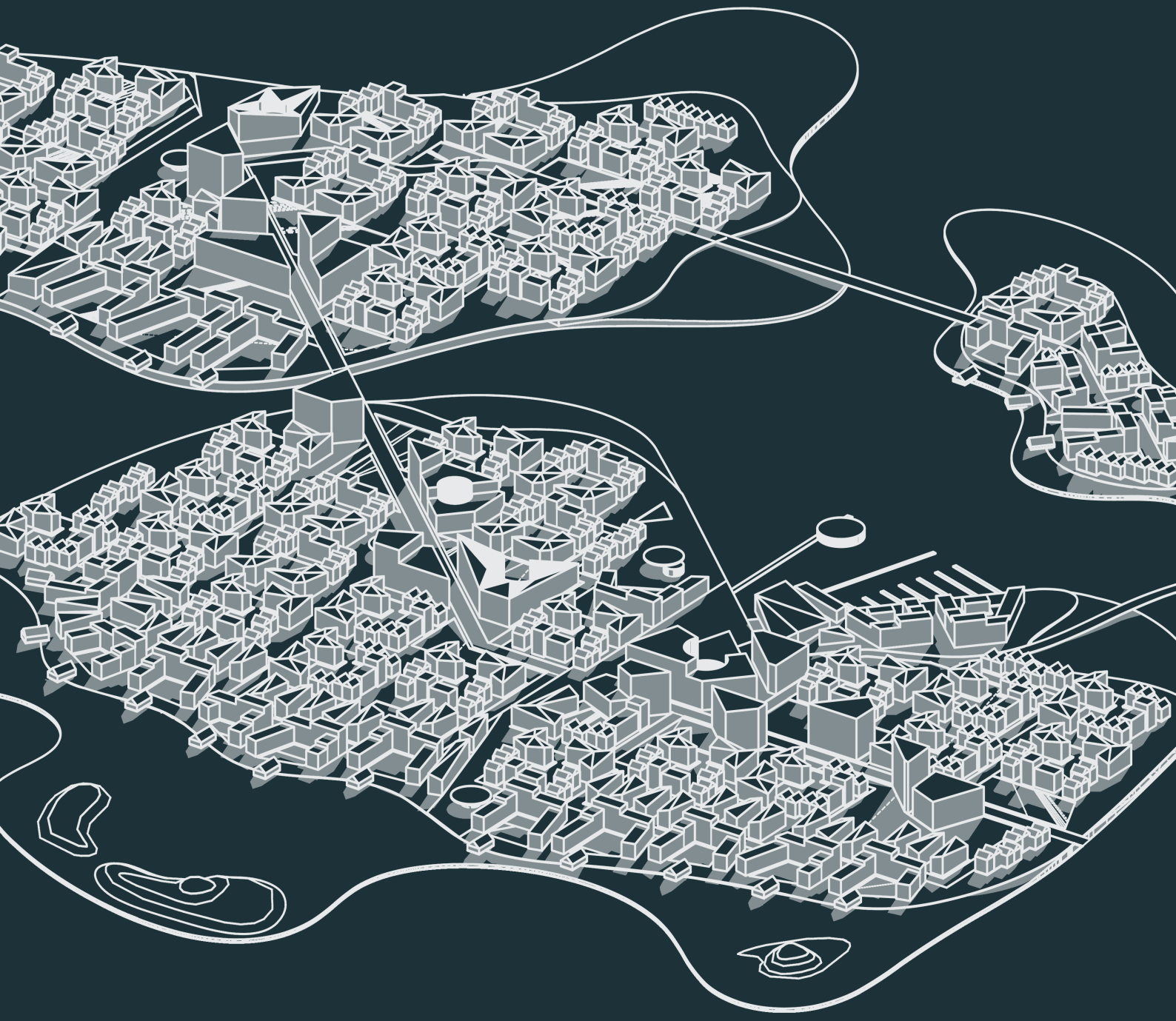

LYNETTHOLMEN
THE URBAN ARCHIPELAGO

SHAPING A NEW DISTRICT IN RESPONSE TO SEA LEVEL RISE

COPENHAGEN, DENMARK

ORLANDO MIJAIL GARCIA SANCHEZ

Master Thesis Report
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Lund University, Faculty of Engineering,
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All images and illustrations presented in this report is done by the author unless noted otherwise in the references.

LUND UNIVERSITY | LTH FACULTY OF ENGINEERING

SUDes Sustainable Urban Design

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ABSTRACT

Global sea-level rise is projected to reach 1.5 to 1.8 m higher in 2100. As a result, the frequency and damage of storm surge events, sea-level rise and rainfall are expected to become more violent and costly for the urban areas. Copenhagen, the second biggest metropolitan area in Scandinavia with high historical and economic value, is located in a low-lying land area vulnerable to sea-level rise.

The urban archipelago aims at a sustainable and resilient district that combines climate protection with urban design into one. The proposal offers unique proximity between urban life and outdoor activities. This uniqueness goes beyond the physical characteristics of the city. From biodiversity to the economy, everything is expected to grow outside.

The new district creates a new urban ecosystem that adds a new layer to the Copenhagen green infrastructure. These will increase the resilience capacity of the site and the quality of life for the residents.

Lynetteholmen maintain Copenhagen strategy of claiming land to the ocean. Therefore, the proposal is designed as an urban archipelago on the water.

In 40 years, Lynetteholmen will become a vibrant district, providing room for 20,000 people and jobs opportunities. Furthermore, it will ensure the existence of the historic centre by dealing sustainably with the future effects of global warming.

CONTENTS

PART 05 THE SITE

PART 06 VISION

PART 07 DESIGN PROPOSAL

PART 08 CONCLUSIONS

01

INTRODUCTION

INTRODUCTION

1.01 Purpose

This thesis research aims to find a solution for rapid climate change by designing a sustainable neighbourhood that protects and enhances the edge of Copenhagen. Mother nature and scientists are warning us of the severe damage that global warming is producing in the world.

The thesis is divided into research and design chapters. The research part is divided into an introduction, analysis of the challenges, the background of the site in a general perspective, study cases and research regarding types of sea level protection, analysis of the site and the municipality plans and strategies. The design proposal consists of a new coastal district in Copenhagen that adapts and protect the city centre against sea-level rise. This project can be described as an urban design project that combines the urban realm, climate protection, and housing idea.

1.02 Introduction

Due to the increase in world temperatures caused by human activity and climate change, global sea-level rise is projected to reach 1.5 to 1.8 m higher in 2100. (1) The frequency and damage of storm surge events, sea-level rise and rainfall are expected to become more violent and costly for the urban areas.

About 40% of the European population are living in coastal areas with a high risk of flooding. (2) Copenhagen, the second biggest metropolitan area in Scandinavia, is located in a low-lying land area that is vulnerable to the effects of sea-level rise. So far, the most common method for dealing with sea-level rise has been building sea walls and filling wetland. However, those solutions have affected natural environments and created barriers between natural and urban areas.

Besides, the world is experiencing historical population growth. It is expected to increase to 2 billion people in the following 30 years (3). Copenhagen is expected to grow from 1,300,000 people to up to 1,500,000 people in 2035, which means it needs almost 10,000 new houses every year to fulfil the housing needs of Copenhagen. (4)

(1). **Shiraz, H.** *Reasons to Global Warming. 2014. http://mawdoo3.com/%D8%A3%.*
(2). **Settlements, Population in Coastal.** European Environment Agency. November 29, 2012. https://www.eea.europa.eu/data-and-maps/figures/population-in-coastal-settlements-2001.

Images source: David Suzuki Foundation, https://davidsuzuki.org/story/the-woman-who-discovered-global-warming-in-1856, 2020

02

CHALLENGES

2.01 GLOBAL WARMING

It has been intensively studied that natural disasters like storms, flooding and sea-level rise have increased their frequency in the last 50 years. (5) The concept of global warming was wrongly perceived by many people as an issue affecting only the ice melting in the artic and not their daily lives. Today, the effects of global warming and climate change are present in activities. Winters that used to be extremely cold are becoming rare as global warming is changes the patterns of how the weather was. According to World Meteorological Organization, the global average temperature in 2019 was 1.1 Celsius above the pre-industrial period and average temperatures for the last five and ten years are the highest on record. (5)

In the words of Cambridge academic dictionary, global warming definition is "*as a gradual increase in world temperatures caused by gases such dioxide that is collecting in the air around the earth and stopping heat escaping into space*". (6) This phenomenon occurs after several years of constantly increased greenhouse gases.

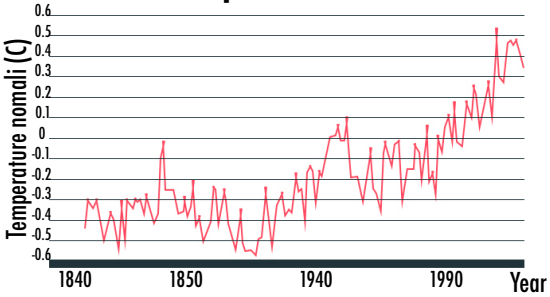
2.01.01 Reasons

In my opinion, societies are becoming more complex and depending more on technology that needs more energy. Unfortunately, the rise of energy demands means burning more fossil fuels which produce greenhouses gases and harm the atmosphere.

Greenhouse emissions are the gases that emit energy radiation to the atmosphere, which means the increase in the earth temperature to the perfect conditions for human life. Without greenhouse gases, the earth surface would be about -18° C.(7)

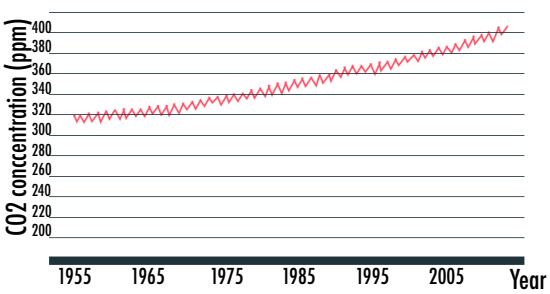
After the industrial revolution, greenhouse gases have increased exponentially. (5) According to the United Nations, the increase can be explained by the large scale of agriculture, industrialisation and high consumption habits. Overexploitation of natural resources has affected the resiliency of the earth, making the renovation process of the ecosystem slower. (5)

Global annual temperature from 1850 to 2008



Graph source: Climatic research unit, Univesity of East Anglia.

Co2 concentration in the atmosphere



Graph source: Earth system research laboratory, National Oceanic and Atmosphereric administration.

2.01.02 Effects

Global warming is raising the earth surface temperature to levels that human has not experienced before. The unbalance level of temperature causes a change in weather patterns. Therefore, warmer periods during the year are affecting the ice and snow in the poles. (5) Melted snow is rising in the last years due to the fact that the average temperature in 2019 was 1.1 degrees Celsius above the pre-industrial period, according to IPCC. (5)

Recent research regarding global warming has shown that if the earth surface increased its temperature to 1.5° C, over 70% of coral reefs will die, insects, crops, and plants will reduce to half. (5)

Another consequence will be the partial ice melting in Greenland and Antarctica, leading to an increase to the sea level about 1.5 m higher than the current one. In the most extreme scenario where Greenland is completely melted, the sea level will increase to 5/6 m higher than the current one. (1)

Furthermore, the frequency and intensity of natural disasters such as droughts and storms are growing as fast as the earth surface temperature increased. (8)

(3). **3. Prospects, World Population.** United Nations, Department of Economic and Social Affairs. June 17, 2019. https://www.un.org/development/desa/publications/world-population-prospects-2019-highlights.html.
(4). **Projections, Population.** Statistics Denmark. 2021. https://www.dst.dk/en/Statistik/emner/befolkning-og-valg/befolkning-og-befolkningsfremskrivning.
(5). **Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, and K. Zickfeld.** Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the. s.l. : IPCC, 2018.

Images source: TRT World, https://www.trtworld.com/magazine/global-warming-undercuts-all-of-the-world-s-other-crises-24778, 2019

2.02 SEA LEVEL RISE

About 71% of the earth surface is water, and it is in constant movement from one place to another and from one form to another. (9) Sea level is rising unquestionably as glaciers and polar ice melt and ocean water expand. (9) The effect of global warming sea level rise is becoming a severe threat to the coastal cities worldwide. (8) The frequency and intensity of natural disasters such as storm surges, flooding and damage to coastal areas are growing as fast as the earth surface temperature increased. Extreme conditions such as the 100 years flood are expected to be as often as every 15 years and the 500 years flood every 100 years. (8)

Reducing green areas is one of the reasons that lead to a flood. Green spaces can absorb water and reduce the harmful effect of a potential surplus of water. The way I see things is that construction, deforestation and industrialisation have been damaging and cutting down the green surfaces that have worked as a buffer for a natural disaster.

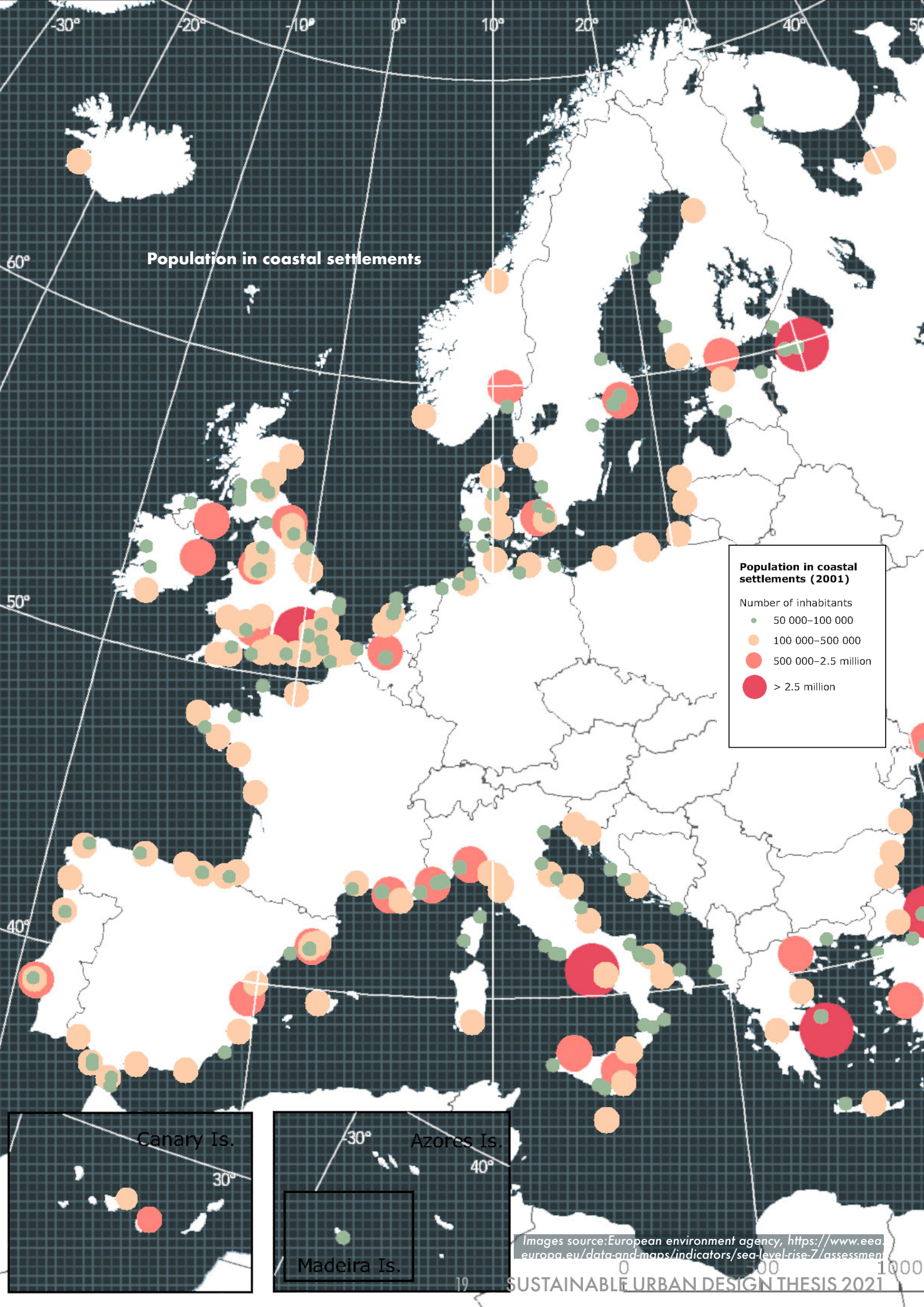
2.02.01 European context

Europe has a coastline of over 100,000 km, with many areas at high risk of flooding due to the sea-level rise. (10) Many countries have different levels of exposure to the sea level rise depending on topography, land use and existing flood defences (10). Nearly 50 million of the population in Europe are living in coastal areas and more than 500 million in a ratio within 50km from the coastline. (11) Netherlands and Denmark are the countries with the most vulnerability to this flooding due to the low-lying land where they are located.

Several countries in Europe have implemented flood defences throughout history. For example, a country such as the Netherlands has already protected areas for the expected sea-level rise in 20 – 100 years. Other countries are in the design process to reduce the effects of flooding.

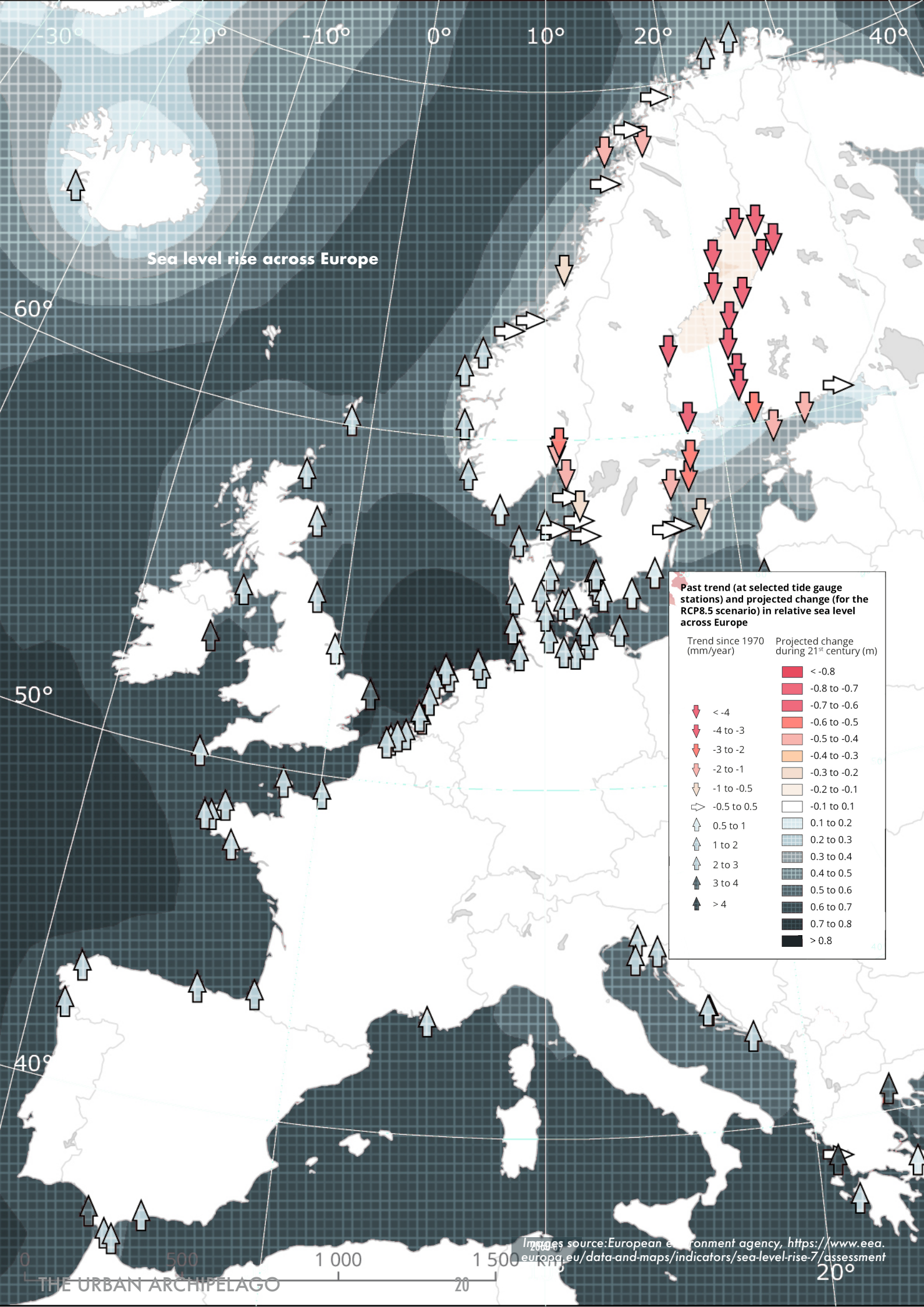
Planning could reduce coast damage in future cities. According to the research of Vousdoukas, countries like Cyprus, Norway, Ireland and Denmark coastal flood damage could rise to 5% or more of national GDP in 2100. (12)

(6). **Warming, Global.** Cambridge dictionary. 2021. https://dictionary.cambridge.org/dictionary/english/global-warming?q=Global+warming+.
(7). **Ma, Qiancheng**. Greenhouse Gases: Refining the Role of Carbon Dioxide. [Online] March 1998. https://www.giss.nasa.gov/research/briefs/ma_01/.



Images source:European environment agency, https://www.eea.europa.eu/data-and-maps/indicators/sea-level-rise-7/assessmen

0 500 1000



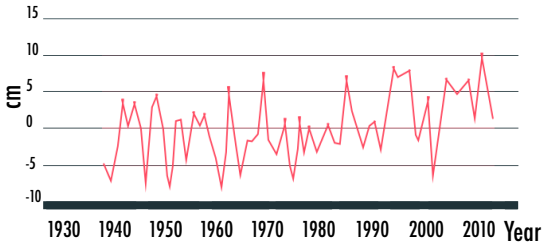
Images source:European environment agency, https://www.eea.europa.eu/data-and-maps/indicators/sea-level-rise-7/assessment

2.02.01 Denmark context

Denmark has a coastline of about 7,300km. Coastal areas with a small tidal range might be forced to retreat from the coastline or protect their assets. (13) Sea level rise might reduce the shallow waters and coastal habitats around fjords and inlets because the temperatures and weather pattern will change. (13)

At the regional level, the Oresund region and metropolitan Copenhagen area face a threat of rising sea level in the Baltic sea. South regions are the most vulnerable because of the flat topography, and the current water flow is coming from the South. (14) In northern regions, the risk is higher and the impact slightly less harmful but the infrastructure cost damage is unquestionable higher than in the South. (14)

Seawater level in Copenhagen



Graph source: PSMSL, National Oceanography, psmsl.org

Copenhagen municipality has developed a climate adaptation plan. This plan describes and analyses the cost damage and possible solutions for future storm-surge events affecting the city. The analysis is based on a risk value calculation that has considered frequency storm events, cost measurements, cost of damage and environmentally sustainability. (8) The risk value and the combined cost of damage for the next 100 years are shown in the following tables.

10 YEAR RISK (DDK MILLION)	0-500	501-1500	> 1500
ASSESSMENT CRITERION	LOW RISK	MEDIUM RISK	HIGH RISK

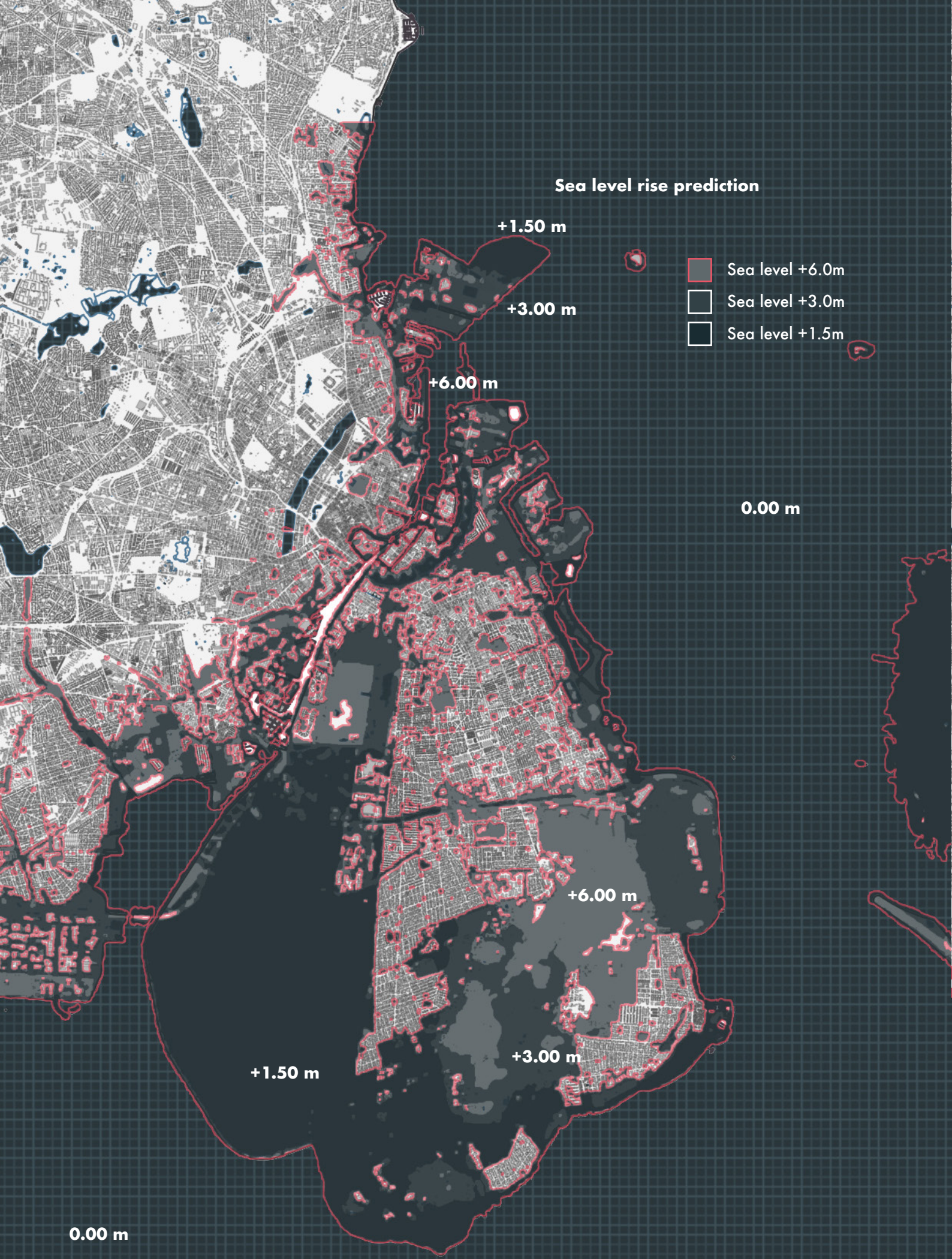
TIME	RISK VALUE	COMBINED ASSESMENT
2010-19	304	LOW RISK
2020-29	557	MEDIUM RISK
2030-39	1,039	MEDIUM RISK
2040-49	1,967	HIGH RISK
2050-59	3,770	HIGH RISK
2060-69	7,288	HIGH RISK
2070-79	14,157	HIGH RISK
2080-89	27,546	HIGH RISK
2090-99	53,504	HIGH RISK
2100-2109	103,414	HIGH RISK

HIGH WATER	FRECUENCY	YEAR	COST
137 cm	16 years	2010	0
158 cm	85 years	2010	465 million
200 cm	73 years	2060	1,576 million
226 cm	11 years	2110	4,647 million
255 cm	70 years	2110	9,287 million
285cm	300 years	2110	13,583 million

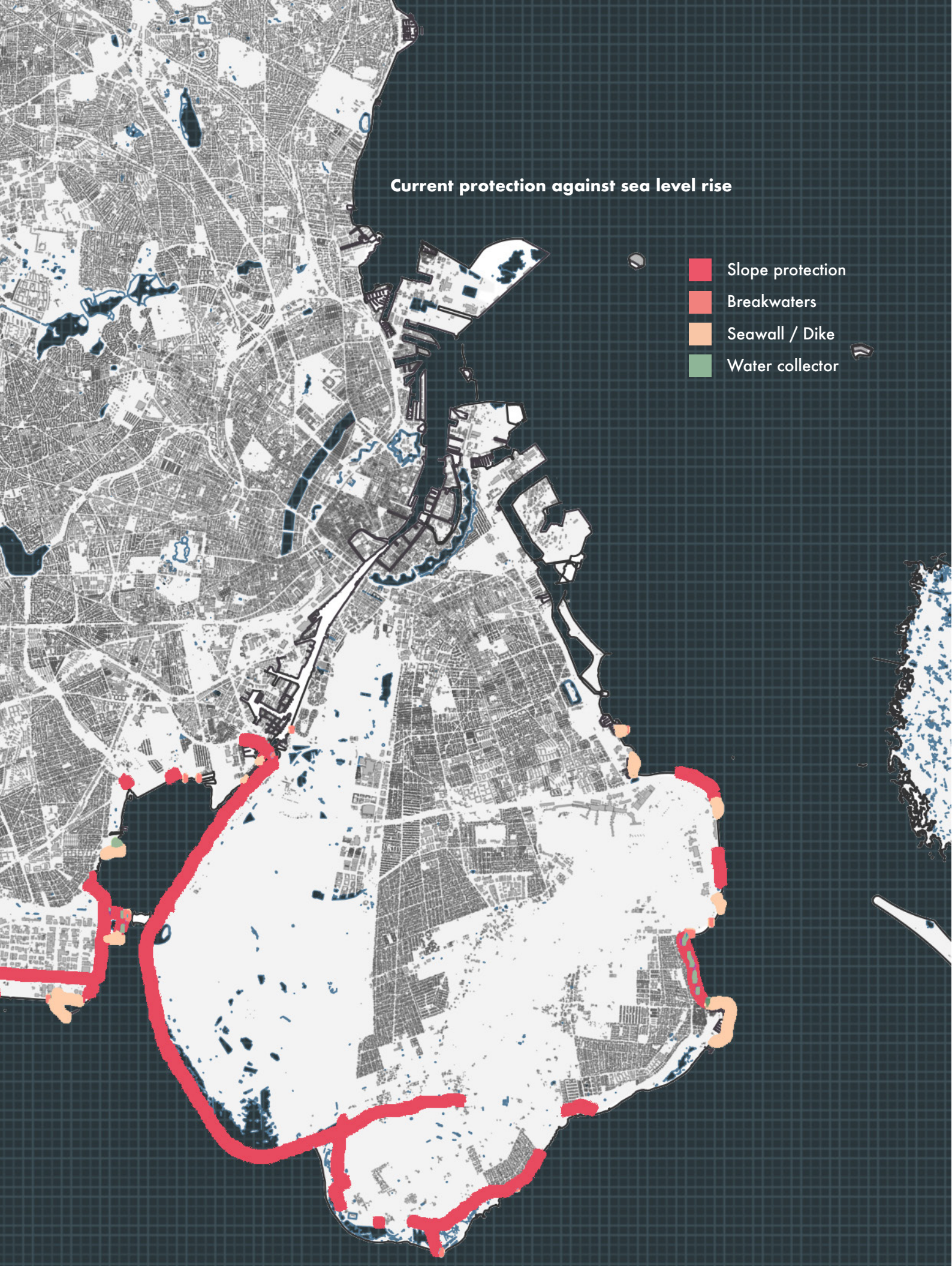
COMBINED COST DAMAGE 100 YEARS	19,908 DKK billion
COST OF MESURE	3,997 DKK billion
NET SAVING	15,911 DKK billion

Table source: Copenhagen adaptation plan 2025

(8). **Københavns kommune, Cowi, Deloitte, Ramboll, Dmi, Ku-Life, Dhi, Gras.** Climate Adaptation Plan. Copenhagen : Kobenhavns Kommune, 2011.
(9). **Shiklomanov, Igor.** World fresh water resources. New York : Oxford University Press, 1993.



Images source:Klimatilpasning, https://www.klimatilpasning.dk/vaerktoejer/havvandpaaland/havvand-paa-land/



Images source:Klimatilpasning, https://www.klimatilpasning.dk/vaerktoejer/havvandpaaland/havvand-paa-land/

2.02.03 Why Adapt

The predictions made by scientists about sea-level rise are frightening. Adaptation or extinction are the only solutions for human activities. (1) The danger of sea-level rise will be catastrophic if it is not attended to. Not only economically but also environmental. (12) The human population might experience a shortage of food production, extreme weather conditions that will make life harder and the most extreme consequence, the extinction of the human being. (5)

I consider, mitigation and reducing greenhouses emissions to the atmosphere will help the ecosystem adapt naturally to climate change. New urban projects need to integrate natural and artificial environments into one instead of two different aspects. Adapt cities to future changes is a must that needs to be achieved by decision-makers and urban planners. Better management and restoration of natural reserves that have been overtaken for the urban sprawl could reduce greenhouse emissions. Urban projects need to adapt and change the biological threats into opportunities such as green energy.

(10). **EEA Topic Centre on Terrestrial Environment (ETC-TE), ETC Biological Diversity (ETC-BD), ETC Water (ETC-W).** The changing faces of Europe's coastal areas. Copenhagen : European Environment Agency, 2006. 6.
(11). **Sadie McEvoy, Marjolijn Haasnoot, Robbert Biesbroek.** How are European countries planning for sea level rise? 2021.

Images source: Gettyimages

2.03 WORLD POPULATION GROWTH

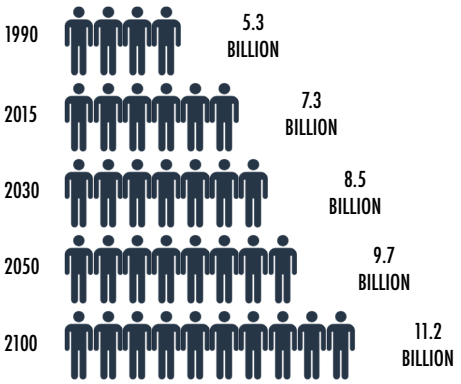
Another big challenge that the world is facing is the rapid increase in the global population. After two centuries with constant population growth, the world's population growth from 1 billion in 1800 to nearly 2 billion in 1900.(15) After the second world war, the growth rate has reached its peak, and the population has increased to 7.7 billion people living nowadays.(15) The world's populations are expected to increase by 2 billion more people in the next 30 years and 4 billion around 2100.(3)

Some of the reasons for the rapid increase in population are the increase of people surviving reproductive age, longevity, and faster migration. (3)

This challenge needs to be addressed by the cities creating a more sustainable and efficient place for the expected population. Densification and shared spaces are the option to reduce urban sprawl. Also, urban design is essential for keeping and improving the current characteristics of quality of life.

World Population

Projected world population until 2100



Source: United Nations Department of Economic and Social Affairs, population division 2015.

2.03.01 Denmark context

Denmark has a current population of 5,803,562 people with a density of 135 persons per km2. (4) Denmark is the second largest population in the Scandinavia region after Sweden. (4) It is expected to increase 200,000 more people in 2030 and about 1,000,000 people in 2100. (4) This trend means an increase of about 17% of the current population. The population density is 135 persons per km2, with 88.2% of the population living in urban areas. (4)

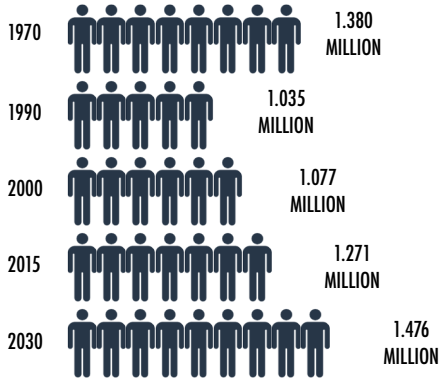
Copenhagen is the second-largest metropolitan area in Scandinavia, with a population of 1,153,615 people. (4) After decades of population decrease from 1970 to 2000, Copenhagen is in the middle of population growth. It is expected to reach its peak around 2100. (4)

(12). **Vousdoukas, Michalis I.** Climatic and socioeconomic controls of future coastal flood risk in Europe. September 2018. https://doi.org/10.1038/s41558-018-0260-4.
(13). **Nature, Climate Change impact on.** Climate Change Adaptation. Ministry of Environment of Denmark, 2020. https://en.klimatilpasning.dk/sectors/nature/climate-change-impact-on-nature/#:~:text=In%20the%20long%20run%2C%20climate,winter%20periods%20in%20the%20future.

Population growth is forcing the housing sector to increase their available spaces by about 10,000 dwellings per year in order to fulfil the city needs. (16)

Copenhagen Population

Projected world population until 2030



Source: Statistics Denmark, population information and statistics, 2021.

2.03.01 Housing situation

Restrictions and protection of agricultural land have affected the housing supply in Copenhagen (16). The shortage of suitable land to build has created a gap between the supply and demand for housing. (16) In consequence, land and houses have increased their prices, which means that living in the city centre is becoming more expensive and only a few people can afford it. (16) As a result, loss of jobs and unequal economic growth in the different demographics might affect the social equality and inclusion that Copenhagen is famous for.

Furthermore, suppose too many new houses are built in the suburbs and not enough in the Copenhagen area. In that case, this may result in a more significant difference between prices and social inclusion.

In the words of the Danish Ministry of Transport Buildings and Housing, there is a need to increase the housing supply by 5,000 – 9,000 houses per year for the next 20-30 years. (16) It is expected to have a high demand for small apartments to fill the needs of younger generations moving to Copenhagen city centre. (16)

A potential strategy to reduce the gap between supply and demand has been implemented throughout the City history. Reclaiming land to the ocean has been a long-term solution to provide houses and infrastructure to the city. Besides that, Increasing the housing supply in the right location will stabilise the housing market. (16) Also, it will reduce the risk of the housing bubble, which means a rapid increase in prices and demand. (16)

(14). **Maria Farago, Eva Sara Rasmussen, Ole Fryd, Emilie Ronde Nielsen, Karsten Arnbjerg-Nielsen.** Coastal protection technologies in Danish context. Frederiksberg C, Denmark : Vand i Byer – Innovationsnetværk for klimatilpasning. http://www.vandibyer.dk/, 2018.

(15). **Roser, Max.** Our world in data. 2019. https://ourworldindata.org/future-population-growth.

03

UNDERSTANDING THE CITY

3.01 LOCATION

Copenhagen, Denmark's capital, is located on the eastern coast of Denmark. It is situated in the dynamic Öresund region that links the binational area of Denmark and Sweden. The region has a population of 3,8 million inhabitants, with 2.5 million living on the Danish side. (4) The Öresund region is one of the waterways that connect the Baltic Sea to the Atlantic ocean.

3.02 HISTORY

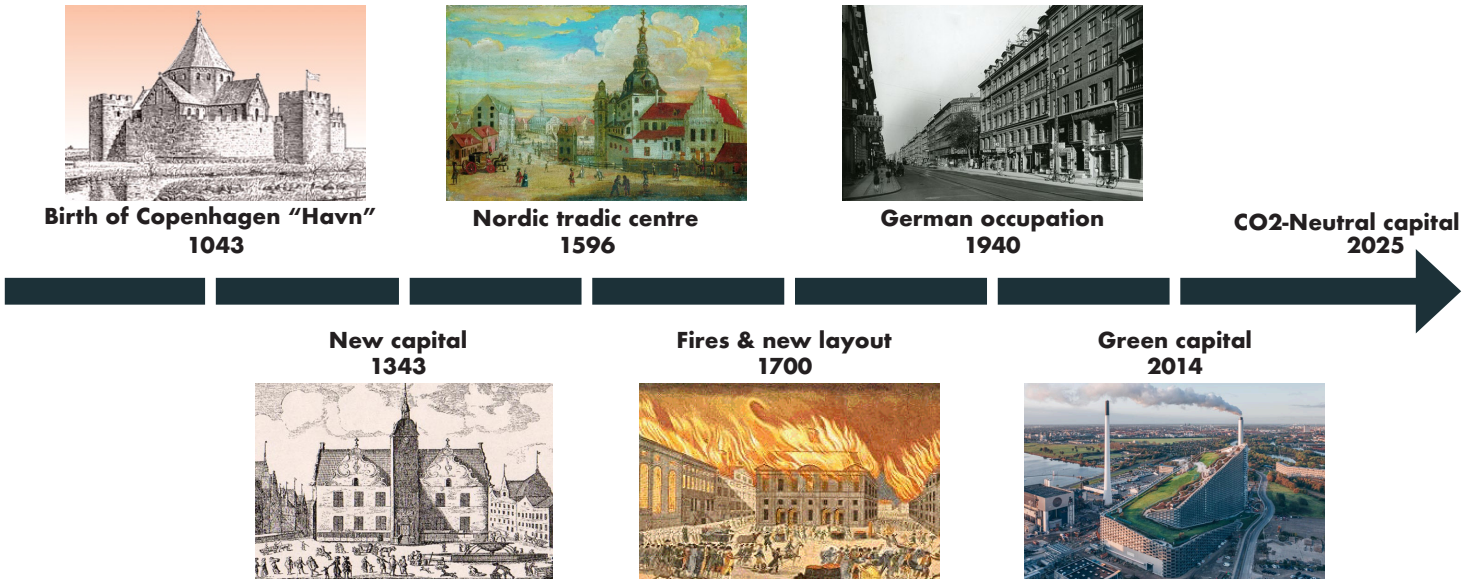
Copenhagen was founded as a fishing village in 1043 AC. The city started growing from a small town to become a strategic and political place. In 1343 Copenhagen became the Danish capital and turned into a wealthy city. (17) In the 17th century, King Christian IV inspired by the Dutch city model of that time planned an extension of the city. He reclaimed land to the sea to create a new fortification of the city. (18)

After creating a new district on artificial land, the city has transformed the whole coastal edge into an industrial and residential area. In addition to the fire disasters in the 18th century, those changes modified the city's layout. Since then, new layers have been added to the town, transforming the city into what we know nowadays, "The Green capital".

3.02.01 Shorelines through the time

The shorelines and urban fabric of Copenhagen have evolved. The city has reclaimed land to the sea in order to protect the farmland in the periphery of the city. Those changes are visible through the hard edges in Nordhavn harbour and Amager island. Also, the star shape in the canals of the Christianshavn area and city centre remembering the defence facilities that once were there.

The earliest traceable map of Copenhagen is dated 1659. (19) The city centre, the castle and the beginning of urbanisation in the area of Norrebro are evident. However, there is only one connection to the Amager island, and the rest of the land has been untouched.



(16). **Helge Sigurd, Naess-Schmidt.** Housing Market Analysis of greater Copenhagen. Copenhagen : Danish Ministry of Transport Building and Housing, 2018.
(17). **History, Copenhagen.** Copenhagen. Quality Unlimited, 01 01, 2020. https://www.copenhagen.com/historical-facts.

In 1730 the city expanded to the Christianshavn by creating a land divided by canals that protected the city centre. (19) In 1858 Copenhagen started growing to the southeast by reshaping the edge of Amager island. It increased residential and farming area.

In 1900 the northeast of the shoreline shown the first filling land in the area of "Refshaleoen". This area was designed for industrial purposes. Also, fort Trekoner was built to protect the city. (19)

In 1950 the need for a better harbour made the municipality transformed the district of Freehavnen and the beginning of Nordhavn. (19) Hard edges replaced the natural shapes of the coastline in order to make it more suitable and efficient.

Nowadays, Copenhagen's shoreline has increased with the new addition of Nordhavn harbour, new islands in the central canal and a new waterfront in the Amager island.

Images source:Historical mapas of Copenhagen, https://kortviseren.dk/side/koebenhavn.html

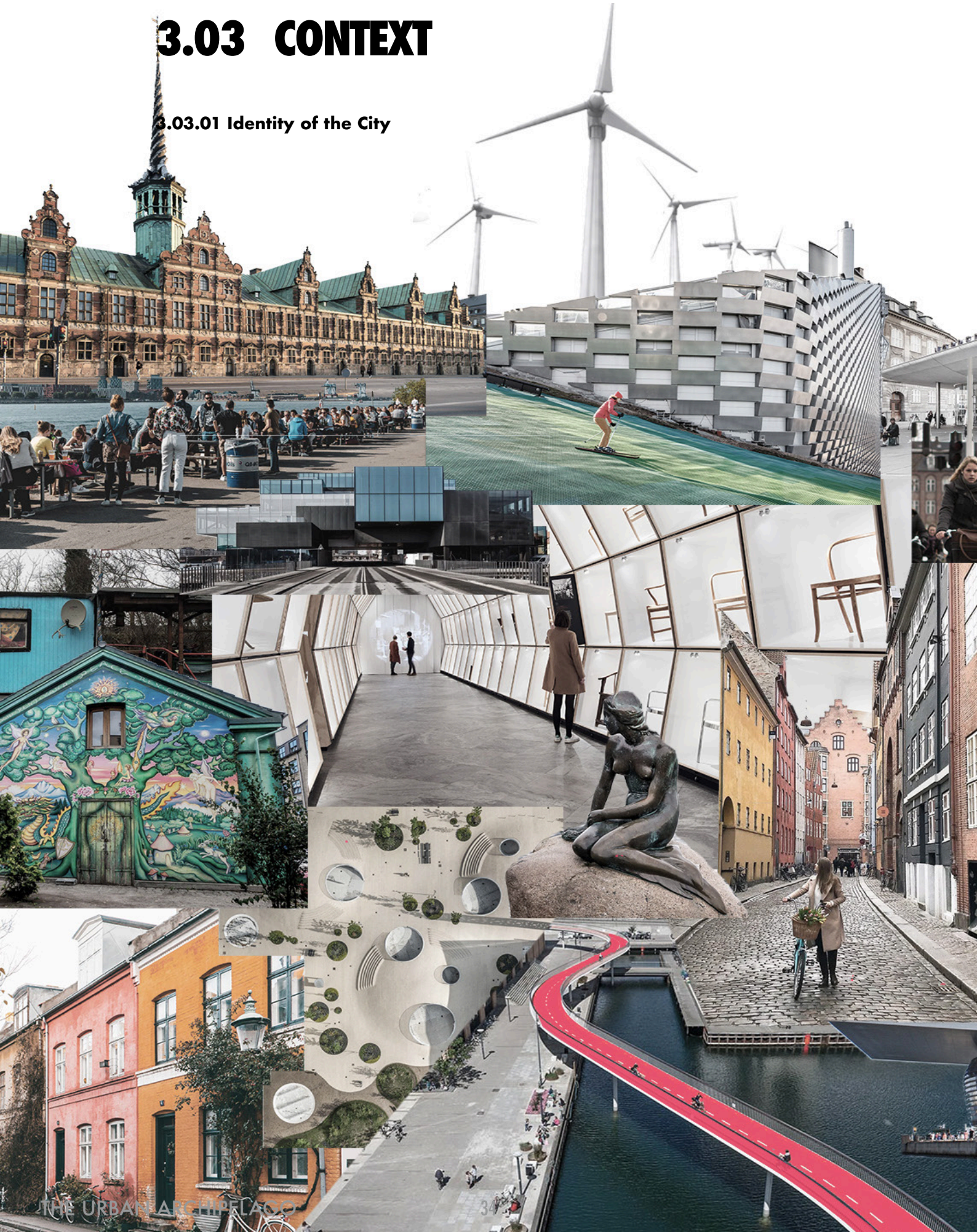
(18). **Dahl, Bjørn Westerbeek.** Guide til Københavns Befæstning. Københavns : Kbh., kobenhavnshistorie. dk,, 2006..

Images source:Historical mapas of Copenhagen, https://kortviseren.dk/side/koebenhavn.html

(19). **Maps, Historical.** Kortviseren. Royal Library and Copenhagen City Archives, 2017. https://kortviseren.dk/side/koebenhavn.html.

3.03 CONTEXT

3.03.01 Identity of the City




HYTTEFADET
SKUTTERBOEN
SLAMESIDE
ZOOS

3.03.02 Urban form

The Copenhagen urban form is based on the iconic "finger regional plan" design in 1948. The concentration of urban development and railway network along with the fingers corridors is the main idea of this plan. Radial roads are linking the fingers in between them and the city centre. The space that separates the city fingers remains as green and recreational spots. (20) However, central Copenhagen has a dense urban core with various mixed-use areas, combining living and working environments. The city has a density of 25,340 inhabitants per km2. (21)

The shortage of land and crowded districts in the city centre made the finger plan only suitable for the suburbs. This challenge has brought new opportunities to the municipality to develop former industrial areas into residential and commercial nodes. The municipality has explained that it is desired to let the city grow within the city borders as it is where jobs and infrastructure are. (20) Although, the significant demand for housing cannot only be reached by building on non-agricultural land.

Images source:The finger Plan of Copenhagen,, https://theurbanweb.wordpress.com/2016/11/06/the-finger-plan-of-copenhagen-a-planning-solution/

(20). **The Finger Plan.** Copenhagen : The Danish Nature Agency, 2015.

(21). **Matthew Ulterino, Duncan Smith, Karl Baker, Catarina Heeckt.** Green Economy Leader Report. London : Economics of Green Cities Programme at the London School of Economics and Political Science.,2020.

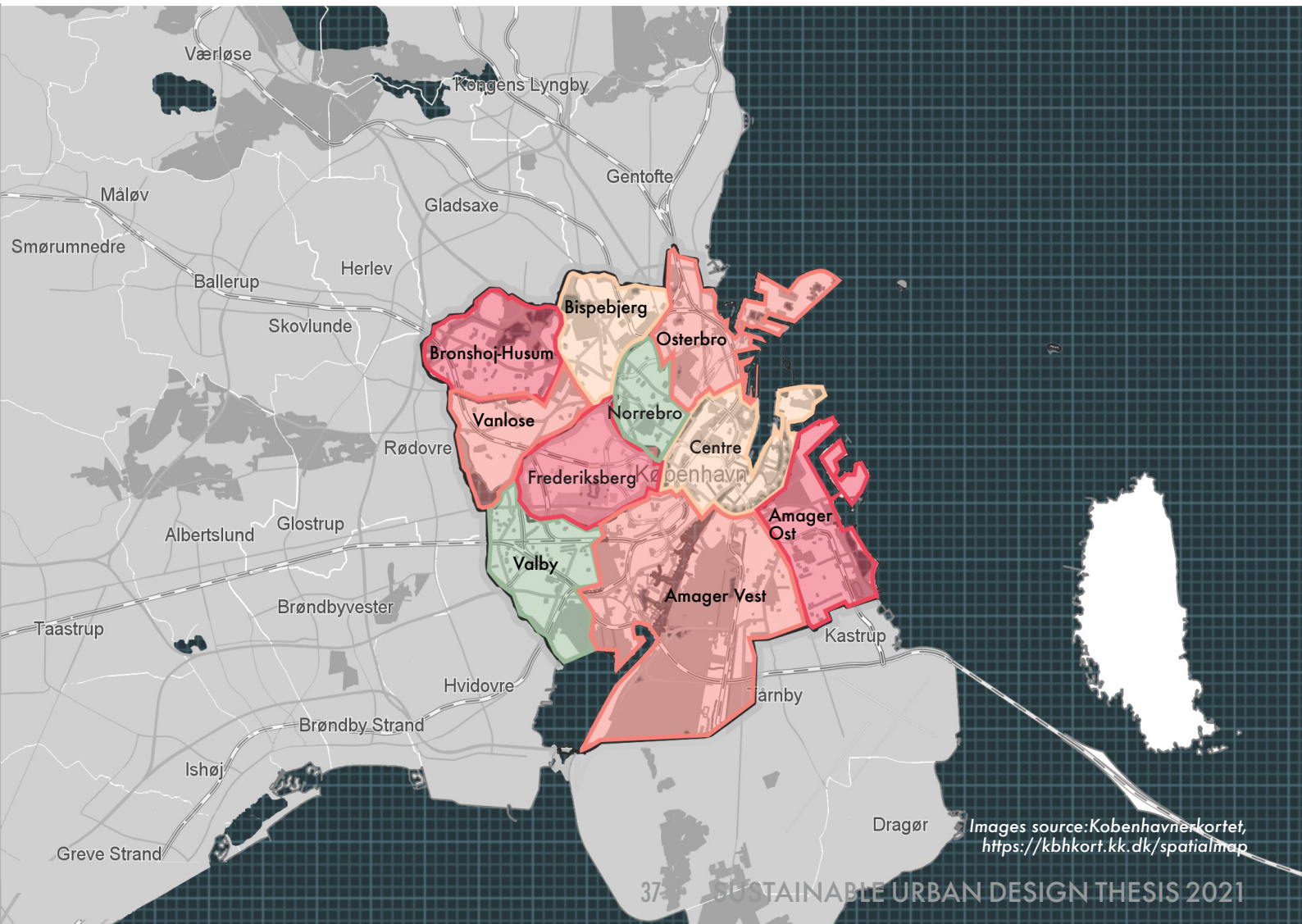
3.03.03 City structure

Copenhagen municipality is divided into ten districts, covering the city centre and stretch east to the waterfront. The most valuable assets such as historic buildings, infrastructure or landmarks are located in the city centre.

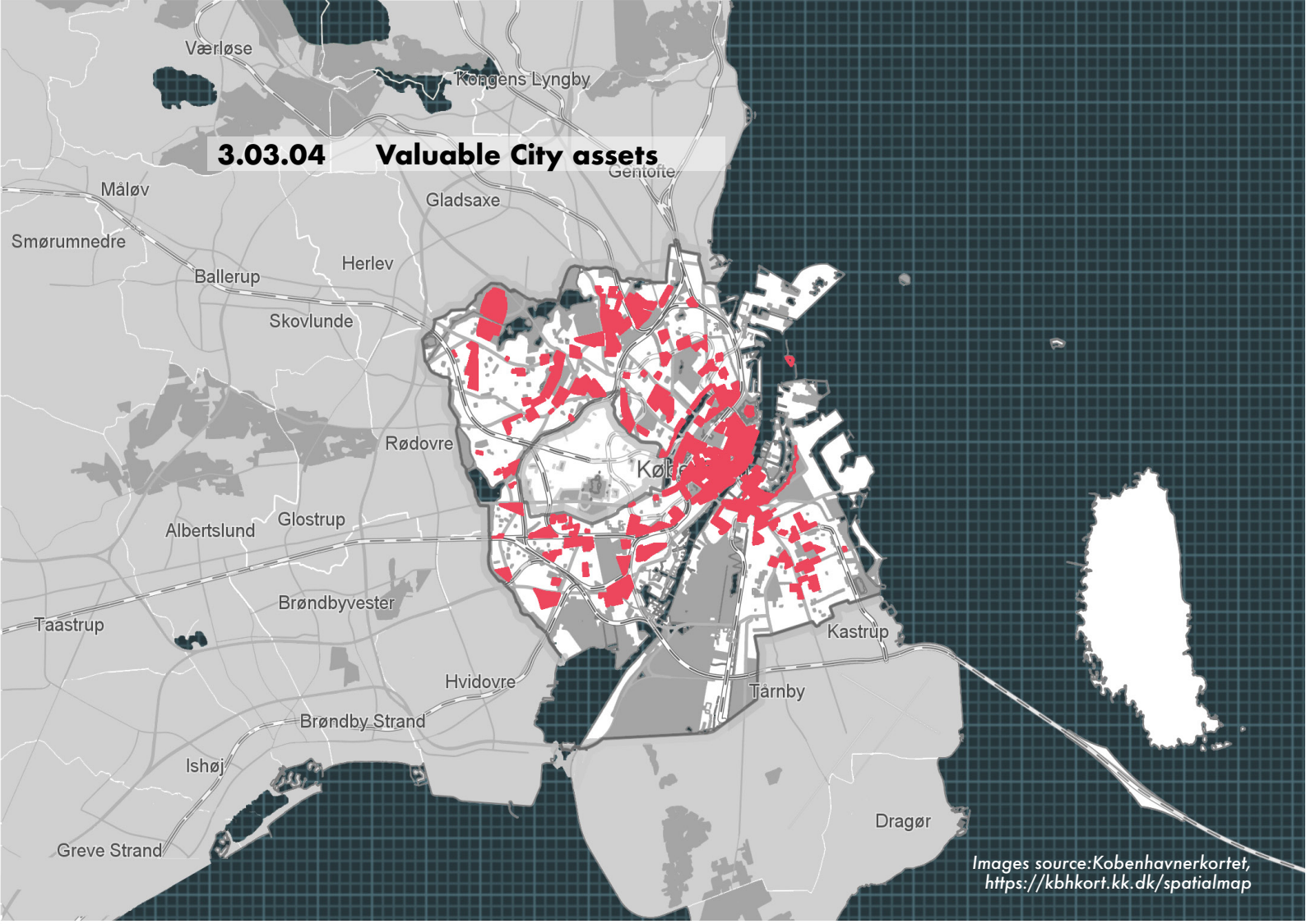
New urban developments are concentrated in areas that will be transformed from industrial sites to residential within the following years..

Copenhagen has 25% of its surface in green areas, which means 31.91 m2 of green areas per person. (21) Green areas include garden facilities, parks, natural areas, pocket parks, sports facilities, cemeteries and lakes are spread all over the city to provide access to every inhabitant.

The municipality is finding new solutions to expand the green infrastructure due to the rapid population growth. New solutions such as green rooftops and green islands are now part of the future vision.

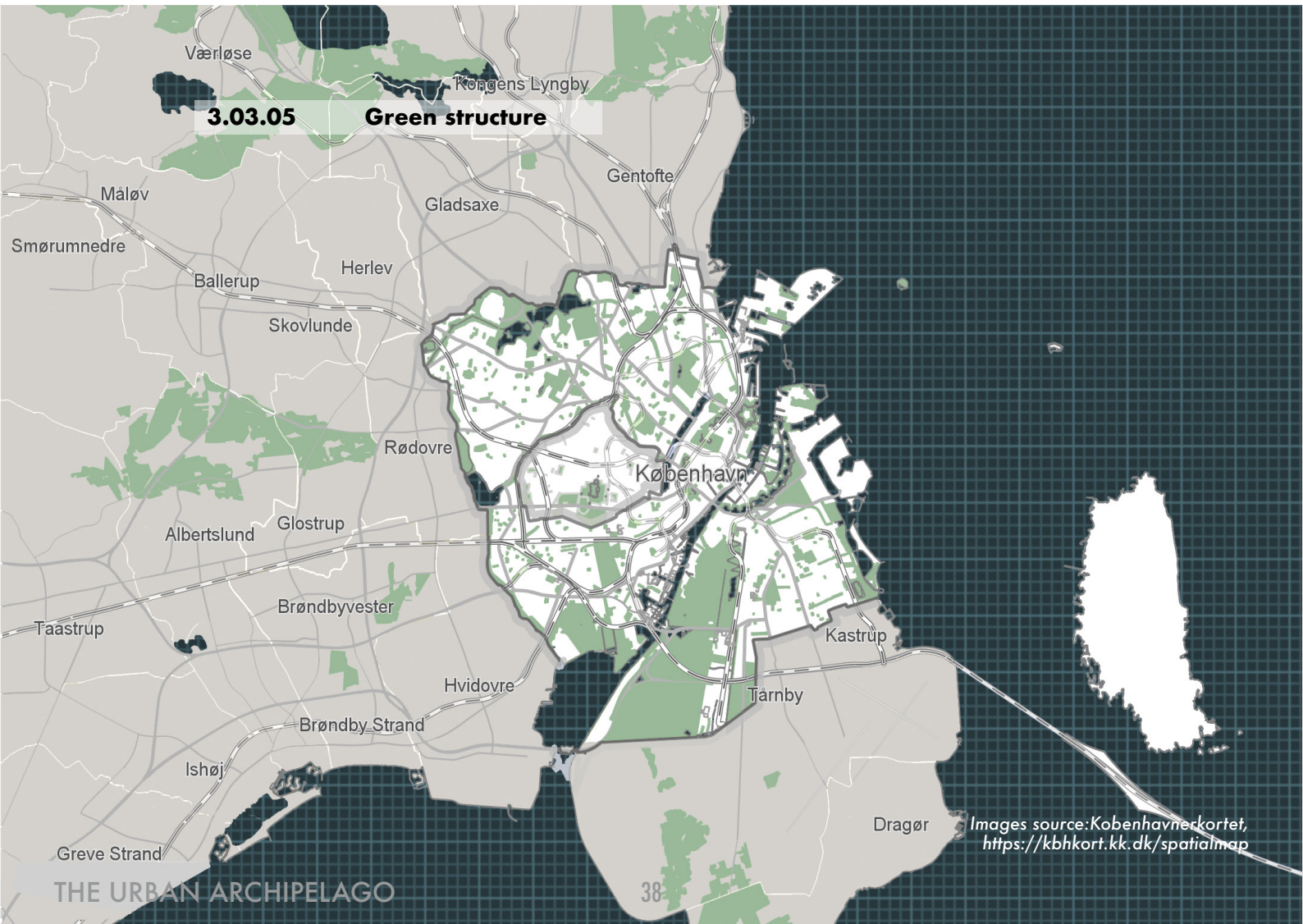


Images source:Kobenhavnerkortet, https://kbhkort.kk.dk/spatialmap



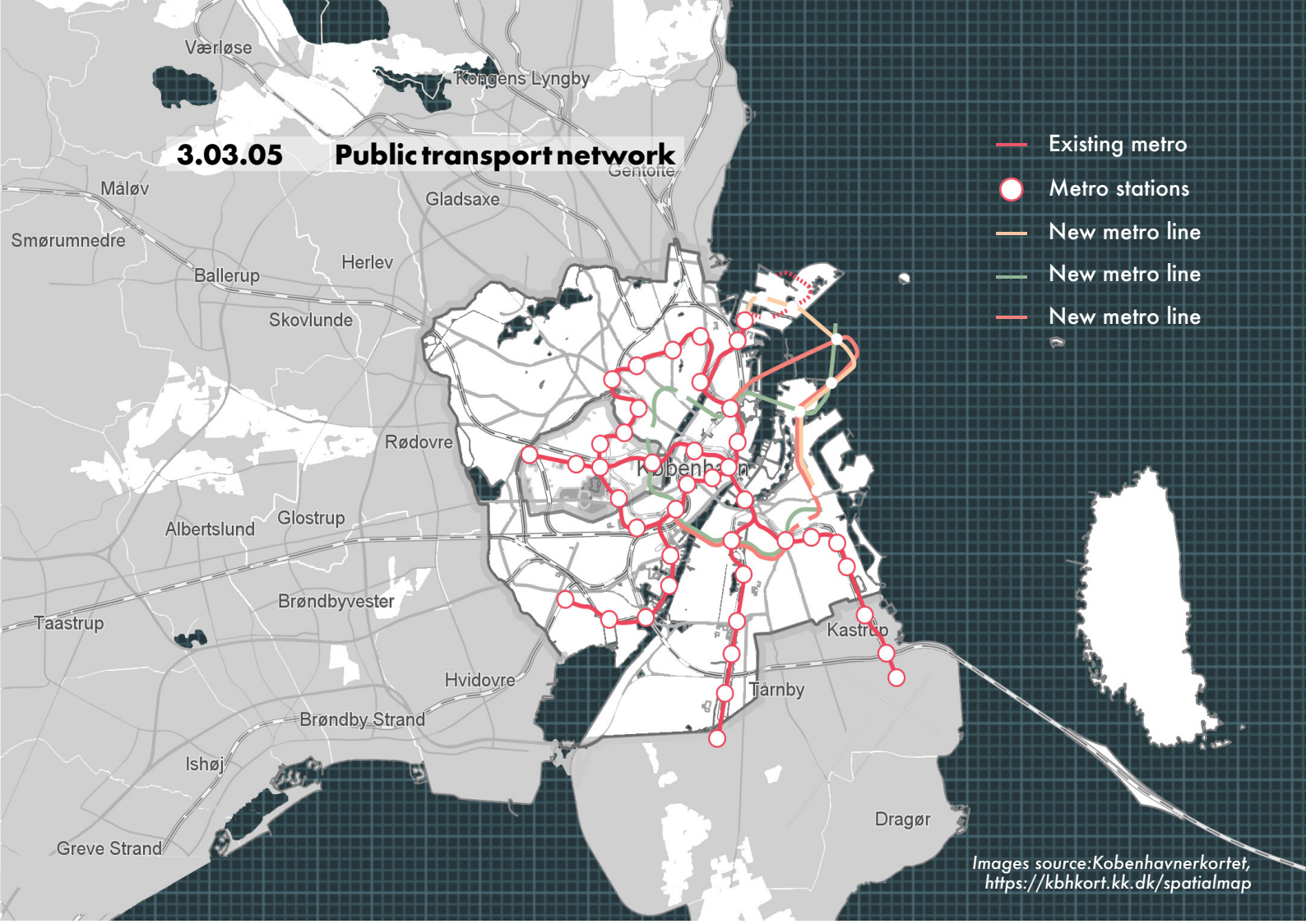
3.03.04 Valuable City assets

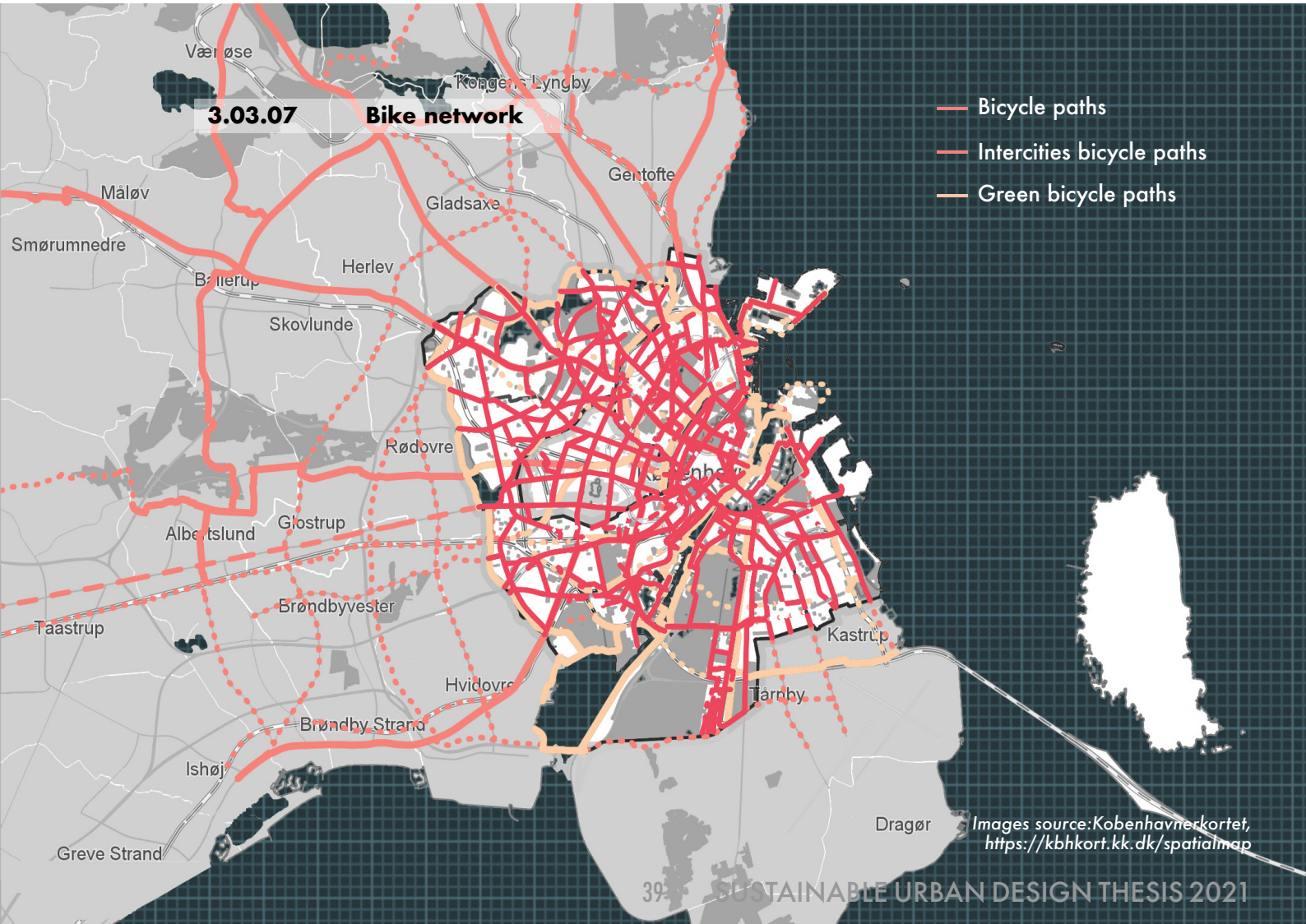
Images source:Kobenhavnerkortet, https://kbhkort.kk.dk/spatialmap



3.03.05 Green structure

Images source:Kobenhavnerkortet, https://kbhkort.kk.dk/spatialmap


3.03.05 Public transport network
Existing metro
Metro stations
New metro line
New metro line
New metro line
Værløse
Kongens Lyngby
Gentofte
Måløv
Gladsaxe
Smørumnedre
Herlev
Ballerup
Skovlunde
Rødovre
Albertslund
Glostrup
Brøndbyvester
Taastrup
Kastrup
Hvidovre
Tårnby
Brøndby Strand
Ishøj
Dragør
Greve Strand
Images source:Kobenhavnerkortet,
https://kbhkort.kk.dk/spatialmap


3.03.07 Bike network
Bicycle paths
Intercities bicycle paths
Green bicycle paths
Værløse
Kongens Lyngby
Gentofte
Måløv
Gladsaxe
Smørumnedre
Herlev
Ballerup
Skovlunde
Rødovre
Albertslund
Glostrup
Brøndbyvester
Taastrup
Kastrup
Hvidovre
Tårnby
Brøndby Strand
Ishøj
Dragør
Greve Strand
Images source:Kobenhavnerkortet,
https://kbhkort.kk.dk/spatialmap

3.04 GREEN AGENDA

After received the award of "The European Green Capital" in 2014, Copenhagen has set a new goal. It is planning to be the first carbon-neutral city by 2025. (22) Copenhagen is expected 110,000 more inhabitants in 2025, (4) which means more need for more infrastructure and energy consumption. To ensure that resources are used as efficiently as possible, smarter, greener and healthier solutions are implemented in city planning. Besides that, the solutions need to enhance the quality of life of the citizens.

The plan is divided into five strategies: Energy consumption, Energy production, Green mobility, City administration initiatives and Economy and investment. Each of the strategies contained initiatives to be implemented in future development.

The overall focus of those initiatives is promoting an efficient city. Concepts like "The 5 min city", which means the population need to access every essential urban service within a ratio of 5 min walking or cycling. (22) Promoting green energy such as wind, biomass or geothermal will help to reach the 2025 goal.

Furthermore, the brand of a green city is becoming essential for potential investors in order to create more job opportunities for the new people moving into the city.

The strategies presented are initiatives that can adapt to the design project.

(22). **Copenhagen 2025 Climate Plan.** Copenhagen : The Technical and Environmental Administration, 2012.
(23). **Al, Stefan.** Adapting Cities to Sea Level Rise. Washington DC : All Island Press, 2018.

COPENHAGEN CARBON NEUTRAL BY 2025

04

SEA LEVEL PROTECTION

4.01 DANISH CONTEXT

Denmark has a coastline of 8,750 km, of which dikes or other solutions protect almost 1,800 km.(14)

According to the report of Coastal protections in Danish context by Maria Farago, the first sea-level solution in Denmark date from 1500 when the dikes system at the Wadden sea started. From 16th to 18th century, coastal protection in Jutland island becomes more intense with dikes and sand slopes solutions.(14)

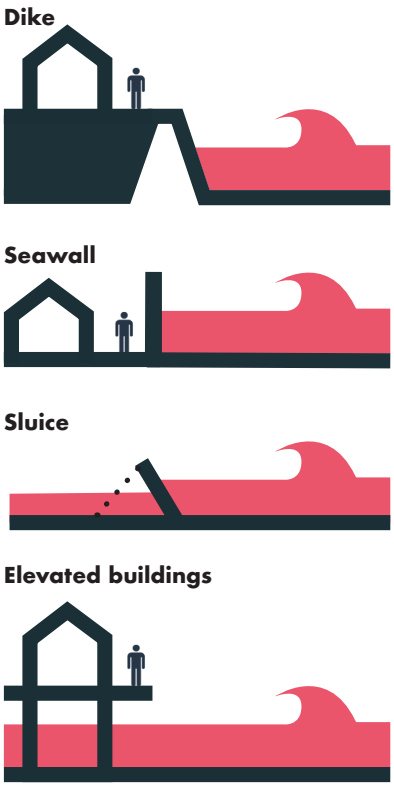
After several high storms surge events in the 19th century, Copenhagen decided to implement dike protection in the south part of the city to protect it from the strong water flow of the Baltic sea. In the 20th century, combine solutions have been implemented in Copenhagen to protect the city and reduce land erosion.(14)

4.02 TYPES OF PROTECTION

There are three well know strategies of flood management.

1.- **Protection,** which includes hard and soft solutions. These strategies aim to keep the water out by defending the shoreline with a permanent feature or claiming land to reduce wave energy. These solutions are the most commonly used to reduce the impact of sea-level rise. (24)

Hard solutions are permanent grey structures that protect from the high tide by holding the line of defence. Examples: dikes, seawall, breakwaters, rock walls, sluices and elevated buildings. (14)

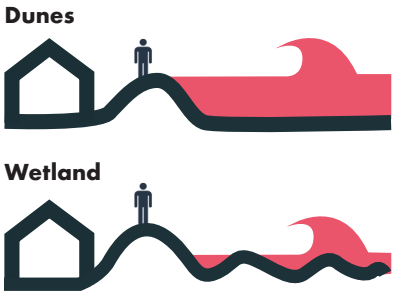


(24).**Storm Flods Plan.** Copenhagen : Kobenhavn Kommune, 2017.
(25). **COWI.** Byernes udfordringer med havvandsstigning og stormflod**.** Kongens Lyngby : Realdania, 2017.

Seawall in Grein, Austria
Images source:www.reddit.com/r/pics/comments/1sl1fb /mobile_flood_wall_in_austria_amazing_feat_of/

Maeslantkering sluice, Rotterdam, Netherlands
Images source:https://www.earthmagazine.org/article/dutch-masters-netherlands-exports-flood-control-expertise

Soft solutions are strategies to hold the line of defence using natural and green elements. Examples: dunes, sand nourishment, wetland and revegetation. (24)

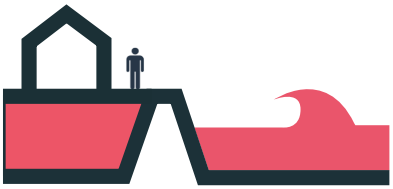


Sand dunes
Images source:https://dementiaadventure.co.uk/sand-dune-project/

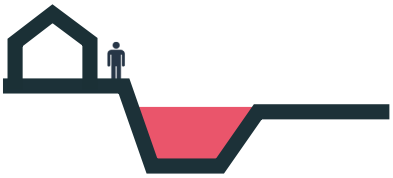
South America Wetland
Images source:https://chinadialogueocean.net/12925-water-lands-picturing-the-worlds-wetlands-and-their-peoples/sand-dune-project/

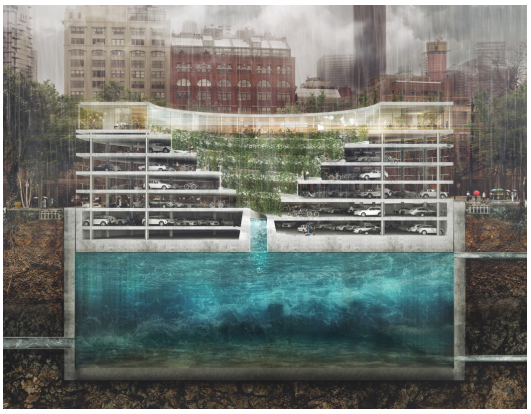
2.- **Store**, in contrast with the previous approach, the aim of this strategy is retaining water to reduce the pressure in the sewage system. The most common example of this solution is water tanks. However, new ideas such as adapting urban spaces into water collectors in extreme conditions are gaining popularity. (24) Copenhagen city recommends that new buildings and infrastructure are safe for 100 years storm event with an elevation of 2,63m above the current sea level. (25)

Parking water collector



Urban space water collector





Parking lot as water collector
Images source:https://www.tredjenatur.dk/en/2021/02/third-nature-shortlisted-to-danish-design-award-2021/

Urban square in Copenhagen
Images source:https://theurbandeveloper.com/articles/climate-change-flood-park-plans-copenhagen

3.- **Retreat**, this strategy aims to move the infrastructure away from the risk zone. This approach is usually the first solution. It can be a planned retreat or unplanned after a natural disaster. The retreat strategy is the most long-term solution and avoids the cost of protection.

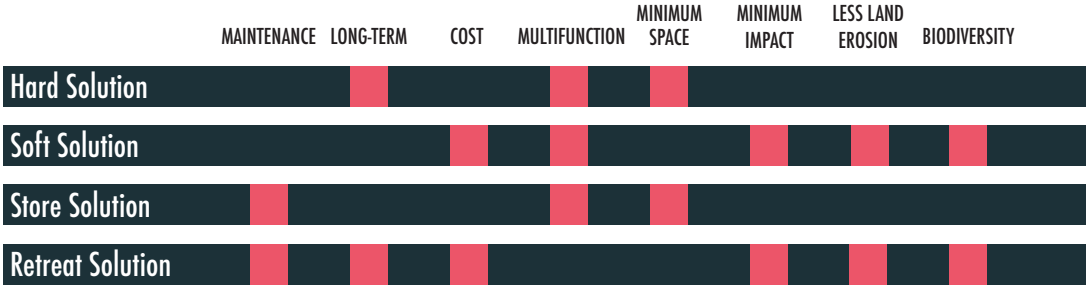
However, the historical value of buildings and the cost of relocating a whole area are still high. (24)

Retreat

Retreat strategy Rio Bogota, Colombia
Images source:http://wilchesespecieurbana.blogspot.com/2014/01/conversaciones-con-el-rio-bogota.html

Overdiepse polder, Room for the river, Netherlands
Images source:https://www.dutchwatersector.com/news/restored-to-full-glory-dwelling-mounds-for-flood-protection

Comparison Table



4.01.02 Conclusions

Working with sea-level rise and coastal protection is a complex task. It is evident in the solutions presented that any of them on their own cannot fully protect without harming the ecosystem. For that reason, engineering solutions are only viable if they are combined with green solutions.

Multipurpose solutions are not only going to protect the city. Also, it will provide recreational spaces that can transform the threat of sea level into an opportunity to improve the quality of life. Besides that, to compensate for the impact on the ecosystem that these solutions create, introducing more biodiversity into the site might balance the blue and green environment.

4.03 CASE STUDY KØGE BUGT

4.03.01 Background

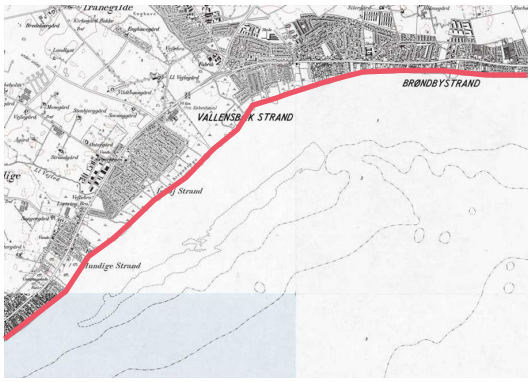
Køge Bugt is an area located in the south coastline of the Copenhagen metropolitan area. Low-lying lands and wetlands define the site. The 30 km of shoreline characterise by shallow waters and low exposure to wave energy from the open sea. (14) From the 1960s to recent days, Køge Bugt has been developed into a residential suburb as a part of the "finger regional plan". (20)

In 2011, the Danish Coastal Authority classified Køge Bugt as a flooding risk zone (14). Sea levels in 100 years are expected to increase by approximately 100 cm of the current level. (26) According to a report, nearly 180,000 people in six municipalities in the region are currently at risk of flooding. (26)

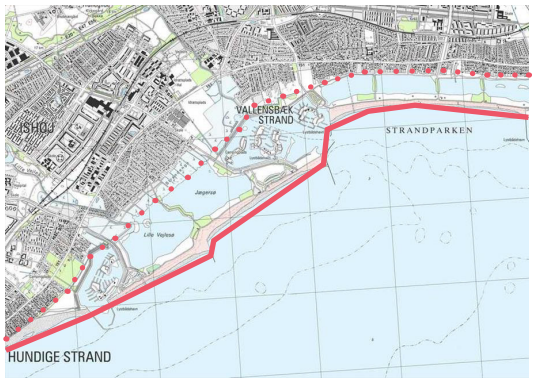
4.03.02 Solution

In the 1970s, the municipality decided to build an artificial island. The goal of this project was partly to protect the settlements on the coastline and increase recreational spots. (27)

The result of the project is a two offshore island connect with the mainland with several arms that create six lakes and 7 km of new coastline. The development includes beaches, sand dunes, vegetation and several marinas. (14) The floodgate system was designed to manage 3 m of rising sea level. (26) In addition, dikes were built under the dunes to reduce land erosion and absorb wave energy.



Køge Bugt coastiline in 1967
Images source:https://historiskatlas.dk/@55.6128610,12.3973650,16z



Køge Bugt coastiline in 1995
Images source:https://historiskatlas.dk/@55.6128610,12.3973650,16z

(26).**Strandparken.** Strandparken I/S, 2020. https://strandparken-kbh.dk/om-strandparken/.
(27).**Klimatilpasning.** Ministry of the Environment / Danish Environmental Protection Agency, 2020. https://www.klimatilpasning.dk/vaerktoejer/havvandpaaland/havvand-paa-land/.

The new islands have improved access to the sea from the settlements, have increased the biodiversity by introducing more vegetation and wildlife. Also, this project has demonstrated how soft solutions can combine recreational and floodable protection into one.

Section Køge Bugt

Køge Bugt offshore islands
Images source:https://strandparken-kbh.dk/strandparken-boer-vaere-danmarks-naturkanon/

Køge Bugt dunes
Images source:https://strandparken-kbh.dk/strandparken-boer-vaere-danmarks-naturkanon/

05

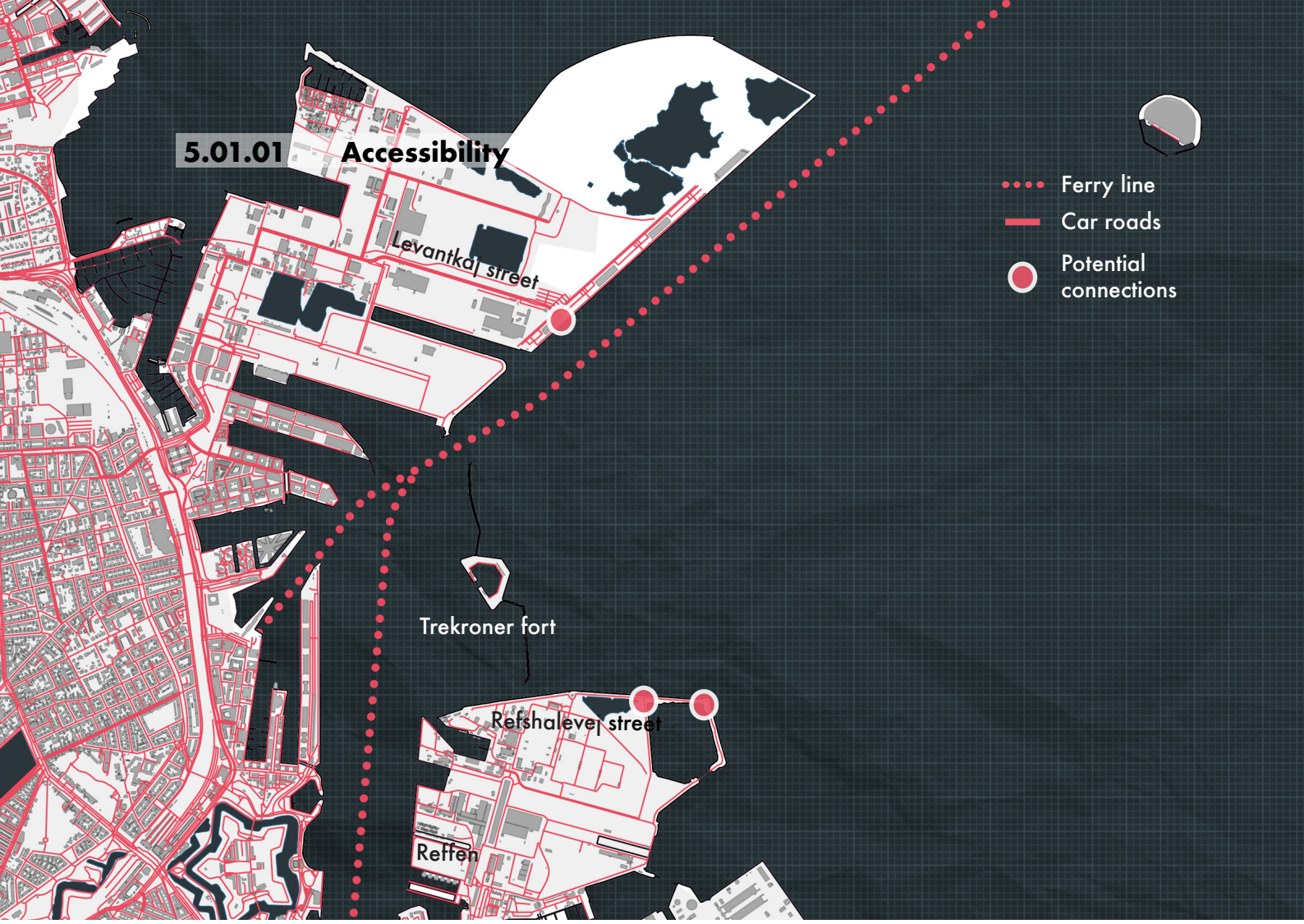
THE SITE

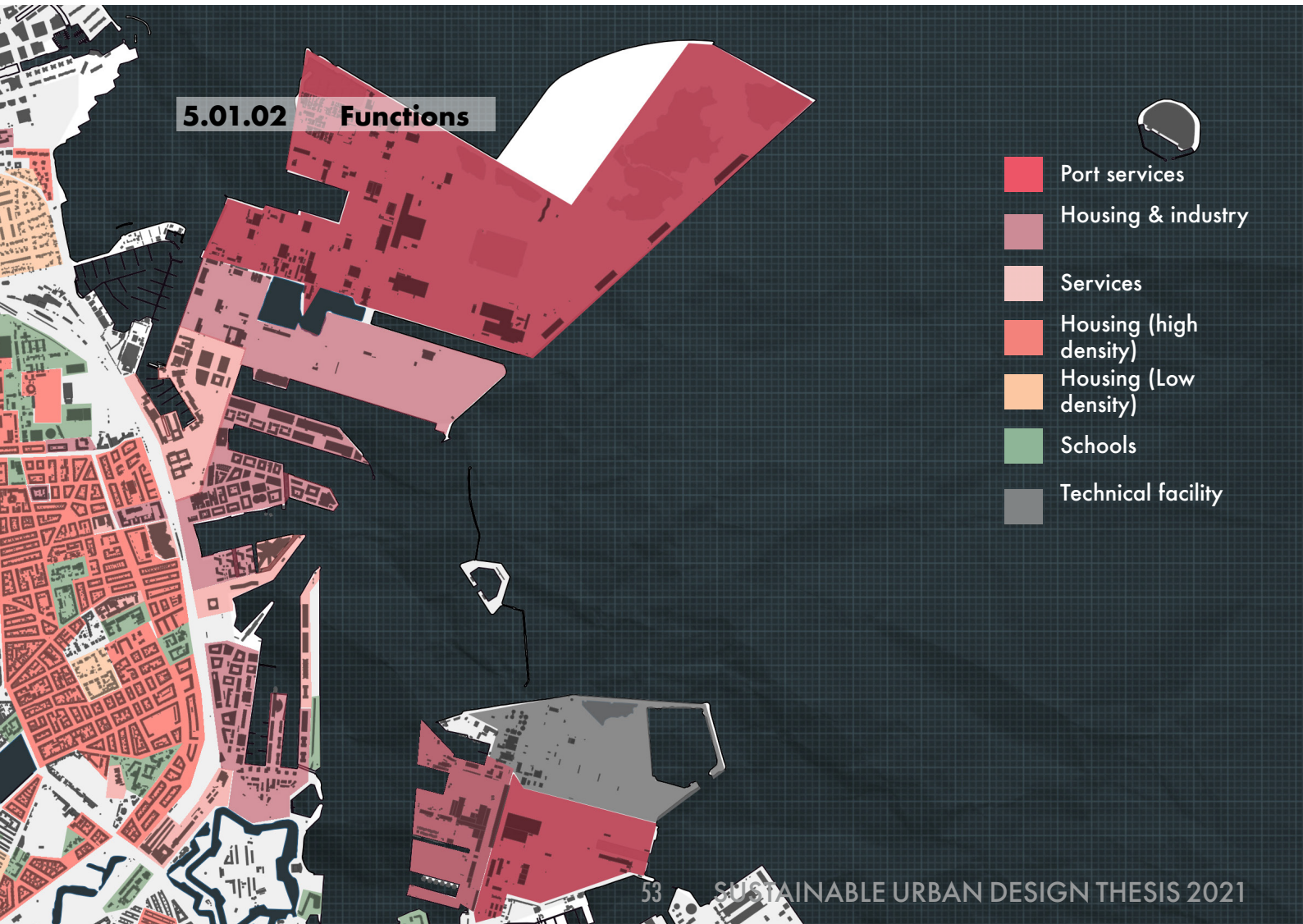
5.01 STUDY AREA

The site is located on the water between two former industrial islands Nordhavnen and Refshaleoen, at Copenhagen harbour entrance in the east part of the city. The variations in the coastline make evident the historical changes at the edge of the town.

Access to the site is possible by boat, and potential connections to the edge at Nordhavnen are by the road Levantkaj and from Refshaleoen is by the road Refshalevej at the edge of the area call Lynetten.

Nowadays, there is a transformation from industrial buildings into residential and mix-used facilities on the northern side of the site. A valuable historical asset is located within the area; the Trekroner fort now functions as a cultural and recreational centre. In the southern part of the site, industrial facilities dominate the landscape of the island. Water management plant and complimentary services are essential for the city infrastructure. However, the Reffen at the edge of Refshaleoen is well known as a commercial and creative space.


5.01.01 Accessibility
Levantkaj street
Trekroner fort
Refshalevej street
Reffen
Ferry line
Car roads
Potential connections


5.01.02 Functions
Port services
Housing & industry
Services
Housing (high density)
Housing (Low density)
Schools
Technical facility

5.01.03 Flooding risk

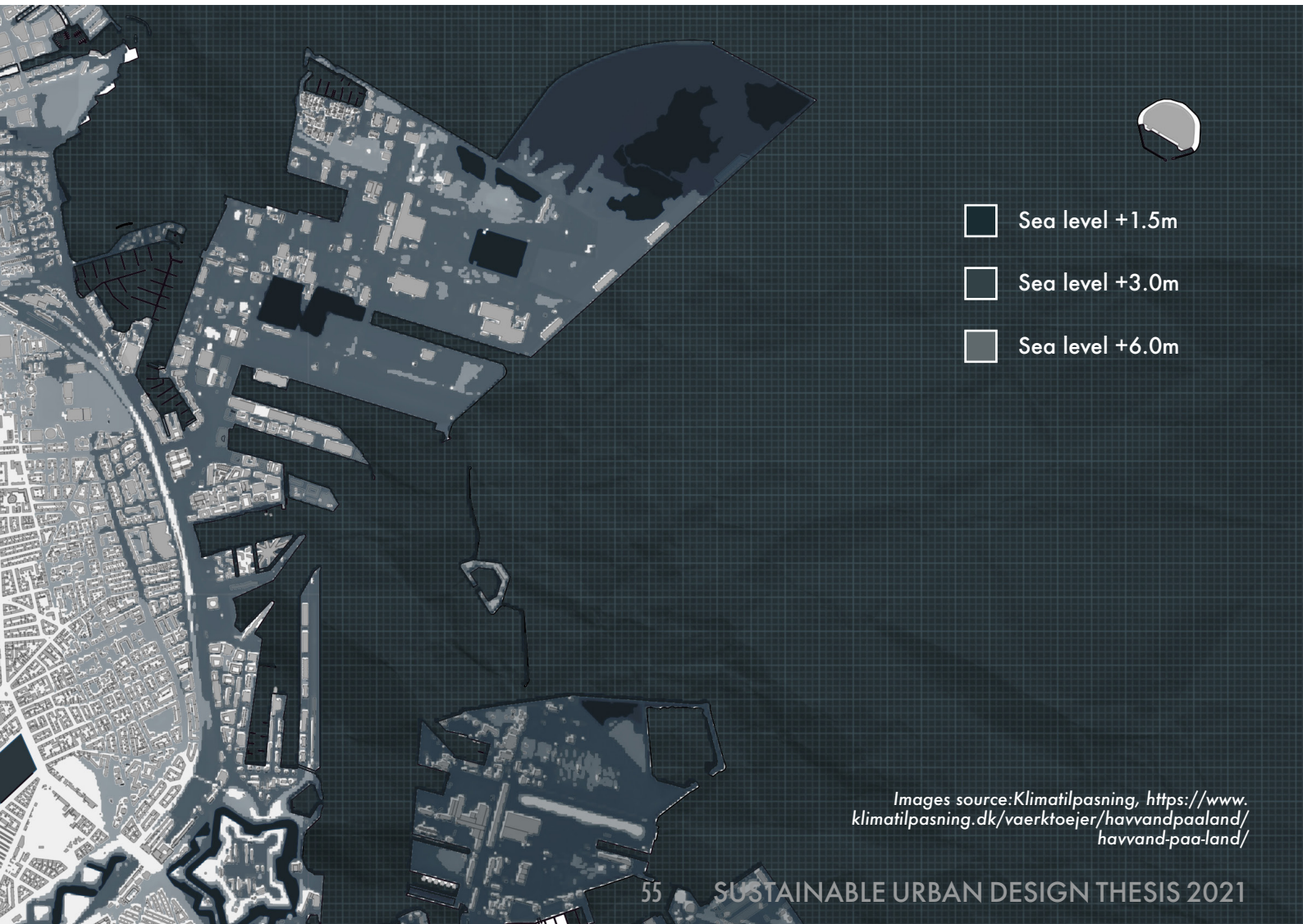
Infrastructure, historical buildings and living areas at the edge of Copenhagen are in danger of the effects of sea-level rise. This particular site falls into a significant risk of flooding. Taking the estimated predictions by 1.5 to 3.0 m of sea-level rise for 2100 (28) the city centre faces a substantial risk of flooding. With a 1.5 m high tidal, industrial area and commercial spaces will be damage. (28)

With 3.0 m higher than the current sea level, housing area, historical assets, and many of the economic generators of the area might be affected. (28) The most extreme prediction with 6.0 m higher than the current sea level, infrastructure, historical buildings and inner living areas will be damaged significantly. (28)

(28).**Kadri Kuusemäe, Sophia E. B. Nielsen, Mads N. Madsen, Bo Brahtz Christensen, Jesper Goodley Dannisøe.** Anlæg af Lynetteholm. Copenhagen : DHIs ledelsessystem, 2020.
(29).**Mårtensson, Ida.** Baltic Sea . 2021. http://www.balticsea2020.org/english/the-baltic-seas-challanges.

Images source:Klimatilpasning, https://www.klimatilpasning.dk/vaerktoejer/havvandpaaland/havvand-paa-land/

Images source:Klimatilpasning, https://www.klimatilpasning.dk/vaerktoejer/havvandpaaland/havvand-paa-land/



Images source:Klimatilpasning, https://www.klimatilpasning.dk/vaerktoejer/havvandpaaland/havvand-paa-land/

5.01.04 Water aspects

Water is one of the main concerns of the site analysis. Therefore, it is important to consider water aspects such as bathymetry, water ecosystems, and water flows in order to create a new island.

The area is located at the entrance of the central canal of Copenhagen from the Baltic sea. The area is characterised by shallow water with a depth range from -2 m to -14m of sea level. (29)

The main water flow is directly north, coming from the South of the Baltic sea. (29) The Baltic sea is described as a species-poor ecosystem. (30) However, an eelgrasses area around the Trekroner fort was introduced as a strategy to reduce land erosion and improve water quality. (29)

The information described will help me shape the new islands considering land erosion and more efficient use of natural resources.

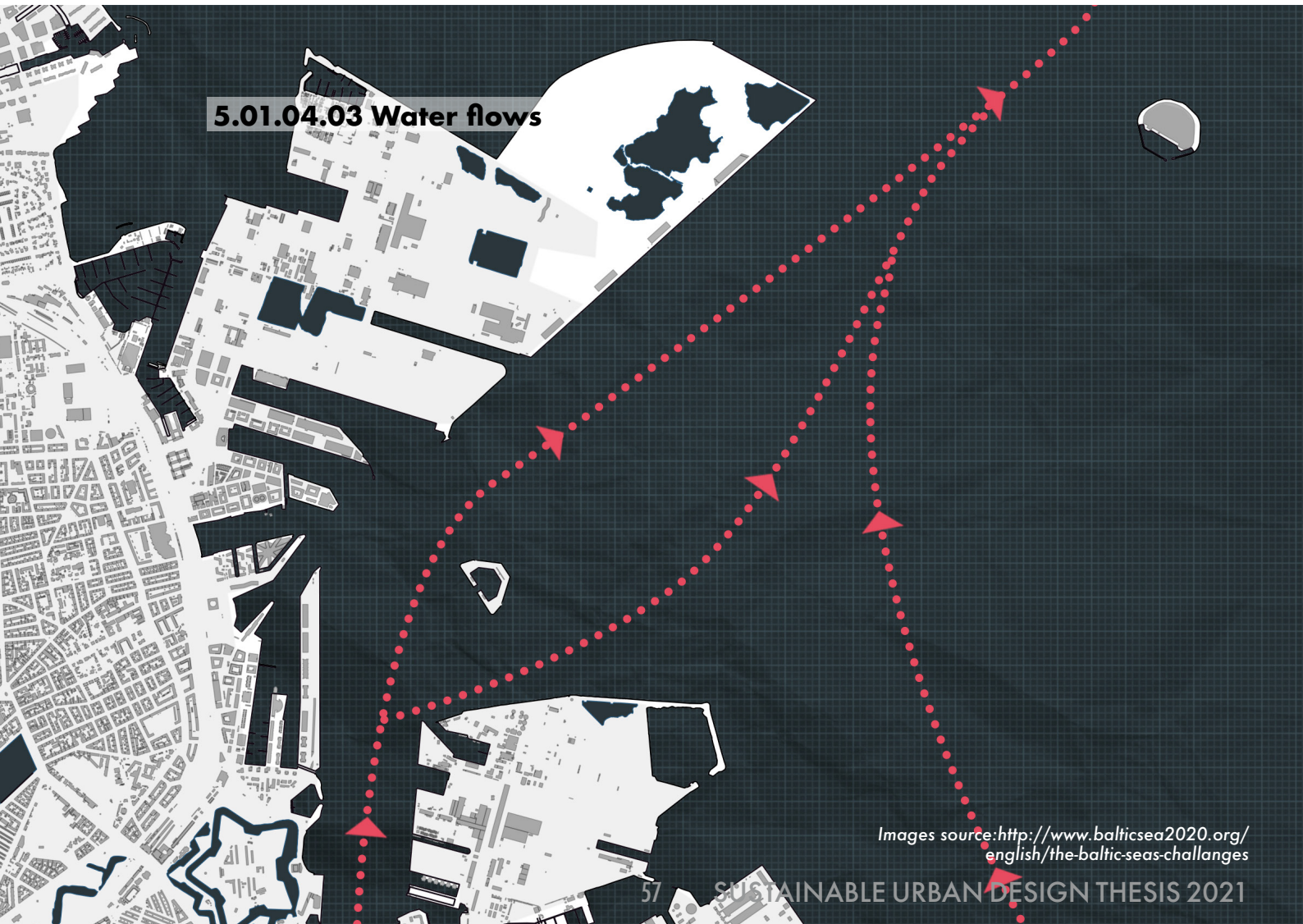
(30). **Kobenhavns Kommune about the municipality.** Kobenhavns Kommune, 2018. https://www.kk.dk/lynetteholm.

Images source:Anlæg af Lynetteholm, report, 2020

5.01.04.02 Water ecosystem

Images source:Anlæg af Lynetteholm, report, 2020

5.01.04.03 Water flows



Images source:http://www.balticsea2020.org/english/the-baltic-seas-challanges

5.01.05 Municipality plan

In 2018 Copenhagen municipality has announced the construction of a new island as a response to sea-level rise. The design proposal is based on the adaptation plan 2011, (8) in which different solutions are explained in order to protect the city from flooding events. However, the municipality has decided that coastal protection should have other purposes rather than only flooding protection.

The final proposal is a new district that includes housing, offices and recreational spots. The area referred is linked with the coastal protection plan along the edge of Copenhagen. The site is planning to create a space for 35,000 inhabitants and many jobs opportunities.(31)

The island is connected in the South with the Refshaleon area. A floodgate is proposed in the north to control the sea-level rise. (32)

(31). **Rambøll.** PORTLØSNINGER I KRONLØBET. Copenhagen : Københavns Kommune, 2019.

Images source: https://en.klimatilpasning.dk/media/568851/copenhagen_adaption_plan.pdf

5.01.06 Site visit

The site visit aimed to identify the accessibility and potential connections to the new islands. Also, to understand the functions and typologies of the surrounding area.

During the site visit, I identified the disconnection between Nordhavnen and Refshaleon. Both areas are located 1.5 km away from each other. However, to reach one place from the other takes about 45 min with the closest route via the city centre.

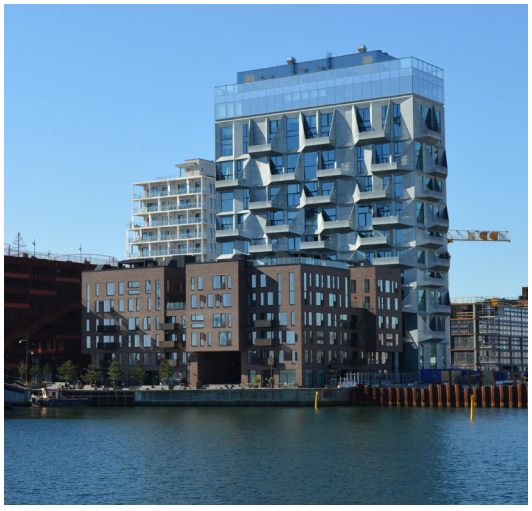
Refshaleon has industrial functions needed for the city infrastructure, such as the water management plant. On the other hand, Nordhavnen has mixed-use functions. The current harbour activities are planned to move to another location to create a new and vibrant residential area.

Another important asset of the study area is the Trekroner fort. A historical building that nowadays is a landmark of the site. It is possible to reach by boat and offer recreational activities during summer.

Trekroner fort


Refshaleon


Nordhavnen



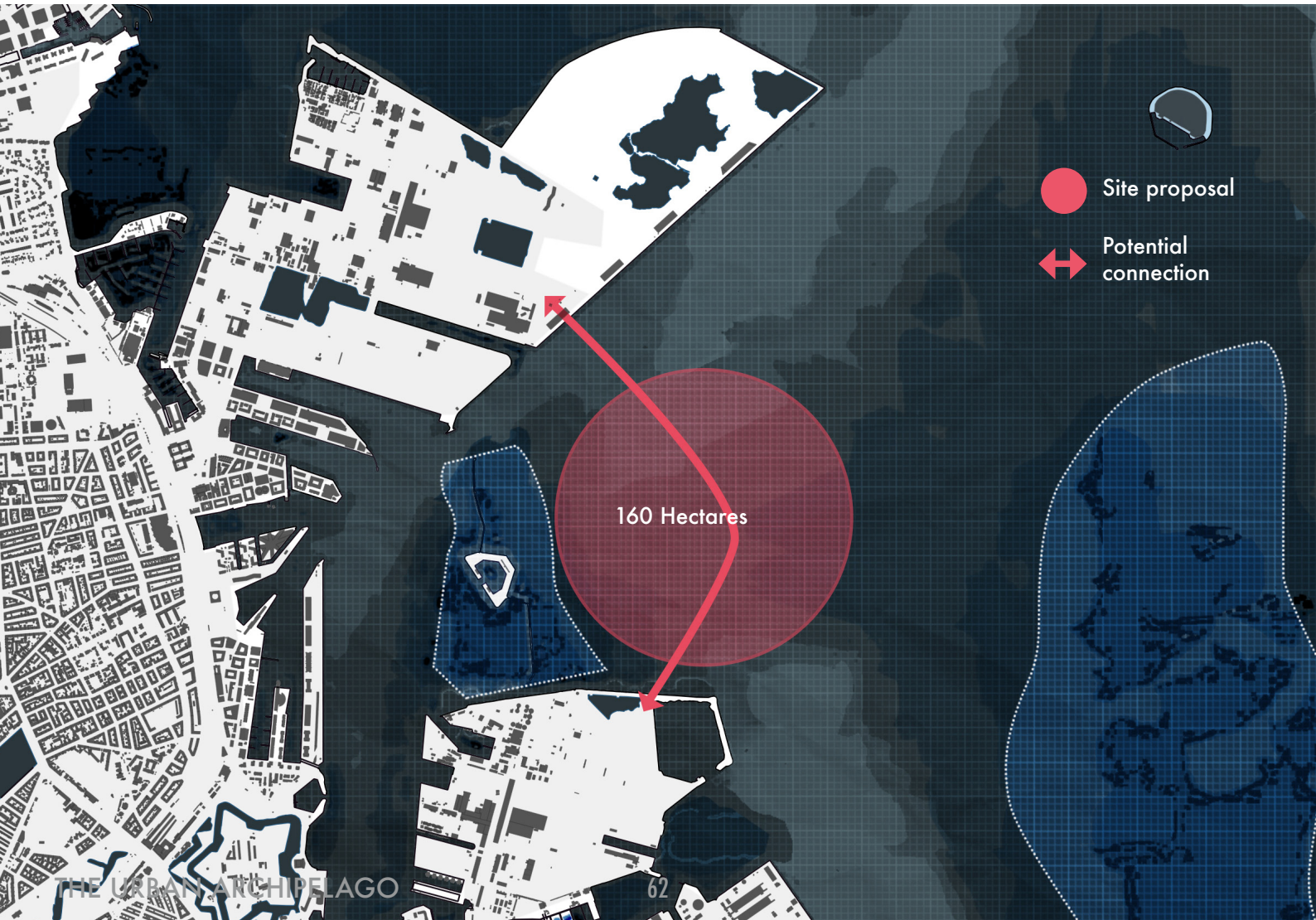

Refshaleøen
EVERGREEN

5.02 SUITABLE AREA

After the site analysis, I overlapped the different layers in order to find the most suitable area for the design project. The site lies in the middle of the room, taking into consideration the bathymetry to reduce the number of sand needs it to fill the land. The restrictions delimit the site's boundaries to minimise the negative environmental impact and the good function activities. The area is potentially connected by road and metro line following the existing roads on both sides of the island.

5.02.01 Spatial analysis

Lynetteholmen will be a large development project with approximately 160 hectares. Spatial comparison between four different areas is conducted to understand the scale of the area. The analysis started fitting the city centre of Copenhagen, the neighbour district of Nordhavnen, the well-known area of Vastra Hamnen and the new section of Hafen city in Hamburg, in the area of 160 hectares to compare density, scale, green spaces and urban pattern.



As a result, I identified the qualities of more minor dense areas that allow more green and recreational areas. On the other hand, dense regions such as the city centre of Copenhagen is narrowed within its boundaries for further development. Also, the low amount of sun exposure in outdoor spaces reduces recreational activity.

Nordhavnen
360 Hectares
40,000 Inhabitants
Density 111 x ha

City centre
100 Hectares
58,100 Inhabitants
Density 581 x ha

Vastra Hamnen
185 Hectares
20,000 Inhabitants
Density 108 x ha

Hafen city
127 Hectares
14,000 Inhabitants
Density 110 x ha

5.03 DISTRIBUTION OF SPACE

Copenhagen general information

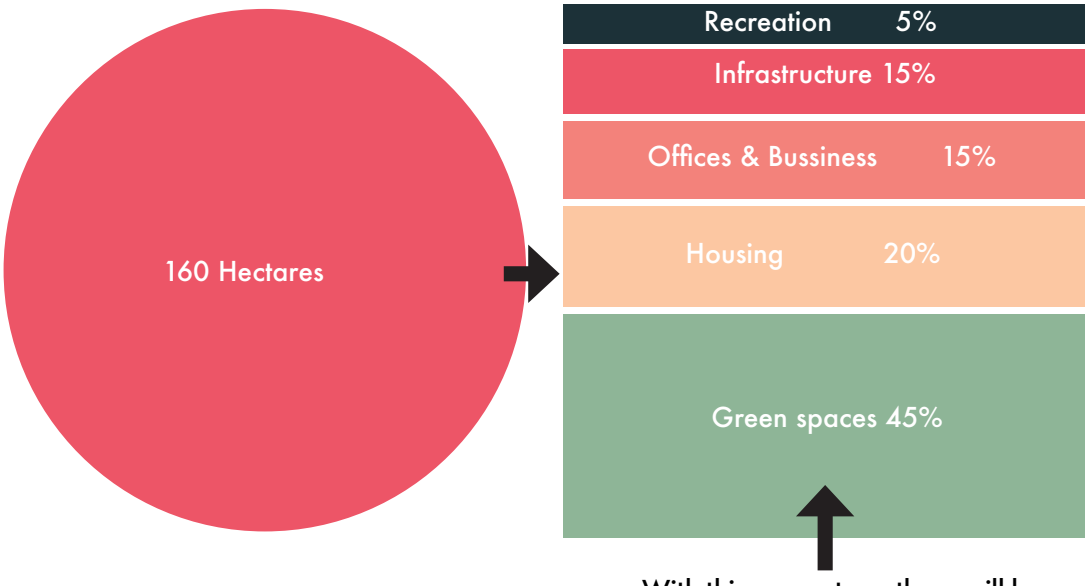
- Copenhagen has 31.91 m2 of green areas x person
- Copenhagen has 25% of its surface in green areas
- Copenhagen has and average household of 2.1 persons x house
- Copenhagen has a population growth rate 0.90% in 2019 = 13,000 new inhabitants

Site proposal

(Based on analysis of different projects, reccomendations of Copenhagen municipality and World Health Organization)

- 140 -160 Hectares
- 20,000 - 25,000 Inhabitants
- 10,000 - 12,000 Houses (2.1 persons x house)
- 10,000 - 15,000 Workers
- Density 142 persons x ha / 156 persons x ha
- 4 - 12 Stories buildings
- 30 Years of develped with 3.3% yearly growth rate = 666 new inhabitants every year = 5% of the total Copenhagen growth rate

Distribution of space

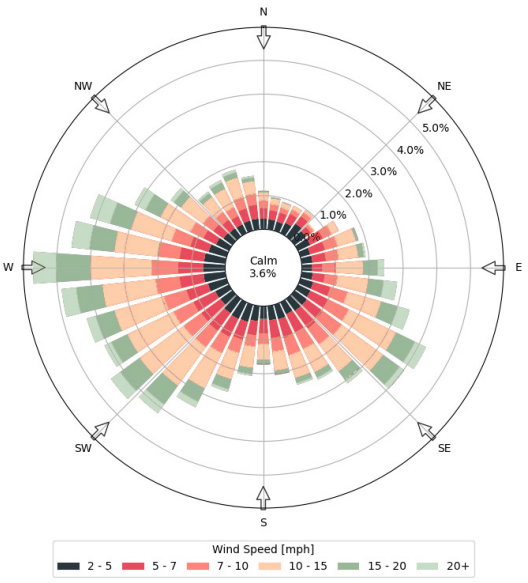


With this percentage there will be 32 m2 of green area x inhabitant

5.04 CLIMATE

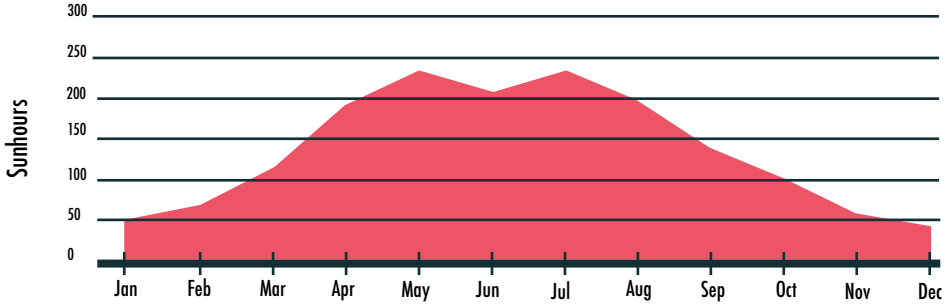
5.02.06 Climate

Copenhagen is exposed to a relativity high wind speed primarily coming from the southeast. Half of the year, the city has long sun exposure and medium to high temperatures. As a consequence, the project design needs to take advantage of microclimate qualities. Open spaces and good orientation will enhance sun exposure. Moreover, greenery and asymmetric urban fabric will protect the urban areas from strong wind.



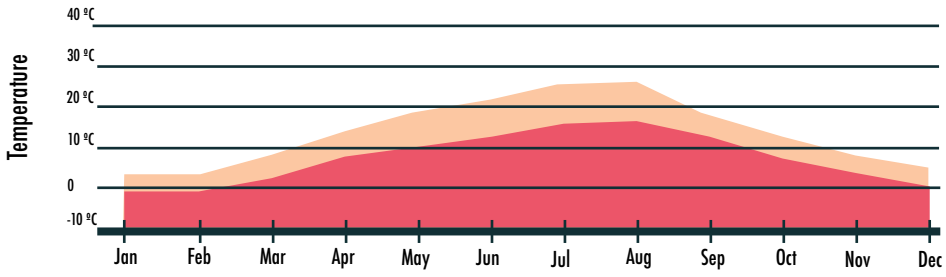
Graph source: https://mesonet.agron.iastate.edu/sites/windrose.phtml?station=EKAH&network=DK__ASOS

Monthly hours of sunshine



Graph source: www.weather-and-climate.com 2020

Average day and night temperature



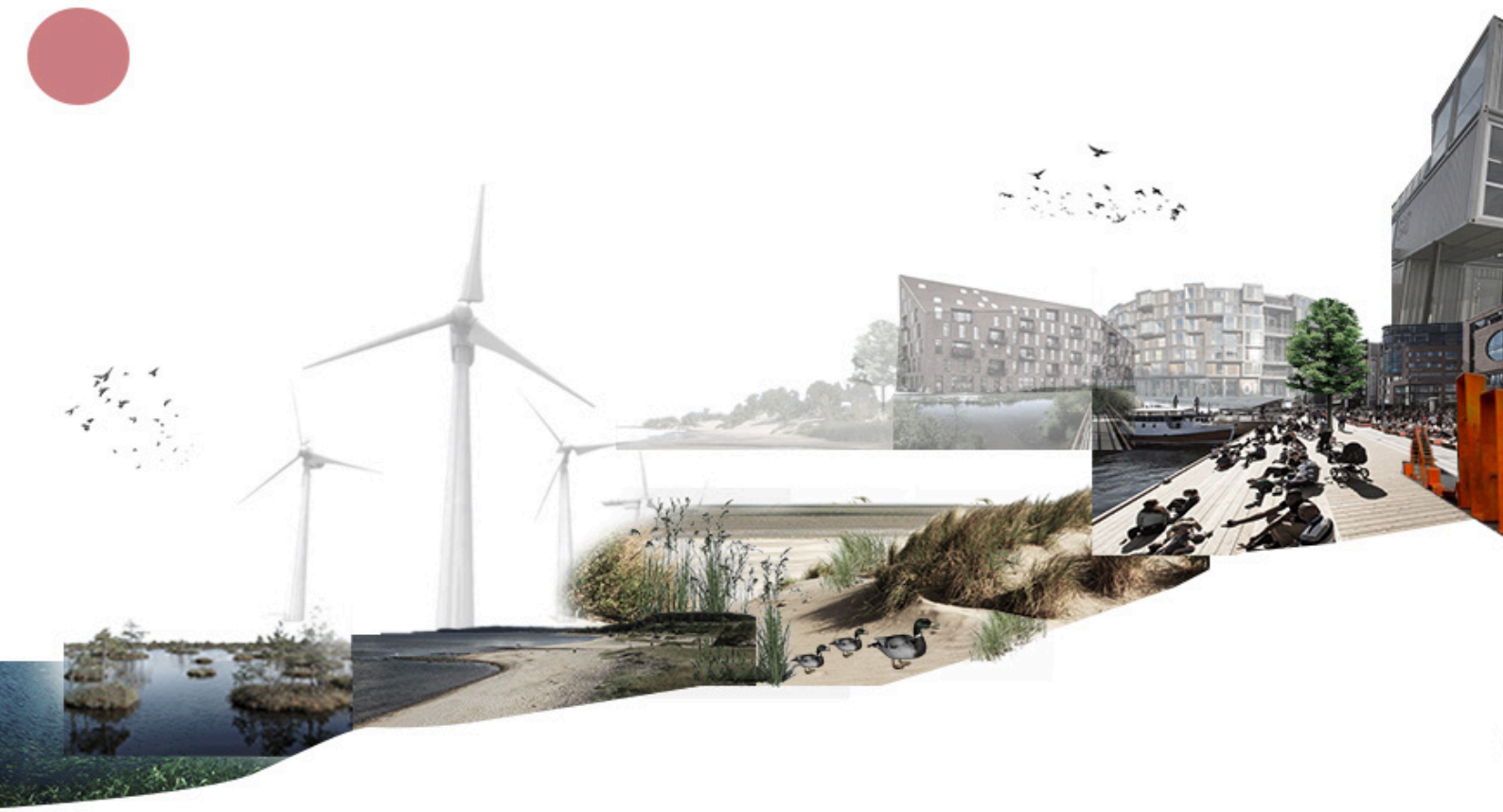
Graph source: www.weather-and-climate.com 2020

06

VISION & STRATEGIES

6.01 VISION

A sustainable and resilient district that combines climate protection with urban design into one.



6.02 IDENTITY

The outdoor district

The urban archipelago offers unique proximity between urban life and outdoor activities. This uniqueness goes beyond the physical characteristics of the city. From biodiversity to the economy, everything is expected to grow outside.

The new district creates a new urban ecosystem that adds a new layer to the Copenhagen green infrastructure. These will increase the resilience capacity of the site and the quality of life for the residents.

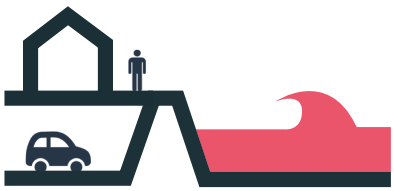
6.03 DESIGN STRATEGIES

6.03.01 Design principles

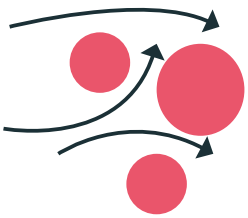
The project proposes guidelines based upon the site analysis and site visit that will shape the design of the urban space.

Protection: The proposal must provide strong protection against sea-level rise that ensure long-term district development

Multipurpose: Coastal protection should have a different purpose in order to reduce financial cost and take advantage of the extensive infrastructure provided. Recreational spots can be the solution as potential activities that occur in a layer about protection.



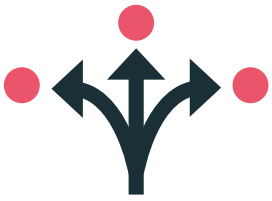
Minimum damage: The design has to consider the least possible impact on the water ecosystem. Spreading the masses of land will keep the current water flows.



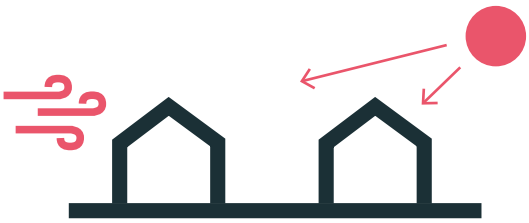
Green: The design proposal should create a new green lung for the city. It will enhance the green network and add value to the city.

Biodiversity: The idea is diversifying the landscape proposed in order to improve the green habitats that allow new flora and fauna within site.

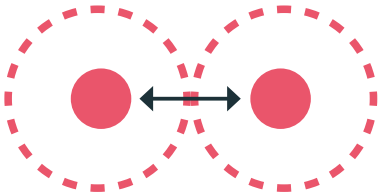
Flexible and adaptable: The project needs to adapt for the future. Allowing squares to became buildings or ground floors to commercial areas will ensure long-term development.



Microclimate: In the Nordic climate, sun access and wind protection need to be considered to reduce energy waste and ensure outdoor activities.

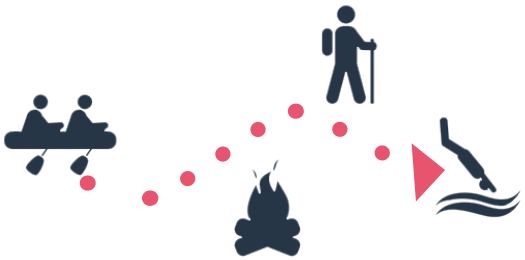


Connectivity: Access to the new islands must be created. Also, the proposal will ensure the basic need within a ratio of 5 min cycling distance of any place in the area.



Social Interaction: Urban spaces should establish centrally and connect with generators and mobility nodes to improve social interaction.

Leisure: The project should implement a range of recreation spots that create an identity of the area. These spaces will bring value and job opportunities to the residential area.



Pedestrian and bike priority: There is an opportunity for the design proposal to reduce car dependency by creating a safe and friendly walkable and cycling area

Enhance Identity: All principles described will improve the urban qualities of the city. As a result, creating a stronger connection between the users and place that enhance Copenhagen identity.

6.03.02 Site strategies

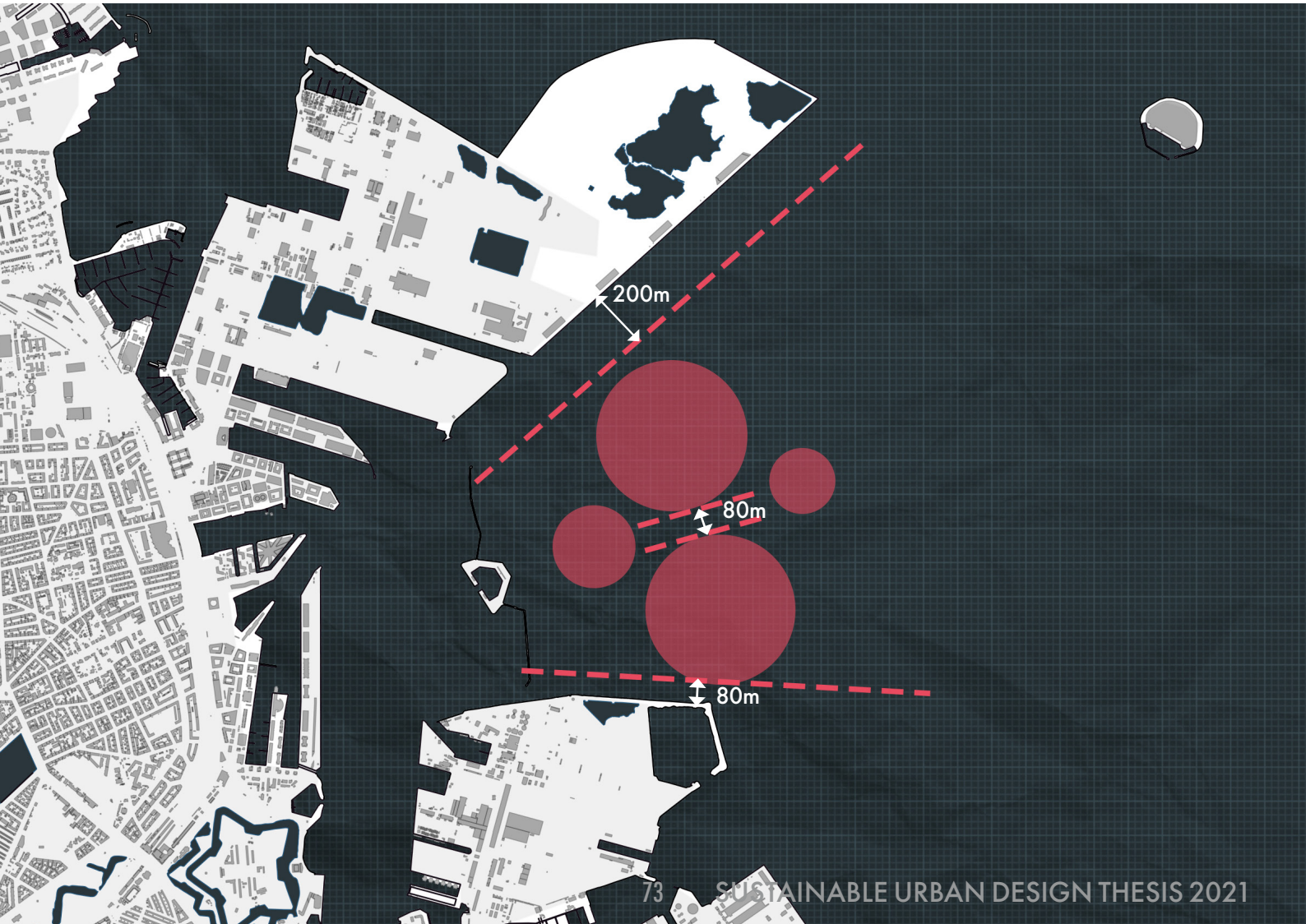
Land erosion: The design focus on creating a few islands to reduce the impact on water flows. Several waterways will help to reduce wave energy and delay land erosion of the filled land (32).

More extensive protection is needed at the southeast of the site to defuse the strongest water flow from the Baltic sea.

(32). **Afrapportering af forundersøgelse af metrobetjening af Lynetteholm.** Copenhagen : Københavns Kommune, 2020.

Canal restriction: The proposal adapts to the existing harbour activities that are in surrounding areas. A 200 m restriction for the primary canal (32) will keep the possibility that larger ships can come in and out to the harbour area. The secondary water access that the proposal is suggesting are following the regulations of an 80 m distance between the two islands to allow small and medium boats (32).

These canals will give service to residents and recreational activities. All water accesses are planned to have a floodgate that controls the sea level rise in extreme conditions.

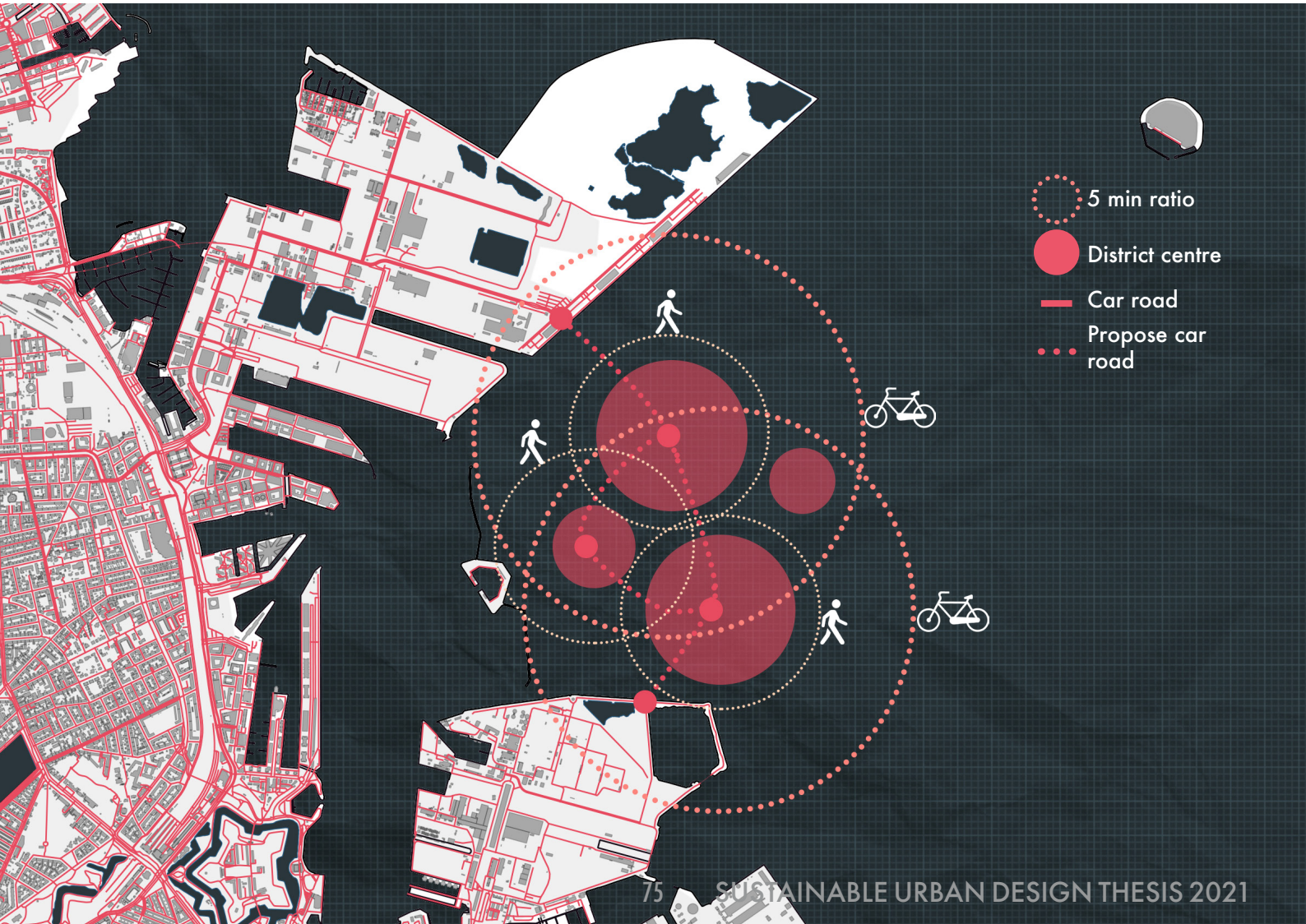


Flood protection: A new layer is proposed to protect the city centre. Shifting the flood protection to the edge will grant more space for further developments.

In addition, the new layer has the opportunity to enhance the front area by implementing green solutions that link the grey with the green structure.

5 min city: The new district considers walking and bike distance in order to size the new islands. A centre is placed on every island to centralise essential services and facilities. The users will be able to reach these services within 5 min distance from their homes.

Car roads are connected from the Nordhavnen area to the Refshaleoen island along the cores of each island to allow different transportation methods.



Accessibility: : Following the 5 min city strategy, the design proposal includes two metro stations within the larger islands. These stations are connected to line 4 and with the future metro plan (33), in which two new lines are going to join the new neighbourhood with the city centre.

As a result, the residents will have the opportunity to reach other districts within the 5 min distance from their home place.

(33). **World Ocean Review.** 2017. https://worldoceanreview.com/en/wor-5/improving-coastal-protection/coping-with-rising-sea-levels/.

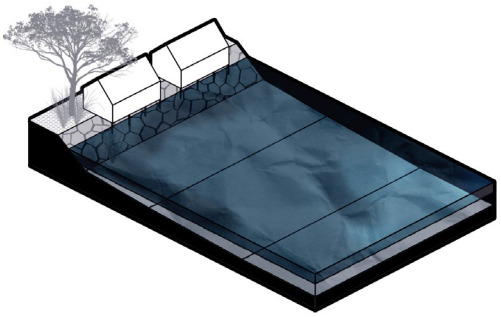
6.03.03 Living shorelines

The shoreline idea for the project regarding flood protection is based on the "living shoreline" concept. A strategy that use plants, sands and limited hard solutions to ensure coastal protection. This approach reduces land erosion, protect the coastal ecosystem and help reduce the effects of storm surge. (24) According to the research "Ecosystem-based coastal protection", vegetation reduces the waves high of about 50 to 70% before reaching the shore. (34) I developed a toolbox that classifies hard and soft solutions that the design needs.

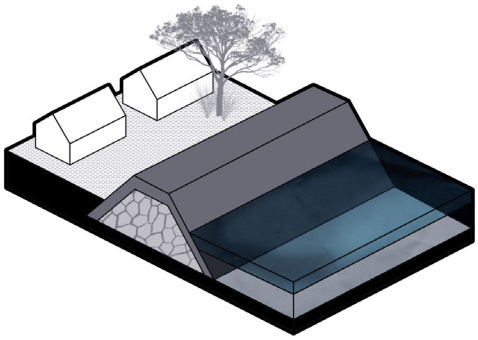
6.03.03.01 Hard solutions

These flood solutions are often permanent concrete structures. The proposed strategy is to minimise the use of this solution. Dike structure and water floodgate are only presented for areas where restriction or lack of space make not possible a soft solution.

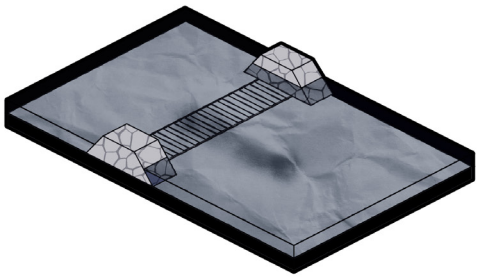
Current situation



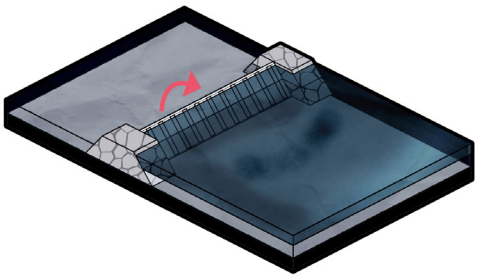
Hard solution (Dikes)



Floodgate open



Floodgate close



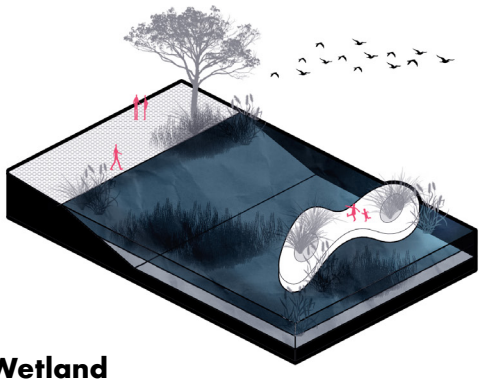
(34). **Stenak, Morten.** De inddæmmede landskaber: en historisk geografi. s.l. : Landbohistorisk Selskab. , 2005.

6.03.03.02 Soft solutions

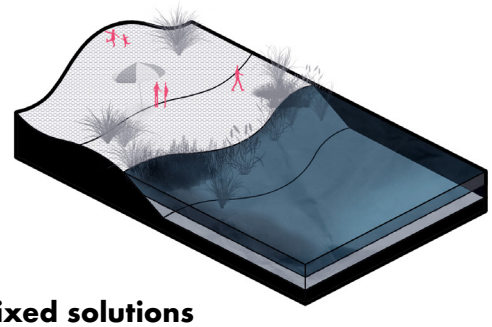
Soft interventions utilise ecological principles to reduce erosion and stabilise the shore (24). Large spaces in combination with diverse vegetation create a space where recreational activities can take part. Reef & eelgrasses solution is implemented to improve the water quality and increased biodiversity in the water ecosystem. Dunes and wetland interventions are applied in the most exposed areas to absorb the wave energy and delay land erosion.

A mixed solution is a combination of several elements to prevent any failure. This strategy implements offshore island, dunes, small dikes and water storage in parking spaces as the last protection.

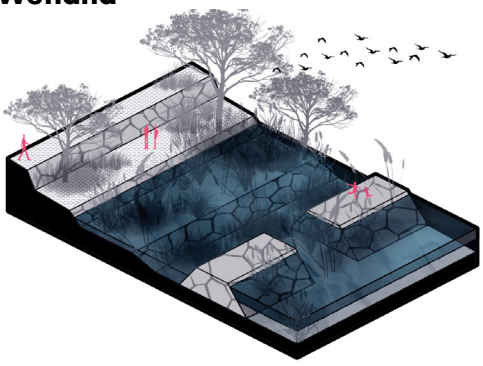
Reef / Eealgrases



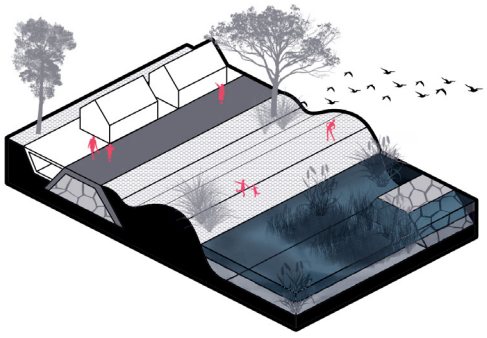
Dunes / Beach nourishment



Wetland



Mixed solutions



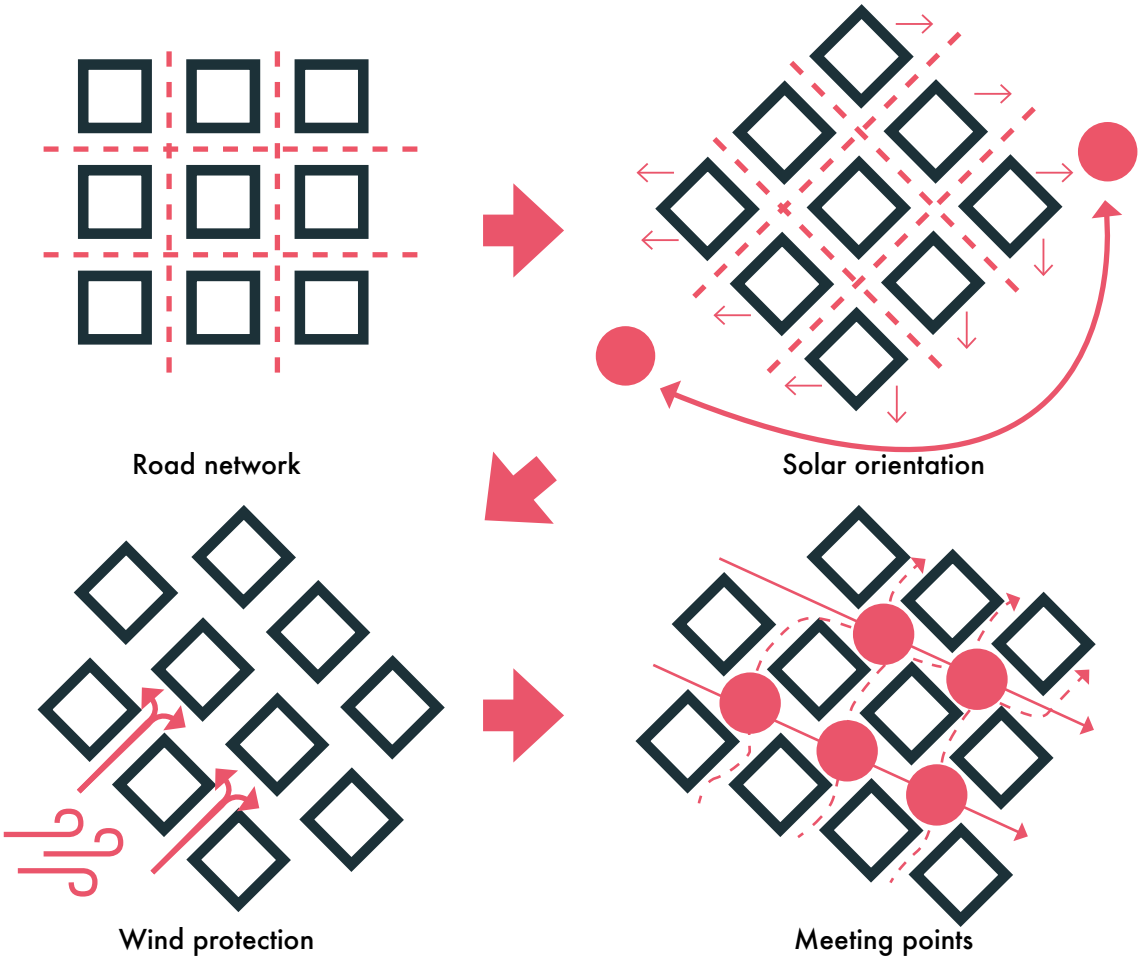
6.03.04 Neighbourhood strategy

The neighbourhood design started defining a symmetric grid pattern of 80m x 80m. This dimension based on the average block size that I observed in the Copenhagen plan. The grid pattern helps to organise the road network and define public spaces.

Secondly, to ensure better sun access to every building and urban spaces, the urban structure rotates 45°.

Thirdly, to improve urban spaces, a few blocks are slides slightly southeast to reduce wind exposure.

Finally, in order to create meeting spaces, small squares are conceived in between buildings. These spaces result from shaking the grid pattern to increase the urban areas at the block corners.



07

DESIGN PROPOSAL

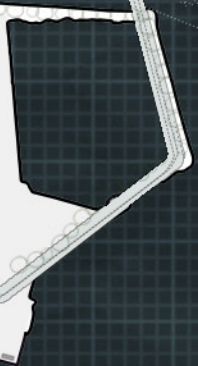
7.01 MASTER PLAN

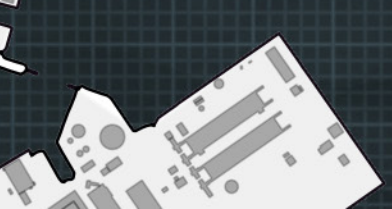
Project stats

140 Hectares

20,000 Inhabitants

Density 142 x ha





7.01 Master plan

The Master plan proposes an ambitious long-term vision for the study area. Regional and local strategies work as a fundament for this design proposal.

Lynetteholmen maintain Copenhagen strategy of claiming land to the ocean. Therefore, the design proposal is designed as an urban archipelago on the water. These islands will be filled with the surplus sand that the city is extracting from the new metro lines and buildings around the city. The main concept is to defend the city infrastructures by adding a new layer to the city to take care of the threat of sea-level rise.

The layout interprets Copenhagen's history by creating urban spaces and typologies with similar dimensions, scale and qualities. Additionally, the living shorelines approach is implemented to the form in order to deal with flooding and land erosion. This idea is a way of addressing one of the most significant challenges of coastal cities these days.

The living shorelines establish a green loop around each island, including promenades, squares, and green spaces such as beaches, wetlands, forest and reefs. These public spaces are reference points for visitors or residents.

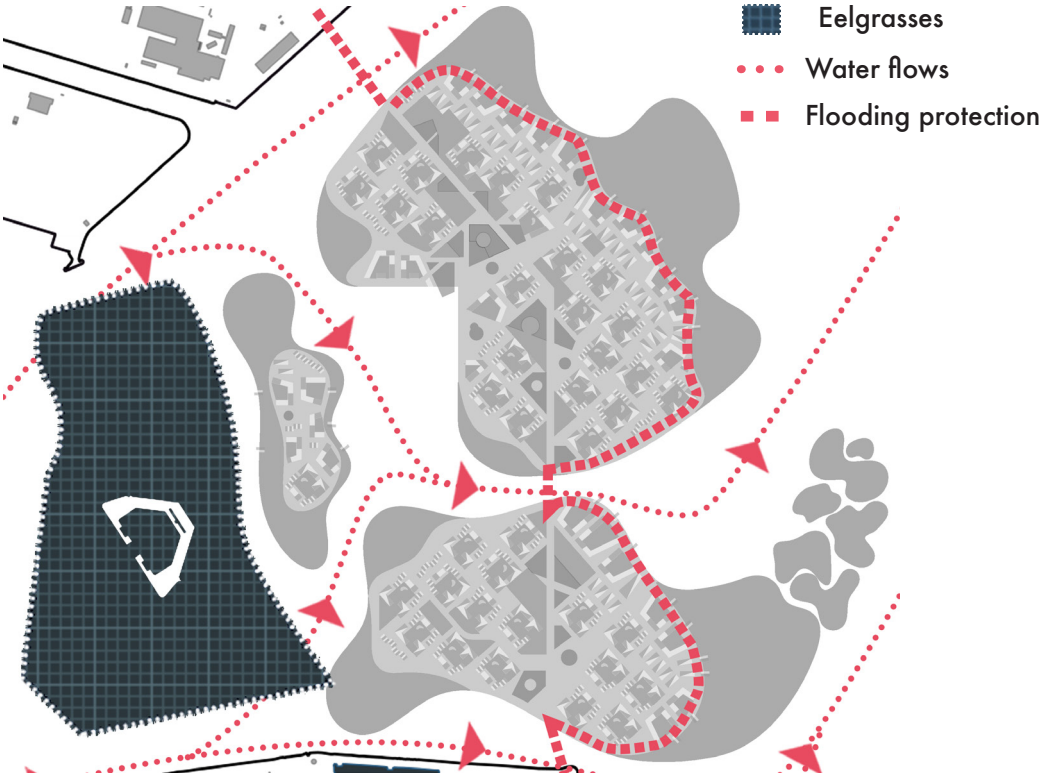
The street network is conceived as a mixed-use road that connects the individual islands and Copenhagen. The main bike-car road emerged as the main connector to the site; for this reason, an independent bus line and an underground metro line along the route are proposed.

During the first development phase, the beach and wetland islands are coming alive. The metro stations and access are built. Additionally, first jobs generators and apartment buildings around the centre of the island are implemented.

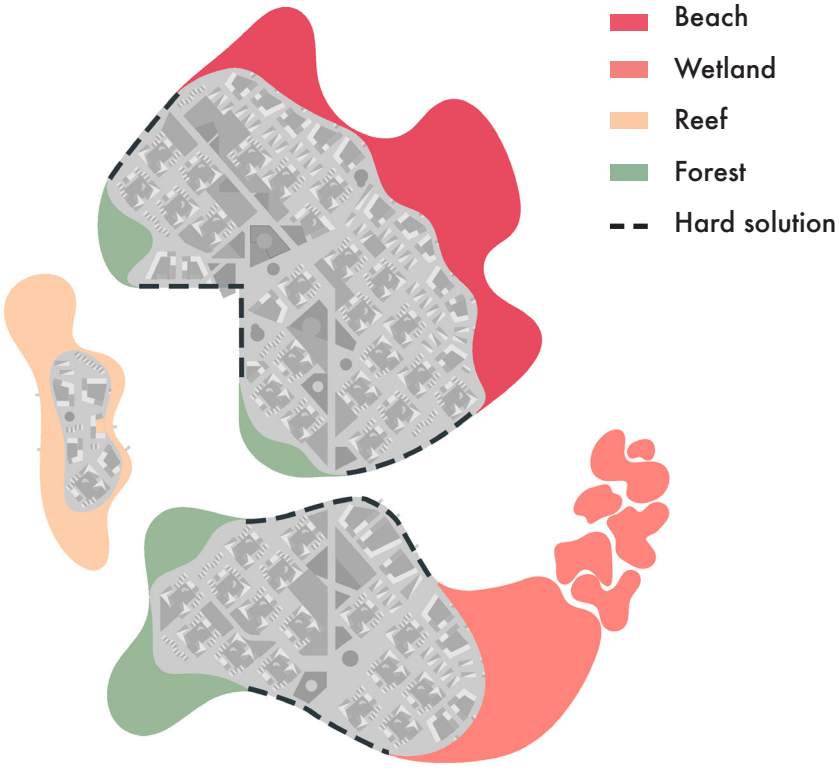
Ten years later, the urban archipelago evolves by adding new developments along the edge and recreational infrastructure in the shorelines. Also, the addition of a new island complement and create an active waterfront.

In 40 years, Lynetteholmen will become a vibrant district, providing room for 20,000 people and jobs opportunities. Furthermore, it will ensure the existence of the historic centre by dealing sustainably with the future effects of global warming.

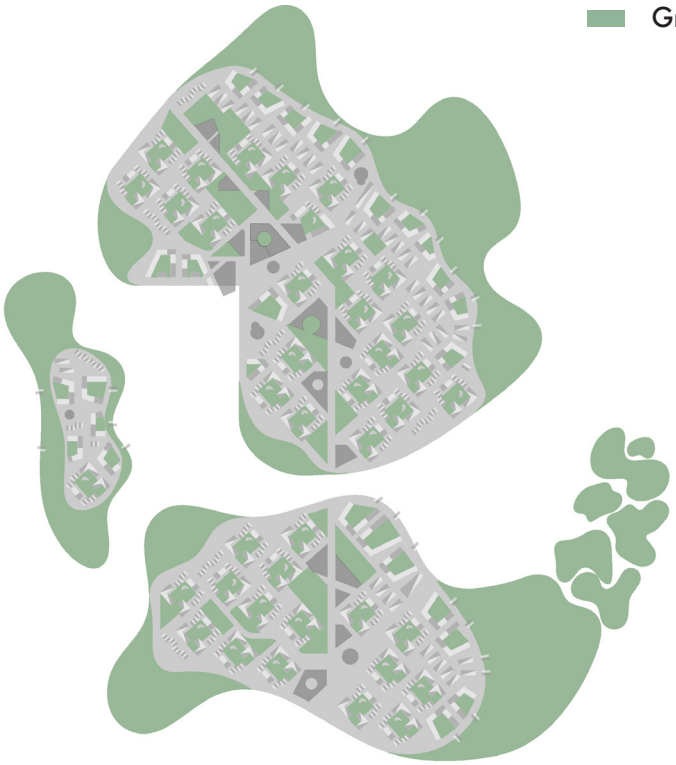
Shape reasons



Shoreline

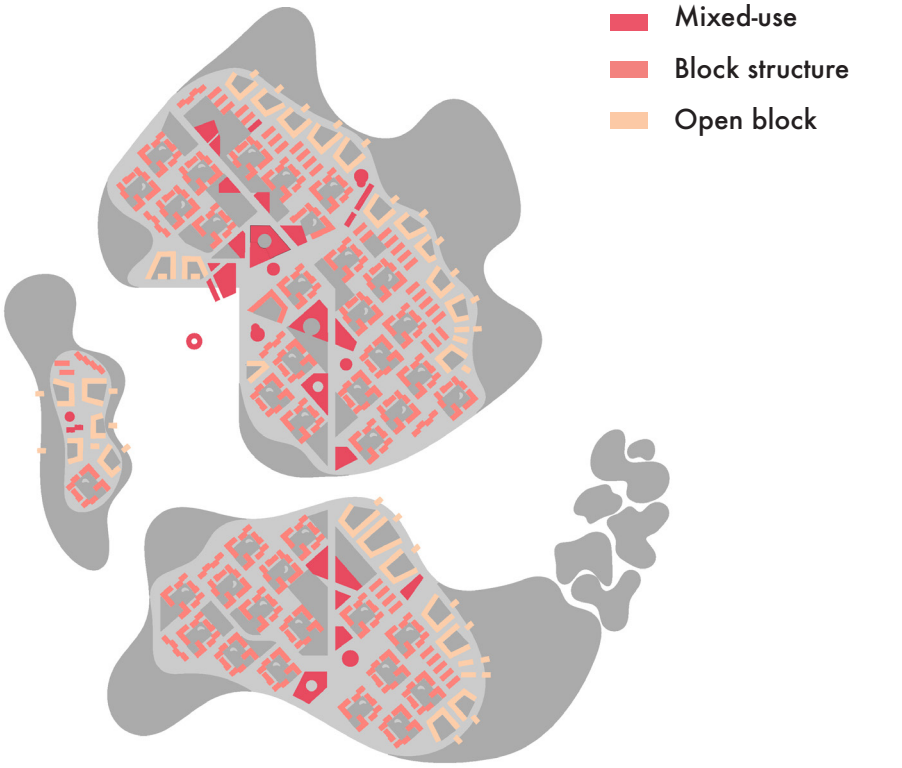


Green network

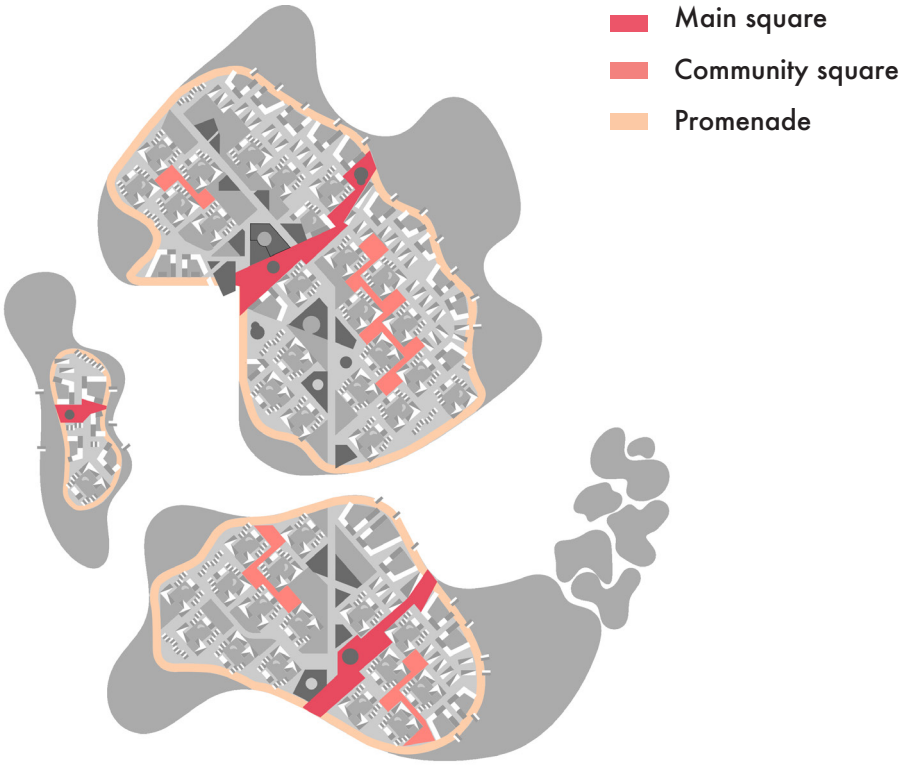


Road network

Typologies



Key places

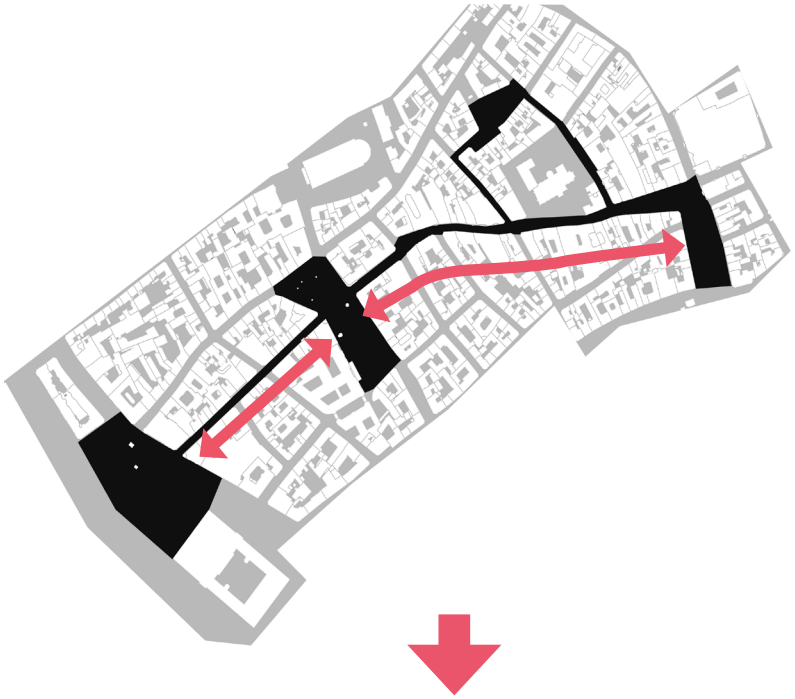


Benchmark cases

Stroget (Copenhagen city centre)

Why I selected it

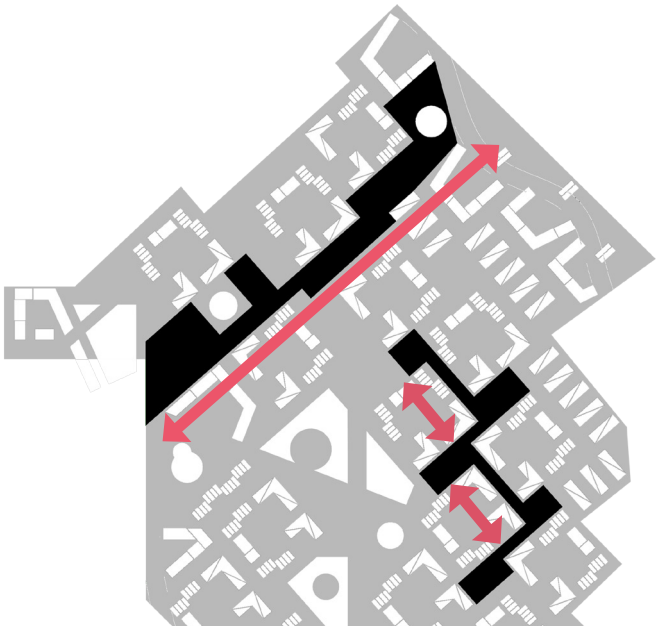
- Meeting point
- Hierarchy
- Node
- Size
- Transitions
- Variety of urban character
- Program
- Flexibility



Urban Archipelago (Key places proposal)

What I learned

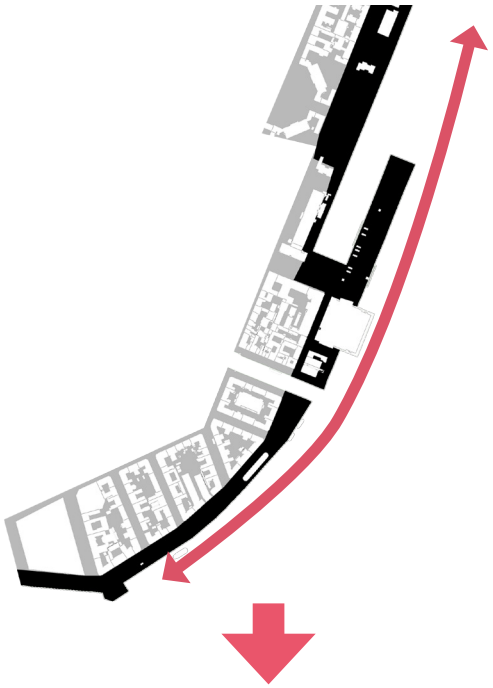
- Hierarchy of spaces
- Transitions between squares
- Scale
- Importance of urban character
- Creation of generators
- Implement transportation nodes
- Flexibility



Waterfront (Copenhagen city centre)

Why I selected it

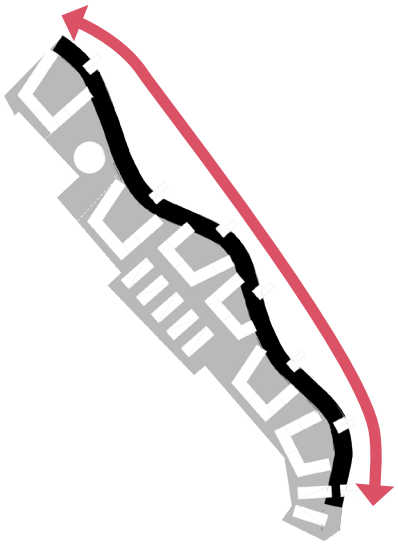
- Adaptability
- Shape variation
- Scale
- Variety of urban Program
- Flexibility
- Interaction with apartment buildings



Urban Archipelago (Key places proposal)

What I learned

- Flexibility in every space
- Open and close spaces create a dynamic shape
- Hierarchy of spaces
- Variety of urban program
- Creation of generators
- Greenery implementation



7.01.01 Time perspective

Phase 01 (2040)


0
100
200
300
400


Phase 02 (2050)


0
100
200
300
400

Phase 03 (2060)


0
100
200
300
400

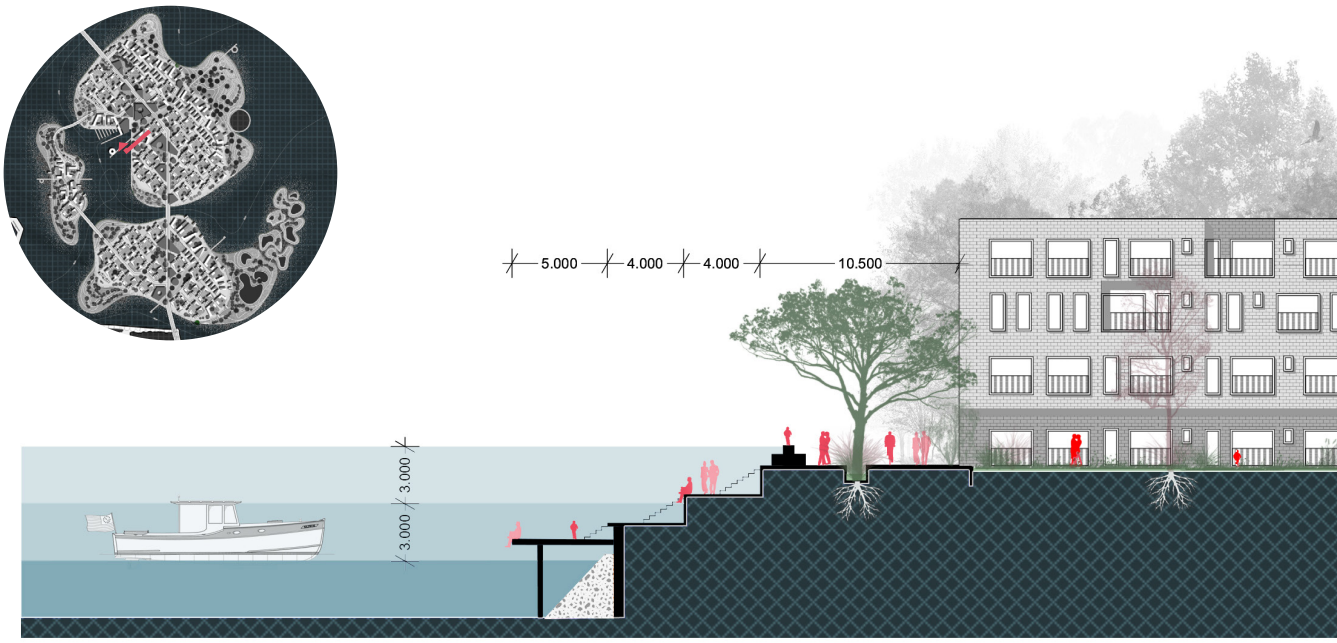
Urban program

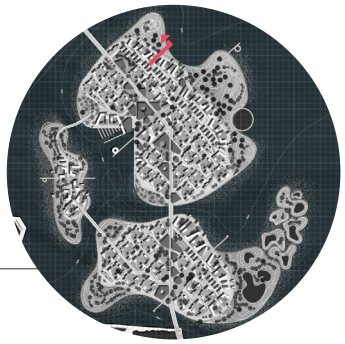

Generators
1 Beach
2 Wetland
3 Reef
4 University
5 Offices
Complementary facilities
6 Train station
7 Markets
8 View points
9 Bath
10 Playgrounds
11 Sport court
12 Harbour
13 Commercial streets
14 Museum
0
100
200
300
400

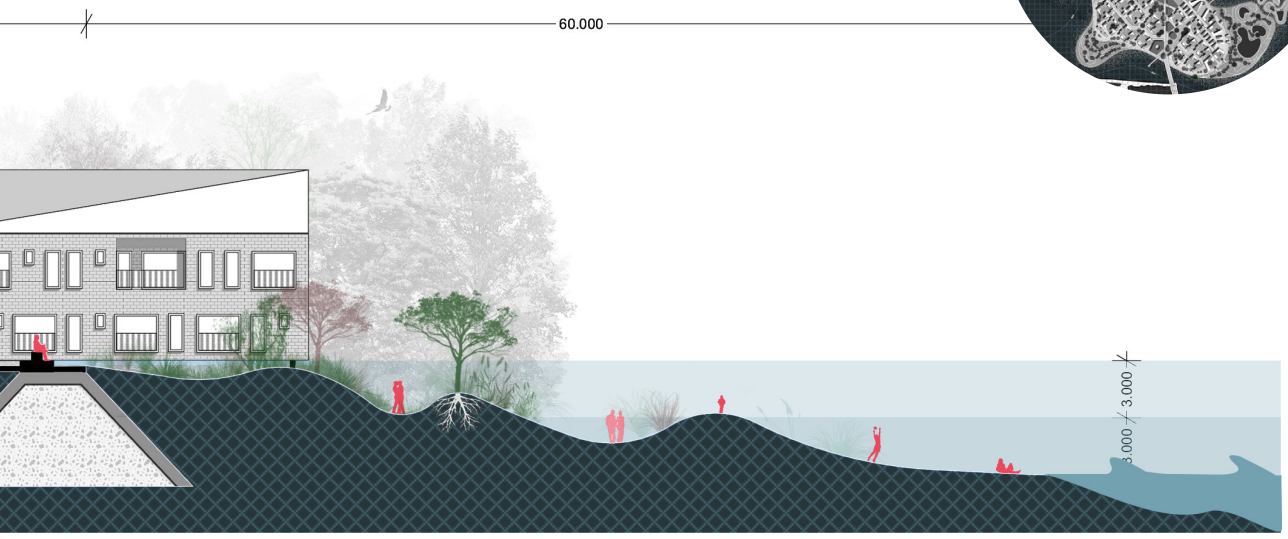
7.02 SECTIONS

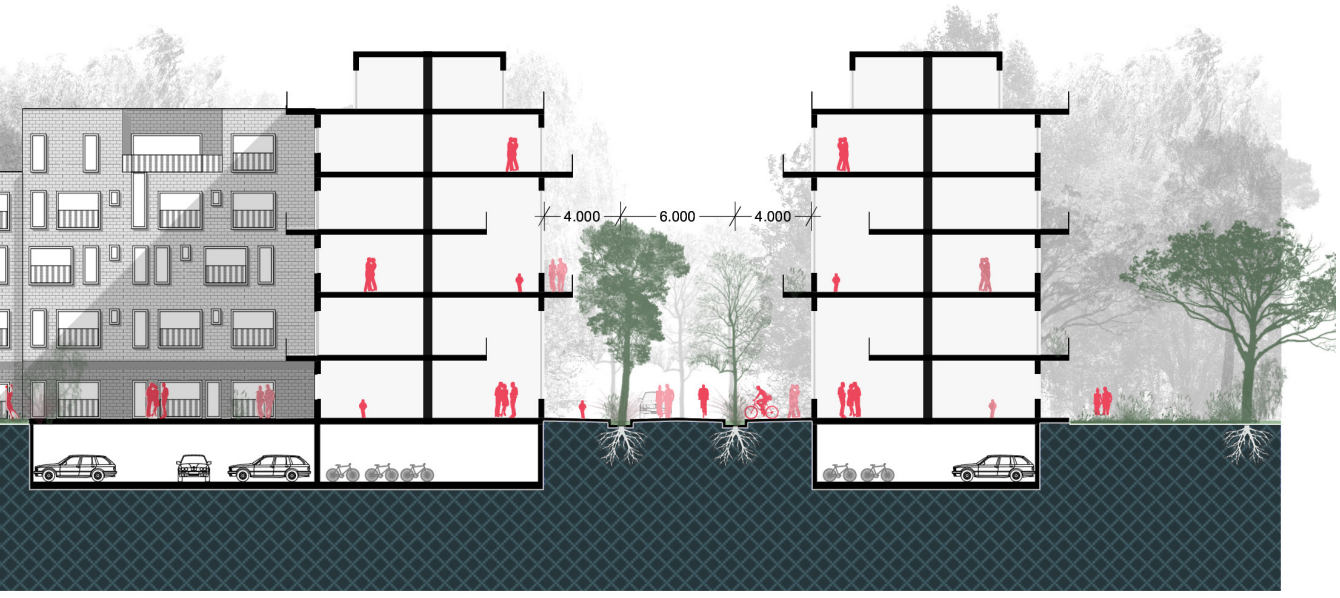
Beach Section

Harbour Section









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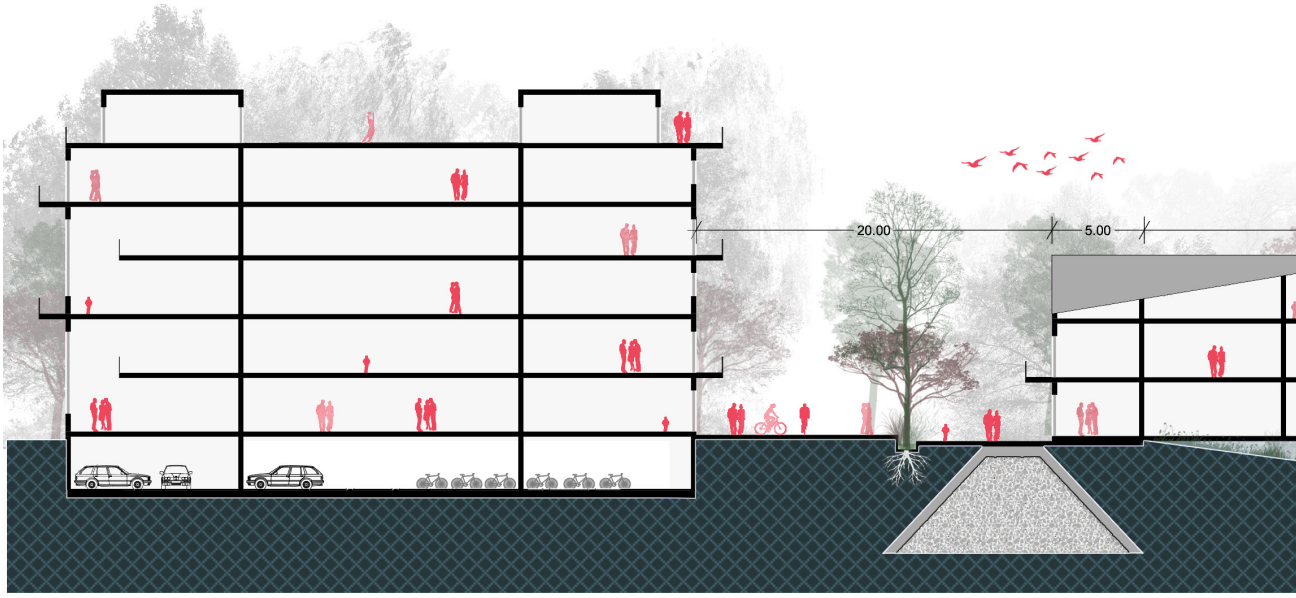
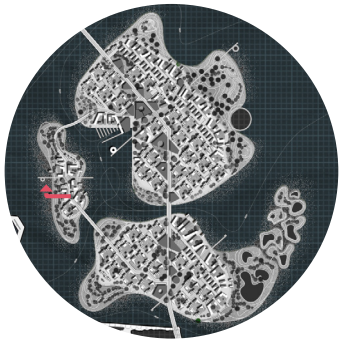
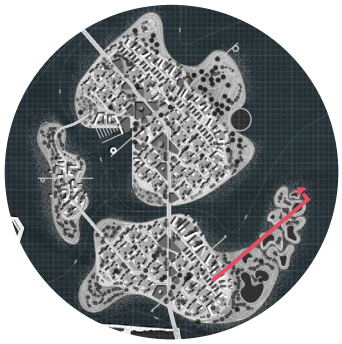
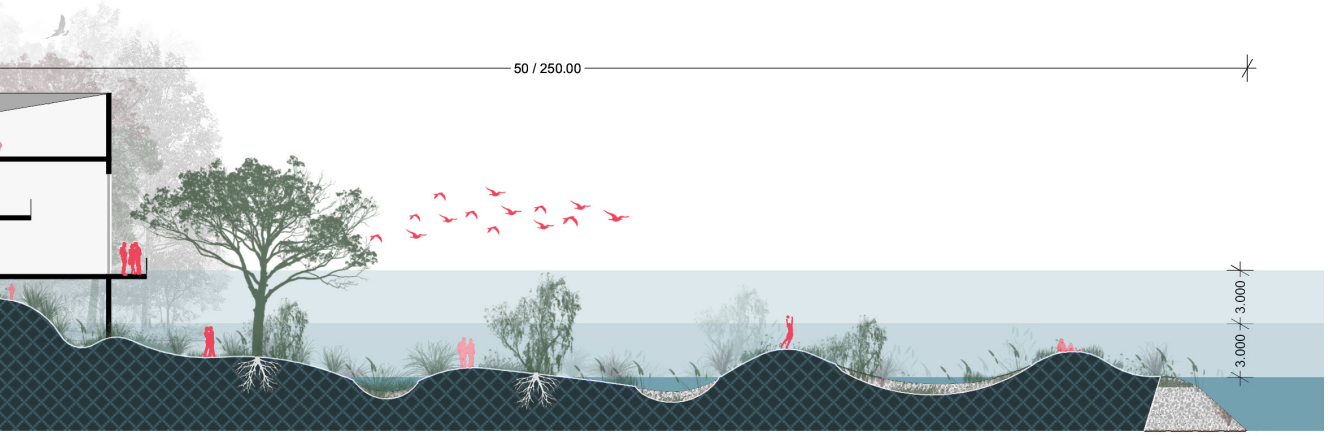
Wetland Section



Reef Section



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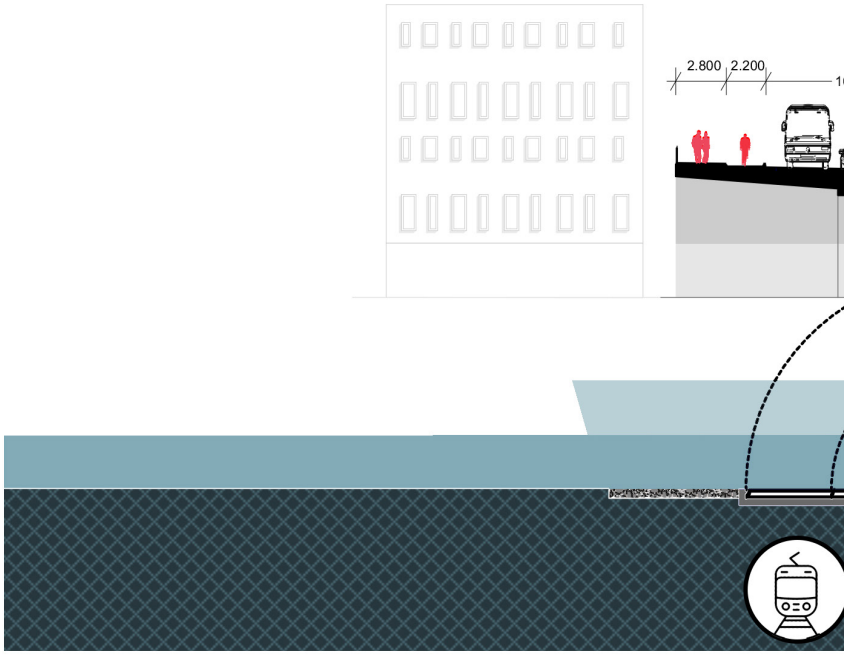
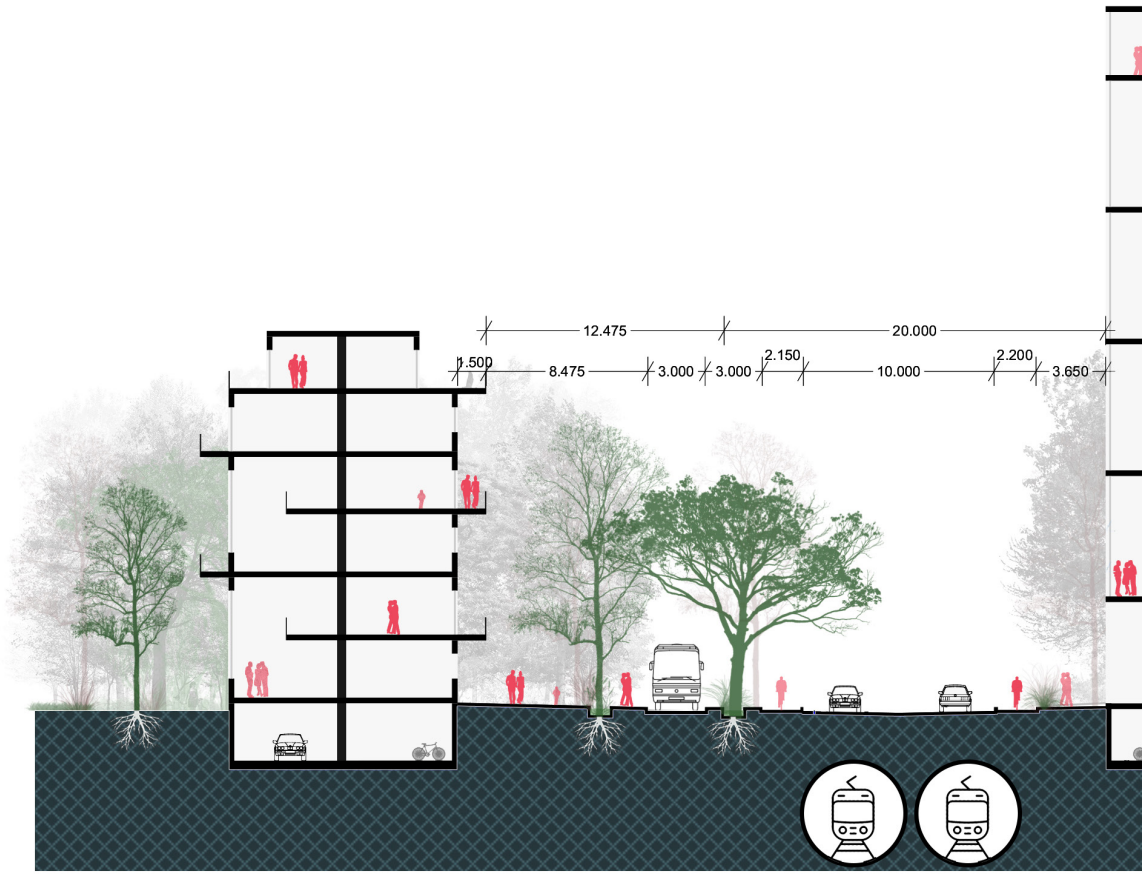
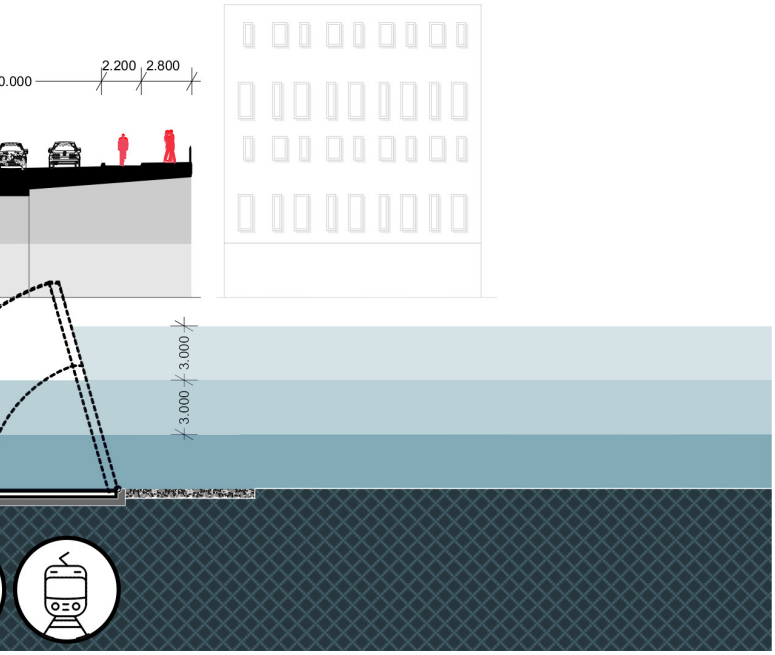
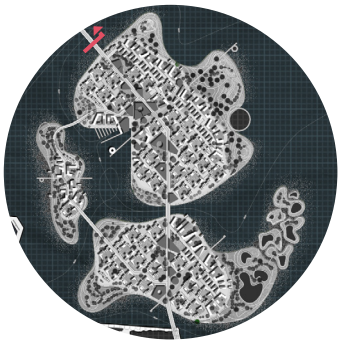
Floodgate Section

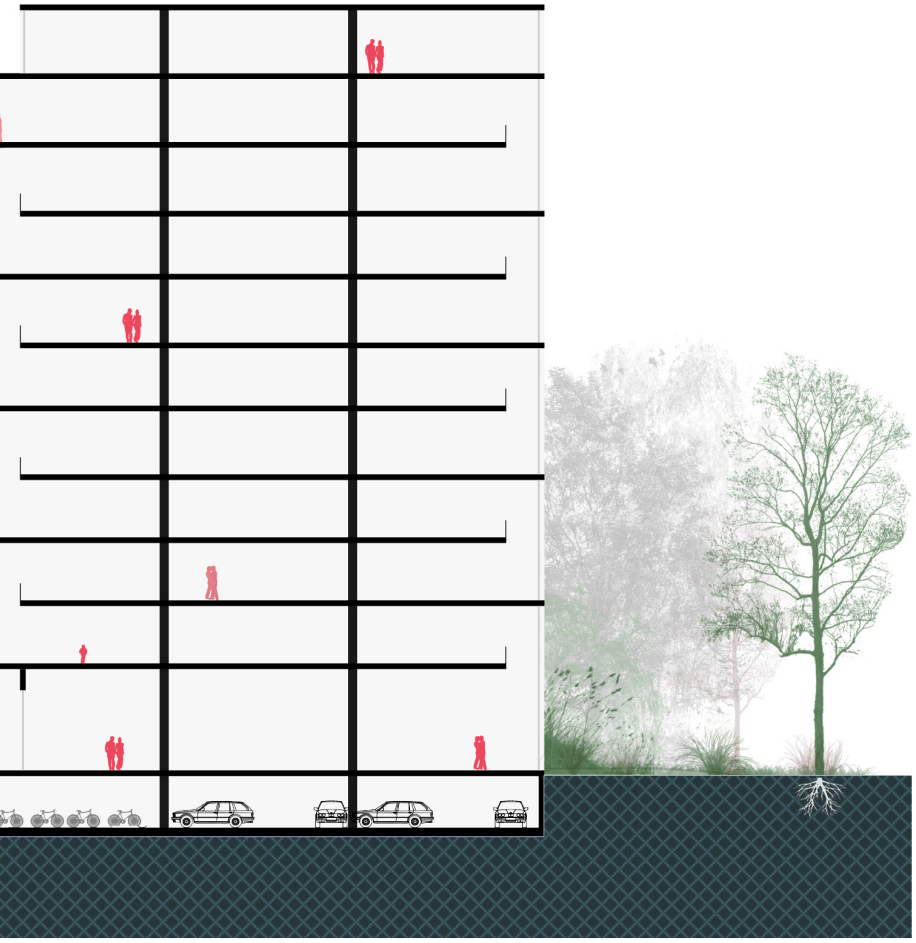


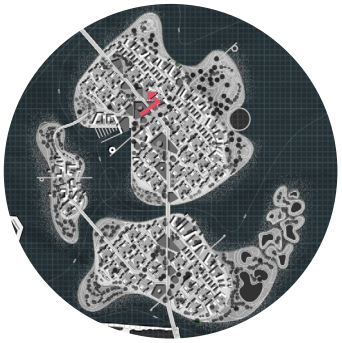
Main Road Section





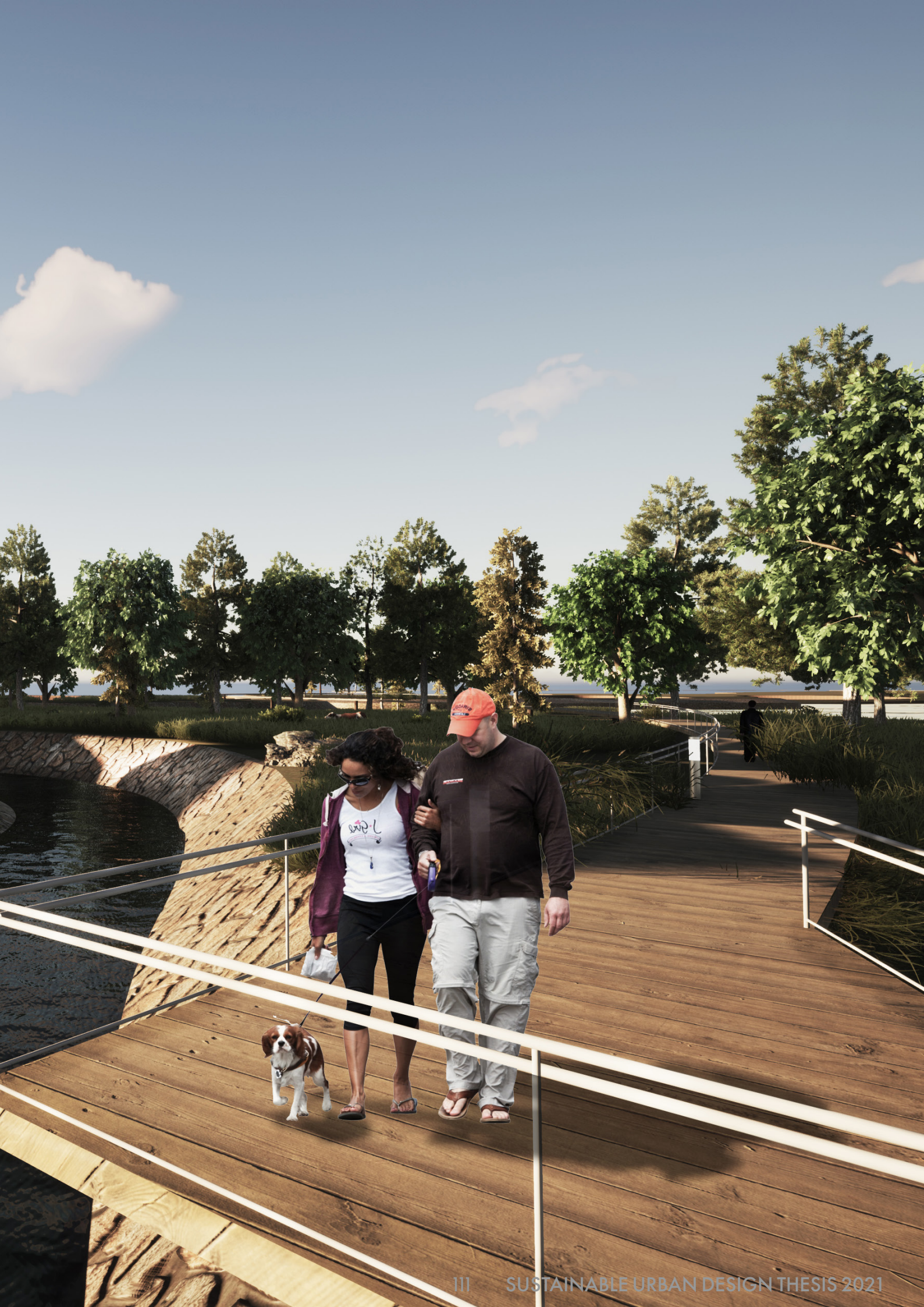






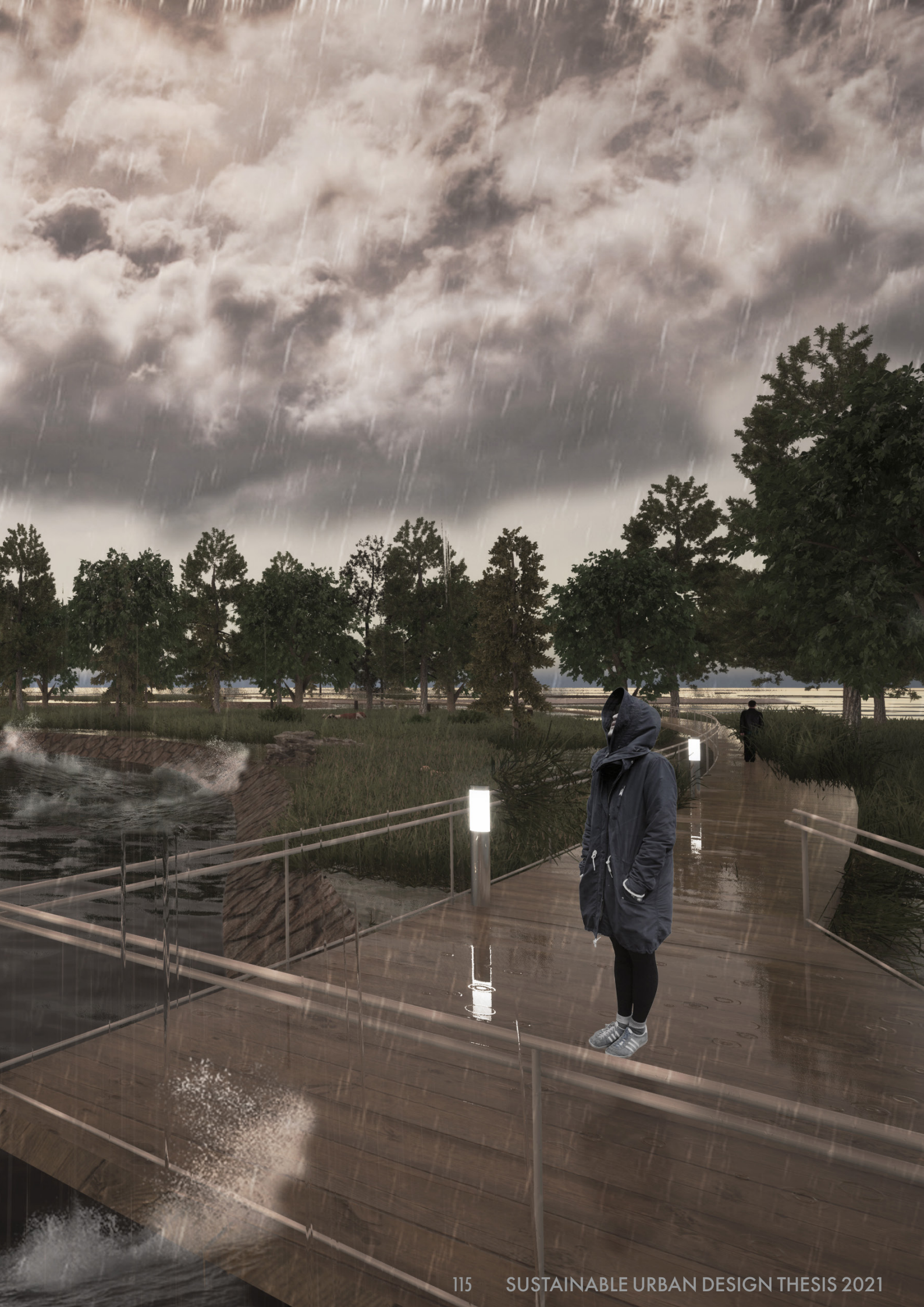
0 10 20 30 40 50


Current Sea-level




+0.5 m Sea-level

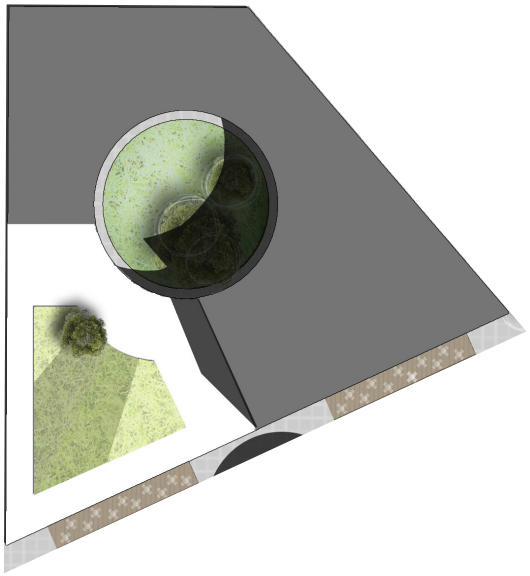

+1.5 m Sea-level

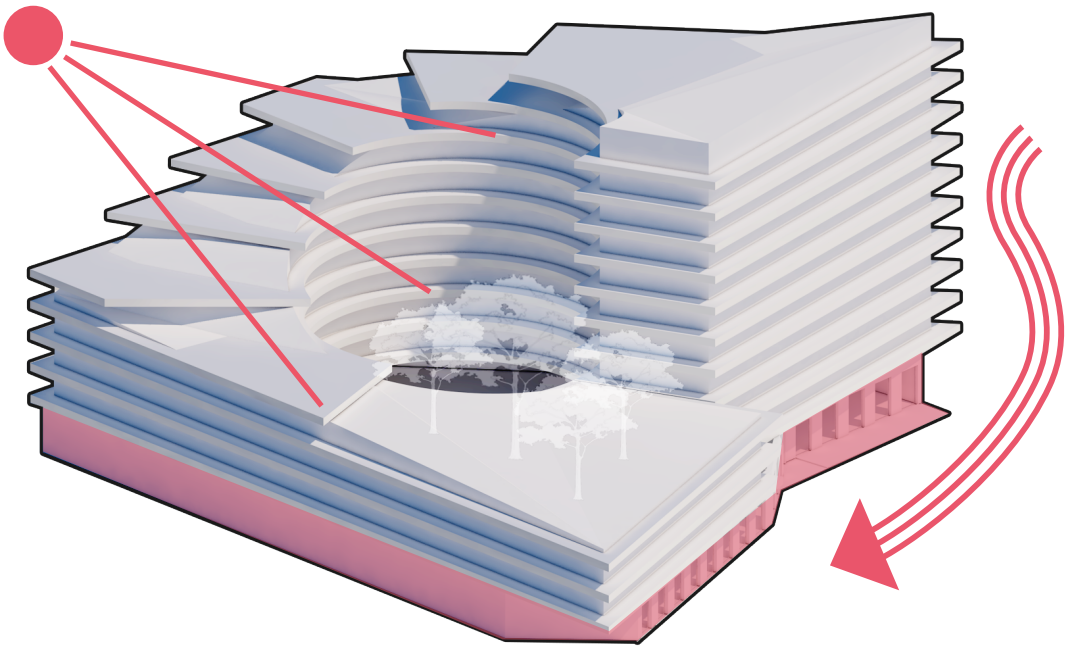


7.03 TYPOLOGIES

Mixed-use

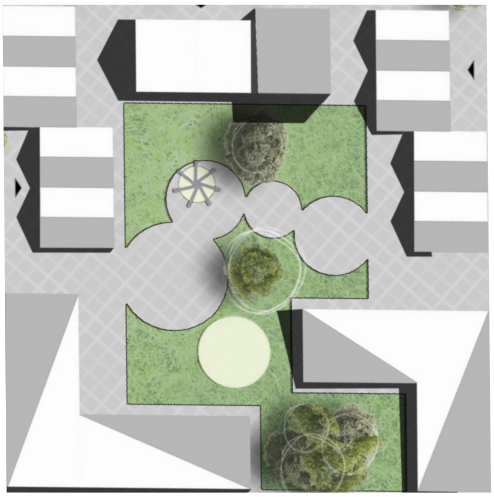
This typology is located along the main street as well as a complementary building at the community squares. The building shape is in response to sun exposure. The tower height varies from 3 stories to up to 12 levels to create a more dynamic structure. The building gives a room for housing, offices and a variety of business. The ground floor is meant to be commercial to activate the urban space.

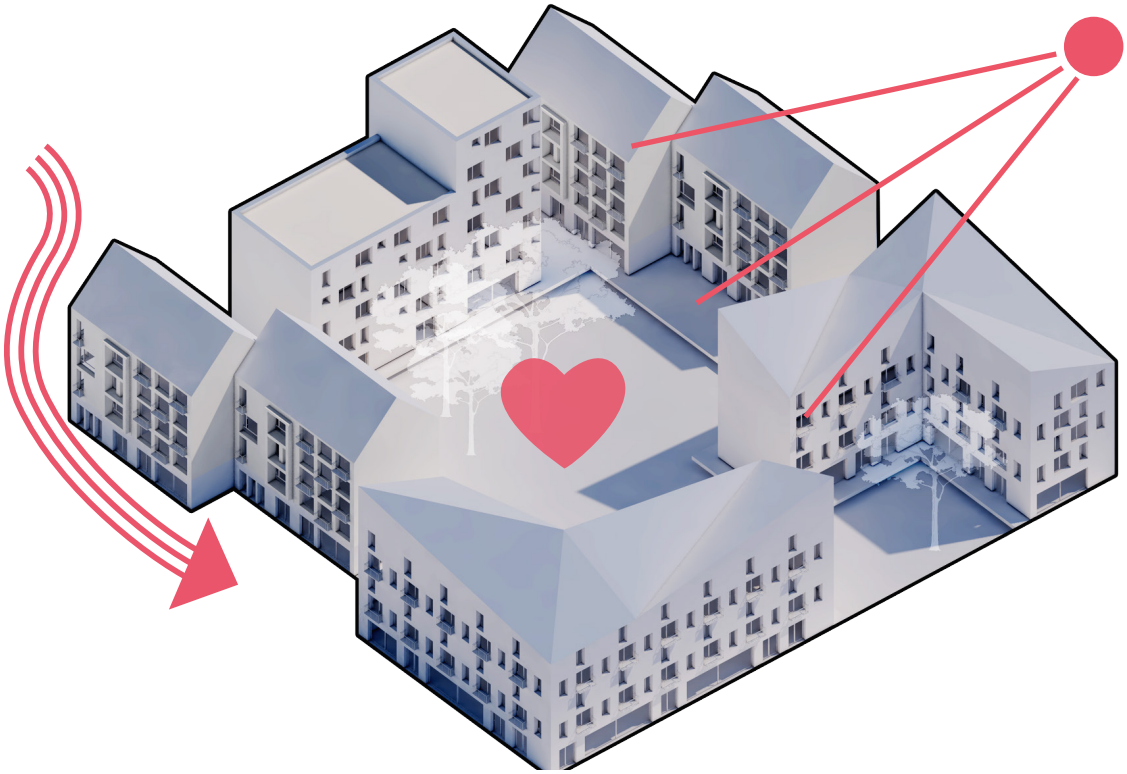




Block structure

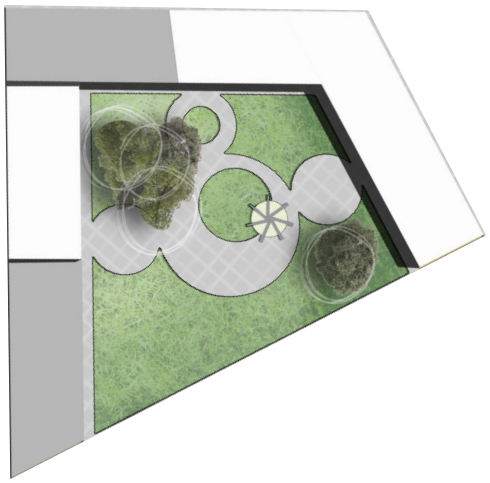
The block structure is placed in the inner parts of the neighbourhoods. This typology is characterised by the inner core surrounded by diverse building styles. The idea is to create an identity of each block that will produce a sense of ownership to the residents. The scale of the buildings is based on the Copenhagen city centre from 4 to 6 stories. Open corners and green spaces give a stronger link with the urban areas.

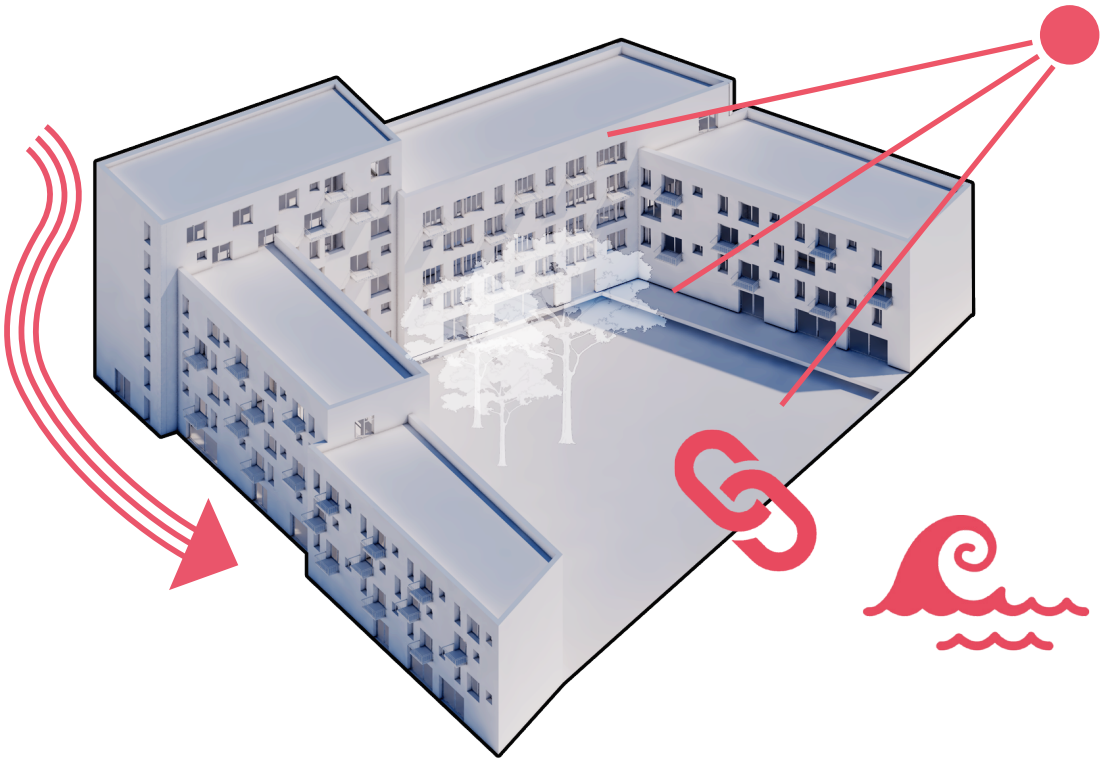




Open block

The open block typology is situated at the edge of the district. Therefore, The relation between water with the building is vital. The form faces the green spaces rather than grey, increasing the visual to the ocean from every place in the building. Additionally, terraces are formed on different levels of the building to improve greenery and urban agriculture. An extra building is added as commercial space to enhance urban qualities to the edge in some cases.





7.04 DETAIL PLANS

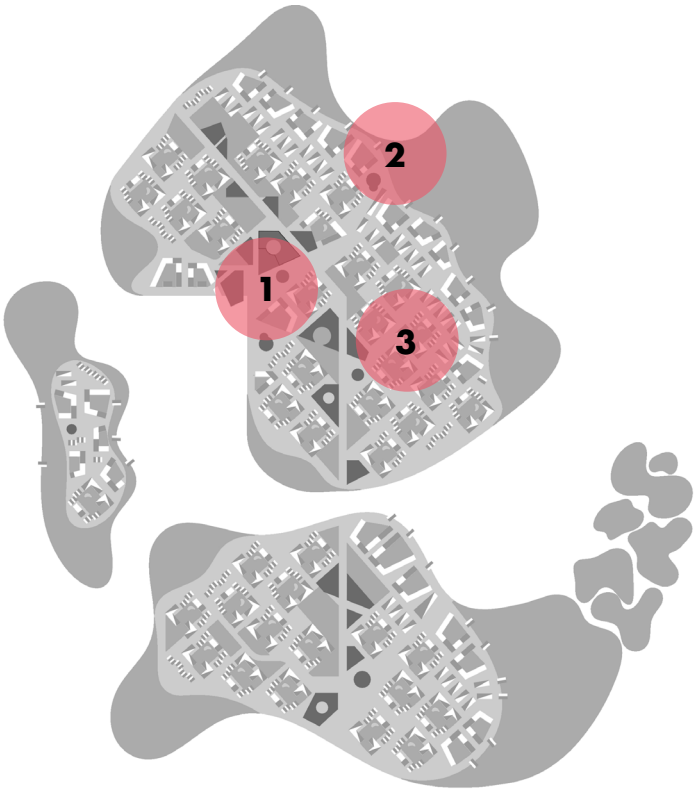
Three detail are selected in order to understand the urban spaces.

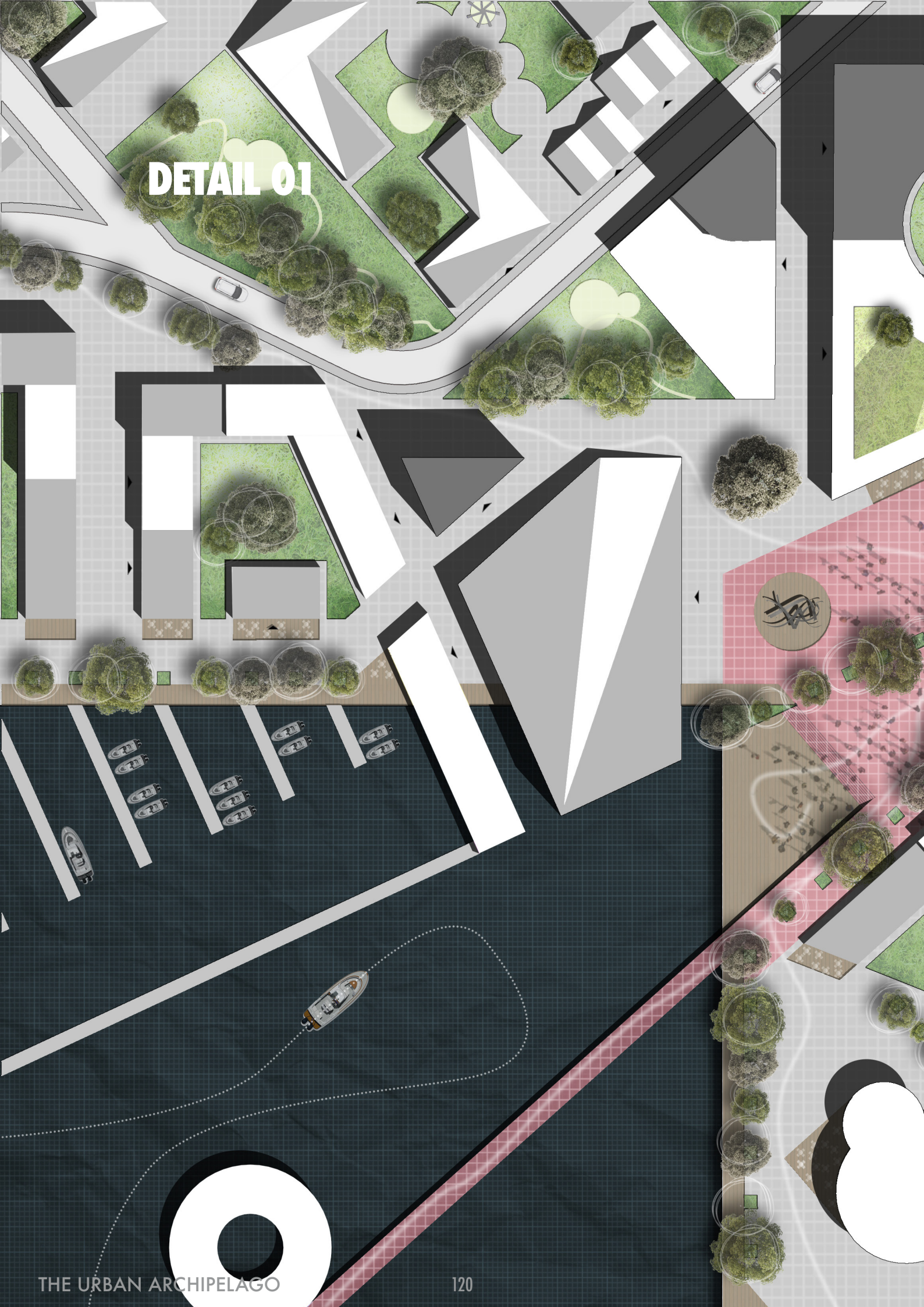
The first one is showing the relation between mixed-use block typologies with the main square. Pavements and platforms define the hierarchy of the space. Greenery and urban elements suggest a way to the waterfront.

The shoreline is presented in the second detail plan. The landscape and the promenade are merged to diffuse the physical limit between the green and grey infrastructure.

A dynamic organisation of buildings top off the edge district. Small pavilions provide commercial facilities at the edge of the promenade. The edge of the promenade works as the last flooding barrier in case of extreme sea-level conditions.

The last one gets closer to the community squares. Urban squares that complement each other. Local needs, for example, social interactions, sports activities and kids activities are addressed in these places.

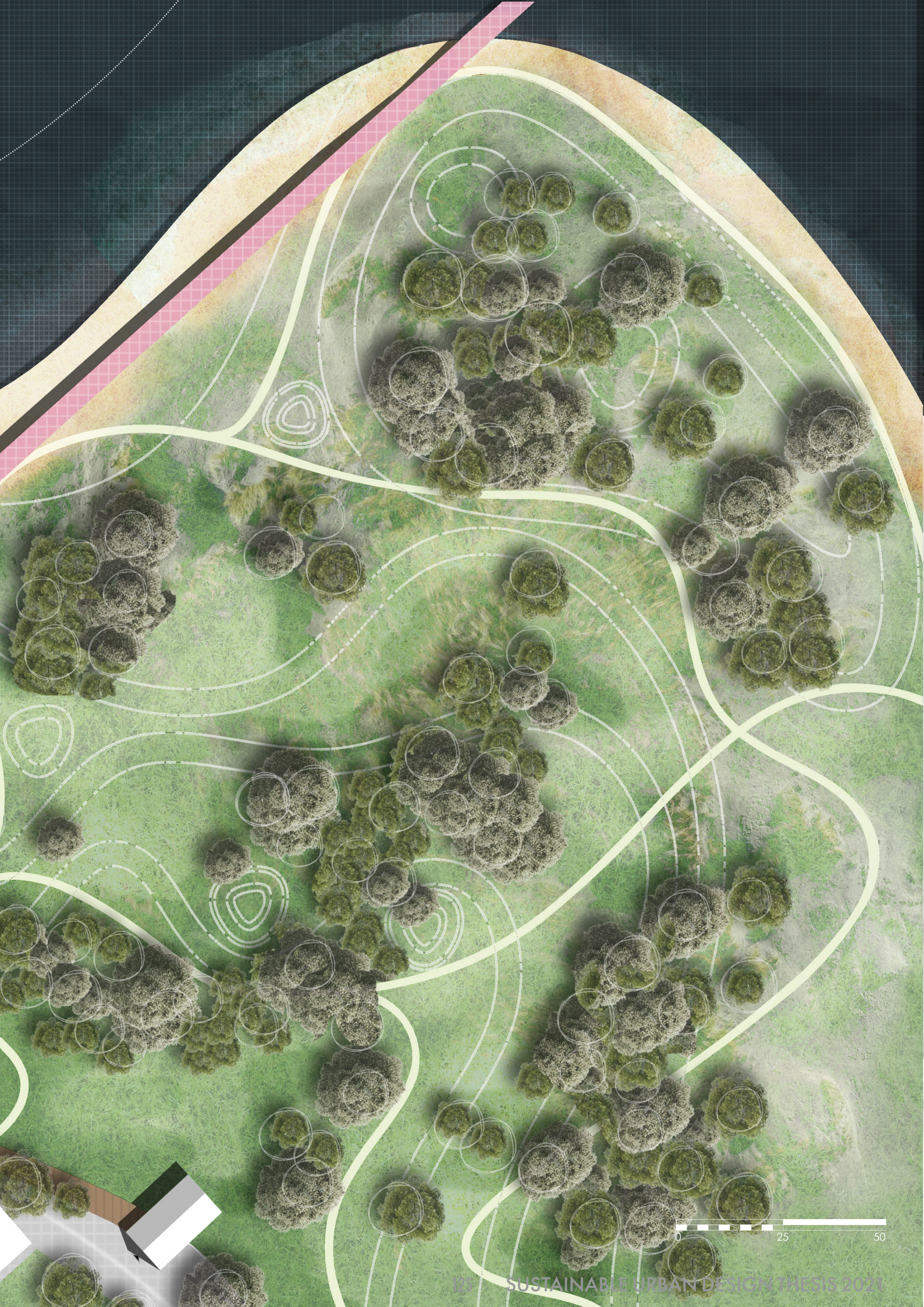



DETAIL 01


0
25
50


LYNETTEHOLMEN

DETAIL 02


0
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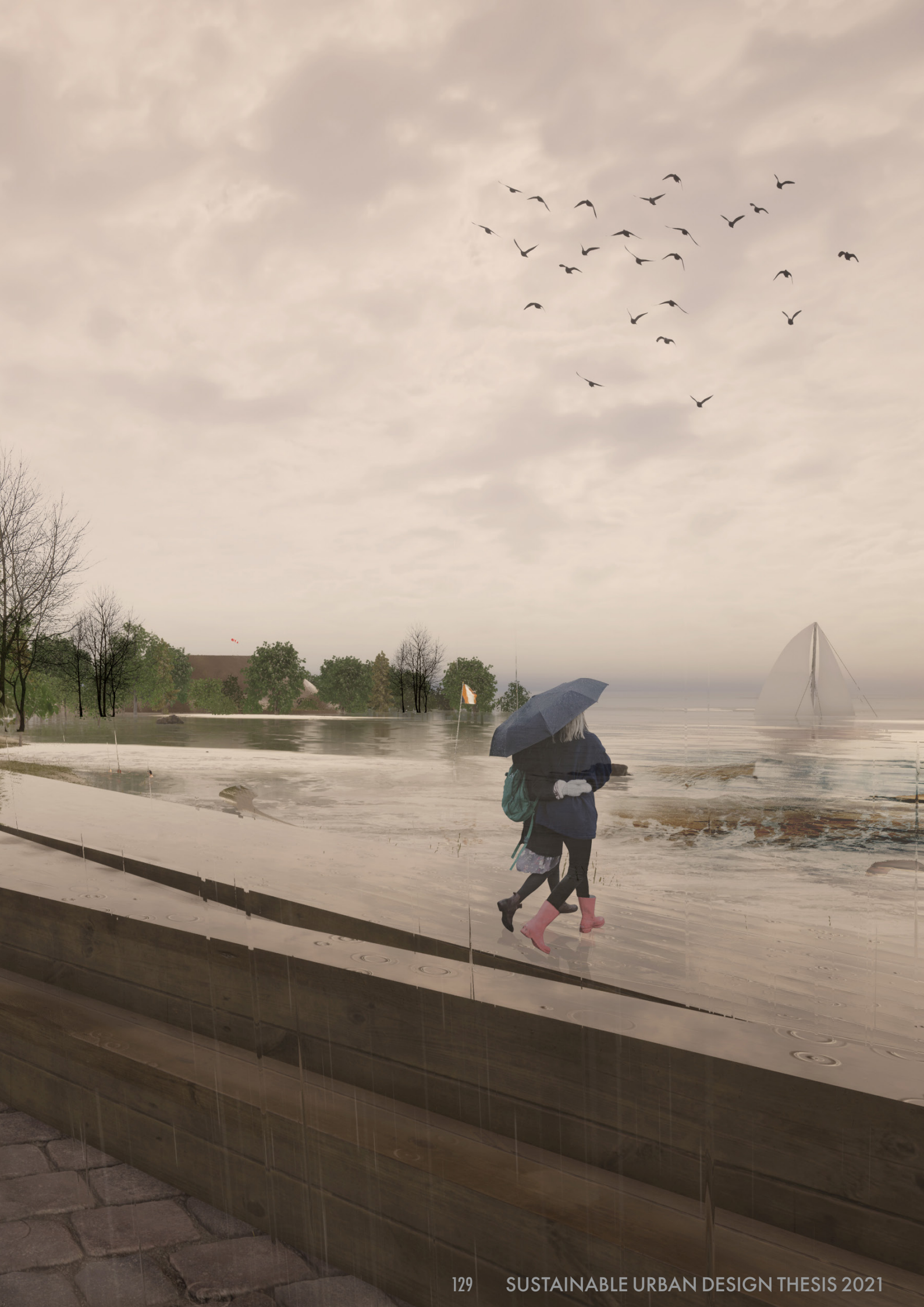
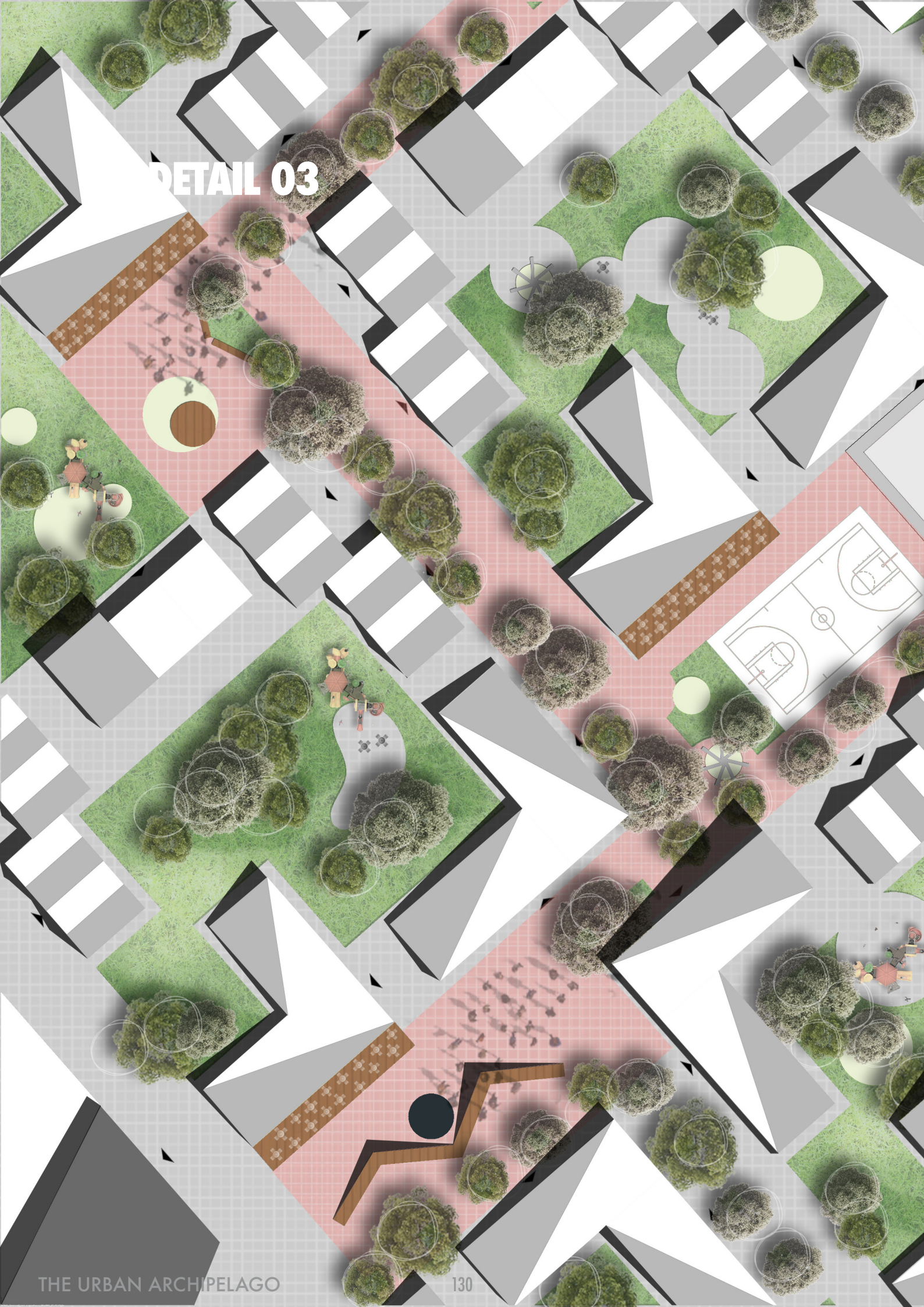
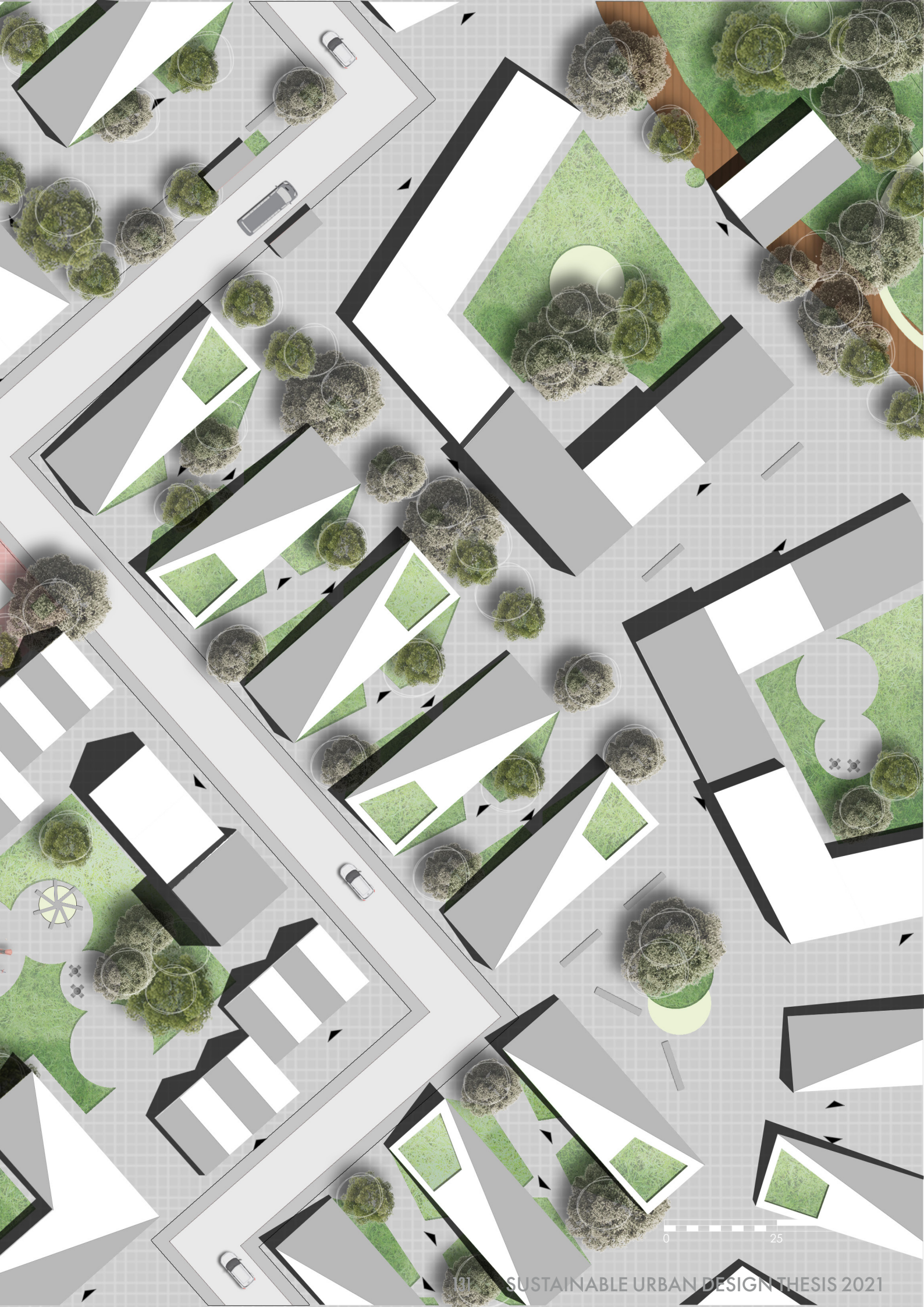
+3.0 m Sea-level




DETAIL 03


0
25


DELIKATESSEN
DRINKS
MENU

08

CONCLUSIONS

8.1 Conclusion

The initial intention of this thesis evolves from the awareness about climate change and the rapid urbanization that the world is facing.

Cities are changing, and many challenges are coming together with the changes. Climate change and global warming is a long-term process. Fortunately for Copenhagen, the effects of it are not very harmful yet. However, time is running, and now is the last opportunity to act ahead of these challenges.

Besides that, rapid urbanization puts pressure on cities to find enough space for more people without destroying natural resources. City expansions and over dense areas are becoming standard around the world. Therefore, periods like the Covid-19 help us rethink how we live, how we work and how we use the cities. These moments are breakpoints for cities to reimagine the ways to make a better city. Places where sustainability is the primary driver of development must be on the agenda of our leaders.

THE URBAN

The urban archipelago attempts a resilient project that envisions how new urban districts in coastal areas can use green solutions to the rising sea level. Lynetteholmen tries to address all challenges mentioned by reclaiming new land into the ocean that convert the threat of flooding into an opportunity. This new island is an idea to build a suitable area for the current needs, for example, housing and food production.

The project has been a challenge due to the dimension and components that need to be considered.

Unfortunately, it was impossible to dig into many of them, but further questions have risen for future projects.

How can food production complement the site?, How does waste management affect the design of a new district?, How to create third urban spaces that democratize the place?. These and many other questions I wish I could have time to work on. However, I believe those topics are thesis case on their own.

ARCHIPELAGO

8.02 Bibliography

1. Settlements, Population in Coastal. European Environment Agency. November 29, 2012. https://www.eea.europa.eu/data-and-maps/figures/population-in-coastal-settlements-2001.

2. Prospects, World Population. United Nations, Department of Economic and Social Affairs. June 17, 2019. https://www.un.org/development/desa/publications/world-population-prospects-2019-highlights.html.

3. Projections, Population. Statistics Denmark. 2021. https://www.dst.dk/en/Statistik/emner/befolkning-og-valg/befolkning-og-befolkningsfremskrivning.

4. Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, and K. Zickfeld. Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the. s.l. : IPCC, 2018.

5. Warming, Global. Cambridge dictionary. 2021. https://dictionary.cambridge.org/dictionary/english/global-warming?q=Global+warming+.

6. Ma, Qiancheng. Greenhouse Gases: Refining the Role of Carbon Dioxide. March 1998. https://www.giss.nasa.gov/research/briefs/ma_01/.

***7.* Shiraz, H**. Reasons to Global Warming. 2014. http://mawdoo3.com/%D8%A3%.

8. Københavns kommune, Cowi, Deloitte, Ramboll, Dmi, Ku-Life, Dhi, Gras. Climate Adaptation Plan. Copenhagen : Kobenhavns Kommune, 2011.

9. Shiklomanov, Igor. World fresh water resources. New York : Oxford University Press, 1993.

10. EEA Topic Centre on Terrestrial Environment (ETC-TE), ETC Biological Diversity (ETC-BD), ETC Water (ETC-W). The changing faces of Europe's coastal areas. Copenhagen : European Environment Agency, 2006. 6.

11. Sadie McEvoy, Marjolijn Haasnoot, Robbert Biesbroek. How are European countries planning for sea level rise? 2021.

12. Vousdoukas, Michalis I. Climatic and socioeconomic controls of future coastal flood risk in Europe. [Online] September 2018. https://doi.org/10.1038/s41558-018-0260-4.

13. Nature, Climate Change impact on. Climate Change Adaptation. Ministry of Environment of Denmark, 2020. https://en.klimatilpasning.dk/sectors/nature/climate-change-impact-on-nature/#:~:text=In%20the%20long%20run%2C%20climate,winter%20periods%20in%20the%20future.

14. Maria Farago, Eva Sara Rasmussen, Ole Fryd, Emilie Ronde Nielsen, Karsten Arnbjerg-Nielsen. Coastal protection technologies in Danish context. Frederiksberg C, Denmark : Vand i Byer – Innovationsnetværk for klimatilpasning. http://www.vandibyer.dk/, 2018.

15. Roser, Max. Our world in data. 2019. https://ourworldindata.org/future-population-growth.

.

16. Helge Sigurd, Naess-Schmidt. Housing Market Analysis of greater Copenhagen. Copenhagen : Danish Ministry of Transport Building and Housing, 2018

17. History, Copenhagen. Copenhagen. Quality Unlimited, 01 01, 2020. https://www.copenhagen.com/historical-facts.

18. Dahl, Bjørn Westerbeek. Guide til Københavns Befæstning. Københavns : Kbh., kobenhavnshistorie.dk,, 2006.

19. Maps, Historical. Kortviseren. Royal Library and Copenhagen City Archives, 2017. https://kortviseren.dk/side/koebenhavn.html.

20. The Finger Plan. Copenhagen : The Danish Nature Agency, 2015.

21. Matthew Ulterino, Duncan Smith, Karl Baker, Catarina Heeckt. Green Economy Leader Report. London : Economics of Green Cities Programme at the London School of Economics and Political Science., 2020.

22. Copenhagen 2025 Climate Plan. Copenhagen : The Technical and Environmental Administration, 2012.

23. Al, Stefan. Adapting Cities to Sea Level Rise. Washington DC : All Island Press, 2018. 27. klimatilpasning. Ministry of the Environment / Danish Environmental Protection Agency, 2020. https://www.klimatilpasning.dk/vaerktoejer/havvandpaaland/havvand-paa-land/.

24. Storm Flods Plan. Copenhagen : Kobenhavn Kommune, 2017.

25. COWI. Byernes udfordringer med havvandsstigning og stormflod. Kongens Lyngby : Realdania, 2017.

26. Strandparken. Strandparken I/S, 2020. https://strandparken-kbh.dk/om-strandparken/.

28. Kadri Kuusemäe, Sophia E. B. Nielsen, Mads N. Madsen, Bo Brahtz Christensen, Jesper Goodley Dannisøe. Anlæg af Lynetteholm. Copenhagen : DHIs ledelsessystem, 2020.

29. Mårtensson, Ida. Baltic Sea. 2021. http://www.balticsea2020.org/english/the-baltic-seas-challanges.

30. Kobenhavns Kommune about the municipality. Kobenhavns Kommune, 2018. https://www.kk.dk/lynetteholm.

31. Rambøll. Portløsninger i kronløbet. Copenhagen : Københavns Kommune, 2019.

32. Afrapportering af forundersøgelse af metrobetjening af Lynetteholm. Copenhagen : Københavns Kommune, 2020.

33. World Ocean Review. 2017. https://worldoceanreview.com/en/wor-5/improving-coastal-protection/coping-with-rising-sea-levels/.

34. Stenak, Morten. De inddæmmede landskaber: en historisk geografi. s.l. : Landbohistorisk Selskab. , 2005.

Other Sources

Praharaj, Sonali. Shifting Shorelines, Adaptation to sea level rise along transportation corridors. San Leandro Bay, Oakland : s.n., 2016.

Copenhagen City Vision. Copenhaguen : Sustainia, 2013.

Lynetteholm. BY&Havn. BY&Havn, 2020. https://byoghavn.dk/lynetteholm/.

Linhares, Jean. Rolihlahla village: Bottom-up process for the rehabilitation of human settlements in Port Elizabeth, South Africa. Port Elizabeth : Lund University, 2020.

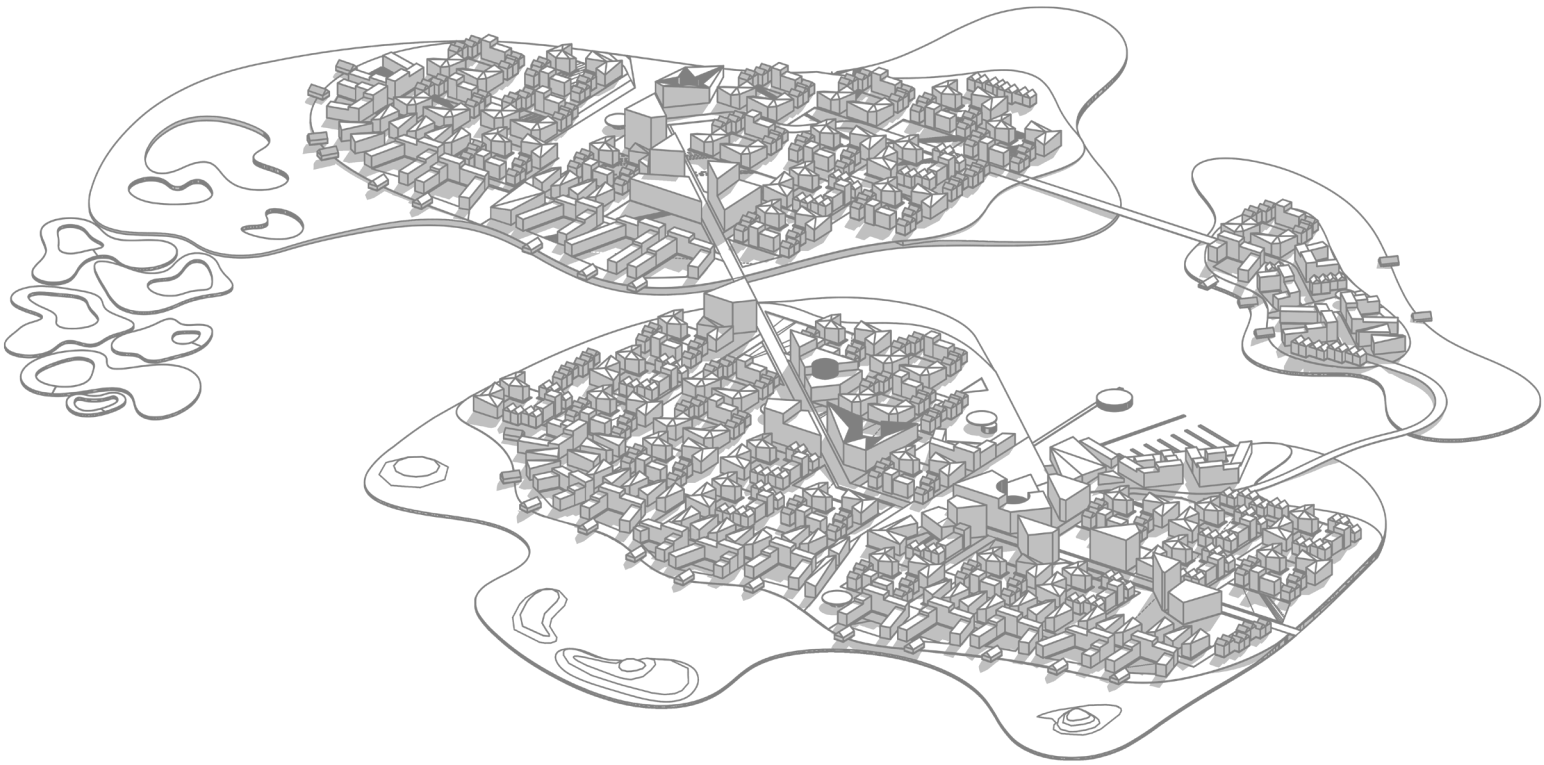
Smith, Susan. Pearls Airport's Urban Village. Lund : Lund University, 2020.

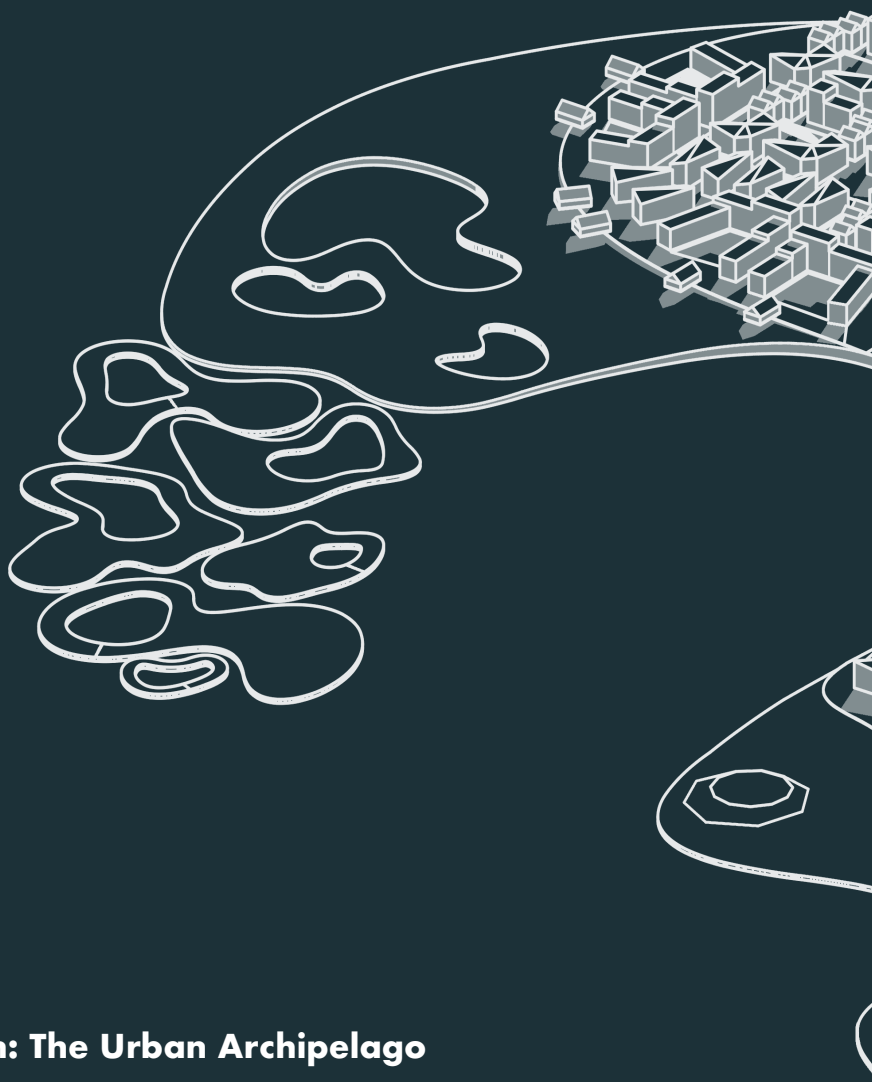
Majid, Zainab Waleed. Let it Flood. Kävlinge : Lund University, 2016.

Peng, Lu. Sustainable Urbanism, Rising Sea Level, And Green Infrastructure: New Strategies For Central London. Urbana, Illinois : University of Illinois at Urbana-Champaign, 2011.

Einarsson, David. Urban foodprint - exploring a design that merges urban landscape and local food production. Lund : Lund University, 2021.

Design for Rising Sea Levels. Kristina Hill, Jonathan Barnett. Cambridge, MA : Harvard Design Magazine, 2021, Vol. 27.





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Lund University, Faculty of Engineering,
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2021

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