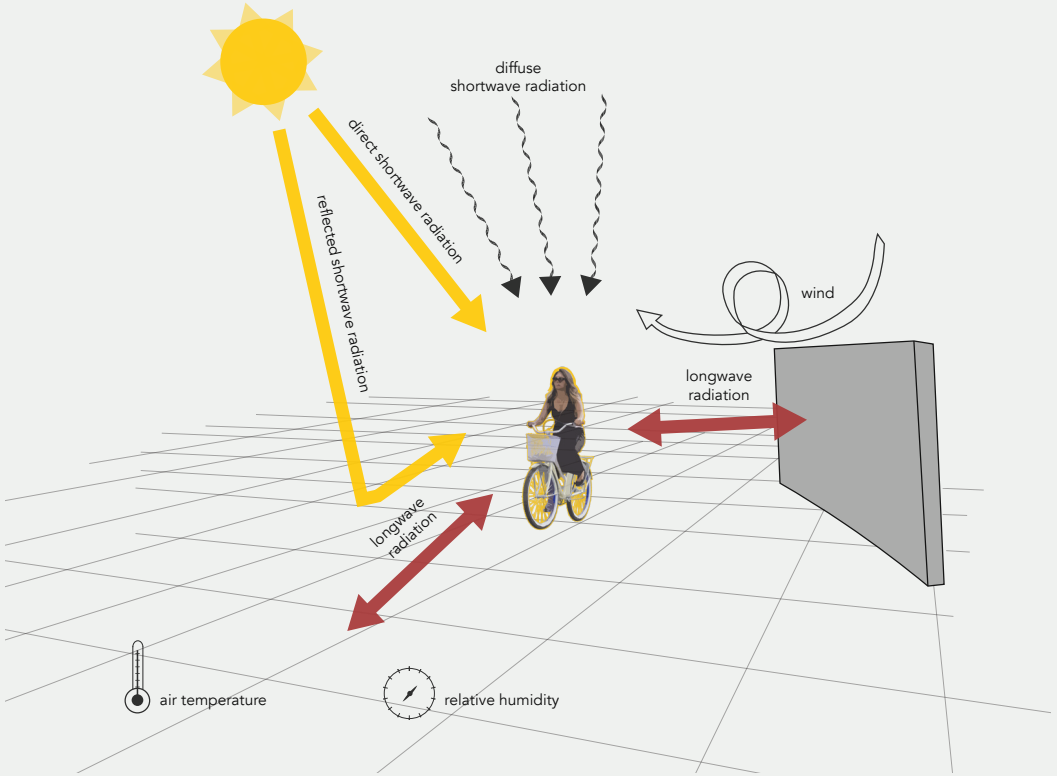
Heat stress

Extreme heat conditions can strongly influence people's thermoregulation which might have serious consequences. It applies especially to **the impact of heat** because heat is much harder to prevent than cold is, as people can react by putting warmer clothes or going indoors.

Heat stress does not only make people feel uncomfortable but also it decreases their productivity and concentration. The latter, which is even 10% is a very big cost for society.

More vulnerable groups as elderly, children or people hurting from various heart-related issues are greatly exposed to various health problems because of the heat.

Moreover, the **heatwaves** we have had in recent years resulted in higher mortality rates. A short heat wave lasting a couple of days can lead to a higher mortality rate of 10 - 15 % in many countries.

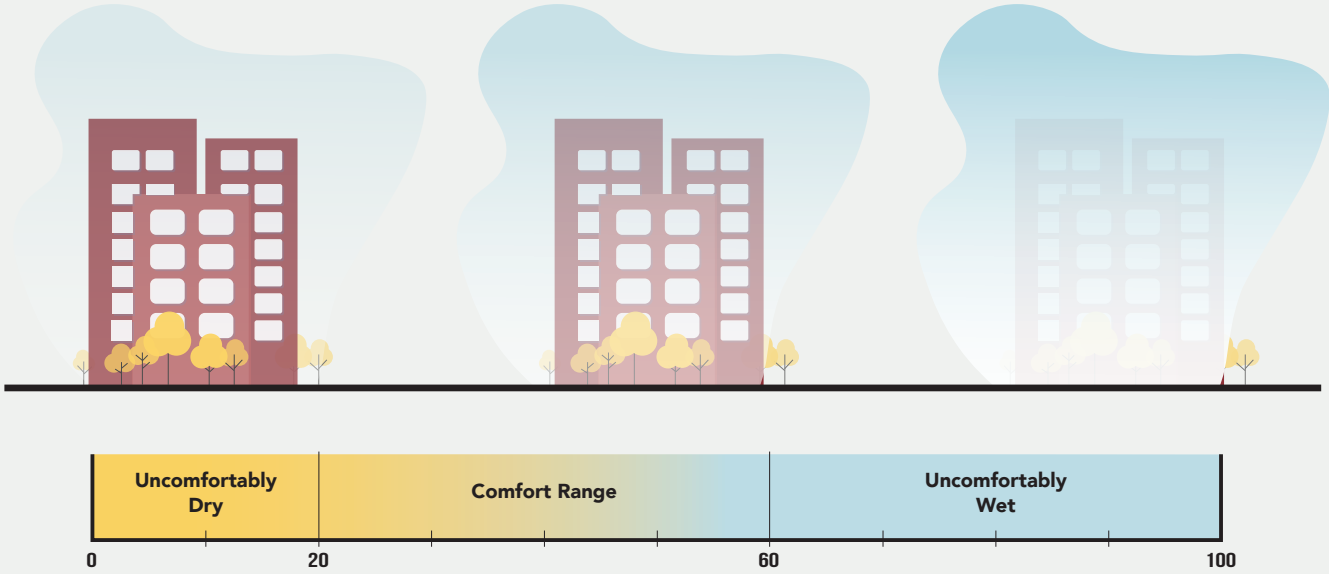


HUMIDITY AND PRECIPITATION

Humidity simply refers to **the amount of moisture in the air.** In other words, relative humidity is the percentage of water vapor that's in the air at a certain temperature. When the relative humidity is at 30 %, for example, the air is holding 30 % of the moisture it's capable of containing. People are very sensitive to humidity, as our skin relies on the air to get rid of moisture. The process of sweating is the body's attempt to keep cool and maintain its current temperature.

A result of 100 % relative humidity means that the air is totally saturated with water vapor and cannot hold any more, creating the possibility of rain. In these circumstances, sweat will not evaporate into the air. As a result, we feel much hotter than the actual temperature when the relative humidity is high. Our clothes may become saturated with perspiration that doesn't go anywhere, leaving people feeling discomforted.

If the relative humidity is low, we can feel much cooler than the actual temperature because our sweat evaporates easily, cooling us off. For example, if the air temperature is 24 degrees Celsius and the relative humidity is 0%, the air temperature feels like 21 C to our bodies. If the air temperature is 24 C and the relative humidity is 100 %, we feel like it's around 27 C, then people can hardly breathe and do any activities.



HUMIDITY AND PRECIPITATION

Precipitation (rain, snow, sleet and hail) is associated with areas of rising air and low pressure. When air rises it cools, and the moisture it contains condenses out as clouds, which eventually produce precipitation. In regions of high pressure, the air is descending, the atmosphere is stable, the skies are usually clear, and precipitation is rare.

As temperatures rise and the air becomes warmer, more moisture evaporates from land and water into the atmosphere. More moisture in the air generally means we can expect more rain or snow and more heavy downpours.

But this extra **precipitation is not spread evenly around the globe**, and some places might actually get less precipitation than they used to get. That's because climate change causes shifts in air and ocean currents, which can change weather patterns.

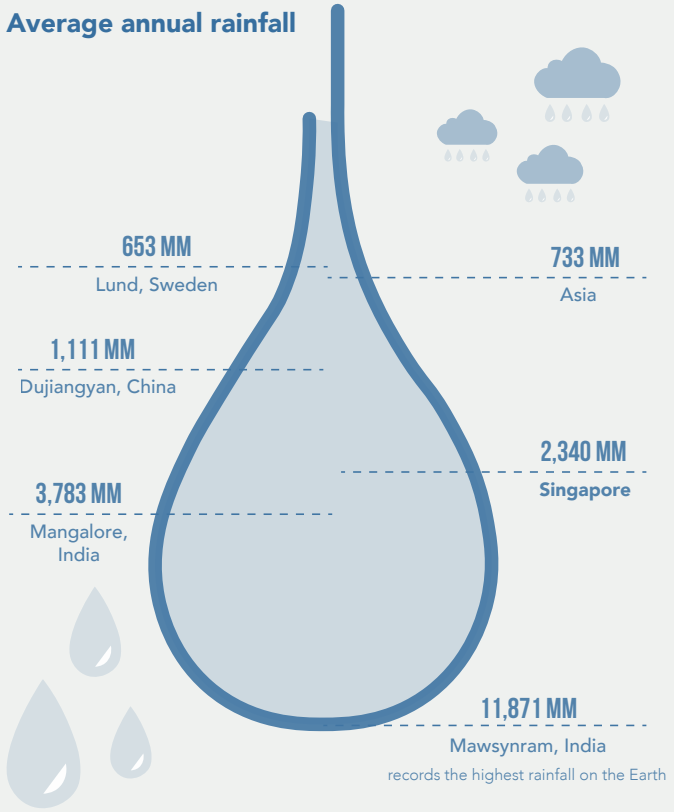
The highest rainfall totals occur near the equator in the tropics, where the strong heating by the Sun creates significant vertical uplift of air and the formation of prolonged heavy showers and frequent thunderstorms.

Annual rainfall totals in the tropics usually **exceed 2,500 millimetres** and can be as high as 10,000 millimetres, particularly if influenced by the monsoons or if mountains enhance the uplift of air.

The greater presence of condensation nuclei over urban areas can lead to **cities being wetter** and having more rain days than surrounding rural areas.

However, other factors play a major role, especially **the heat islands.** These can enhance general uplift, and the strong thermals that are generated during the summer months may serve to generate or intensify thunderstorms over or downwind of urban areas.

Storms cells passing over cities can be 'refuelled' by contact with the warm surfaces and the addition of hygroscopic particles. Both can lead to enhanced rainfall, but this usually occurs downwind of the urban area.

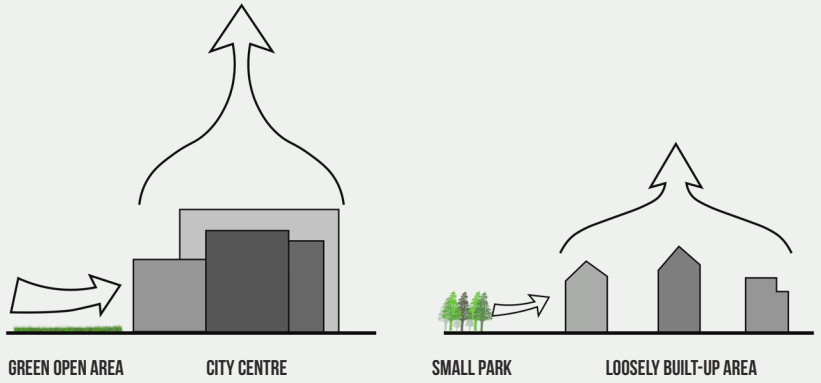


WIND IN A CITY CONTEXT

Urban wind between warm and cool areas

Urban heat island can create airflows themselves. The air over the warmer parts of the city rises and air from a nearby cooler area is sucked in. The bigger the difference in temperature, the more cool air is sucked in, resulting in more wind.

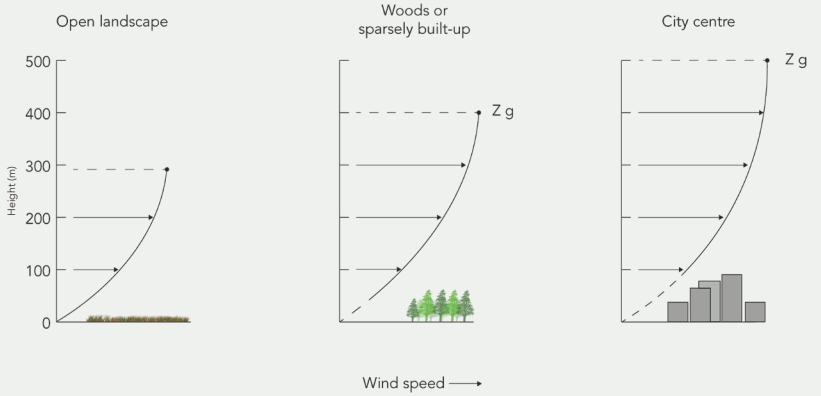
The airflow between a densely built-up residential area will only ever be light. If cool breezes are given the space to flow, they can find their way into the warm areas of a city, thus providing ventilation. But these airflows are weak too and unable to pass higher obstacles.



Different wind speeds in cities and open landscape

Close to the ground, obstacles on the earth's surface slow down the large-scale wind. A city with many tall buildings standing quite close together will be a bigger obstacle than a city with many low-rises. The average wind speed in urban areas is around 30-50% lower than outside of the city.

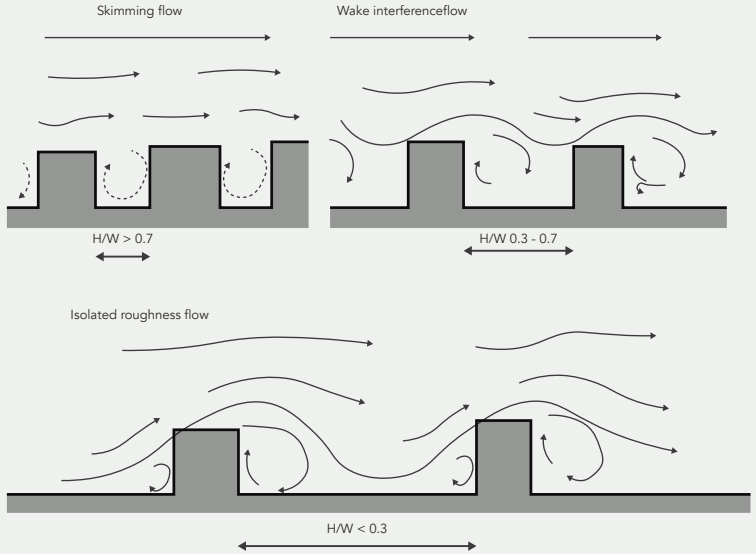
At densely built-up cities with high-rise buildings, the large-scale wind is deflected up to a height of 500 metres over the roofs. Sometimes it can be even higher as tallest skyscrapers can reach over 800 meters. Only above it does the wind reagin its original speed.

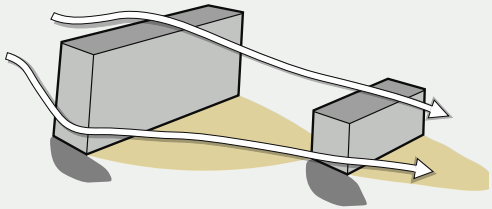


Typical wind flow regimes

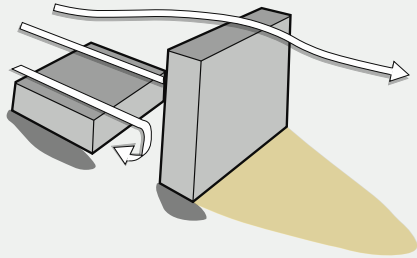
The wind climate in open spaces in a city is mostly influenced by the volumes of the surrounding buildings. Continuous buildings structure along the streets can have a channelling effect on the wind if the street is more or less parallel to the prevailing wind direction. The proportions of open space like streets and squares have a significant impact on wind patterns. The ratio between the buildings height (H) and the width (W) if the areas between the buildings are of influence.

The skimming flows occur in relatively narrow streets. Most of the wind stays above rooftops leaving the quite sheltered area between the buildings. When the street or square is wider (with H/W ratio of 0.3-0.7) there is a wake interference flow pattern, which means that the sheltered area behind the buildings overlaps the small sheltered area in front. With H/W of 0.3 or smaller the isolated roughness flow occurs where wind can almost resume its original flow pattern and speed. It often leads to wind nuisance on big squares.

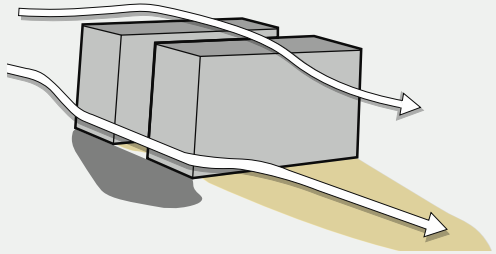




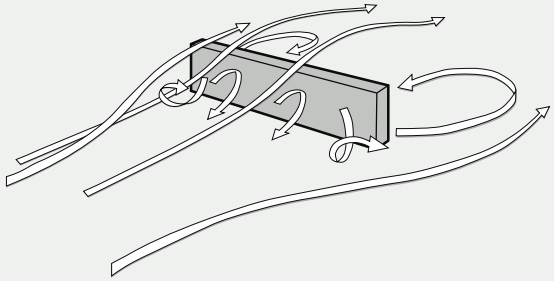
Buildings at a distance from each other with



Buildings with clearly interacting wind flows

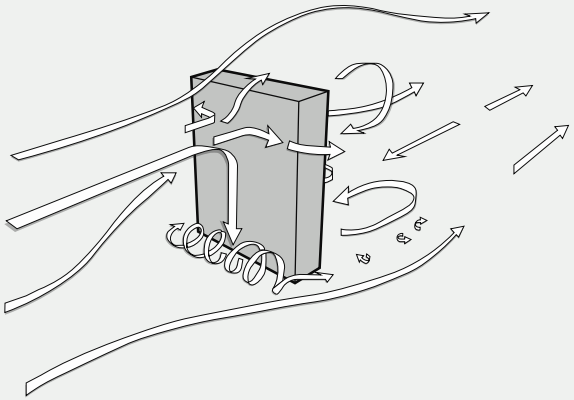


Buildings with clearly interacting flows and corner



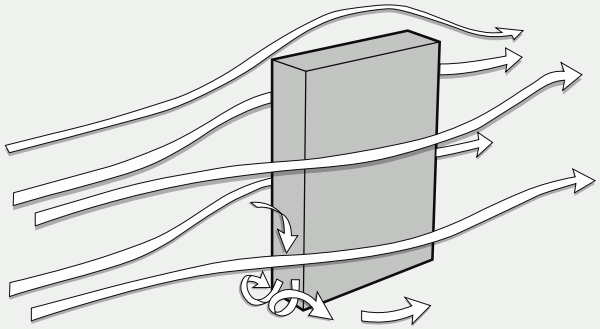
Wind patterns around freestanding buildings of medium height at right angles to the wind

On the windward side a little above the middle of the building front, you get eddies to the bouncing of the wind. A way of the foot of the building there is a small sheltered area where the main flows are divided. At the sides of the building, there are corner streams with higher wind speeds due to the compression of the air flowing around the building. On the leeward side behind the building, the pressure is lower and there is a sheltered area.



Wind patterns around freestanding high-rise buildings at right angles to the wind

Around the tall buildings of over 20 meters at right angles to the direction of the wind, there are some other phenomena occurring. There is, for example, extra corner streams develop at the top. At the windward side of the building, winds blowing over the rooftops at higher speeds are 'scooped' down. This phenomenon is called downwash and can be the cause of higher and dangerous wind speeds which are a threat for pedestrians or cyclists.



Wind flows around tall buildings parallel to the wind direction

When a building is parallel to the direction of the wind, the flows are deflected considerably less. The air pressure at the windward side is much smaller and there are hardly any corner streams. When wind hits buildings with passageways, other patterns occur. The wind hitting the building is also forced through the small openings of the passage. This creates a compression of airflows and those high wind speeds, which can be dangerous for pedestrian and cyclists as well.

02

SINGAPOREAN CONTEXT

SINGAPORE INTRODUCTION

Singapore (officially the Republic of Singapore) is an **island city-state** in Southeast Asia. It lies one degree north of the equator, at the southern tip of the Malay Peninsula, with Indonesia's Riau Islands to the south and Peninsular Malaysia to the north.

Singapore's territory consists of one main island along with 62 other islets. Since independence in 1965, extensive land reclamation **has increased its total size by 23%** (130 square kilometres).

The country is known for its **transition from a developing to a developed one** in a single generation under the leadership of its founder Lee Kuan Yew.

In 1819, British statesman **Sir Stamford Raffles founded colonial Singapore** as a trading post of the British East India Company. After the company's collapse in 1858, the islands were ceded to the British Raj as **a crown colony.**

During the Second World War, **Singapore was attacked by Japan** from the Malaysian side and was occupied for 3 years what led to the fall of the British colony. As consequence, it gained **independence from the British Empire in 1963** by joining Malaysia along with other former British territories (Sabah and Sarawak), but separated two years later over ideological differences, becoming a sovereign nation in 1965.

After early years of turbulence and a lack of natural resources or hinterland, the nation developed rapidly as an **Asian Tiger economy**, based on **external trade** and its **workforce.**

Nowadays Singapore is a **global hub** for education, entertainment, finance, healthcare, human capital, innovation, logistics, manufacturing, technology, tourism, trade, and transport.

THE TIMELINE OF SINGAPORE'S HISTORY

COLONIAL SINGAPORE

founded by British statesman Sir Stamford Raffles

1819

INDEPENDENCE

from the British Empire, after the Japanese occupation during the II WW, which led to the fall of the British colony

1963

ECONOMIC BOOST

Singapore progresses as a First World country and starts to plan it's ambitious future. It began to upgrade to higher--technological industries.

1980'S

1858

CROWN COLONY

Singapore becomes ceded to the British Raj - the rule by the British Crown on the Indian subcontinent from 1858 to 1947

1965

SOVEREIGN NATION

Singapore becomes a sovereign nation after separation from Malaysia after having joined it 2 years before

2000'S

ASIAN TIGER AND GLOBAL HUB

Singapore becomes developed country with huge ambitions. It leads in many rankings for ex. world's smartest or safest country

SINGAPORE FACTS

The Economist has ranked Singapore as the most expensive city to live in, since 2013 and it was confirmed by another study including a CNN report from 2019 making Singapore the most expensive city tied with Paris and Hong Kong.

It is identified as a tax haven. Singapore is the only country in Asia with an AAA sovereign rating from all major rating agencies, and one of 11 worldwide. Globally, the Port of Singapore and Changi Airport have held the titles of leading „Maritime Capital" and „Best Airport" respectively for consecutive years, while Singapore Airlines is the 2018 „World's Best Airline".

It is placed highly in key social indicators: education, healthcare, life expectancy, quality of life, personal safety and housing. Although income inequality is high, 90% of homes are owner-occupied.

Democracy Index: Singapore is described as a „flawed democracy" which is described as a nation where elections are fair and free and basic civil liberties are honoured but may have issues (e.g. media freedom infringement).

Total area:
722,5 km^2

Ethnic groups:
- 74,3 % Chinese
- 13,3 % Malay
- 9,1 % Indian
- 3,3 % other

Religion:
- 33,2 % Buddhism
- 18,8 % Christianity
- 18,5 % irreligious
- 14 % Islam
- 10 % Taoism
- 5 % Hinduism

The view on the ArtScience Musuem and the Central Business District

SINGAPORE ACHIEVEMENTS

The government of Singapore nowadays has **enormous amibtions**. The city ranks highly in numerous international rankings, and has been recognised as:

- **9th** on the UN **Human Development Index**
- **3rd** highest **GDP per capita**
- the most „**technology-ready**" nation,
- top **International-meetings** city,
- city with „**best investment potential**"
- world's **smartest** city,
- world's **safest** country,
- second-most **competitive** country,
- third **least-corrupt** country,
- third-largest **foreign exchange market**,
- third-largest **financial centre**,
- third-largest **oil refining** and **trading centre**,
- fifth-most **innovative** country,
- the second-**busiest container port**.

World's financial center

>7000 multinational corporations
60% have their asian headquarters based here
home to 126 banks,
out of which 121 are foreign banks

Asia's largest foreign exchange hub
financial services account for 13% of Singapore's GDP

One of the biggest landmarks of Singapore: Marina Bay Sands hotel and the Helix Bridge leading to it

SINGAPORE DEVELOPMENT DIRECTIONS

Land reclamation and urban regeneration

Due to the land scarcity, the Urban Redevelopment Authorities carried out uncomparable in scale land reclamation project over several decades. **Singapore has grown by 23%** of its original area over 50 years and is the biggest importer of sand worldwide importing 14,6 million tons in 2010 alone. The other side of the medal is that it poses an enormous threat to the environment. Moreover, the authorities are forced to rejuvenate already established areas to provide (new and future) citizens with education, leisure and housing. Consequently, **long term planning is practised**.

Tourism

The tourism sector contributes to **4% of GDP** and provides 160,000 jobs and more than 18,5 million tourists came to Singapore in 2018 and spent S$30 billion.

Passenger millstones at Changi airport

1986
>10 million passengers
1994
>20 million passengers
2004
>30 million passengers
2013
>50 million passengers

>100 airlines operating
>6,700 weekly flights to
>300 cities worldwide

World's most awarded airport with
>490 awards

Changi serves **150,000 passengers daily**

Shining star in the global world

Singapore has a huge ambition of being one of the most renowned, developed and visited countries not only in Asia but worldwide. It aims in organising **unique events** (like first Formula 1-night city race, World Cities Summit) and having **uncomparable architecture** (like Gardens by The Bay or Marina Bay Sands).

Supertree Grove - the artifical Supertrees in the Gardens By The Bay

SINGAPORE URBAN PLANNING

Urban Redevelopment Authority

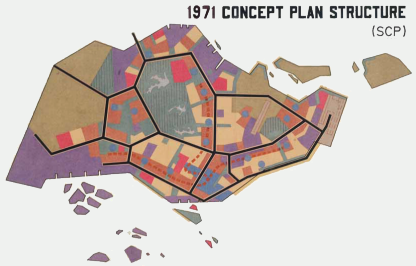
URA is the national urban planning authority of Singapore and a statutory board under the Ministry of National Development of the Singapore Government. It is the main body responsible for the development of the country. URA presents a long-term and comprehensive planning approach to formulate strategic plans such as the Concept Plan and the Master Plan to guide the physical development of Singapore in a sustainable manner. plans and policies are focused on achieving a quality living environment for Singapore.

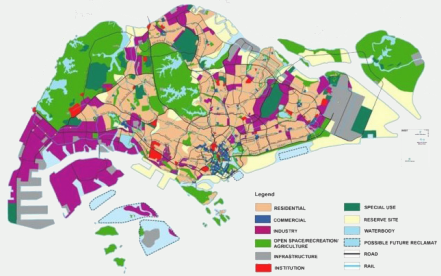
URBAN REDEVELOPMENT AUTHORITY

To make Singapore a great city to live, work and play

Concept Plan

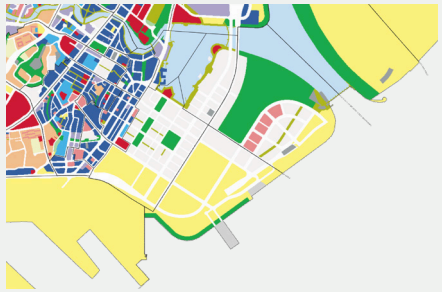
This guides Singapore's development over the next 40 to 50 years and covers strategic land use and transportation. It ensures that there is sufficient land available to meet the needs of the long-term population and economic growth, balanced with a quality living environment. The Concept Plan is reviewed every 10 years.

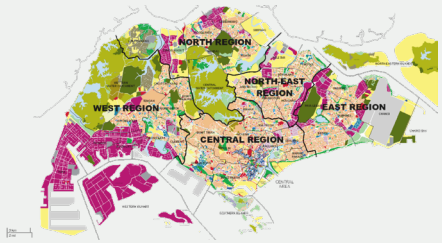




Master Plan

The Master Plan translates the broad, long-term strategies set out in the Concept Plan into more detailed plans for implementation. It specifies permissible land use and densities, with the aim of guiding development over the next 10 to 15 years. The Master Plan is reviewed every five years.





Past overlooking to the future. The statue of Singapore's founder - Sir Thomas Stamford Raffles overlooking the Marina Bay Sands hotel

SINGAPORE CHALLENGES

Even though, Singapore is perceived as a successful nation it has its challenges too as every other country. To start with, Singapore is the financial capital and a wealthy country but the economical success brings the dark side of it, I would call it some kind of curse, which is the extremely high **cost of living, inequalities and poverty**. Of course, Singapore is successful as a country both in the world and in the region but obviously not every citizen can benefit from the enormous wealth. There is the Central Business District, as well as there, are less affluent or ever poor neighbourhoods.

Another set of challenges is the **demography**, to be more specific it is the ageing population, declining birth rate and some ethnic inequalities. However there might be some sense of integrity and unity, there are differences between the three main ethnic groups: Chinese, Malay and Indian. There are also many migrants doing demanding physical job and most of them are Indian.

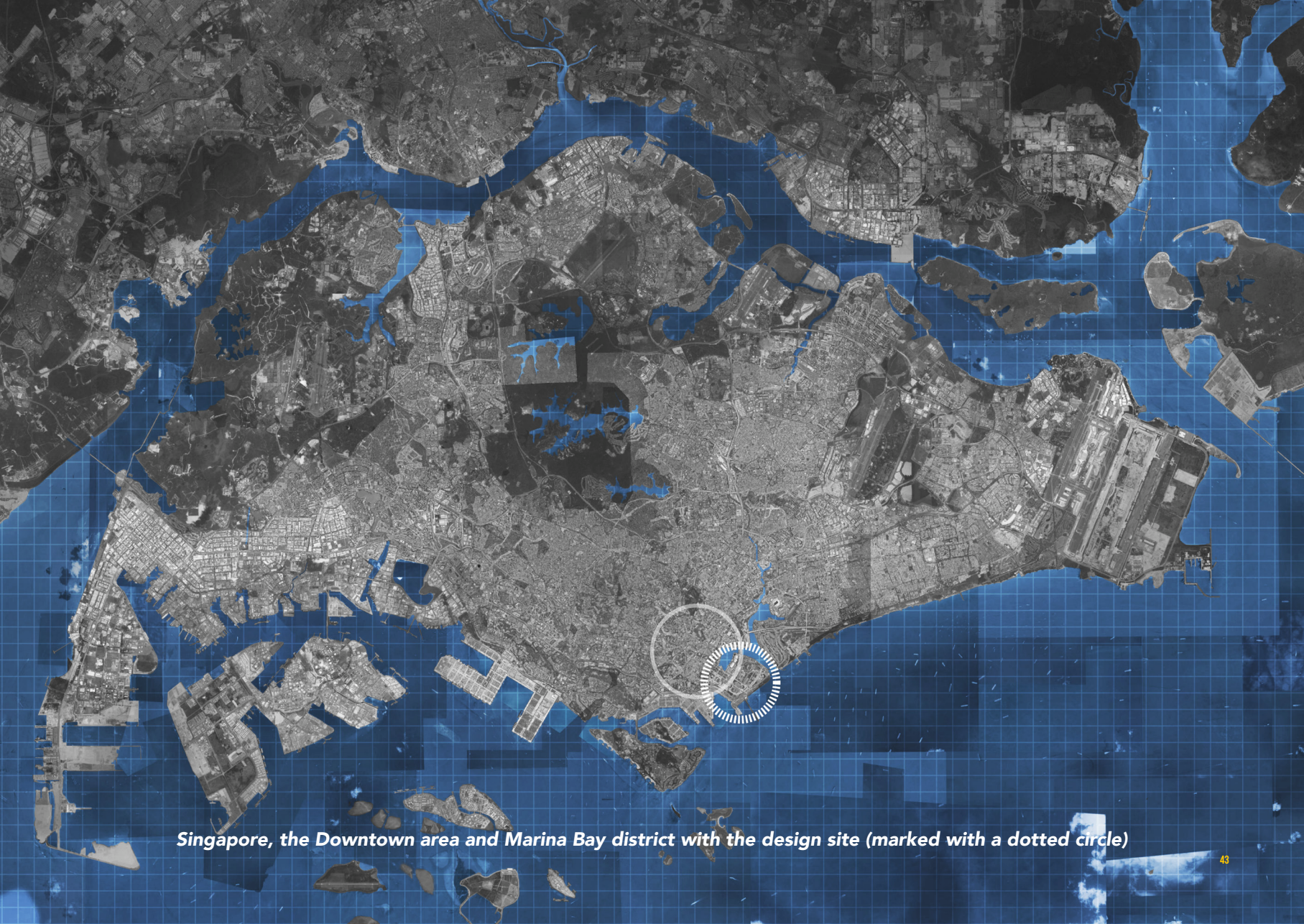
Hence Singapore is a unitary parliamentary republic and the elections are considered generally free **the government exercises significant control over policies and society**. There was also only one ruling part (People's Action Party) that ruled since independence.

Yet, the most challenging and most inevitable challenge is the environmental one. Due to rapid changes, the enormous amount of concrete used to build all the new developments, the scarcity of land and a tropical climate Singapore is heading straight towards a huge **climate crisis.** This master thesis will take into consideration the urban heat island effect crisis but one could ask various questions like:

- How to decarbonise?
- How to end Singapore's role in the oil and gas industry?
- How to meet the Paris agreement goals?
- Why was Singapore reclaiming so much land and is still doing it?

These are just a few questions undermining the huge success of Singapore over the last couple of decades.

Answering all those questions is not a task for this master thesis - the questions should be rather answered by the government as there is less and less time to do it. This master thesis will continue with the **urban heat island effect** as the main theme.



Singapore, the Downtown area and Marina Bay district with the design site (marked with a dotted circle)

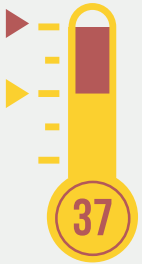
03

CLIMATE IN SINGAPORE

CLIMATE THREATS

Heat threat

If the current rate of carbon emissions will continue to rise, **Singapore's daily temperature will reach 35 to 37 degrees Celsius by 2100.**



There is a reason to worry as because of the high humidity the temperature feels to be even bigger. Because of the high humidity, more seawater evaporates and is present in the air. When both humidity and air temperature rise, our bodies struggle to cope. With higher humidity, we get a higher stress level. What does it mean for the people of Singapore?

Even they would struggle to adjust. With such temperatures and humidity of 60% and more only the professional runners that train in special chambers with higher temperature would manage to function in such conditions, but not for a long time.

Why Singapore is getting warmer faster than in other countries?

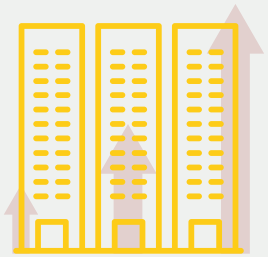
According to NASA satellite key data, since 1950 Singapore has been heating up twice as much as the rest of the world. It was not only due to the tropical climate but especially because of rapid urbanisation and development. In a nutshell, the tropical jungle was replaced by a concrete one. It resulted in a vast urban heat island effect.

Dark vision

There are some unprotected forest areas in Singapore, that cannot be removed or reduced if we want to, not even reduce the UHI effect, but at least just to keep the existing conditions and temperature.

Nowadays 80% of Singaporeans live in HDB flats in big concrete towns around the island. The rapid urbanisation and increase of population led to a shift in typology towards huge residential towers.

Moreover, **in 20 years, over 700 hectares of rainforest will be turned into 42 000 new homes**. Every development like that will add up to the environmental cost and urban heat island, helping to reach the 2100 dark vision. There is a dilemma should Singapore continue the rapid development but decrease the quality of the citizens' life in the future?



SINGAPORE TEMPERATURE

CLIMATE FOR SINGAPORE													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Record high °C	35,2	35,2	36	35,8	35,4	35	34	34,2	34,4	34,6	34,2	33,8	**36**
Average high °C	30,4	31,7	32	32,3	32,2	32	31,3	31,4	31,4	31,7	31,1	30,2	**31,5**
Average rainfall in mm	234,6	112,8	170,3	154,8	171,2	130,7	154,4	148,9	156,5	154,6	258,5	318,6	**2,165**
Average rainy days	13	8	13	14	14	12	14	14	13	15	18	18	**166**
Average relative humidity	84,4	82	83,4	84,1	83,5	81,9	82,3	82,2	82,7	83,1	85,7	86,5	**83,5**
Mean monthly sunishine hours	172,4	183,2	192,7	173,6	179,8	177,7	187,9	180,6	156,2	155,2	129,6	133,5	**2,022**

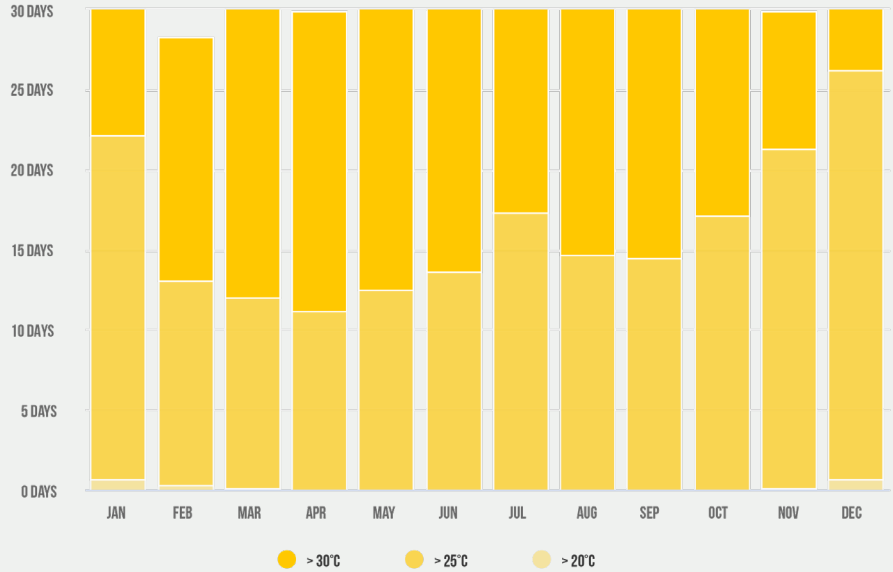
Due to Singapore's tropical location, it lacks the four or even two seasons cycle. As a consequence, there is a warm but sometimes also rainy summer throughout all the year. It brings many challenges.

The record high temperature might come to as high as **36 degrees** Celsius, recorded in March. It's also only 4 degrees more than the average temperature for this month. Due to the climate and humidity, the rainfall is also quite big.

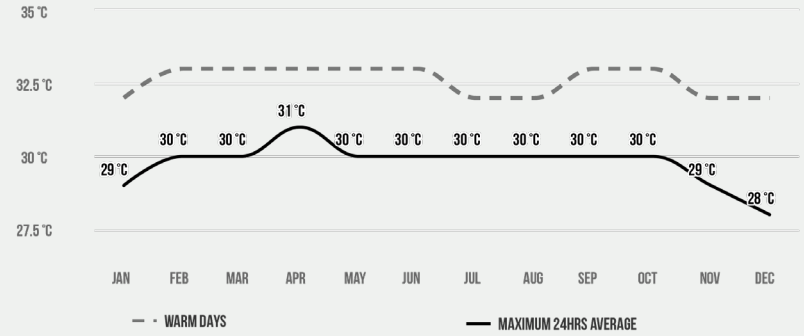
The average yearly **precipitation exceeds 2,100 mm**, whereas in many European cities it stays between 600 and 800 mm.

The average **humidity is around 83%** but daily it can get even to 100. The monthly sunshine hours number does not drop to less than 130, which is also quite remarkable in comparison to for ex. Öresund Region where the number falls under 40 in winter months.

Given that extraordinary weather conditions and analyzing different charts, we need to emphasize the **numerous challenges** that Singapore is facing due to the very specific and extreme climate.



The graph shows the number of days with 20, 25 and 30 °C each month of the year.



The graph shows the temperature peaks over the year.

SINGAPORE AIR CONDITIONING

In 2018 Japan had the hottest summer ever with 41 degrees Celsius. In 1 week it killed 65 people and thousands of them were hospitalized for heat-related conditions. To show the broad and often negative influence of heat, a scientist in Singapore, calculated that there are **27 ways to die from the heat.** To name one, in extreme heat our cells can just fry and die. The heat has a negative influence on our sleep, concentration and life satisfaction in general. This is also why marathons in Singapore are the slowest ones in terms of the results in the time needed to reach the distances.

Air conditioning

Air conditioning consumes **60% of all energy in buildings in Singapore.**

Every air conditioning is ejecting heat to the outside which is sucked into the next air conditioning as the warm air goes up. It leads to some kind of a domino effect where every higher air conditioning is heated up but the lower one. As a consequence, the residents living on the highest floors need to spend on air conditioning the most.

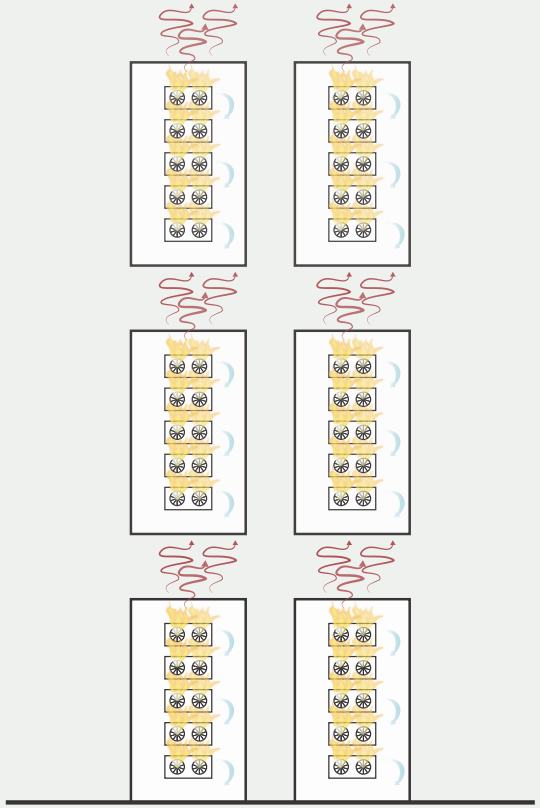
Air conditioning makes people in Singapore switch to indoors life and whenever they are outside, in general, they look for any shade instead of freely using the city. At some point, people would need to spend whole life indoors. At some point, people would need to spend their whole life indoors. At the same time, even a 1-degree Celsius warmer air conditioning air temperature indoors can save up to 5% of the air conditioning cost.

Paradox

Every air conditioner produces heat and ejects it outside to keep the indoors cooler. There is a paradox because the device that cools people off makes them being warmer outside. On a bigger scale, the device that provides people cool and saves them from the unfavourable conditions increases the urban heat island and threatens people's lives in the future.

In 2018 United Nations' report gave a clear message: we have 12 years to reduce the carbon emission by half not to risk a climate catastrophe.

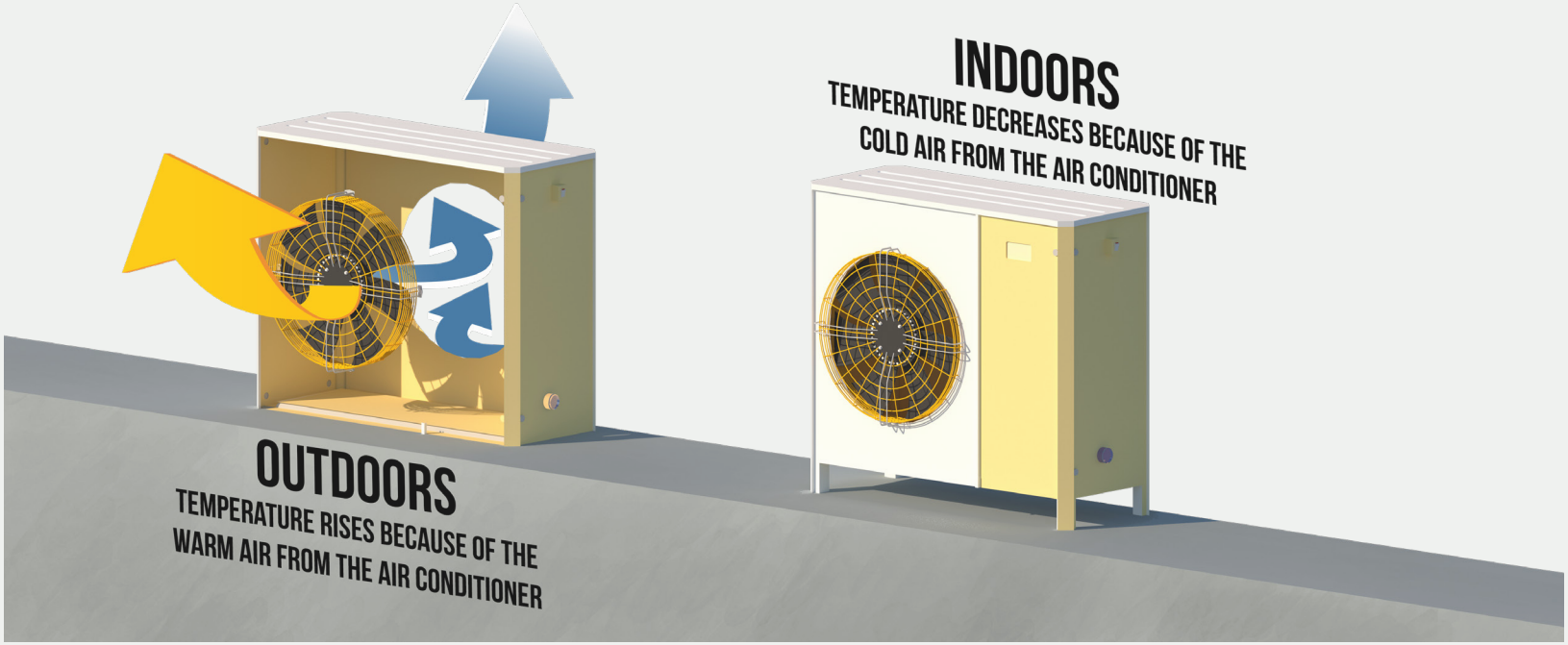
In Singapore, **people soon can be not able to use open public architecture and spaces.** This is why we need to act and this is why my master thesis is about microclimate and tackling the urban heat island effect in Singapore.



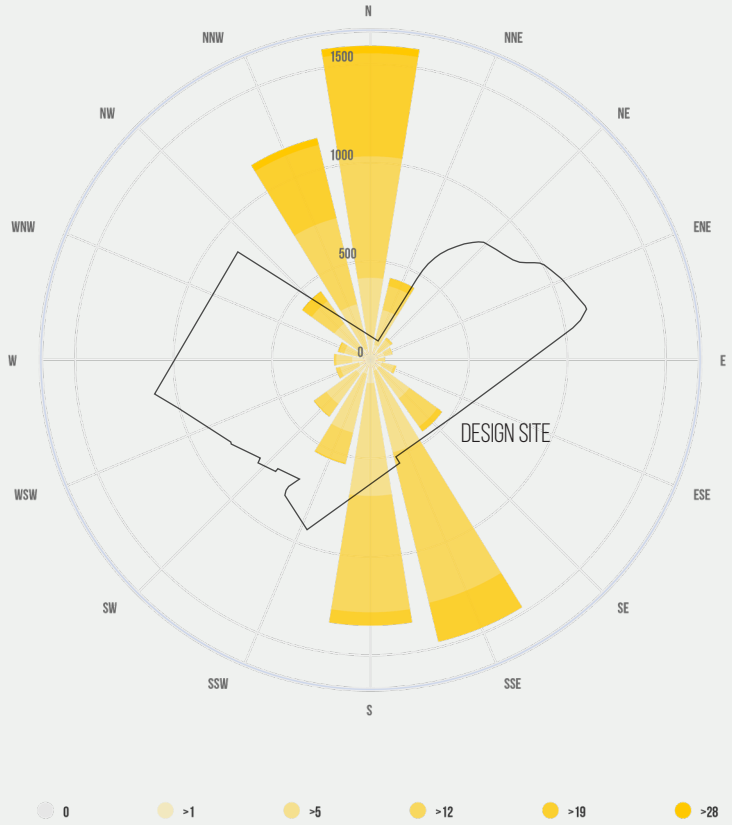
The example of the inefficient use of the air conditioning

HOW DOES THE AIR CONDITIONING WORK?

The diagram visualises how is the air conditioning working. They are placed over each other and every air condition sucks in the warm air from the one below. So technically they need to work even more. Living on the top floor means the biggest expenditures for the AC.



THE WIND ROSE FOR THE DESIGN SITE



The North - South prevailing wind

A frequent scene in Singapore: people are hiding from the sun under the awnings

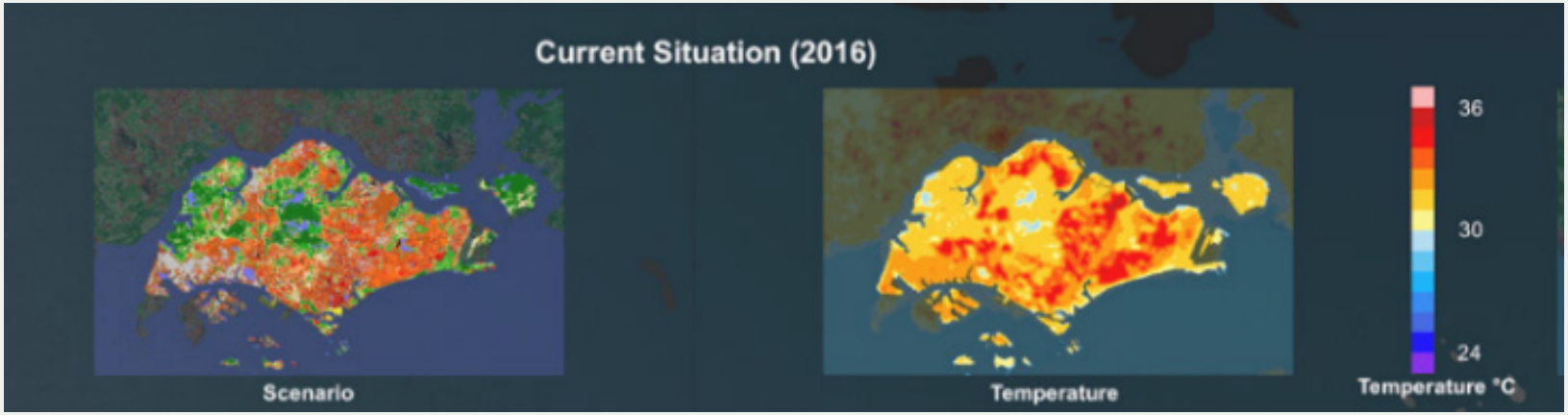
Photo by Jirath Ninchaikovit on Unsplash

COOLING SINGAPORE

Cooling Singapore is not only the aim of my project but also a **cross-institutional initiative** dedicated to **improving the thermal comfort of tropical Singapore**.

The members of the group deduced that reducing the urban heat island effect in Singapore will require a combined effort from many stakeholders from government, academia and the private sector. They believe that **roadmaps** are needed to guide policy and help coordinate long-term UHI mitigation efforts and UHI-related R&D activities.

Besides, a **local task force** was established to facilitate an exchange of knowledge between the various stakeholders. Developing these roadmaps and establishing the UHI task force are important goals of the "Cooling Singapore" project.



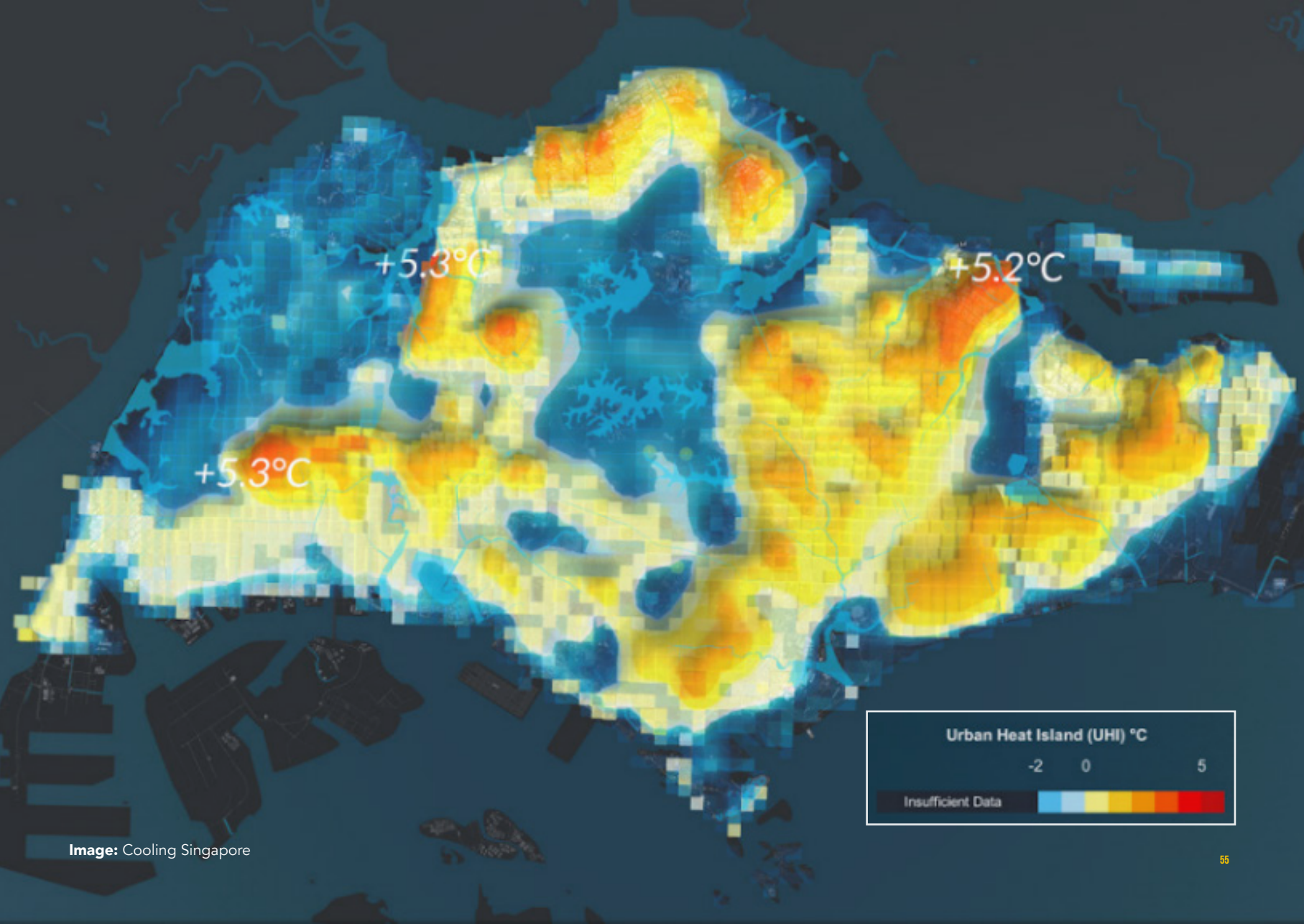


Image: Cooling Singapore

Mitigation Strategies Assesment

One of the Cooling Singapore studies is the Mitigation Strategies Assessment. Using climate modelling techniques, strategies for improving outdoor thermal comfort (OTC) were assessed specifically for green- and brown-fields in Singapore.

In collaboration with two Singaporean Agencies, Urban Redevelopment Authority (URA) and Housing Development Board (HDB), the Cooling Singapore team designed and modelled several specific strategy scenarios for test areas in the Jurong Lake District, in the Central Business District and an HDB estate in Punggol. These scenarios were composed of measures including vegetation, urban geometry and surface materials, aiming to improve the wind flows and reduce heat storage.

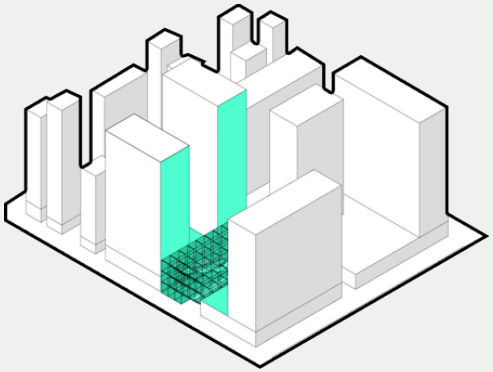
Using micro-scale computational fluid dynamics (ENVI-met model) the team was able to study the thermal environment under different annual meteorological conditions at the building and neighbourhood scale. The team conducted a spatio-temporal analysis that included a sensitivity analysis as well as a thermal comfort exposure mapping for each specific test area. Specific climate-responsive planning guidelines with quantitative and qualitative recommendations will be developed.

Some of the results for Singapore are:

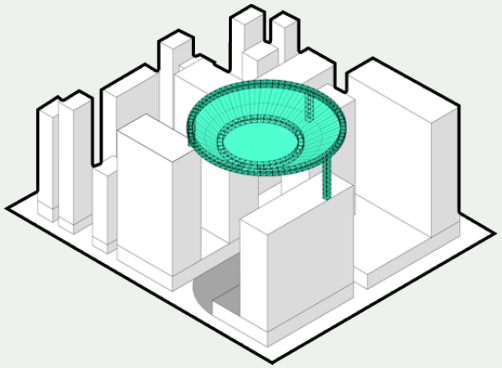
- It is relevant to use reference weather types to analyze OTC throughout the year
- Porosity and increasing ventilation can improve OTC in courtyards and open areas
- Green facades can only have an impact on OTC in areas very close to them (< 2 - 4 m). The orientation of the facade affects significantly its outdoor thermal performance.
- Green roofs have little impact on OTC, if applied only locally.
- Shadowing of trees might not be sufficient to attain an acceptable OTC level in low wind conditions (during midday and afternoon).
- Void deck can improve ventilation and thermal comfort levels in outdoor spaces (e.g. courtyards).
- New developments can increase one category the thermal comfort level (e.g. from warm to hot) in already existing developments.

Source: Cooling Singapore

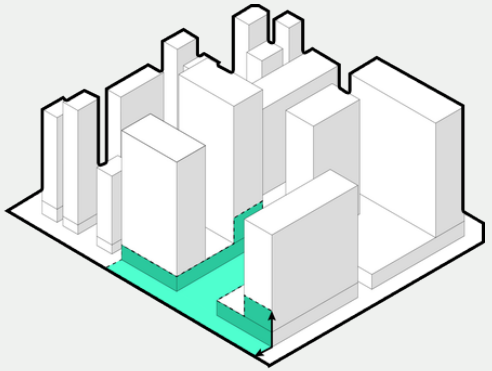
Increase setbacks on ground floor from 4 to 9 meters

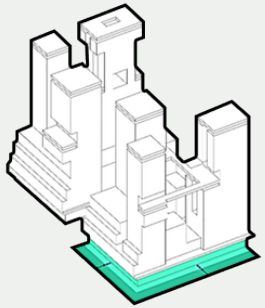


Re-arrange and re-orientate punctual buildings blocks

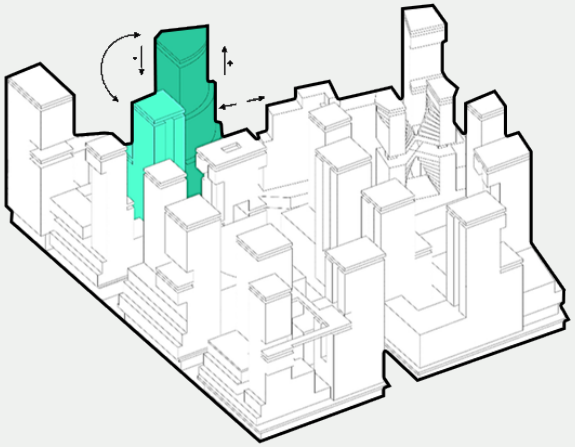


Adjust height, location and form of C-walk

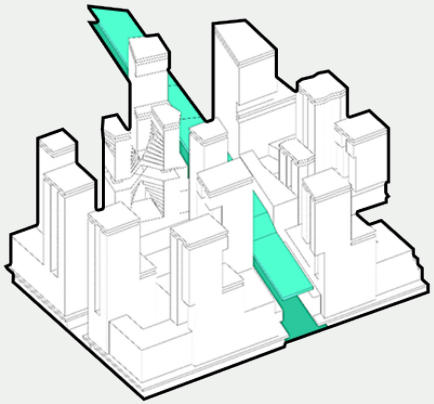




Increase number of trees (33% and 60%)



Install large-scale urban canopy/pergola to increase shading



Retrofit pavement and façade materials with green facades and retro-reflective materials at different heights

Images: Cooling Singapore

04

DESIGN CONTEXT

DESIGN SITE

The design site called Marina Bay is envisioned to become the new heart of Downtown Singapore. However, nowadays most of the site remains empty. The authorities plan includes the extension of the Central Business District as well as some new tall housing.

But before any new buildings will be built, there is an impressive Metro Rapid Transit extension project. It aims to create 4 new MRT underground stations and connect the whole site with the rest of the city.

Notwithstanding the Marina Bay already has some qualities. The most important and recognizable one is admittedly the Marina Bay Sands hotel. The breathtaking landmark building was designed by Moshe Safdie and opened in 2010 enriching the Singaporean skyline.

The second landmark of the site is the Gardens By the Bay, an enormous public garden with tall artificial trees towers (called Supertrees) and two glass domes with one of the biggest artificial waterfalls.

The third attraction is the Marina Barrage which brings three benefits: a source of water supply, flood control and a venue for lifestyle attraction. It is a modern dam construction that creates the Marina Bay reservoir, but also a public space on the roof.

Last but not least, the Singapore Maritime Gallery. The 1,000 sq m building, located at Marina South Pier, tells the story of Singapore's transformation from a small trading post into a global hub port and international maritime centre.

All those landmarks make the site being extremely attractive for both citizens and tourist. Proximity to the centre, and the enormous money investment in creating the Marina Bay as a landfill project makes it natural to design a new district full of life and activities for the current and future users.


MARINA BAY
OLD TOWN
MARINA BAY SANDS
GARDENS BY THE BAY
MARINA BARRAGE
DOWNTOWN
CENTRAL BUSINESS DISTRICT
DESIGN SITE - 166 HA
SINGAPORE'S CARGO HARBOUR
PASSANGER HARBOUR

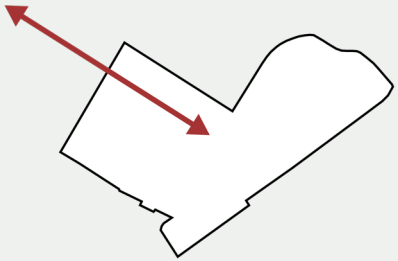
DESIGN SITE ANALYSIS

Key facts:

- 166 ha
- located next to **Downtown and Central Business District** and key touristic features: **Marina Bay Sands hotel, Gardens By The Bay, Maritime Gallery** and the **Marina Barrage** - water cleaning plant with a green public green roof on top of it.
- has very **wide roads** and a **future metro line construction**
- due to big open areas, the constructions, noise and buzz of the roads it is **not widely used by pedestrians**
- **no clear access** to the water edge
- has a very technical character

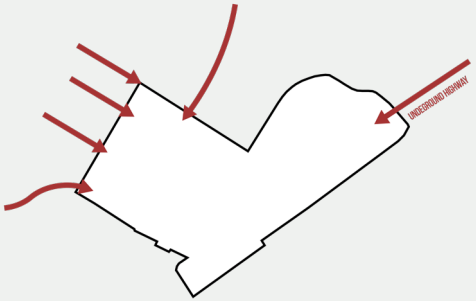
TRANSPORTATION

MAIN CONNECTION TO DOWNTOWN



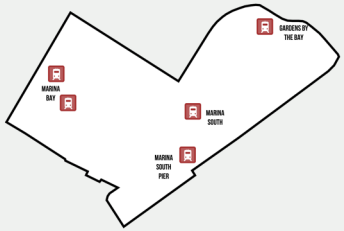
The design site is closely connected to the city's downtown area. The connection is provided by both buses and metro. Moreover, the site is within a walkable distance from the downtown, but due to the heat, it is not attractive to walk this distance.

MAIN ENTRANCES TO THE SITE



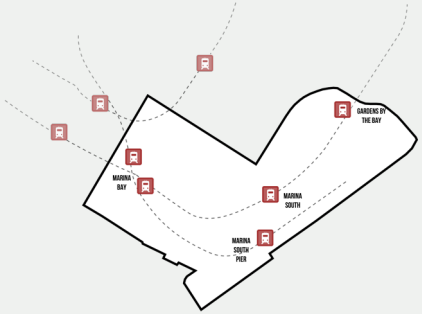
The design site can be approached from different directions. Most of them are from the downtown core, but there are highway connections from the northern-east and southern-west.

MASSIVE RAPID TRANSIT STATIONS



There is already the Marina Bay metro station today, but it is quite far to walk to the center of the design site. Three new metro stations within the design site boundaries are to be opened in the future.

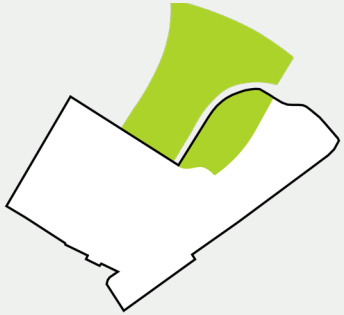
MASSIVE RAPID TRANSIT NETWORK



Together with other existing metro station located around the design area, it becomes a metro network that is a huge incentive for the site's accessibility.

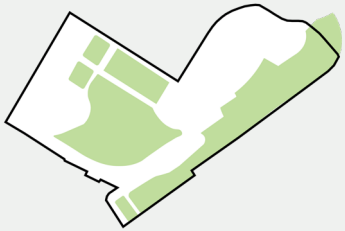
INFRASTRUCTURE

GARDENS BY THE BAY



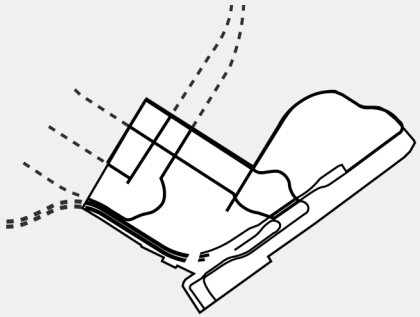
The biggest attraction of the site nowadays is the Gardens By The Bay park. It is both an accessible public park as well as a paid attraction for tourists. One needs a ticket to enter the glass domes, but moving inside the park is free and refreshing.

UNUSED GREENERY



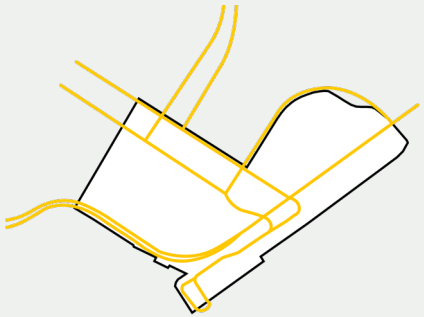
There is a lot of unused greenery on the site in a form of dry meadow land. Due to the climate, those vast green areas are not used by the people, partly because of the lack of any shading. These green bodies are a huge potential for recreation in the future.

ROAD NETWORK



The site is mostly empty nowadays, but at the same time it is occupied with several big roads and even highways (multi-lane roads). Although the site is not populated nowadays the traffic is quite large.

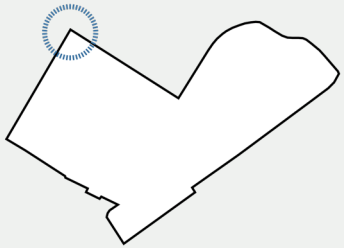
BUS LINES



Several bus connections go through the site nowadays. My observation is that those busses are mostly serving tourists who want to visit the Gardens By The Bay.

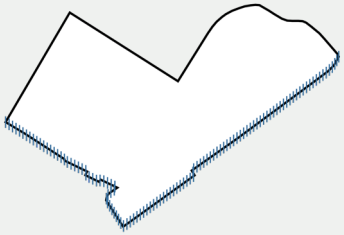
WATER BODIES

MARINA BAY WATER EDGE



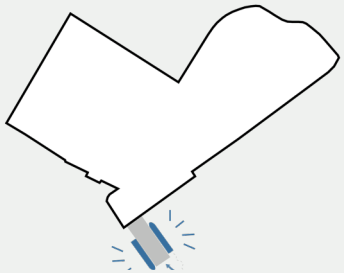
The site has a water edge when it meets Marina Bay. It is possible then to access the most prominent promenade of the city from the design site. However, it is quite far to walk, the site is a part of the main bay of Singapore.

OCEAN WATER EDGE



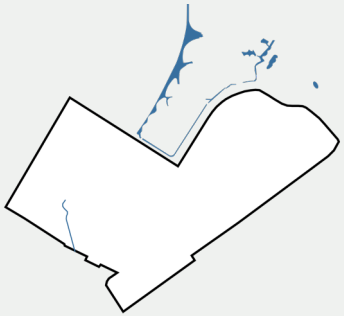
The fact that the site is having a long water ocean edge is used as an advantage in the project. It is a real relief to be able to feel the breeze from the ocean and be able to acces the water.

PASSENGER FERRY TERMINAL



The site is not only accessible from the land, but also the ocean side. There is a ferry terminal located in the southern-east part of the site. However, this type of service might not be the most sustainable one, it is the access point to the island as well.

WATER BODIES IN GARDENS BY THE BAY



There are several water bodies - mostly human made - that are located in this part of the city. Most of them were made as a part of the development of the Gardens By The Bay.

SCALE COMPARISON

The design site in my project is 166 ha, which is a lot compared to the other master thesises or the project that we have been working on during the studies.

This is why I believe that it is crucial to present a proper scale comparison and show the scale of the project site in Singapore.

To be able to show it in a more European context (but not only one) I chose 4 sites and overlayed my design site with the following cities:

1) Lund, Sweden

Motivation: Lund is the town that I have been studying in for almost two years. It is also a valid comparison for all of my colleagues from SUDes.

2) Malmö, Sweden

Motivation: Malmö is the biggest city in southern Sweden and Skåne. It is a city that I have been living in for half a year and I got to know it's an urban scheme.

3) Copenhagen, Denmark

Motivation: It is a city that I am currently living in. It is also second the biggest city in Scandinavia. As it is also one of the most know northern European city, I find it attractive and reasonable to compare with the design site.

4) Gdynia, Poland

Motivation: Gdynia is not only one of the biggest cities in Poland but also one of the youngest ones. Gdynia appeared on the map in the 1920s and is a harbour city prone to many urban changes in the XX century. It is similar to Singapore in a sense of transformation and rapid growth. Moreover, it is also a design site for my girlfriend's master thesis, so it was very interesting to compare the design sites while working on our master thesises.

Conclusion

The main conclusion of the site comparison is that my design site is extremely big comparing to the other cities. It means that in this master thesis I will focus on overall level of principles, guidelines and strategies instead of trying to solve small scale challanges.

05

DESIGN CONCEPT

DESIGN PRINCIPLES

There are numerous measures that I have chosen to tackle the urban heat islands effect in Singapore. The explanation of each of the follows on the next pages. But to be able to present them in a nutshell I propose **3 main design principles** for the project:

1) Harnessing the prevailing wind to enhance ventilation

One needs to remember that we are in the tropical climate of Singapore. A place where there are no winters or cold periods of the year. To be able to propose a sustainable solution we need to use something that is already there - nature.

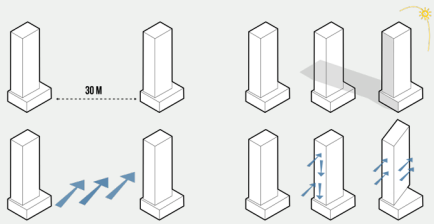
2) Creating wind downwash effect and porosity

Singapore is lucky to be located at the ocean which enables the wind to enter the city. By proper channelling of the wind, we can cool down the city including the proposal's site of Marina Bay.

3) Cooling by nature

Air conditioning might be very helpful to tackle the heat but it has its limitations. As I mentioned in the previous chapter it is only serving inside the buildings and is only a temporary solution as it releases heat to the atmosphere. The answer to that is to cool with the real nature, that can be embedded in the public realm and buildings themselves.

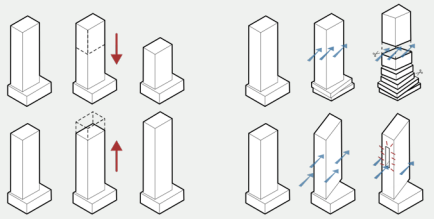
HARNESS PREVAILING WIND TO ENHANCE VENTILATION



WIND CORRIDORS (30 M)

BUILDINGS ORIENTATION

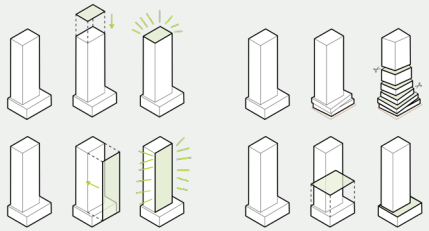
CREATING WIND DOWNWASH EFFECT AND POROSITY



VARIED BUILDINGS HEIGHTS

BUILDINGS POROSITY

COOLING BY NATURE

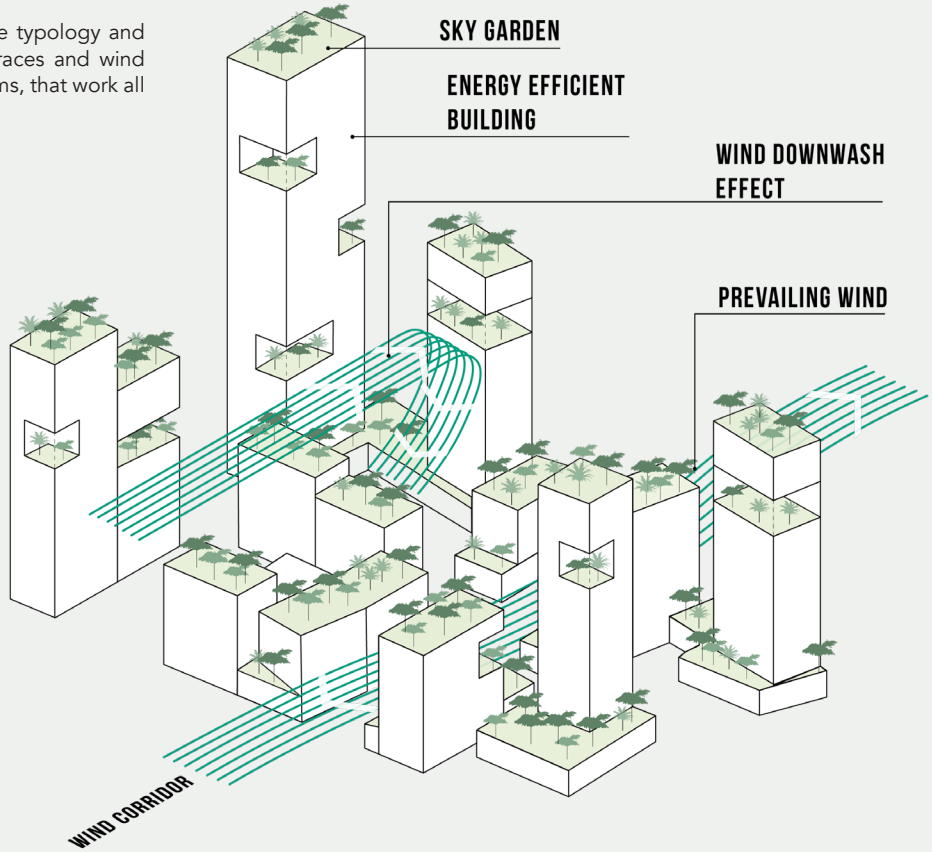


GREEN ROOFS AND FACADES

GREEN TERRACES AND PODIUMS

CONCEPT DIAGRAM

By using the typical Singaporean high-rise typology and enriching it with the green podiums, terraces and wind channels I propose effective cooling systems, that work all the year-round.

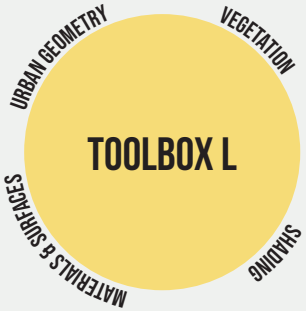


TOOLXBOX

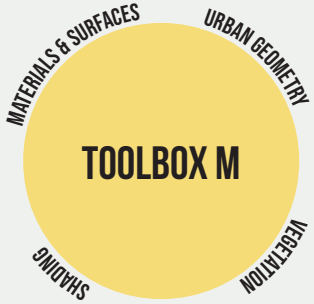
During the extensive research on how to tackle the urban heat island effect, I identified manifold solutions. I decided to group them on different scales to make them simple and implementable in different places around the world.

The identified solutions are presented in **different scales** to be able to implement them step by step. It is the easiest to start with small interventions on the street level. Once they are implemented we can think about a bigger scale which is the scale of the building.

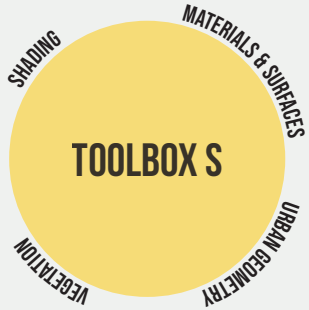
If the street and buildings solutions are implemented, there is a place for a set of guidelines and rules on the aerial - masterplan level that act on a more holistic scale.



COMPRISES MASTER PLANNING AND SET OF GUIDELINES ON THE AREAL SCALE TO INFLUENCE AIR TEMPERATURE OR VENTILATION

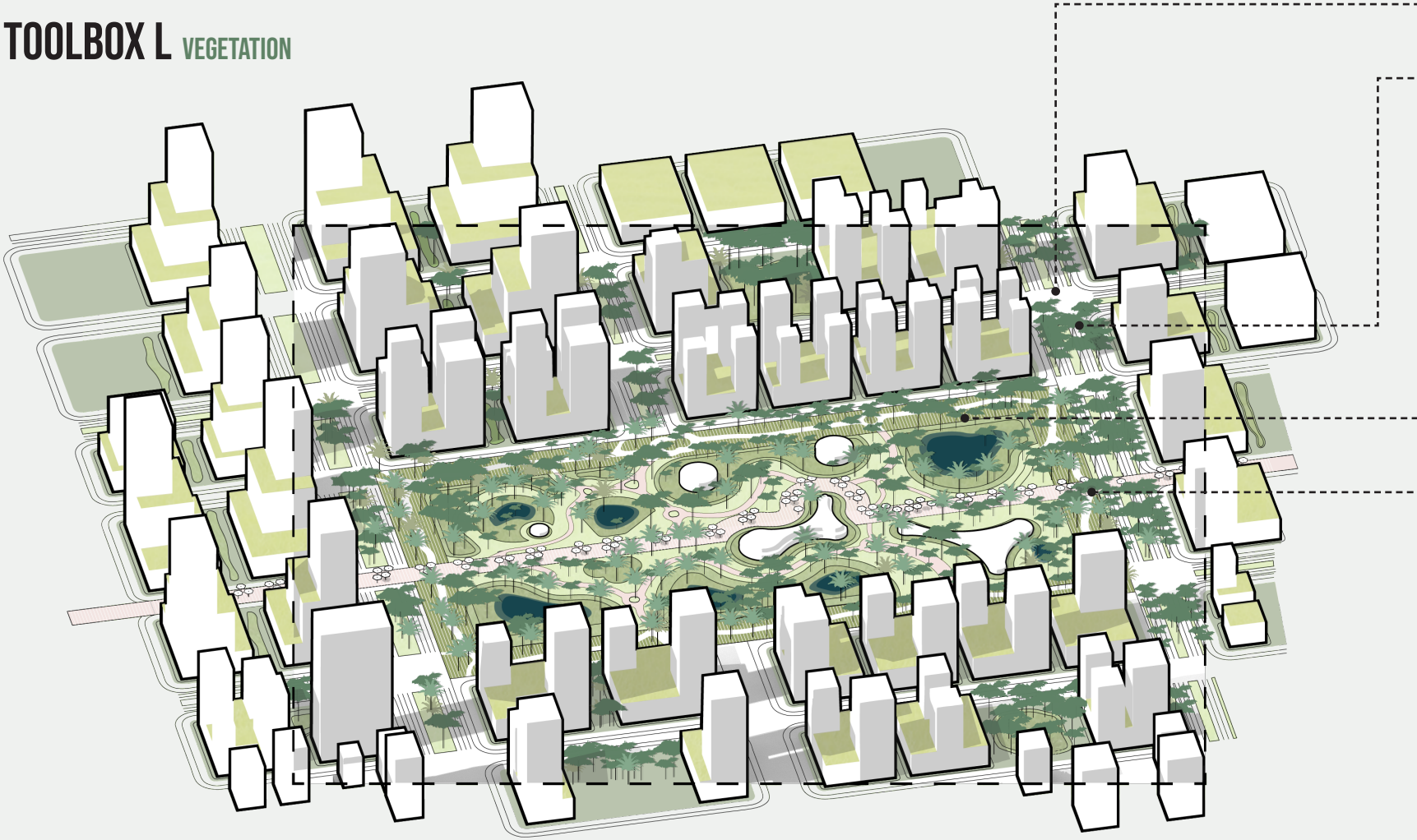


INCLUDES BUILDING TYPOLOGIES THAT CAN EFFECTIVELY PROVIDE WIND AND PROTECT FROM THE HEAT AND SOLAR RADIATION



CONSISTS OF DESIGN ON A STREET LEVEL THAT CAN POSITIVELY INFLUENCE THE MICROCLIMATE

TOOLBOX L VEGETATION



DIVERSE TREES SPECIES

The selection of adequate species should be related to environmental tolerances, functional requirements, and urban design requirements for trees to obtain the best results for generating outdoor thermal comfort.

Different positive effects on heat accumulation and OTC can be achieved depending on not only the number of trees per square meter but also their typology, size and adaptation to tropical areas (Juan Angel Acero).

TRANSPORTATION CORRIDORS

The vegetation arrangement along transport corridors can provide shade to the infrastructure surface. The effect can vary depending on the vegetation density, height and species. But it is also key to combine the reduction on incoming solar radiation with the natural ventilation capacity of these spaces.

Vegetation can absorb incoming solar radiation and thus reduce heat accumulation in urban materials. (Juan Angel Acero). At the same time, it provides shadowing and wind channelling.

GREEN & PERMEABLE PAVEMENTS

This measure reduces the amount of artificial material on urban pavements with the replacement of natural soil elements with grass. But it can also be installed by using permeable pavers, pervious concrete or porous asphalt to increase the permeability of the pavement (Juan Angel Acero).

Green and permeable pavements are the keys to proper water runoff and water management. It is a crucial part of the sponge city concept, parts of which could be successfully implemented in this project.

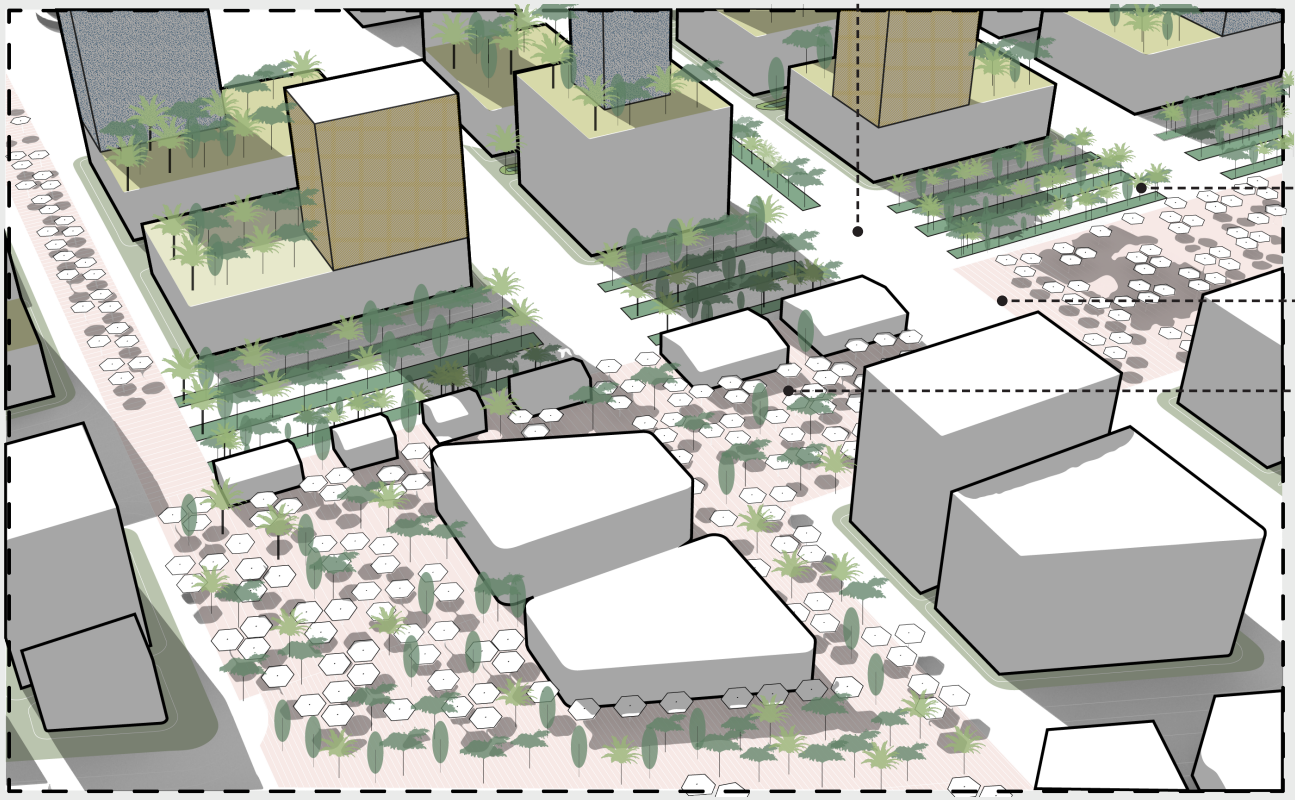
MACRO SCALE URBAN GREENING

Macroscale urban greening aims to increase the presence of vegetation in urban areas focusing on big urban parks, forests and natural reservoirs.

They can be located at the edge or in central areas of the city with different effects on the local climate. They can be treated as ‘cold islands’ which are an important part of the project.

Areas like forests and green belts do not only assure a better thermal perception inside them but can also provide coolness to nearby urban areas, thus helping to regulate the accumulation of heat in the whole urban area (Juan Angel Acero).

TOOLBOX L URBAN GEOMETRY



WIDE STREETS

The wider the streets are the bigger exchange of air inside the street canyons. The streets cannot be extremely wide as then we lose the human scale of the city. But when we allow a reasonable street width (for ex. 30 m) it creates effective wind corridors. The outcome is that the higher the airflow inside a street canyon the bigger the release of urban heat. In general, it is an effective tool but needs to be implemented in the early stages of the planning process, so the buildings are proposed with necessary distances.

OPEN SPACES AT ROAD JUNCTIONS

Similarly to the wide streets, open spaces at road junctions is another large scale urban planning which enables the cooling of the city. The prevailing wind travelling along with breezeways and major roads can penetrate deeply into the open spaces and opened ground floors of the buildings. Linking open spaces with road junctions can produce higher benefits in reducing urban temperatures and improving thermal comfort outdoors (J.A. Acero, L.A. Ruefenacht, M.O. Mughal).

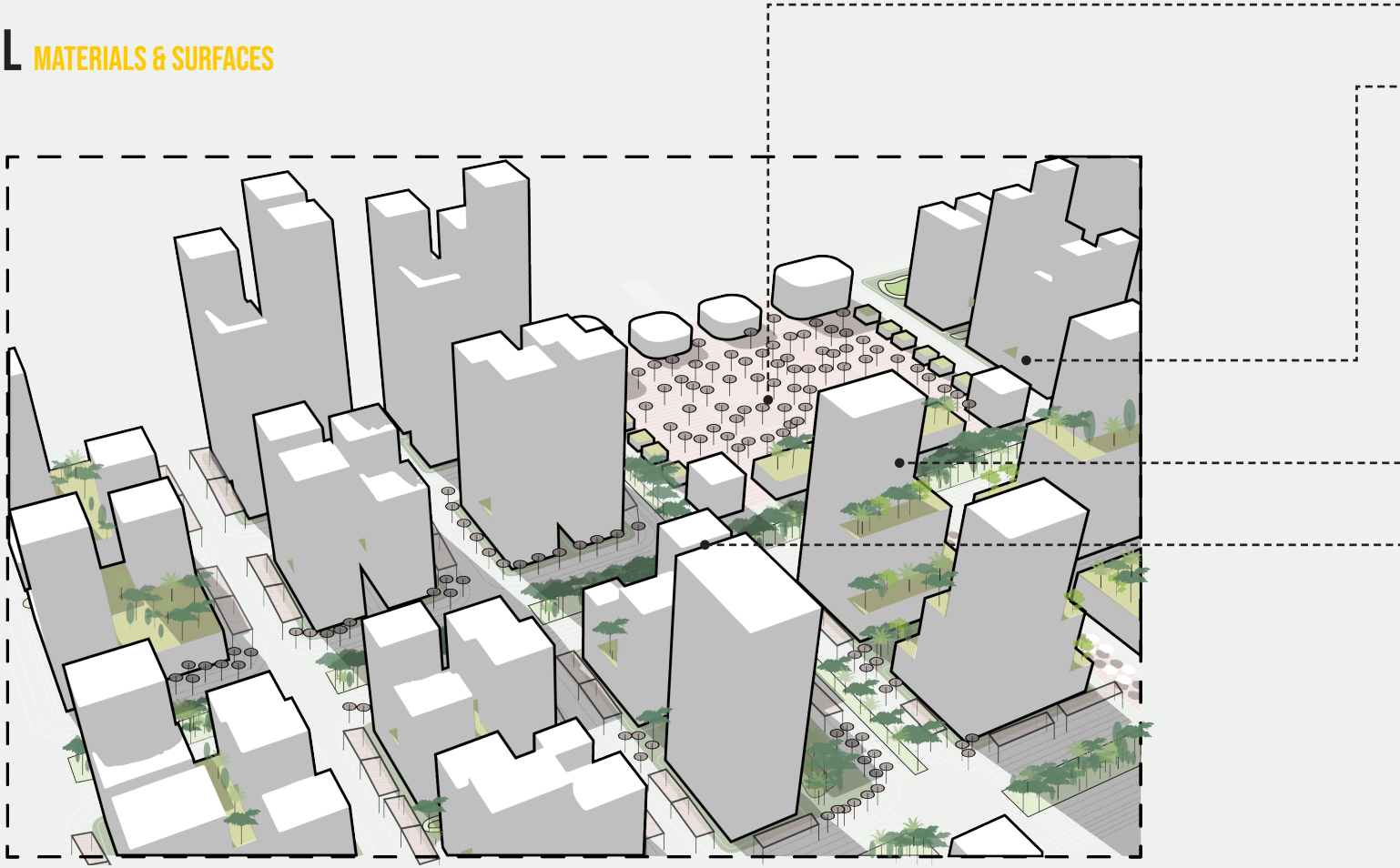
PASSIVE COOLING SYSTEMS

Passive cooling systems are design techniques that prevent heat to enter inside the buildings (J.A. Acero, L.A. Ruefenacht, M.O. Mughal). As stated in the analysis chapter, the air conditioners or chillers are helping to keep the indoor temperature low, but they release the heat to the atmosphere. Passive cooling can especially replace those mechanical systems and provide cooling without using electricity and producing heat. Cost-effective sources of passive cooling could be the orientation and arrangement of buildings and vegetation, water bodies and reflective coatings, but also the use and combination of open and semi-open spaces allowing cross-ventilation (J.A. Acero, L.A. Ruefenacht, M.O. Mughal).

STREET AXE ORIENTATION

To provide effective and low-cost cooling we should orientate the streets in a way that they are parallel to the winding corridors. Thanks to that they can use natural cooling. By that, it can improve outdoor and indoor environments, solar access inside and outside the buildings, but also the urban ventilation in general. Streets aligned to breezeways can promote air movement into and within the urban areas, thus reducing UHI (J.A. Acero, L.A. Ruefenacht, M.O. Mughal). This strategy similar to the other urban geometry solutions should be considered during the first phase of the planning of new development.

TOOLBOX L MATERIALS & SURFACES



THERMOTRONIC MATERIALS

Thermotropic materials offer immense potential in adaptive solar control. These materials can be applied to the facades of the buildings and decrease the heat by elimination of the excess heat in the indoor environment of the buildings, and maintain high levels of thermal comfort. Therefore this technique enables the prevention of the heat gains inside the building (G.Pignatta). These technically advanced but also very promising materials are contributing to the improvements in the urban microclimate as well.

HIGH ALBEDO MATERIALS

High albedo facades or so to say - cool facades are strongly recommended while working with microclimate especially with cooling the buildings. This measure incorporates using bright materials on the facades of the buildings so that they reflect the sun as much as possible and hence they do not absorb the heat and energy from the sun. It both reduces the building energy consumption for cooling, as well as influences the temperature outside the building in the whole city.

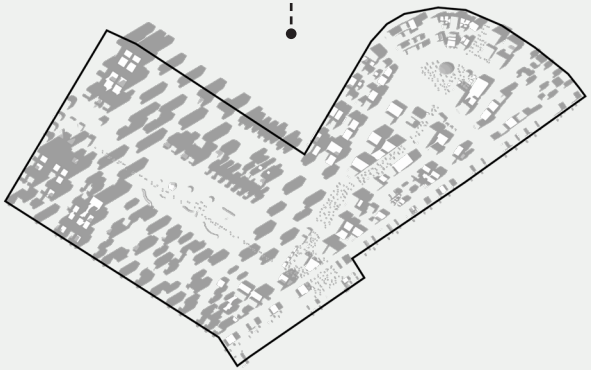
SOLAR COLLECTORS

Solar collectors are more and more widely used tools to capture solar energy, store it and use once needed. They enable saving money on energy but at the same time reducing the emissions from the power plants. The collectors can be also designed in a way that they blend with the street infrastructure or greenery. They do not need to be freestanding elements but can be easily placed on the buildings' facades or rooftops.

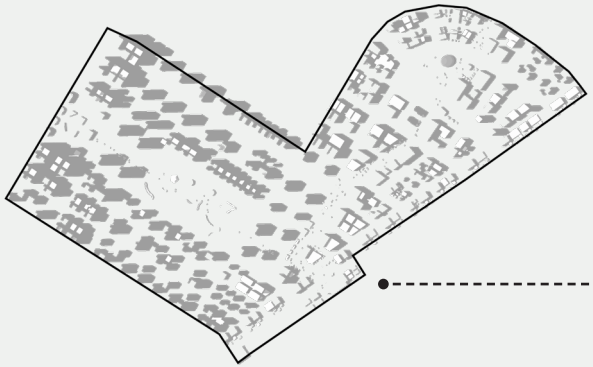
SOLAR PANELS ON SHADING DEVICES

This rather widely know measure is extremely effective if it comes to producing energy in an environmentally friendly way. The proposed shading devices can be accompanied by solar panels which give two benefits at the same time. The shading devices not only give shade to the people but also produce energy during the day. The energy can be easily used for streets lighting at night.

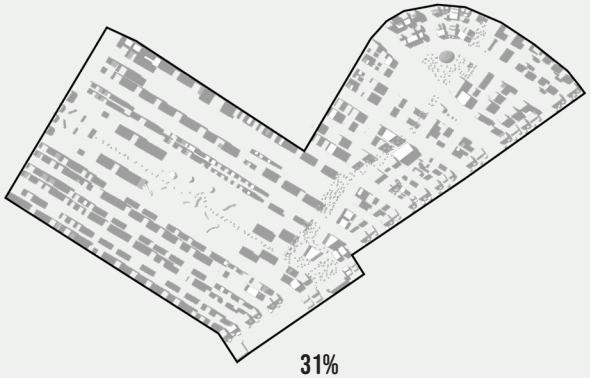
TOOLBOX L SHADING



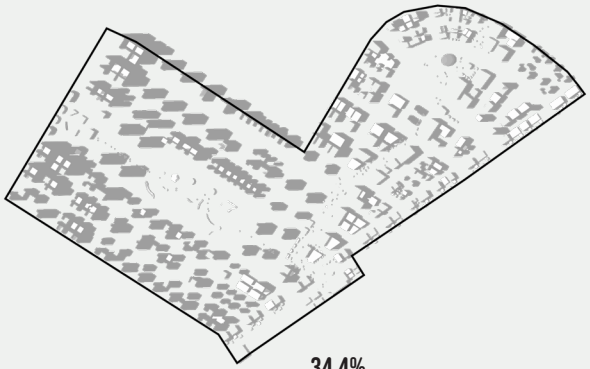
24%
MORE SHADOW (CASTED BY BUILDINGS)
ON THE STREETS WITHIN THE PROJECT AREA



32,5%
MORE SHADOW (CASTED BY BUILDINGS)
ON THE STREETS WITHIN THE PROJECT AREA



31%
MORE SHADOW (CASTED BY BUILDINGS)
ON THE STREETS WITHIN THE PROJECT AREA



34,4%
MORE SHADOW (CASTED BY BUILDINGS)
ON THE STREETS WITHIN THE PROJECT AREA

BUILDINGS ORIENTATION

By observing the sun path and adjusting the buildings location and orientation to it, we can increase the building performance and provide shade to the nearby outdoor spaces (public realm, squares, streets, sidewalks). The proper building orientation can lower sun exposure and minimise the heat from the sun on the facades (L.A Ruefenacht).

Example: sun study during the autumn equinox (23 September)

SHADING ON BUILDINGS

Buildings themselves can be designed and equipped in a way that they minimalise the amount of sun heat they receive. Those elements like canopies, louvres, blinds or roof overhangs help to provide shading to the public realm. They also improve the thermal comfort of both indoor and outdoor elements (L.A Ruefenacht).

Example: sun study during the summer solstice (21 June)

PERMANENT SHADING DEVICES

Similarly to solar panels on the shading devices or shading elements on the buildings, there can be permanent freestanding shading devices as well. Their main role is to provide shade while people move between the buildings but at the same time, they should cool the streets enough that people should be encouraged to stay outside. They are a very sufficient supplement for the shading offered by the buildings.

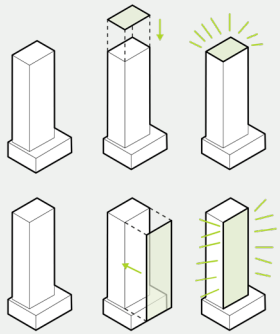
Example: sun study during the autumn equinox spring equinox (21 March)

MOVEABLE SHADING DEVICES

Another effective measure is a vast network of movable shading devices that can be transported to certain places on certain occasions. While for ex. the National Day of Singapore is celebrated and thousands of people gather to celebrate it, the whole area could be provided with shading devices making it possible to stay outside for many hours.

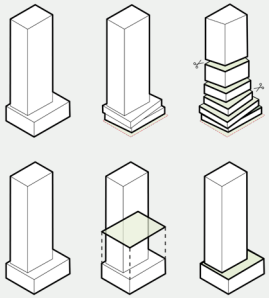
Example: sun study during the autumn equinox spring equinox (21 March)

TOOLBOX M VEGETATION



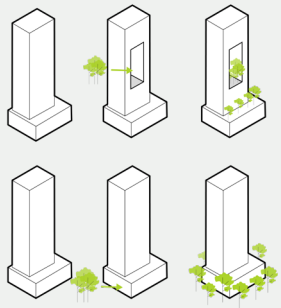
GREEN ROOFS AND FACADES

The vegetation is the main tool used to tackle the Heat in the project. This is why the green roofs and facades of the buildings are proposed in the very first place. It is important to mention that the green roofs and facades are an existing feature of the Architecture of Singapore. Therefore, this tool focuses on strengthening the existing approach and multiplying this Solutions onto all the proposed buildings in the project. The green roofs and facades do not only impact the heat but by the presence itself, it increases the mental health of the citizens who can See the green elements while walking in the streets or entering the green roof. All proposed green roofs are opened to the public.



GREEN TERRACES AND PODIUMS

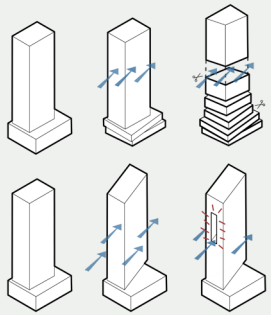
The green terraces are strengthening the existing situation in Singapore as well. The terraces Rich with Lush greenery and Trees are already a thing in Singapore. But to increase the presence of greenery and provide quality public spaces on the buildings the green podiums are proposed. They serve as an inner park for mostly the inhabitants/users of the buildings but not only. Green podiums decrease the temperature of buildings and reduce the cost of heating. Thanks to that a whole floor which is currently devoted to air conditioning infrastructure in many buildings can be replaced by having a floor of only greenery and make it accessible by the public.



VEGETATION IN AND AROUND BUILDINGS

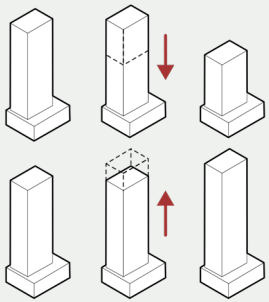
Equally important is that people feel a connection to and the presence of greenery every time they use the public realm. That means that Trees around and even inside the buildings play a key role in decreasing the Heat on the design site. By proposing Trees inside the buildings we prolong the public spaces into the buildings. Citizens are encouraged to spend their lunch breaks in terraces or the inside Parks to get affected by the healing power of nature. Due to the favourable climate, placing trees indoors is possible and is already an existing practice in Singapore.

TOOLBOX M URBAN GEOMETRY



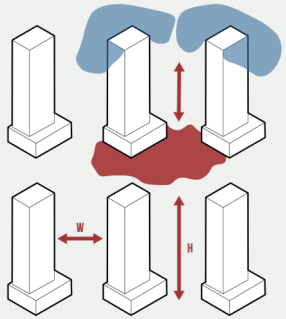
BUILDINGS' POROSITY

Building's porosity is a very efficient tool to use the wind and channel it through and between the buildings. It can be achieved by making some opening in the buildings. The openings can be multifunctional and serve as green terraces for people at the same time. The openings can be both horizontal and vertical, however, hence the proposed tall buildings are not very wide, the latter type of opening was used. This design solution can maximise the air permeability of the urban area and minimise its impact on wind capture and airflow reduction (J.A. Acero, L.A. Ruefenacht, M.O. Mughal).



VARIATION OF BUILDINGS' HEIGHTS

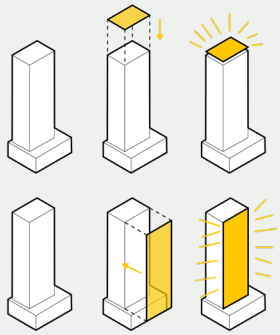
The act of varying between different building heights and building forms (e.g. stepping building heights or podium structures) can improve wind capture with benefits of the outdoor thermal comfort. Wind speed varies with altitude that increases its intensity exponentially. Hence designing an adequate air movement can enhance outdoor thermal comfort. The variation between low- and high-rise buildings allows for increasing wind velocity due to the air dynamics between buildings. In the tropical climate of Singapore, it is therefore relevant to capture and increase wind speed in certain areas. New development should take into consideration both the wind direction and use it's channelling effect as well as to strengthen it by the difference in blocks' sizes (J.A. Acero, L.A. Ruefenacht, M.O. Mughal)



SKY VIEW FACTOR AND ASPECT RATIO

The sky view factor is defined as the ratio of the radiation received by a planar surface to the radiation emitted by the entire hemispheric environment. It is calculated as the fraction of the sky visible from the ground. SVF is a dimensionless value that ranges from 0 to 1. For instance, an SVF of 1 means that the sky is completely visible and there are no obstacles around (J.A. Acero, L.A. Ruefenacht, M.O. Mughal). This is relevant for Singapore due to its tropical climate and the necessity of shade to improve thermal comfort and reduce significantly building cooling energy demand.

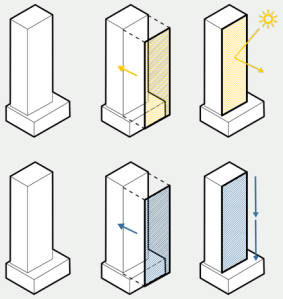
TOOLBOX M MATERIALS & SURFACES



COOL ROOFS AND FACADES

Cool facades are covering layers of building facades that limit the absorption of solar radiation. They help reduce the surface temperature of facades and cut both the heat transferred into the building and the energy consumption needed for interior cooling.

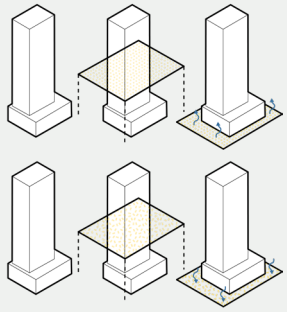
Cool roofs are typically white or lightly coloured reflecting surfaces that can decrease their surface temperature and consequently heat transferred into the buildings below. They can be useful for reducing cooling energy consumption and energy costs in buildings (J.A. Acero, L.A. Ruefenacht, M.O. Mughal).



HIGH ALBEDO FACADES

All the materials used for the facades of the buildings should be retro-reflective materials are directionally reflective surfaces (non-diffusive surfaces) characterised by high albedo and the ability to reflect solar radiation towards its source.

Water cooling facade systems transfer heat by evapotranspiration outside the buildings using water integrated within the building facades. Evaporative cooling is a heat dissipation technique (J.A. Acero, L.A. Ruefenacht, M.O. Mughal).



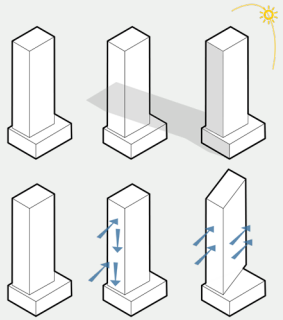
COOL AND PERMEABLE PAVEMENTS

Cool pavements are made of materials that reduce their surface temperature by reflecting a significant percentage of solar radiation and releasing thermal heat into the environment. These surfaces are usually a light colour or white.

UHI & OTC effect

Cool pavements are characterised by high albedo (high solar reflectance) and high thermal emittance. Consequently, this reduces the urban heat accumulation responsible for UHI phenomena, especially in hot climates.

TOOLBOX M SHADING

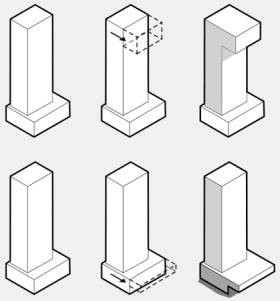


BUILDINGS' ORIENTATION

Buildings can be positioned concerning variations in the sun's path as well as prevailing wind patterns. An adequate orientation can increase the building performance and provide shade on nearby outdoor structures such as sidewalks, public spaces and streets (L.A. Ruefenacht).

UHI & OTC effect

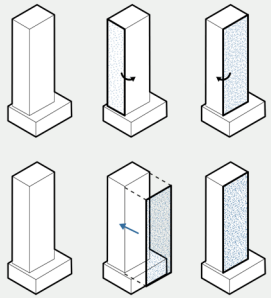
Optimised building orientation can lower the sun exposure and therefore minimise solar heat gains through the facades. Depending on the building orientation, direct, diffuse, and reflected radiation can be blocked, limiting short-wave radiation on surrounding / local outdoor spaces.



SHADING ON BUILDINGS

Building elements as shading devices can be installed outside or inside, on or around the building envelope. They can be fixed elements, such as canopies, brise-soleils, horizontal or vertical louvres, blinds, roof overhang, egg-crate; or moveable elements, such as sun baffles and shutters (Giguere 2009).

These elements function to control direct solar radiation as well as block and diffuse the reflective radiation of building envelopes (Stack et al.). They limit the heat gains and consequently improve the thermal comfort of both indoor and outdoor environments. They also increase the building energy performance by reducing the building peak cooling load, and therefore reducing the UHI effect (L.A. Ruefenacht).

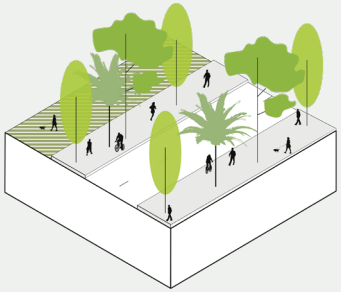


SMART SHADING DEVICES

Smart shading refers to shading devices that apply materials to transform their properties by external stimuli, also called 'shapeshifting materials'. Their transformation is reversible and can be repeated (L.A. Ruefenacht).

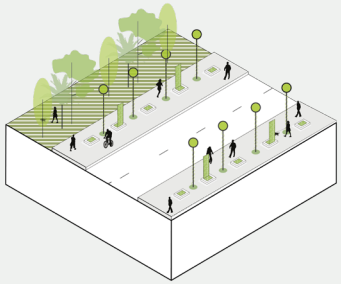
Smart shading can adapt to the varying climatic condition in Singapore. On one hand, it protects from the intense heat during midday, while on the other hand, it gives shelter from the afternoon monsoon rains (L.A. Ruefenacht)

TOOLBOX S VEGETATION



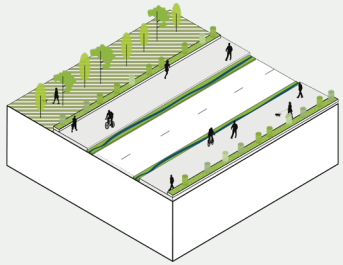
STREET TREES

Many studies show the importane of the street trees in influencing the microclimate of the space. Regardless the location, trees will always provide oxygen, shelter and shade. All of those are extremely imporant in Singaporean context.



INFRASTRUCTURE GREENERY

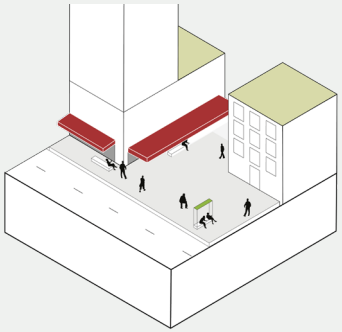
The infrastructure greenery is similar to natural trees when it comes to positive influence on the environment. This solution includes lamp posts with plantings. It also adds up to the visual presence of the greenery in the public realm.



MICROSCALE GREENING

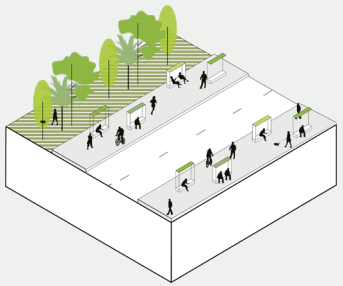
Microscale greening is another example of how the small gestures can infulence the general outcome. By increasing the amount of smaller plantings in the site, we support the biodiversity and natural habitat for smaller animals. The microscale green can be also apocket park or a bioswale that helps the rainwater to infiltrate to the ground and be kept for further use.

TOOLBOX S URBAN GEOMETRY



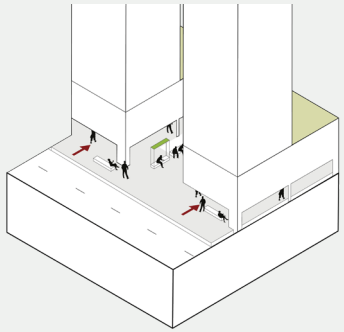
BUILDINGS EDGES

It is imporant to provide as much cooling and shade as possile. To achieve that we need to use every possible structure to reach our aim. In case of urban geometry it will be using the buildings' edges to create awnings, that enable the people to hide and walk underneath while avoiding the stron sun during the day.



STREET BENCHES

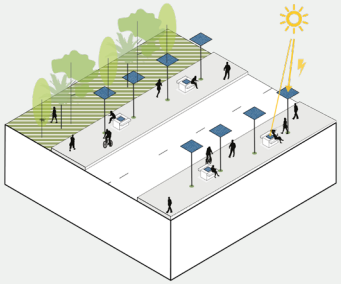
Another important, and yet, simple and cheap to implement solution are the street benches with a roof structure attatched to it. As nowdays it is almost unpleasant to sit on a bench in the sun in Singapore, thanks to shaded benches people can use them all day long.



OPEN UNDERPASSES

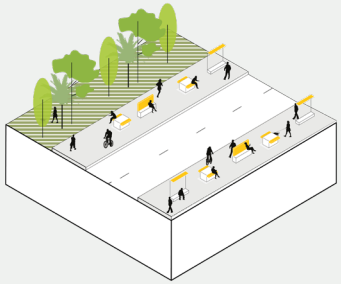
Semi-open spaces allowing cross-ventilation are very effective and low-cost solution for cooling. The hollow and opened ground floor structure enables not only the wind to enter the ground fllor and remove the heat but also provides a seamless connection between the public realm and the building.

TOOLBOX S MATERIALS & SURFACES



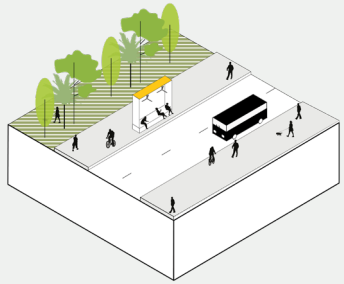
STREET SOLAR PANELS

Solar panles offer multiple advantages as a street furniture. They not only provide shade but also produce renewable energy the whole day. The use of renewable energy sources regulate the anthropogenic inducers of the UHI effect, thus increasing the share of renewables would directly help in decreasing the UHI impact. This also reduces the carbon emissions, thus reducing the global warming potential (Lea A. Ruefenacht).



BRIGHT STREET FURNITURE

The bright street furniture are characterised by high albedo (high solar reflectance) and high thermal emittance. Consequently, this reduces the urban heat accumulation responsible. Dark materials are the ones that heat up very quickly and would make the street furniture impossible to use. Street furniture are not only used for esthetics but to provide better user experience (for ex. support for elderly).

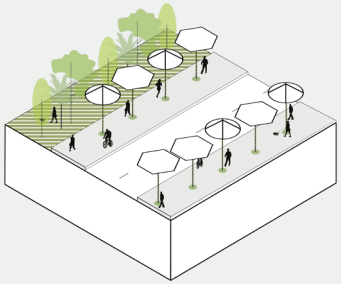


COOL BUS STOPS

This solution is a mix of a shaded street bench and a light-structured bus stop. It is imporant to provide a cool sitting space for passangers waiting for the bus. In orther to provide extra cooling small fans in the roof of the bench are proposed.

Redirecting heat fluxes coming from buses, increasing ventilation at the stop or shielding it from heat emissions can help increase the thermal comfort of commuters (Lea A. Ruefenacht).

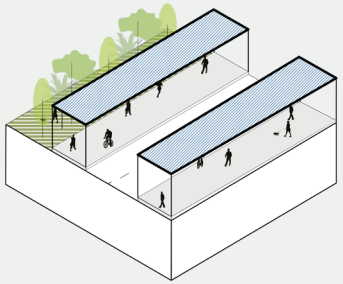
TOOLBOX S SHADING



SHADING UMBRELLAS

The shading umbrellas are a mix of shaded walkways and mobile shading devices. The surface of the umbrella is big enough to provide shade for several pedestrians. But at the same time it is light and flexible enough to be removed and relocated while needed.

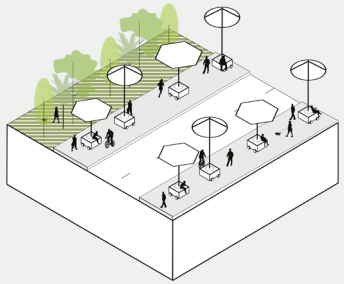
The umbrellas does not need to have the rounded shape. However it is effective shape for providing more shade.



SHADED WALKWAYS

Shading or the protection against direct sunlight of pedestrian spaces can be provided by buildings, canopies or trees.

Shading of outdoor spaces can effectively reduce the air and surface temperature while enhancing the thermal satisfaction of pedestrians (Lea A. Ruefenacht).



MOBILE SHADING DEVICES

Moveable shading devices are operable, manual and automated shades. They allow users to adjust the spatial properties according to personal needs.

Some types of mobile devices are autonomous canopies and temporary tents. They are also commonly light and simple to install (Lea A. Ruefenacht).

06

DESIGN PROPOSAL

MASTERPLAN

Masterplan reveals the main design principles of the project and shows application of the toolbox on the site. Among the most crucial aims to tackle the urban heat island effect is to provide effective cooling.

It is being done with natural resources like wind or greenery. By implementing the design principles (for ex. designing wide streets to prevail the wind, providing a variety of buildings heights to create the wind downwash effect and providing greenery on and around the buildings) the whole district is being effectively cooled.

The implementation of design principles

1) Harnessing the prevailing wind to enhance ventilation

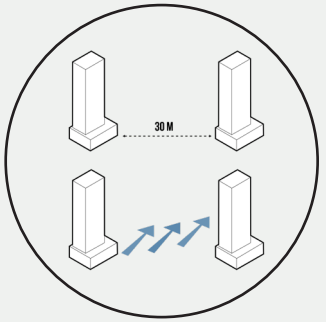
One needs to remember that we are in the tropical climate of Singapore. A place where there are no winters or cold periods of the year. To be able to propose a sustainable solution we need to use something that is already there - nature.

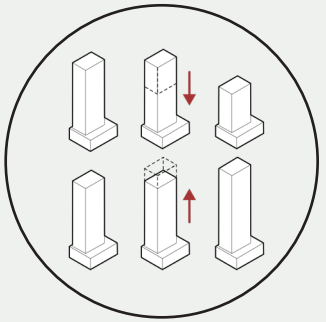
2) Creating wind downwash effect and porosity

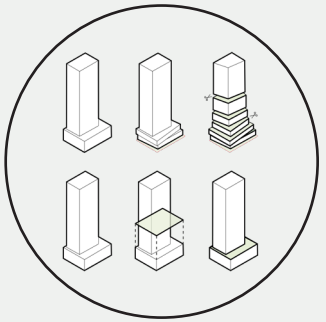
Singapore is lucky to be located at the ocean which enables the wind to enter the city. By proper channelling of the wind, we can cool down the city including the proposal's site of Marina Bay.

3) Cooling by nature

Air conditioning might be very helpful to tackle the heat but it has its limitations. As I mentioned in the previous chapter it is only serving inside the buildings and is only a temporary solution as it releases heat to the atmosphere. The answer to that is to cool with the real nature, that can be embedded in the public realm and buildings themselves.



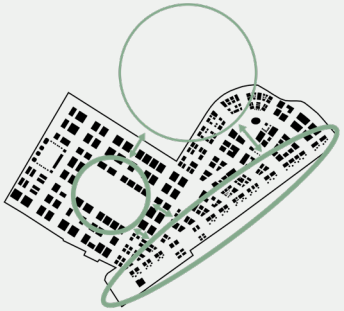





MARINA BAY
GARDENS BY THE BAY
MARINA BARRAGE
DOWNTOWN
METRO STATION SQUARE
URBAN OASIS PARK
MARITIME GALLERY
AND RESEARCH BASE
1:2000

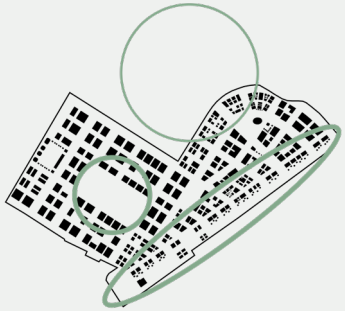
EXPLANATORY DESIGN DIAGRAMS

GREEN CONNECTIONS



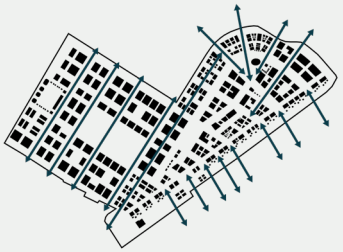
The biggest attraction of the site nowadays is the Gardens By The Bay park. It is both an accessible public park as well as a paid attraction for tourists. One needs a ticket to enter the glass domes, but moving inside the park is free and refreshing.

GREENERY



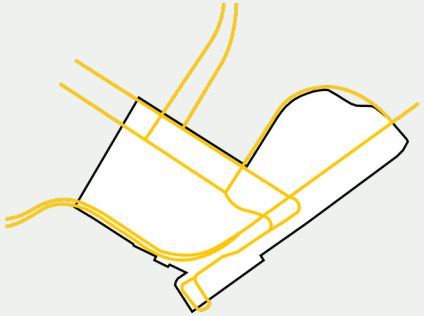
There is a lot of unused greenery on the site in a form of dry meadow land. Due to the climate, those vast green areas are not used by the people, partly because of the lack of any shading. These green bodies are a huge potential for recreation in the future.

WIND



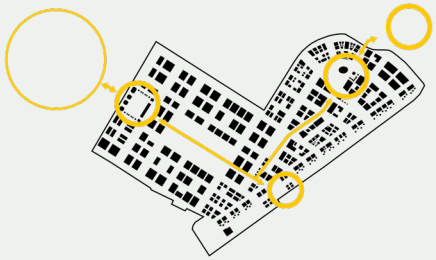
The site is mostly empty nowadays, but at the same time, it is occupied with several big roads and even highways (multi-lane roads). Although the site is not populated nowadays the traffic is quite large.

BUS LINES



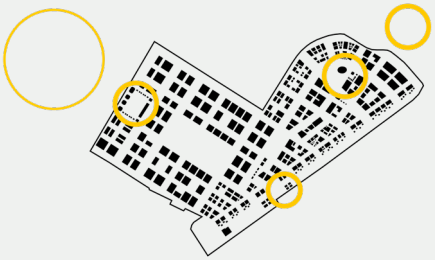
Several bus connections go through the site nowadays. My observation is that those busses are mostly serving tourists who want to visit the Gardens By The Bay. Therrefore I propose to keep them.

CONNECTIONS



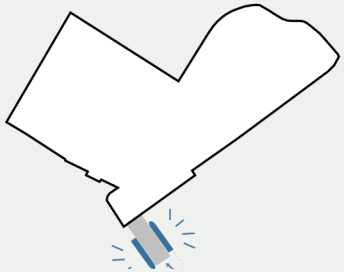
The site has a water edge when it meets Marina Bay. It is possible then to access the most prominent promenade of the city from the design site. However, it is quite far to walk, the site is a part of the main bay of Singapore.

NODES



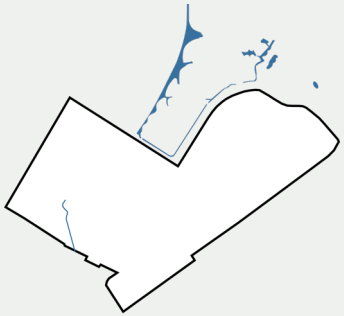
The fact that the site is having a long water ocean edge is used as an advantage in the project. It is a real relief to be able to feel the breeze from the ocean and be able to access the water.

PASSENGER FERRY TERMINAL



The site is not only accessible from the land, but also the ocean side. There is a ferry terminal located in the southern-east part of the site. However, this type of service might not be the most sustainable one, it is the access point to the island as well.

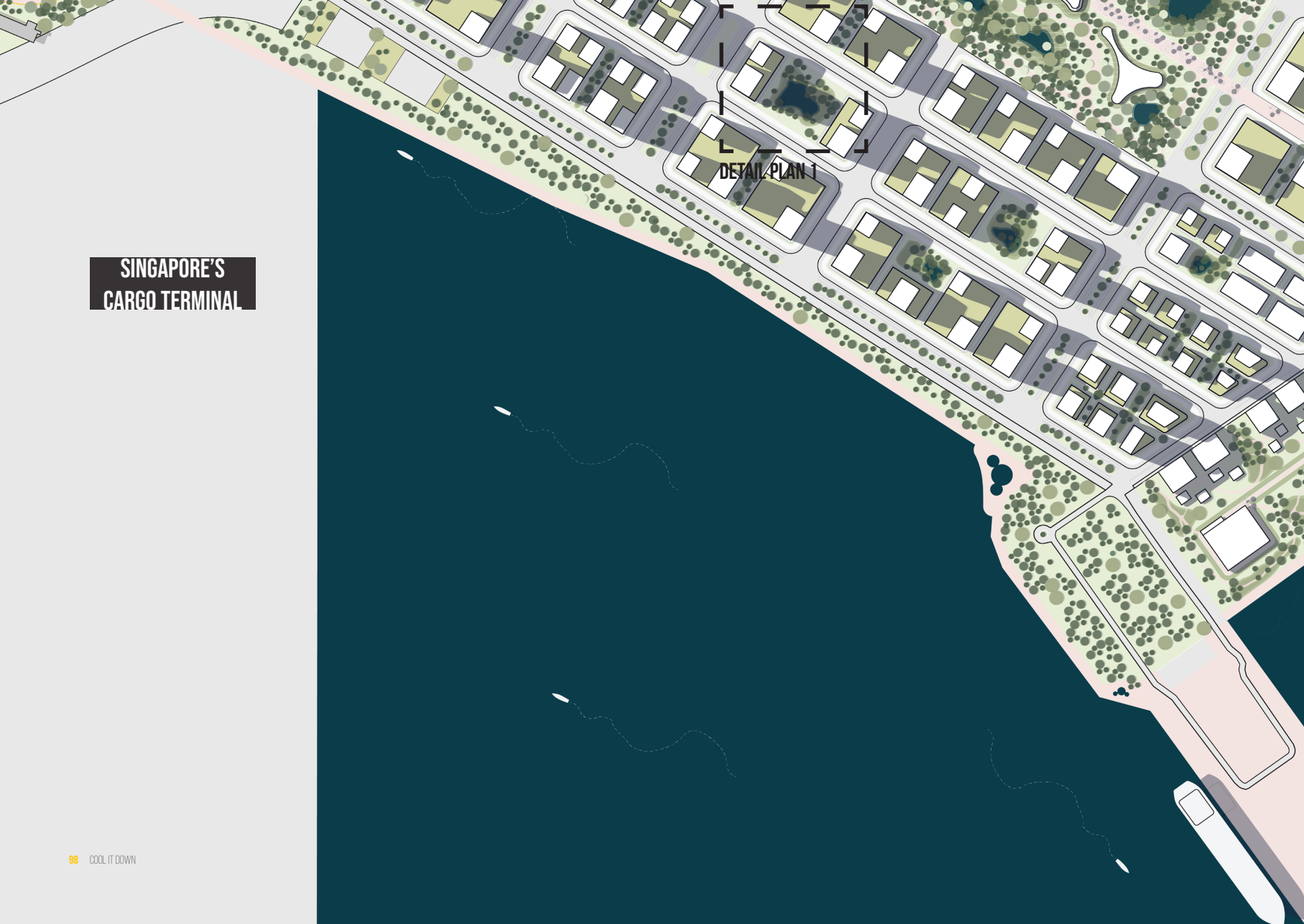
WATER BODIES IN GARDENS BY THE BAY



There are several water bodies - mostly human-made - that are located in this part of the city. Most of them were made as a part of the development of the Gardens By The Bay.


MARINA BAY
DOWNTOWN
METRO STATION SQUARE
URBAN OASIS PARK


MARINA BARRAGE
GARDENS BY THE BAY
METRO STATION SQUARE
1:2000



SINGAPORE'S CARGO TERMINAL


METRO STATION SQUARE
MARITIME GALLERY
AND RESEARCH BASE
DETAIL PLAN 2
MARINA
PASSANGER
HARBOUR
1:2000

DETAIL PLAN PODIUM TYPOLOGY AND RETENTION POND

The first detail plan highlights the proposal's regular grid for the proper wind channelling. It also provides more information on greenery solutions, as well as the use of water and other cooling systems. It the priority for the bus transportation to provide a comfortable ride for the passengers. The green-cool bus stops are proposed to make the waiting time acceptable.

The examples of implementation of M toolbox

1) Green roofs and facades

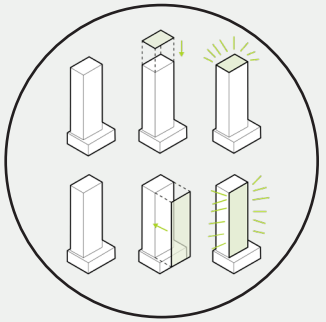
The green roofs are part of the concept. However, I chose not to make all the buildings green in the plan to avoid confusion and to achieve higher readability of the plan. Still, the rooftops are places where people can gather and do not need to but anything to see the city's panorama.

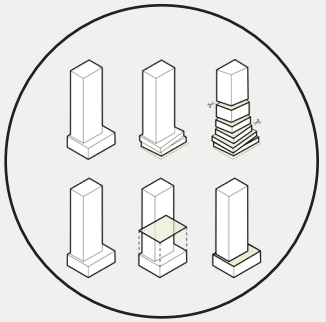
2) Green terraces and podiums

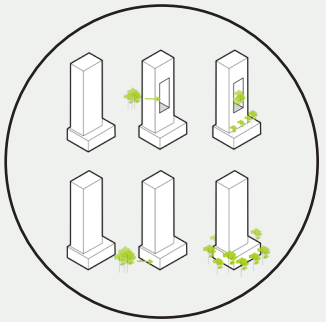
To make the proposal as inclusive as possible all the proposed terraces and podiums are opened to the public. It helps to better understand the city as well and to maximize the plot efficiency. Thank that a public pool or football pitch or another sports facility can be placed on the podium. Podiums can also serve many other purposes including public gatherings or exercising.

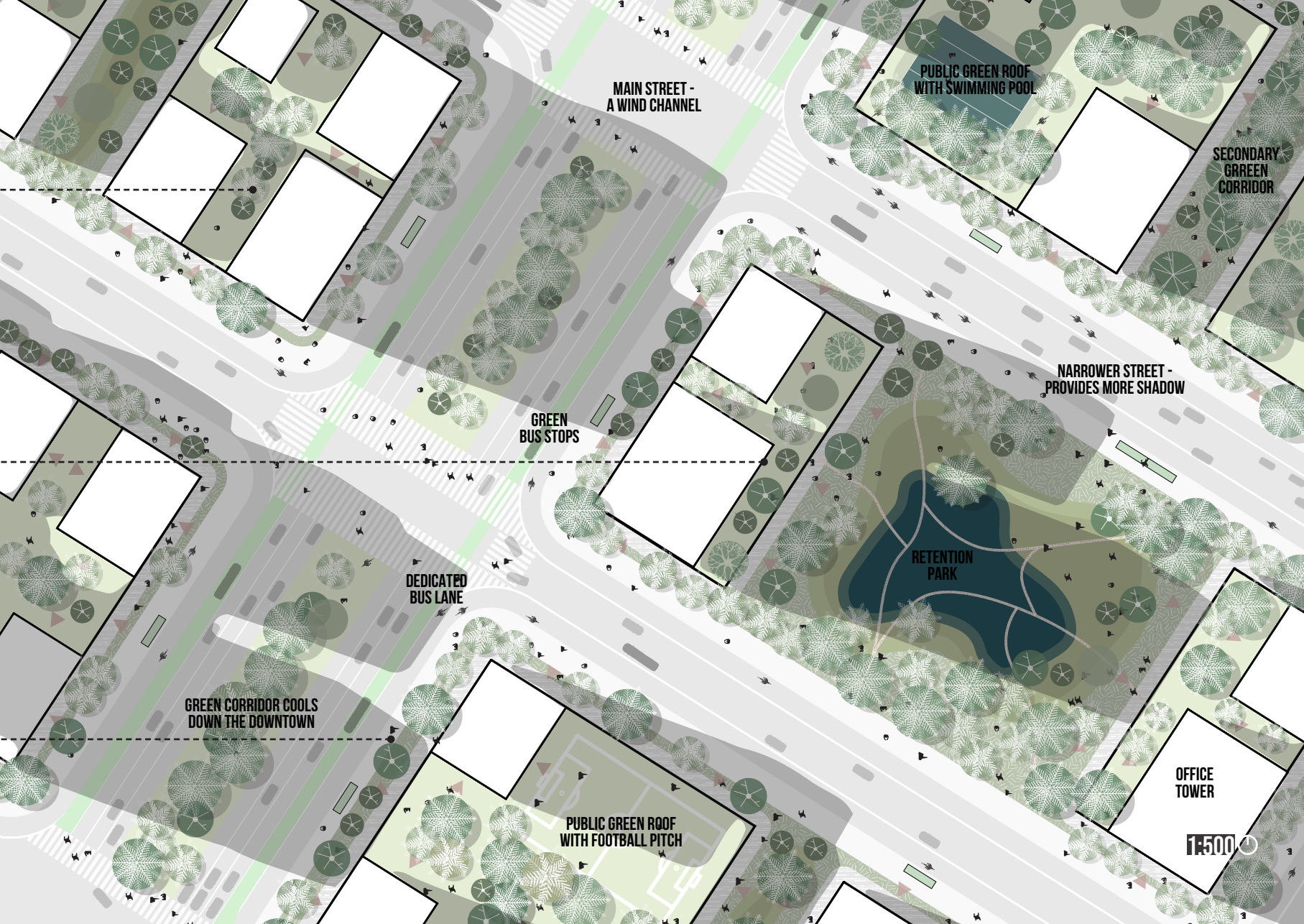
3) Vegetation in and around buildings

Vegetation is another crucial element to fight the urban heat island effect. It is a measure that is being used already in Singapore's space. Even nowadays many buildings can be seen with terraces with trees sticking out of them. Undoubtedly, the favourable climate helps to introduce the vegetation almost everywhere, at every height.








MAIN STREET -
A WIND CHANNEL
PUBLIC GREEN ROOF
WITH SWIMMING POOL
SECONDARY
GREEN
CORRIDOR
NARROWER STREET -
PROVIDES MORE SHADOW
GREEN
BUS STOPS
RETENTION
PARK
DEDICATED
BUS LANE
GREEN CORRIDOR COOLS
DOWN THE DOWNTOWN
PUBLIC GREEN ROOF
WITH FOOTBALL PITCH
OFFICE
TOWER
1:500

DETAIL PLAN METRO SQUARE

The second detail plan highlights the shading devices. Shading is a tool for tackling the urban heat island. We might not think about the shade as an important driver for the design in a Scandinavian context. We would focus on how to get more sun. But in Singapore, it is the opposite. The more shade in some situations the better as the buildings are not heating up so fast. It gives multiple advantages in the fight with warmth.

The examples of implementation of S toolbox

1) The shading umbrellas

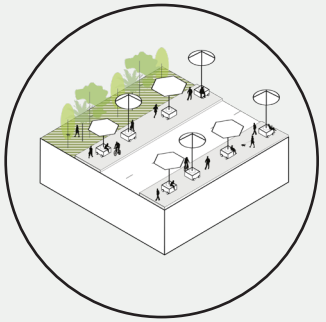
The shading umbrellas are the first example of effective shadow creation. The surface of the umbrella is big enough to provide shade for several pedestrians.

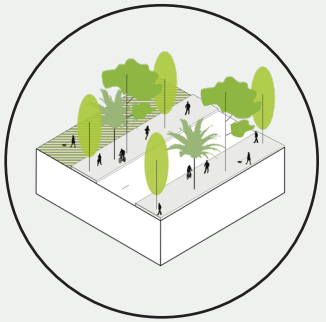
2) Mobile shading devices

Moveable shading devices are operable, manual and automated shades. They can be freely moved which gives enormous mobility and adjustability. They could be used for example for some social gathering or the parades and celebrating of the national holidays.

3) Stree trees

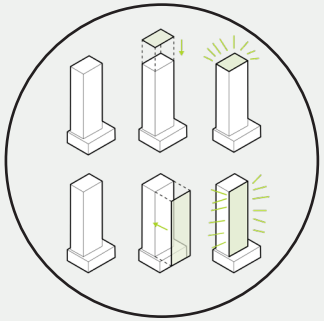
The role of the lush greenery (as trees) cannot be overestimated. It especially sustainable and long-lasting solution to plant as many trees as possible on the streets of Singapore. Regardless of the location, trees will always provide oxygen, shelter and shade. All of those are extremely important in a Singaporean context.

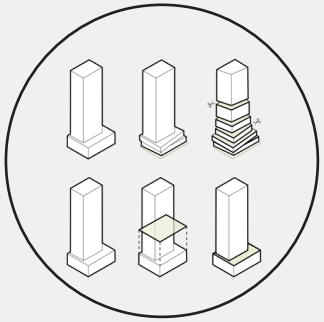


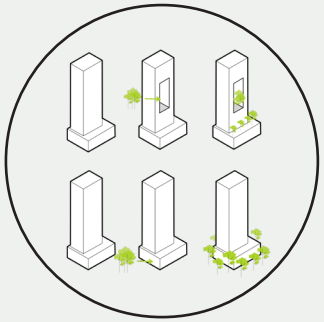



SERVICES
URBAN CANOPY
SPACIOUS PLAZA ENSURING WIND-CHANNELING & EVENING EVENT SPACE
CO-WORK
SHADING UMBRELLAS FRAMING THE PATHWAYS
URBAN CANOPY
GALLERY
SINGAPORE MARITIME GALLERY AND RESEARCH BASE
MIXED-USE
WATER PROMENADE
1:500

PERSPECTIVE COOLING STREET







SECTION OFFICE TOWER TYPOLOGY

The sections present a few more qualities of the project. By looking at the section view of the proposed buildings one can observe several more guidelines being implemented.

The examples of implementation of the toolbox

1) Variation of buildings heights

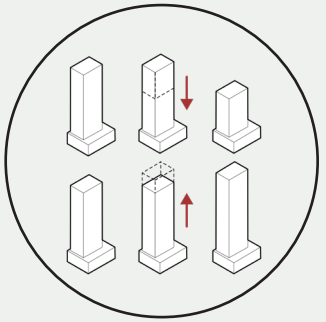
The act of varying between different building heights and building forms (e.g. stepping building heights or podium structures) can improve wind capture with benefits of the outdoor thermal comfort.

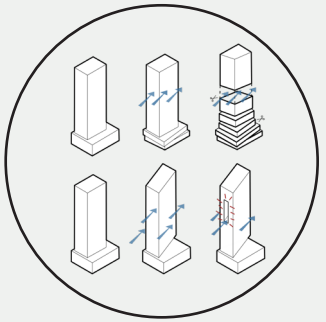
2) Buildings' porosity

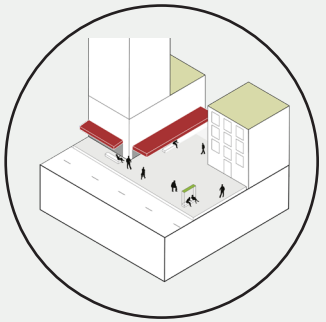
Building's porosity is a very efficient tool to use the wind and channel it through and between the buildings. It can be achieved by making some opening in the buildings.

3) Buildings edges

It is important to provide as much cooling and shade as possible. To achieve that we need to use every possible structure to reach our aim. In the case of urban geometry, it will be using the buildings' edges to create awnings, that enable the people to hide and walk underneath while avoiding the strong sun during the day.





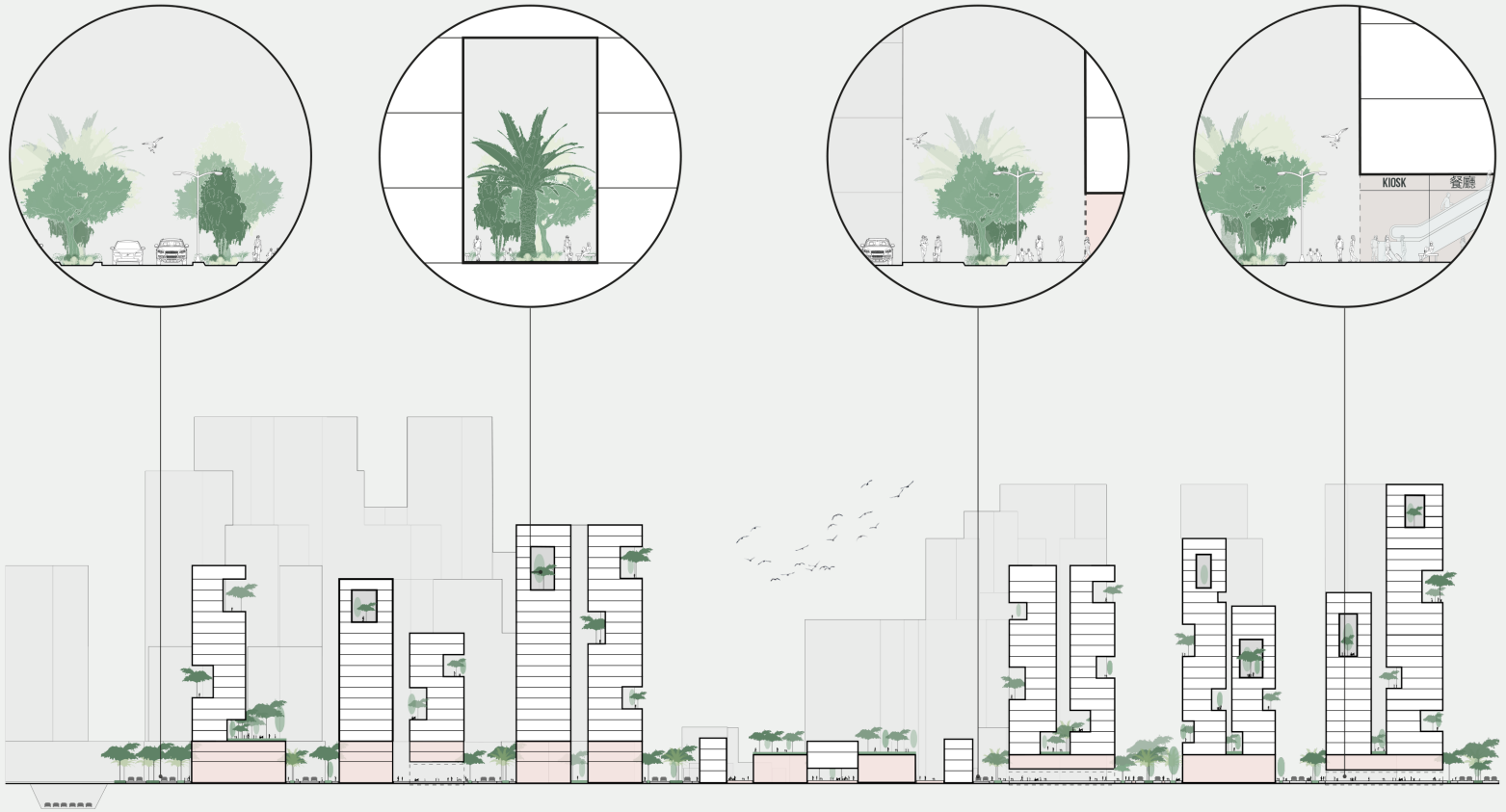


WIDE STREET FOR WIND CHANNELLING

A GREEN TERRACE FOR WIND CHANNELLING

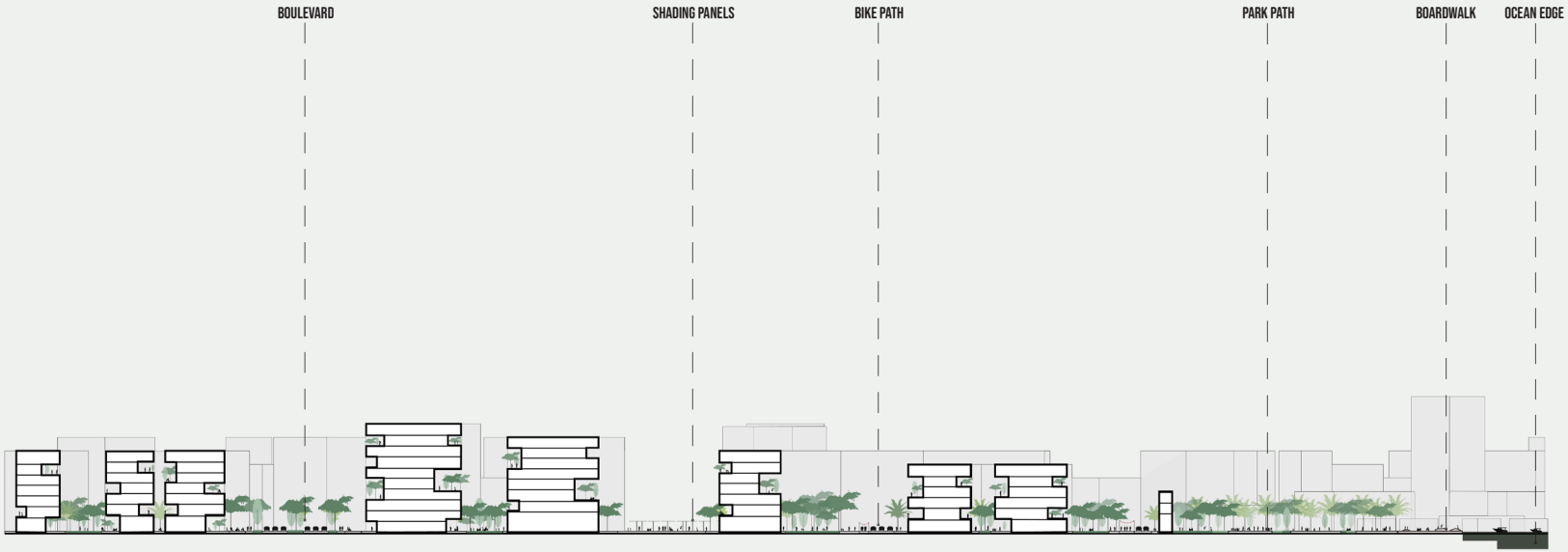
NARROWER STREET FOR MORE SHADE

PUBLIC PASSAGE INSIDE THE TOWER'S PODIUM

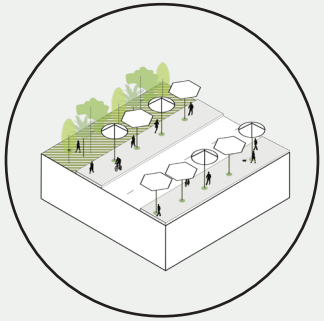


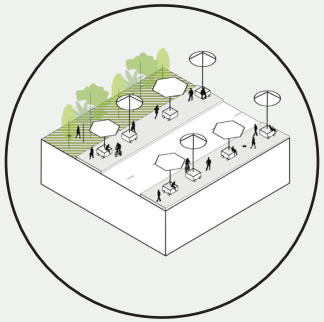
SECTION MEDIUM BLOCK TYPOLOGY

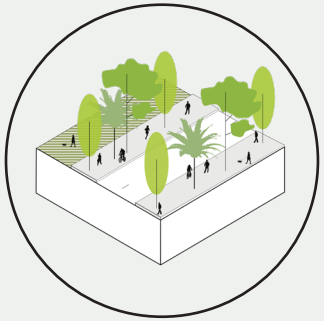
SECTION RESIDENTIAL TYPOLOGY



PERSPECTIVE ON THE PUBLIC PLAZA







07

REFLECTIONS

CHALLENGES

The main challenge during the work was the complexity and magnitude of the urban heat island effect as phenomena. There are many different counterparts of this issue and luckily tons of research.

It is easy to identify the problem itself, it is easy to travel to Singapore and say „Wow, this is hot!". It is also quite easy to read about Singapore and get to know that the urban heat island effect is a problem here. But the real challenge is how to approach it.

Despite the abundance of literature about the heat islands effect itself, I have found way less material about how to tackle it. One of the most useful and important sources was the Cooling Singapore report by Cooling Singapore.

Another challenge is that the urban heat island effect is not a small scale problem. A single individual design will only mitigate it but will never have the critical mass to make a significant change.

Hence, it is not sufficient to design several cooling benches and plant a couple of trees. The UHI depends on the climate of the whole region of the world, the microclimate, as well as whole decades of various decision by city mayors and planner.

UHI effect is a systemic, large scale challenge and should be approached in such a vast scope. This is why it was quite hard for me to go into the design face as I wanted to study and understand the background of the phenomenon.

Needless to say that those 140 pages of the booklet are just a droplet in a pool of urban design solutions and ideas.

The thesis, therefore, provides a systematic analysis of the UHI in Singapore, the explanation of the existing conditions, negative outcomes of thoughtless and comprehensive design and its consequences on the life of Singaporeans. The thesis hopefully offers a practical guide on how to begin thinking about urban transformations from a climate perspective.

CONCLUSION

As mentioned before, the proposal addresses an extremely complicated challenge present in many parts of the world. Even though Singapore, mostly due to brilliant city marketing and branding, might seem to be one of the most successful cities/countries in the world, it has the enormous challenge of the heat island effect.

Singaporean heat is ubiquitous and unbearable, and it was indeed, the first observation I had after coming here. The city grows at an incomprehensible speed (at least from my European perspective), but it is clear that a blind developing new district of „green" skyscrapers is not enough - which can also be suspected to be a greenwashing. Of course, the city needs to grow and meet its housing demands. But what was crucial in this situation is not how much you build but HOW.

It is hard to adapt to current climate circumstances. The proper reaction should be then not to adapt but react. If we still want to be able to use the public realm in our cities we need to change something in the way how they are built, what materials are used or how much nature are we having within the cities' cores.

One of the main lessons that I have learned during the work on this thesis is that the knowledge is already there. There were some studies or even booklets showing how to implement the measures against the urban heat islands effect.

The important part is how to implement it and base the whole design on it. Without new laws, policies and strategies we won't be able to achieve much. But this calls for action on an almost political level which I could only dream to handle in a thesis project.

Nevertheless, I deeply hope that this is a master thesis can add another layer to the UHI effect studies both in Singapore and worldwide.

The solutions provided in this master thesis are basing on the toolbox, which includes design principles and guidelines in four different categories:

VEGETATION is the most important counterpart to start with. Singapore is already a green city, branding itself as a city in the garden. That means that nature was first here and everything that was added later, so the whole development of the city is a 'guest' within the garden. Hence, nature should be present all over the city. No matter if it is the ground or vertically on buildings facades.

URBAN GEOMETRY, emphasizes the necessity of building smartly and respecting the natural laws. Cities need to develop to thrive and fulfil the need of people. But while designing new buildings or districts one should remember about placing them in a way that they have natural sun access but for example, provide shade as well.

MATERIALS AND SURFACES that are sustainable. It means both that they are turning solar energy into the energy used for the building as well are bright, so they do not absorb the heat.

SHADING which can be achieved with buildings, other freestanding elements or even vegetation. But the most important outcome is that we design enough shade in the public realm that people are willing to use those spaces even during the day.

I believe that I achieved my goal, which was to **rethink the following aspects:**

1. How can we design so that, people living in Singapore will spend their time in the public realm - in open outdoor public spaces, instead of crowded, air-conditioned shopping malls?

2. How can design attract people to use the outdoor public space and tackle the urban heat island effect and unfavourable tropical climate?

3. The multiple design guidelines on various scales included in the booklet show that we can try to tackle the UHI effect, influence the microclimate, as well as encourage people to use the outdoor public spaces even in Singapore.

4. By using design solutions basing on VEGETATION, URBAN GEOMETRY, MATERIALS AND SURFACES and SHADING it becomes possible to... **COOL SINGAPORE DOWN.**

08

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SUDes
Sustainable Urban Design

LUND UNIVERSITY

Master Thesis Report
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Sustainable Urban Design

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All visuals and photographs are my work unless stated otherwise.

COOL IT DOWN!

TACKLING URBAN HEAT ISLAND EFFECT IN SINGAPORE

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