



**Politecnico  
di Torino**

**THE APPLICABILITY OF CLIMATIC ANALYSIS AND URBAN METABOLISM  
MODEL INTO DESIGN PROCESS WITH A CASE STUDY IN COPENHAGEN:**

# **REFSHALEØEN**

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Refshaleøen

CC

173A



### **The Aim of the thesis**

2 years of taking the master's course in sustainable design at Politecnico Di Torino was one of the most memorable and exciting time I have ever had in my life. Coming from a developing country like Vietnam, as a young architect, I fully realize the importance of the sustainable thinking.

This thesis was carried out with the intention to search for an interconnection between : urban planning, the priority role of bioclimatic analysis and - above all - the implementation of these processes in a design project proposal that uses specialized tools such as the Bioclimatic Matrix and the urban anthropic multidisciplinary analysis. All of those tools and methodologies are the valuable knowledges that I obtained after several years of practical experiences and theoretical trainings at Politecnico and in international companies.

In the other words, in my personal point of view, it would be very interesting if I can adapt effectively what I have learned or trained into an actual case study which could be where I am living, working or studying and propose a good solution for a feasible future for it, not only in terms of planning policy or feasibility analysis but with a helpful hand from the supervisors, we want to reach the final design steps.

Having done that, I will be able to contribute my efforts towards the goal of sustainable development to a certain extent. Furthermore, I hope this thesis can serve as inspiration or a foundational reference for further studies in the future for those with similar interests.

### **Abstract**

It is not difficult to recognize how our world has changed dramatically over the past few years. Climate change, pandemic or some other social factors could be mentioned as the reasons behind this change, leading to another consequence of how can we adjust our way of living into this "new normal state" or in other words, how can we design a new living environment that can adapt to foreseeable problems and mitigate the negative tendencies globally.

The purpose of this research was to investigate the applicability of climatic analysis and urban metabolism model in the process of architectural design. The project site is located in the Danish capital Copenhagen called Refshaleøen which previously used to be an old shipyard and heavy industrial area. Those activities were closed from 1996 and since then, new life and business have been developed from that historical background creating a new unique and inspirational community that we can see today. However, it seems that beside the on-going activities, the infrastructures and the environment of the area are still far behind the needs and the potentials it deserves. In order to create a new city district with mixed uses of housing, businesses and permanent activities according to the vision of Claus Hovmøller Jensen - The director of urban planning and development of Refshaleøen, this project was carried out to realize the feasibility of that transformation.

With the advisors from environmental technology, urban planning, architecture studio and my own working experiences in Copenhagen, we hope that the study can bring some good analyses and solutions as well as it might illustrate a possible future of Refshaleøen.

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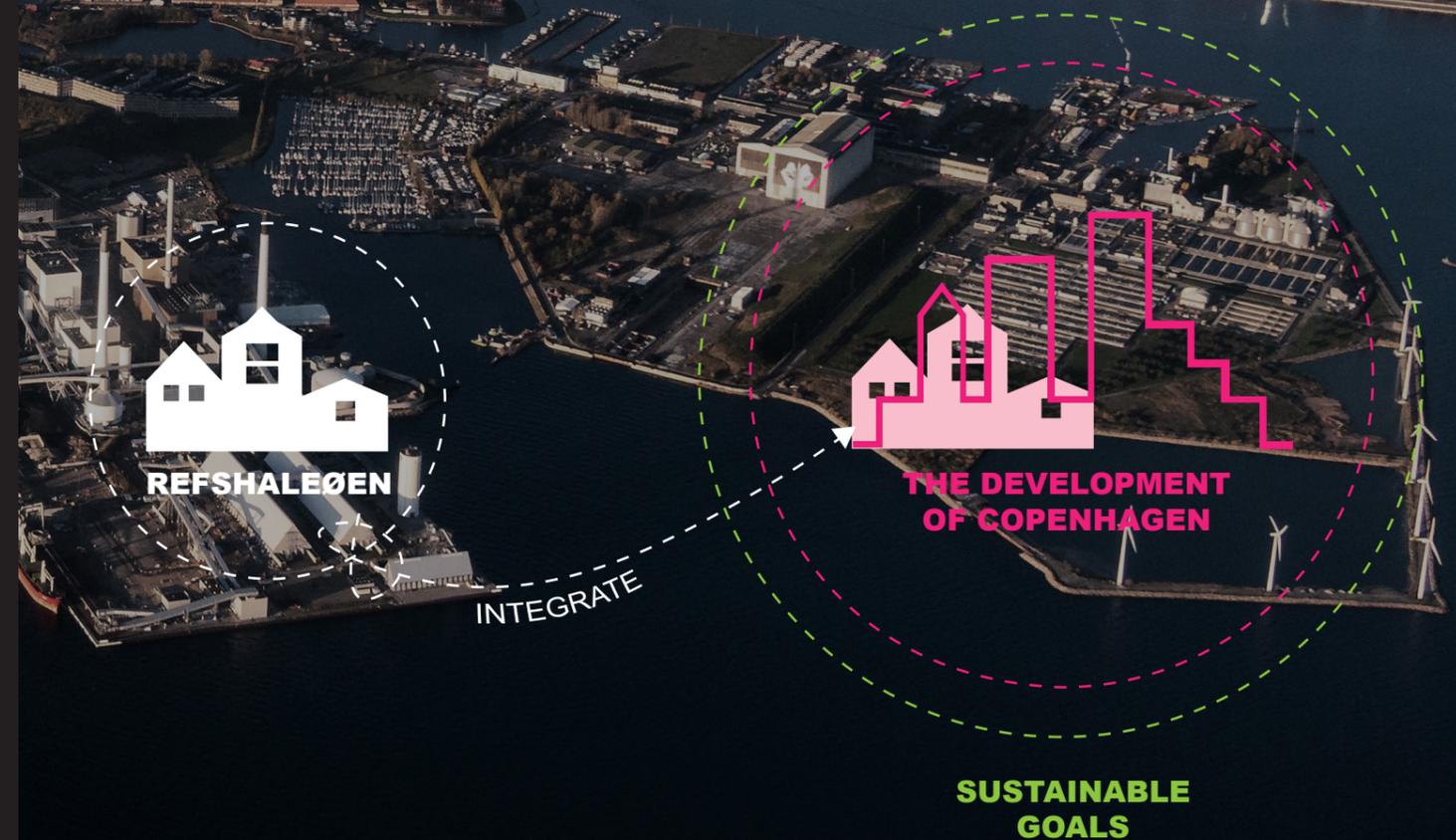


# 1 Introduction

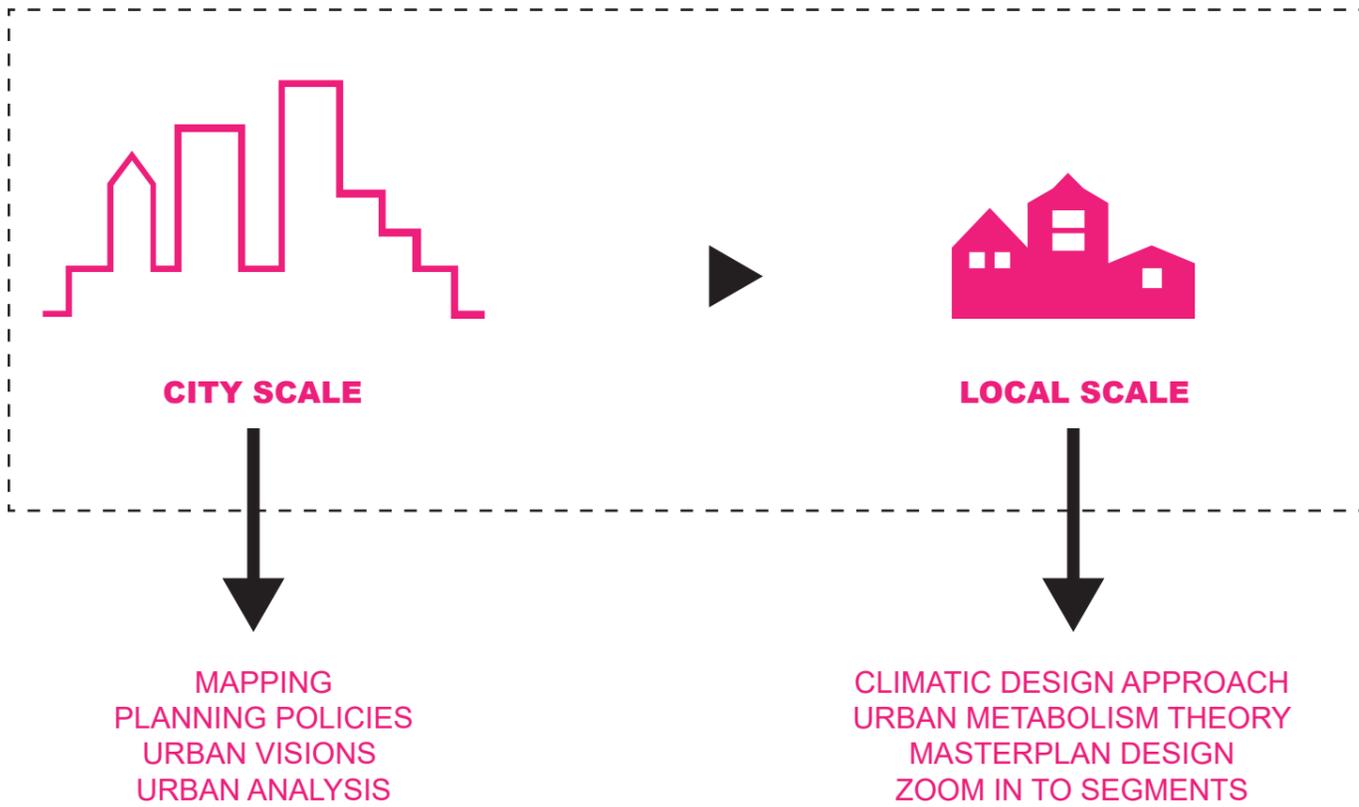
## 1.1 The Purposes Of The Thesis

### The Purposes

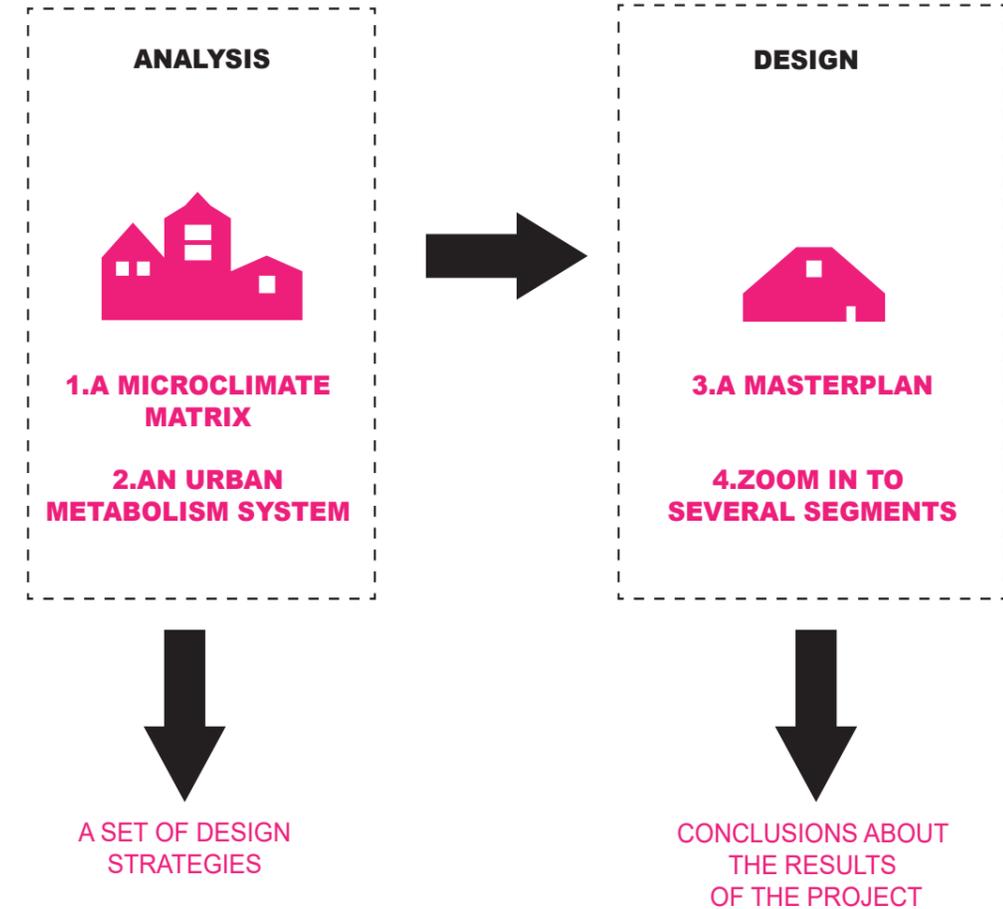
It was stated very clear in the municipality plan 2019 that "Copenhagen will be a world city with unique characteristics that takes responsibility for creating urban development with room for history, the diverse culture and nature of the city and has the courage to develop the urban life of the future". Along with those changing tendencies over the world metioned in the abstract, we also have to take into consideration the holistic development of not only inside the Refshaleøen but also the bigger scale of the city. Standing on the position of an young people living and working in Copenhagen, we fully awared that Refshaleøen has many great potential to become a better habitat and at the same time, there are many challenges need to be adressed in order to integrate the area into the development of the city according to municipality plan.



## 1.2 The Aims And Scope



## 1.3 The Expected Outcomes



### The Scope

This thesis aims to create a holistic and comprehensive solution for the Refshaleøen so that is why it is divided into 2 scales starting from macro scale with the city mapping analysis to smaller scale of the local area with the helps of climatic analysis and urban planning tools in order to provide a set of strategies for the area. At the second scale of the masterplan, specifically in the zoom in part, we will divide the masterplan into several segments in which we can examine and illustrate how chosen strategies were applied.

All of those scales are strongly linked by several researches and interviews about the identity and the cultural history of the area in order to secure a holistic design approach and provide the optimized outcomes.



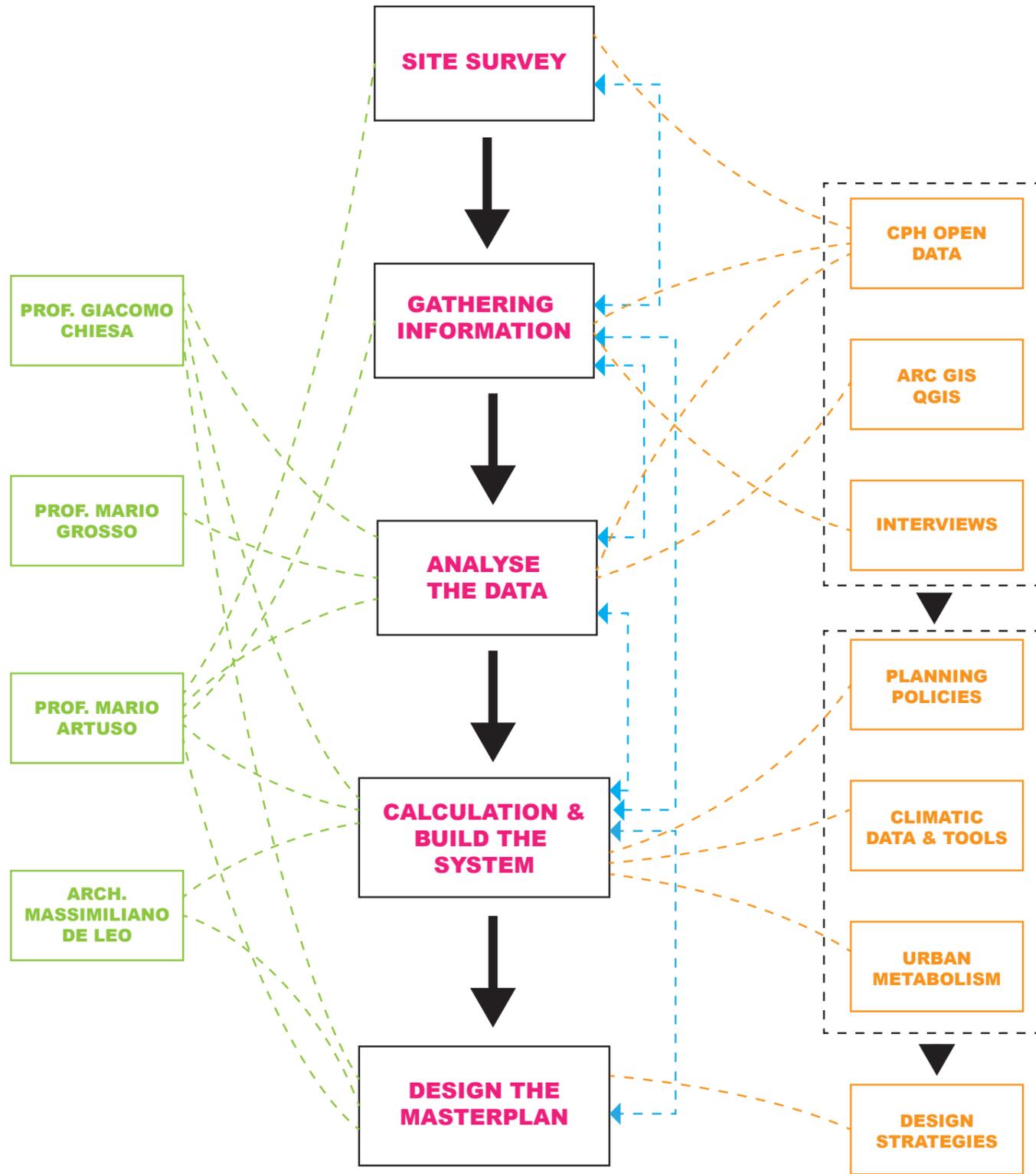
### The Outcomes

Generally, there are 4 outcomes that we want to propose in this project. After the first phase of analysis in marco scale, we will go to the project part in which we carried out several technical analysis about local climate and urban metabolism theory, we came up with the **matrix of seasonal and annual thermal comfort score** and also a **metabolism system for the area**.

In the next phase, we want to propose a **masterplan** for the Refshaleøen in which we tried to propose a series of principles or strategies for the future development taking into consideration that all the related aspects were carefully investigated, both environmental and social and of course the municipality plan.

Finally, we want to **divide the area of Refshaleøen into several segments** and explain in detail how our chosen strategies were used in the site context.

## 1.4 The Methodology



### The Workflow

The methodology of carrying out this project is described by the above workflow diagram which includes both the self-check of me and my professors based on the each phase of the project and also, with the helpful hands of different design and research tools.

- - - - - Self-check
- - - - - Supervisor
- - - - - Tools



## Nordhavn



Architects : Cobe  
Client: CPH City & Port Development

Program: Proposal for a new masterplan of ex-industrial harbour and port area. This project also includes the detail specification of new development plan, landscapes and infrastructures.

Size: 3.6 million m<sup>2</sup>

Location: Copenhagen, Denmark

Nordhavn is located just next to the old central part of Copenhagen. The area has been changing day by day and becoming a busy district for people to live, work and entertain. The project carried out by Cobe was an answer for the question of how can we transform an old industrial harbor area to become a habitat and how can we predict the future environmental changes in order to propose an appropriate solution and different strategies to adapt to those tendencies. In my opinion, this project is very original, holistic and a good source of reference even though there are still some controversial discussions about the environmental impacts of this project.

*Resources: Cobe Architects*

# 1.6 References

The Masterplan



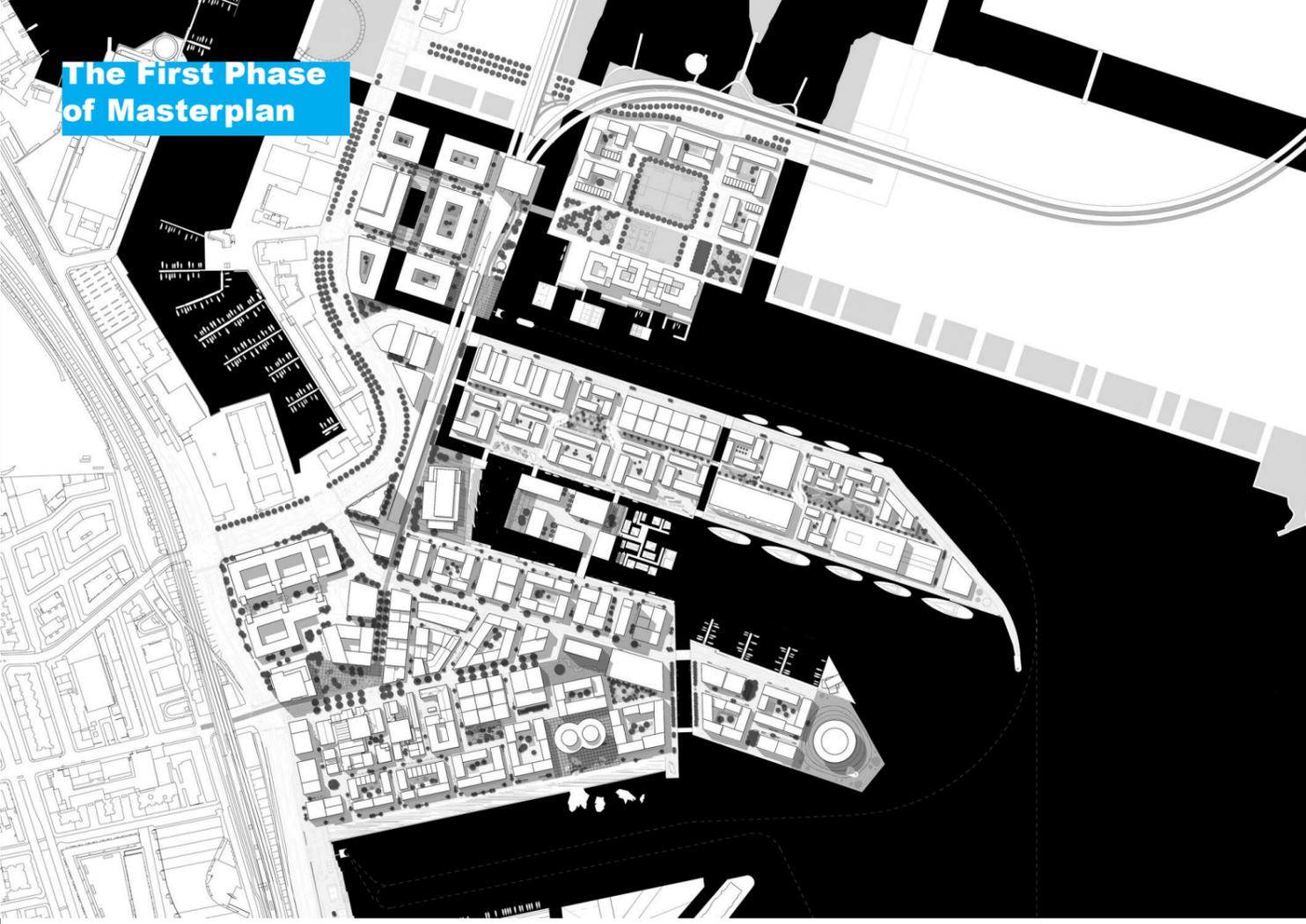
Nordhavn

Refshaleøen

city centre

Resources: Cobe Architects

The First Phase of Masterplan



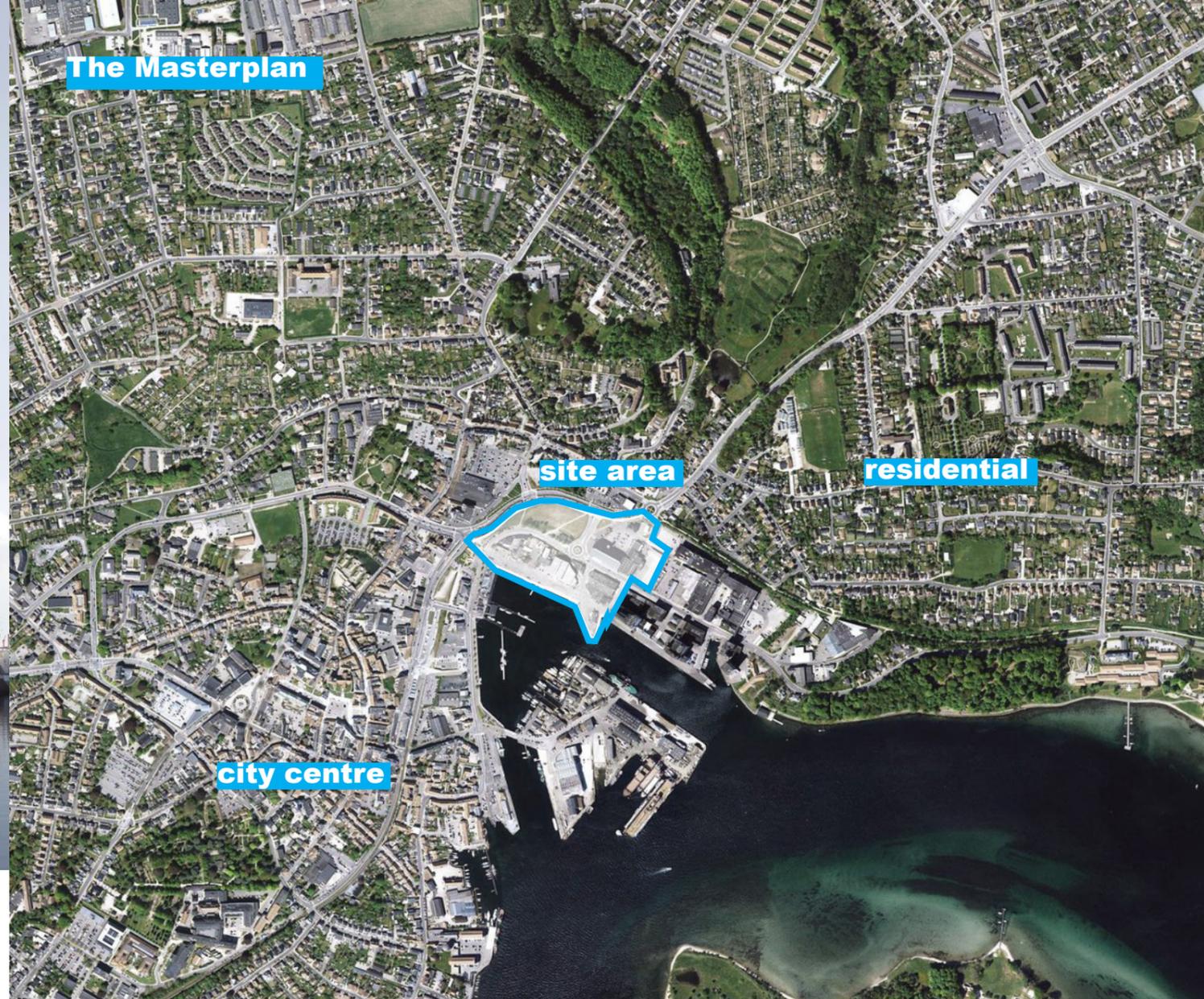
The Aerial View



**Keywords:**  
 +City on water  
 +Urban green  
 +Diverse city

Resources: Cobe Architects

# SIMAC - THE EFFEKT



Architects : Effekt & C.F. Møller Architects

Client: SMUC

Program: Education, Masterplan

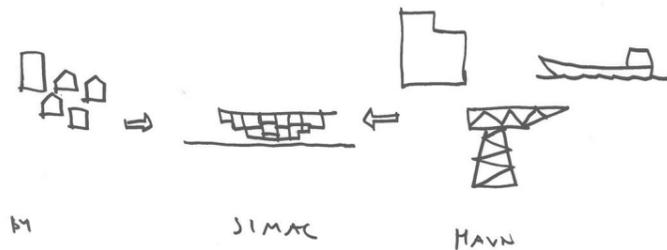
Size: 5,5 ha Masterplan / 12,500 m2 SIMAC Building

Location: Svendborg, Denmark

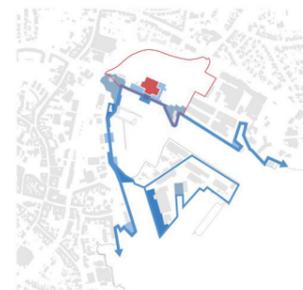
Year: 2019

Located in the city of Svendborg which is a harbor city in Denmark with a great historical heritage in terms of industrial activities, especially the industrial harbor. By winning the competition organized by SMUC Foundation (Svendborg Maritime Education Centre Foundation), the collaboration between EFFEKT & C.F.Møller Architects aims to propose a masterplan as the first outcome and create a design for the new building of teaching rooms, common space and two auditoriums, labs and many other educational functions.

The area is characterized by a mixed-use function with many sorts of activity happening at the same time. The challenges that the architects have to solve is to adapt the new functions as well as find possible strategies to increase the value of built structure, natural landscape and the connectivity to the city's infrastructure, blue and green network.



## The Strategies



### The Blue Edge

The blue edge is the most important line in Svendborg's history, cultural heritage and DNA. The plan places SIMAC in direct continuation of the blue edge building around special urban spaces along the harbor promenade.



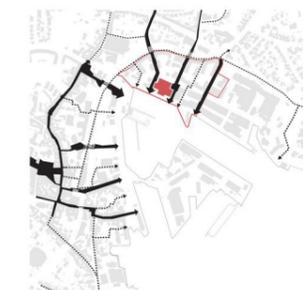
### Green Network

Kobberbækken has been covered years ago, so today the water is led beneath the surface. The opening of the river offers the opportunity to re-establish one of the city's distinctive landscape features, thereby enhancing the neighborhood's coherence with the surroundings.



### Built Structure

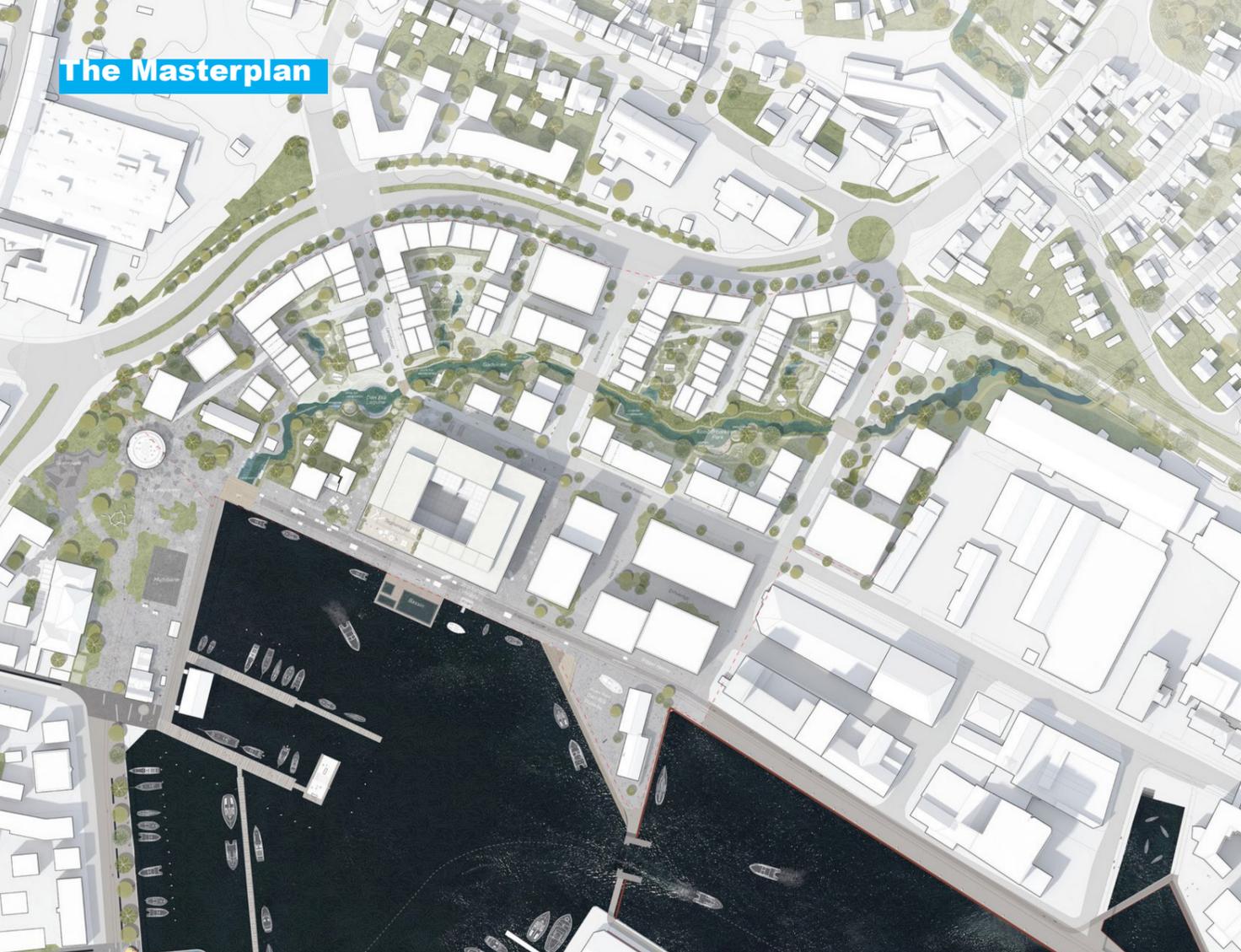
The development plan is designed to combine the surrounding neighborhoods to create meaningful transitions from the city to the harbor, and from the residential buildings to the historic building structure of the industrial harbor.



### Harbour Connections

Svendborg has historically been developed connecting the harbor with the underlying city. We propose to re-establish the connections between the water and the city behind.

## The Masterplan

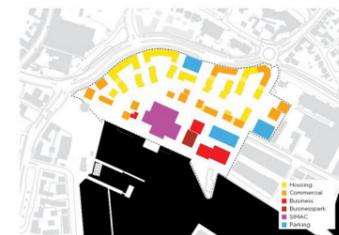
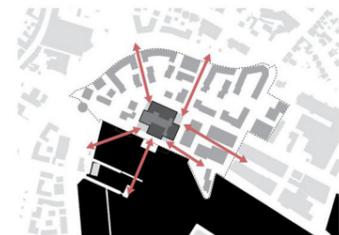
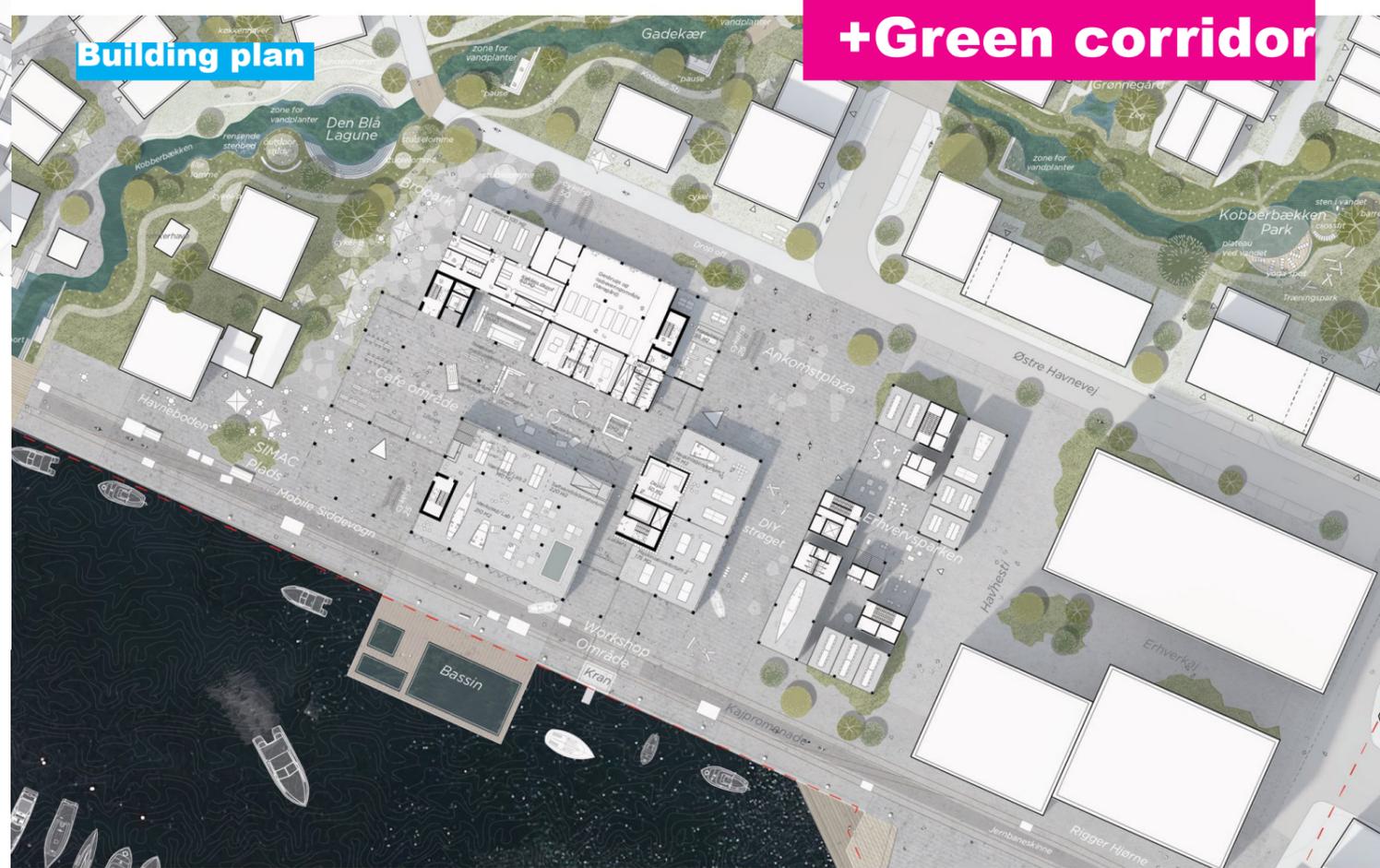


## The Visualization



**Keywords:**  
**+Harbour access**  
**+Green corridor**

## Building plan



### Urban space before building

SIMAC is integrated from the start with the harbor promenade and the reestablished green corridor.

### SIMAC as central hub

The urban structure supports SIMAC as a hub and as a catalyst for the area's urban life and activity.

### Network and access

The new district connects to the surroundings with a close network of different connections.

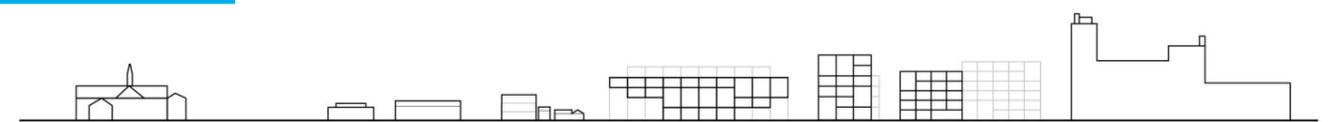
### Functions distribution

The business park is placed in continuation of the active industrial area. The new housing development is placed along Kobberbækken. SIMAC is placed

## The Strategies



## Site section



# Guldborgsund Harbour City



Architects : C.F. Møller Architects

Client: Guldborgsund Municipality

Program: Masterplan

Size: 120600 m<sup>2</sup>

Location: Nykøbing Falster, Denmark

Year: 2021-2022

A new master plan for the harbor in Nykøbing Falster unites the town and the sound, Guldborgsund, and transforms the industrial harbour into a living district with housing, cultural life, and urban spaces with integrated flood protection.

The aim of the project is to integrate Nykøbing Falster into the development of Guldborgsund Municipality development by proposing a set of strategies regarding the blue and green urban space. Water is one of the most important element of every harbor city in Denmark so finding a solution which is balancing the importance of water and green space is really a big challenge that the architects have to overcome.

The solution proposed by C.F.Møller Architects is really good in terms of adapting the existing industrial infrastructure to different new functions and lifestyles. Similar to SIMAC project, this area is a mixed-use function with residential buildings, businesses and recreational facilities. Furthermore, this project is also carried out with the intention to flood protection as a solution to adapt to sea level rising.

Resources: C.F. Møller Architects



Industrihavnens historie

+



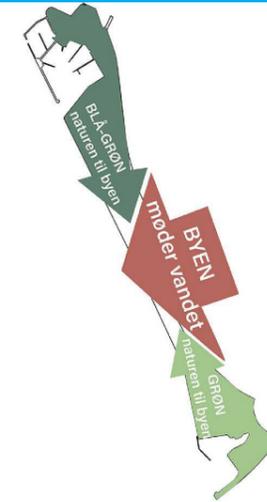
Nykøbing Falsters smukke natur

+

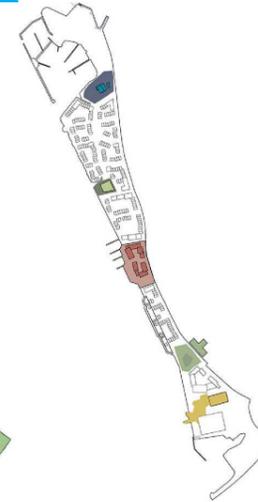


Middelalderstrukturen og bymidtens summen af liv

## The Strategies



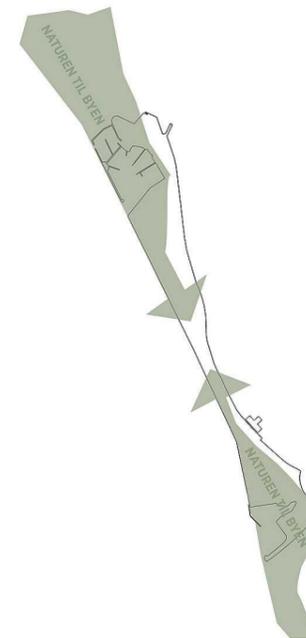
**3 PRIMÆRE LANDSKABS-KARAKTERER**  
HAVNEN BLIVER IKKE ET NYT OMRÅDE, MEN FLERE MINDRE KVARTALER MED HVER DERES UNIKKE KARAKTER.



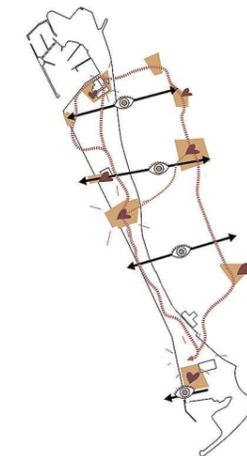
**5 NYE BYRUM**  
NYE BYRUM KOBLES MED HAVNENS HISTORIE OG TILBYDER NYE OG ANDERLEDES OPHOLDS- OG AKTIVITETS-RUM BÅDE TÆT VED OG PÅ VANDET.



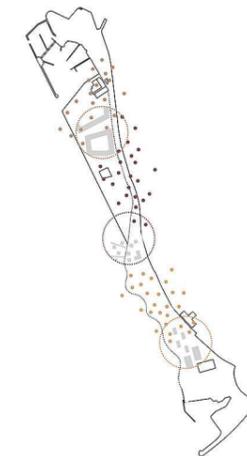
**FORBINDELSER PRIORITERES**  
HAVNEGADE HÅNDETER BÅDE BILERNE OG BLIVER BYENS GRØNNE KORRIDOR. EKISTERENDE OG NYE BYRUM KOBLES Gennem STÆRKE OG STYRKEDE FORBINDELSER FOR GAENDE OG CYKLENDE.



**1. FORBIND DET GRØNNE**  
Det nye bykvarter skal binde kyststrækningen sammen igen, med en natur der forbinder havnebyen fra nord mod syd. Grønne og rekreative byrum skabes til glæde for alle byens borgere.



**2. SKAB SAMMENHÆNG MED EKISTERENDE BY**  
Kig til vandet fra den historiske by bevares og genetableres. De nye byrum supplerer de eksisterende med anderledes karakterer og tilbud, men skaber i udtryk og placering en sammenhæng med de eksisterende.



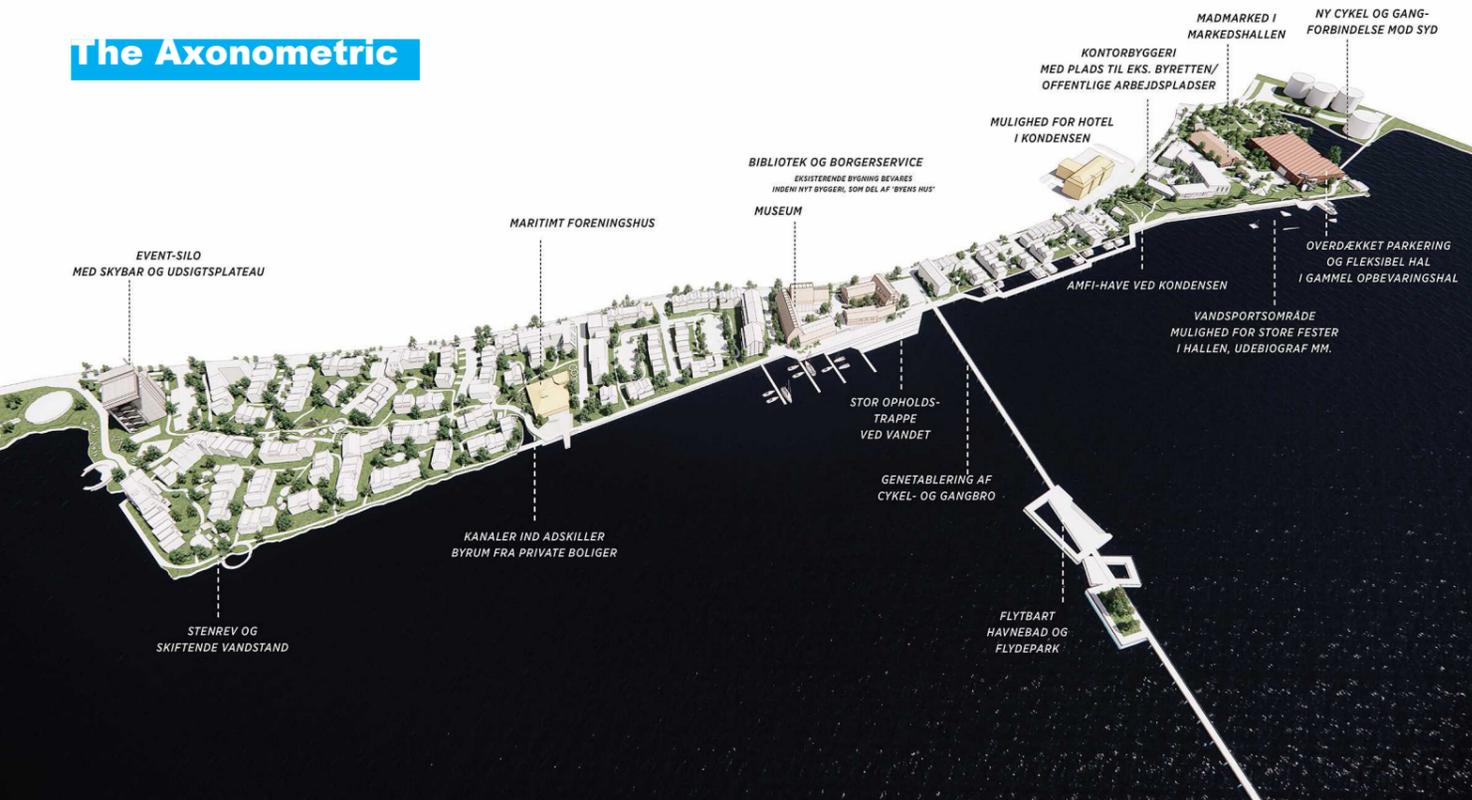
**3. HAVNENS KANT OG MØDET MED VANDET VARIERES**  
Fra at være en monotont, grå kajkant, bearbejdes kanten og bevægelsen langs kysten, så oplevelserne og kajakantens udtryk og forløb varierer op gennem den nye bydel.



**4. BYRUM FØR BYGNINGER**  
Byrumme er placeret som det første i planen og med relation til historien/det bevarede. Bygningerne er brugt som byggesten i helhedsplanen og placeres så der skabes gode rum imellem til både private, semiprivate og offentlige arealer.

Resources: C.F. Møller Architects

## The Axonometric



## The Masterplan



## The Visualization



## The Section



Resources: C.F. Møller Architects

Resources: C.F. Møller Architects

# 2

# Copenhagen

## Urban policies & background

### 2.1 Copenhagen - Urban facts



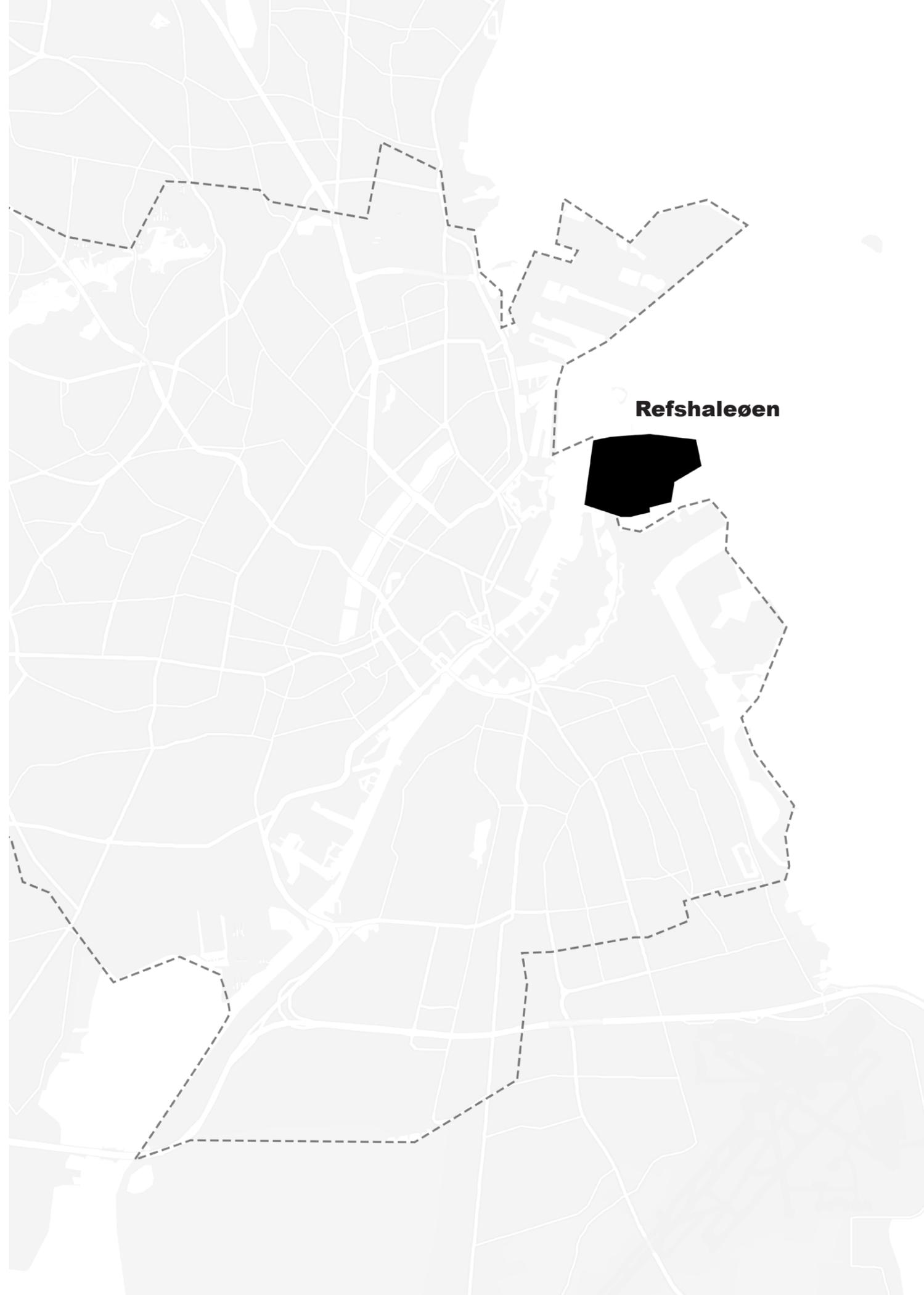
#### IN SHORT

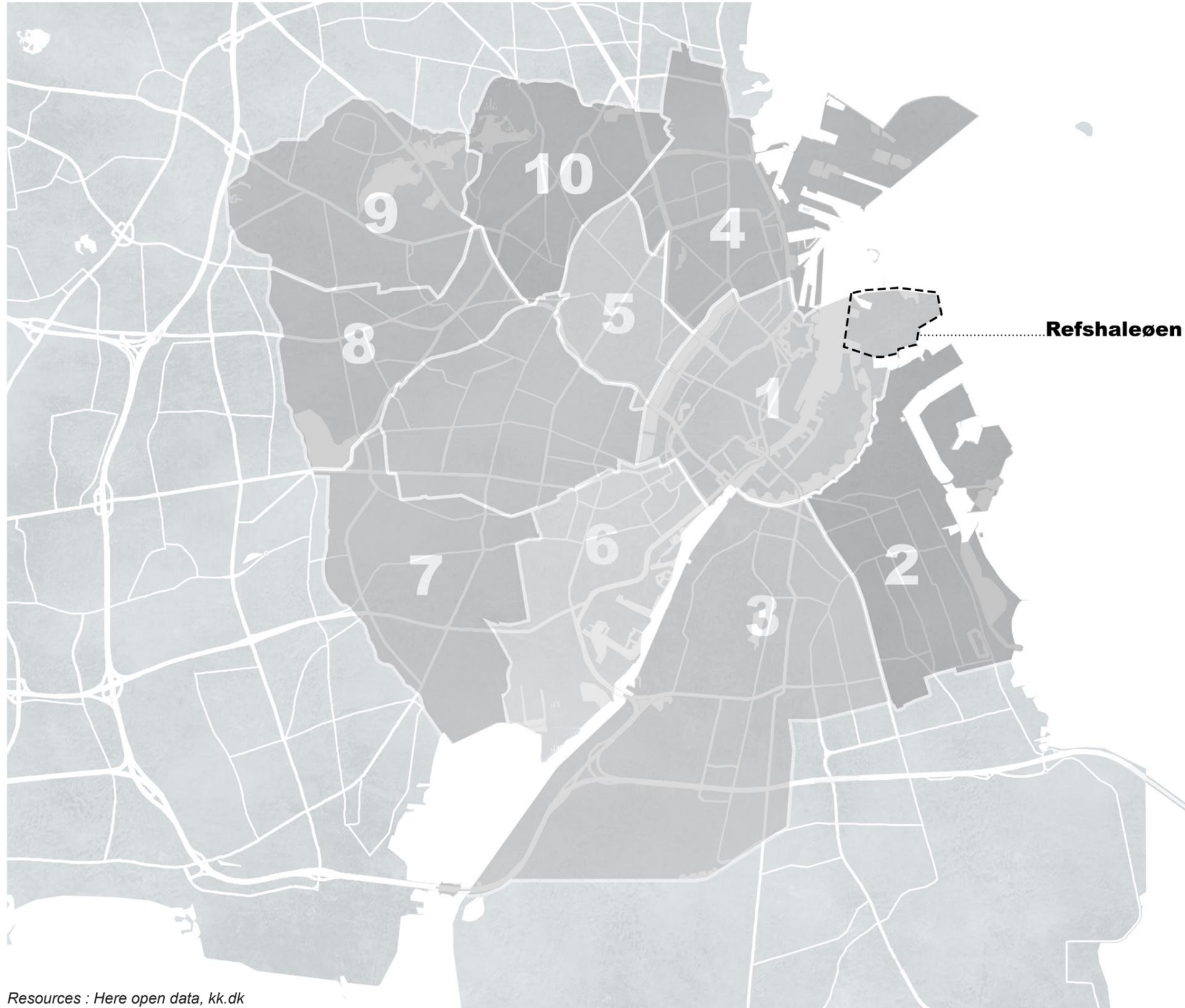
The Danish capital, the city of Copenhagen is one of the most popular destinations in the Scandinavian region. The population of the city is approximately 800.000 (January 2021) and is obviously the most crowded city in Denmark. The city is well known for many effective urban development and planning policies in the few past decades leading to the fact that Copenhagen is one of the most liveable cities in the world.

#### THE SCORE

“Copenhagen continues to inspire and lead as the world’s most bicycle-friendly city. But don’t take it from us – take it from the 41,900 people that cycle along Queen Louises Bridge on any given weekday. Focused on a carbon-neutral future, Copenhagen continues to leverage the timeless efficiency of the bicycle, maintaining the lead this year with sustained investments and unrivaled statistics.”

*James Thoen, Director at Copenhagenize*





- |               |                         |
|---------------|-------------------------|
| 1 Indre By    | 6 Vestebro/Kgs. Enghave |
| 2 Amager Ost  | 7 Valby                 |
| 3 Amager Vest | 8 Vanlose               |
| 4 Osterbro    | 9 Bronshoj-husum        |
| 5 Norrebro    | 10 Bispebjerg           |



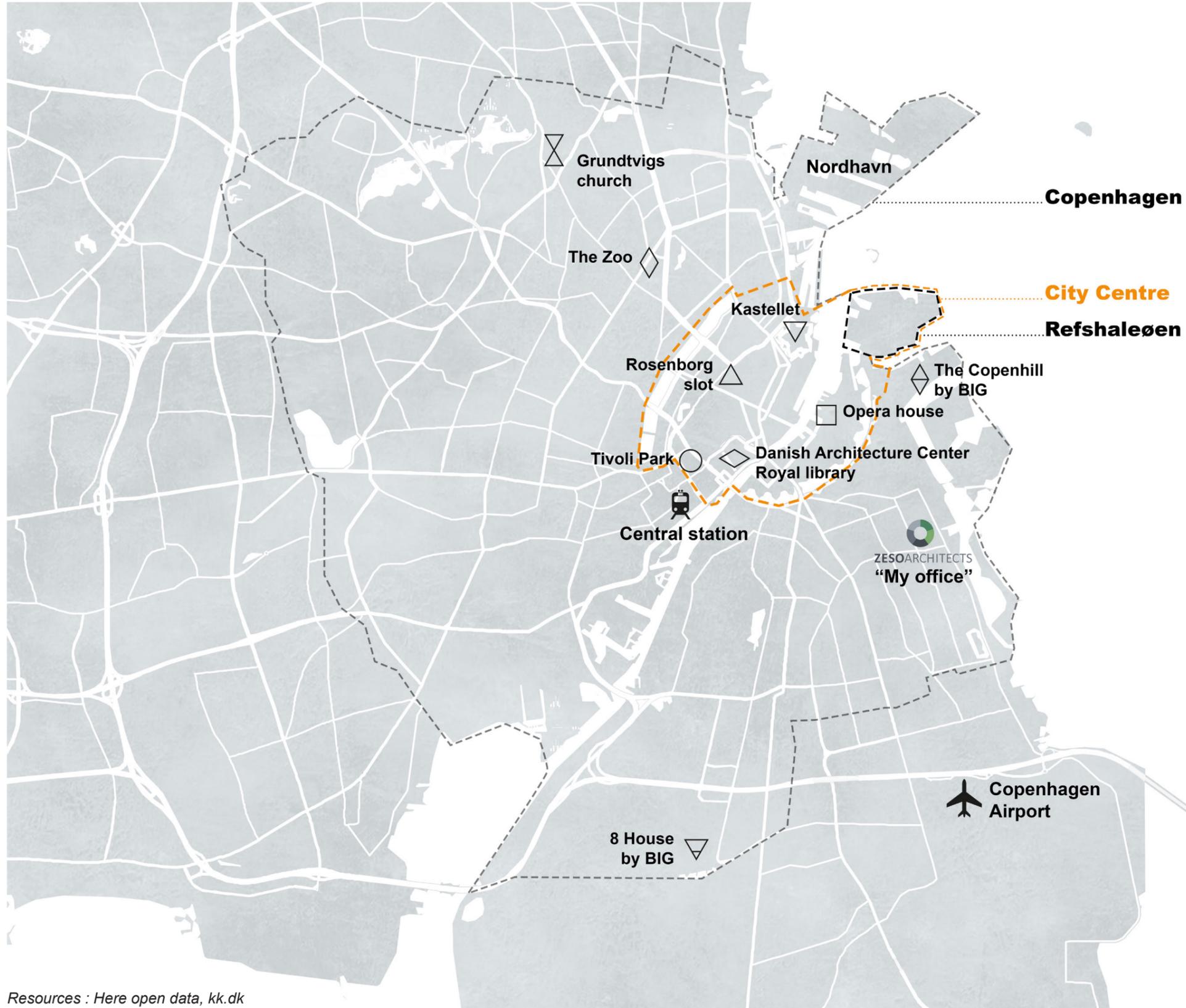
1 Nyhavn



2 Christianhavn

**KEY FACTS :**  
**+ VARIOUS ARCHITECTURE STYLE BETWEEN DISTRICTS**  
**+ THE CITY CENTRE IS DIVIDED BY MANY CANALS**

The city of Copenhagen used to be the main harbor city that held a crucial strategic position in northern Europe for many centuries. For that reason, one of the most special characteristics of the city is that it is divided by many canals and rivers. This fact also led to the consequence that there are several districts that shape the city today with a variety of features, activities, and architectural styles.



1 Rosenborg castle



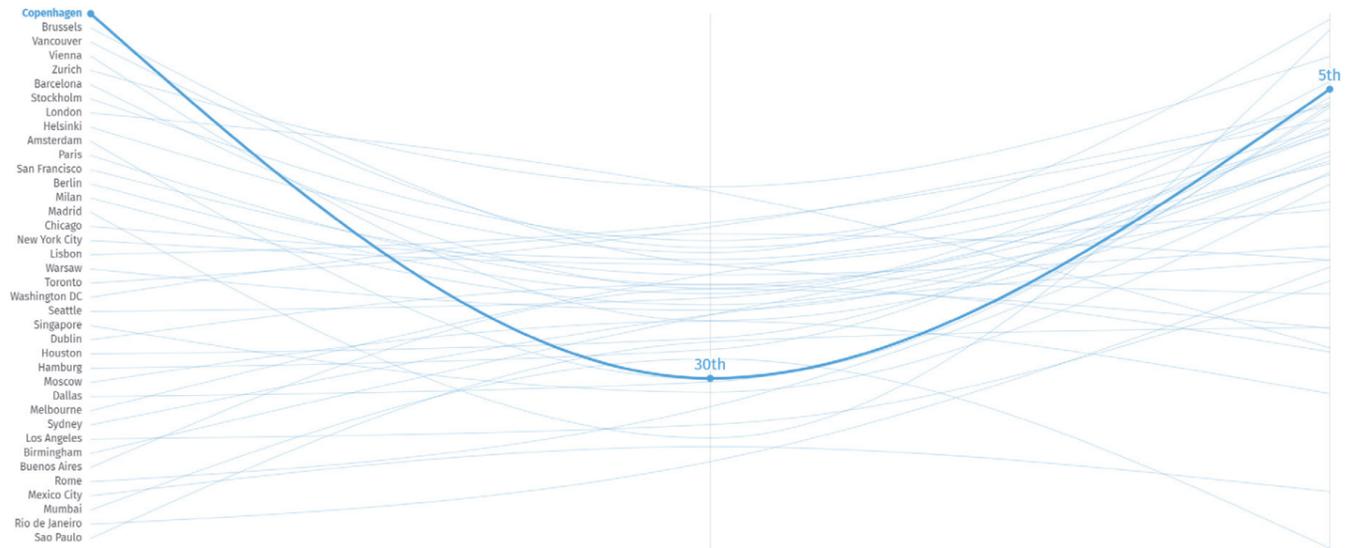
2 Danish Architecture Center by OMA



3 A view towards Opera house, National Theater,...

**KEY FACTS :**  
 + THE AREA IS CLOSE BY MANY FAMOUS LANDMARKS OF THE CITY  
 + THE DIVERSITIES OF ARCHITECTURAL STYLE AND ACTIVITY ARE VERY HIGH

## 2.1 Copenhagen - Urban facts

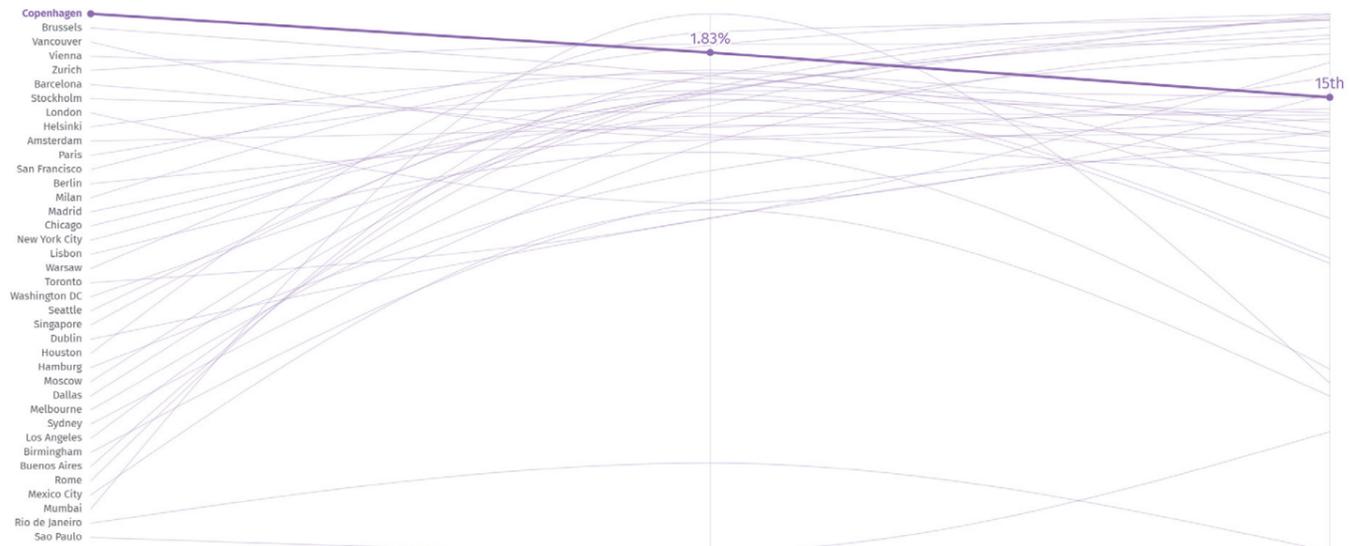


**Public Transport Efficiency**

"Given by the sum of frequency, density, coverage and public transport vs car speed"

**Traffic Flow**

"Given by the sum of percentage of congested roads, time delay in traffic and congestion index"



**Public Transport Expense**

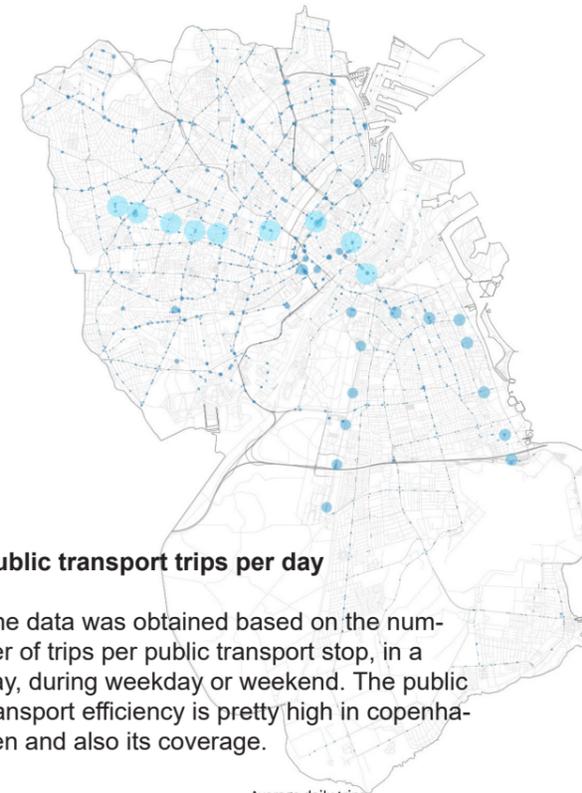
As percentage of monthly income

**Relative Fuel Cost**

As percentage of monthly income

## Mobility

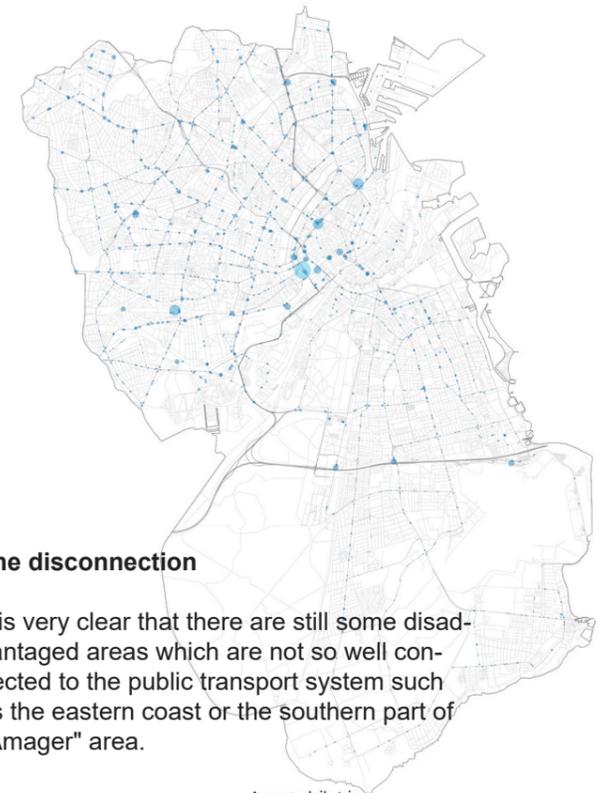
Weekday



**Public transport trips per day**

The data was obtained based on the number of trips per public transport stop, in a day, during weekday or weekend. The public transport efficiency is pretty high in Copenhagen and also its coverage.

Weekend



**The disconnection**

It is very clear that there are still some disadvantaged areas which are not so well connected to the public transport system such as the eastern coast or the southern part of "Amager" area.

### KEY FACTS :

**+ THE PUBLIC TRANSPORT IS VERY GOOD (BOTH QUANTITY & QUALITY)  
+ BUT THE AREA IS NOT SO WELL CONNECTED TO THE SYSTEM**

**Copenhagen has several traffic goals for the vehicular traffic, e.g.:**

+ <<By 2025, car traffic should at a maximum amount to 25% of all trips made in Copenhagen. In addition to this, the number of trips is distributed between at least 25% by foot, 25% by bike and 25% by public transport by 2025>>

(from Municipal Plan 2019)

+ <<At least 75% of traffic should be by bike, foot or public transport by 2025>>

(from The climate plan KBH 2025)

+ <<Cycling amounts to at least half the trips to work or place of education. Towards Municipal Plan 2023 the City of Copenhagen will examine to what extent it is necessary to revise the Copenhagen traffic goals>>

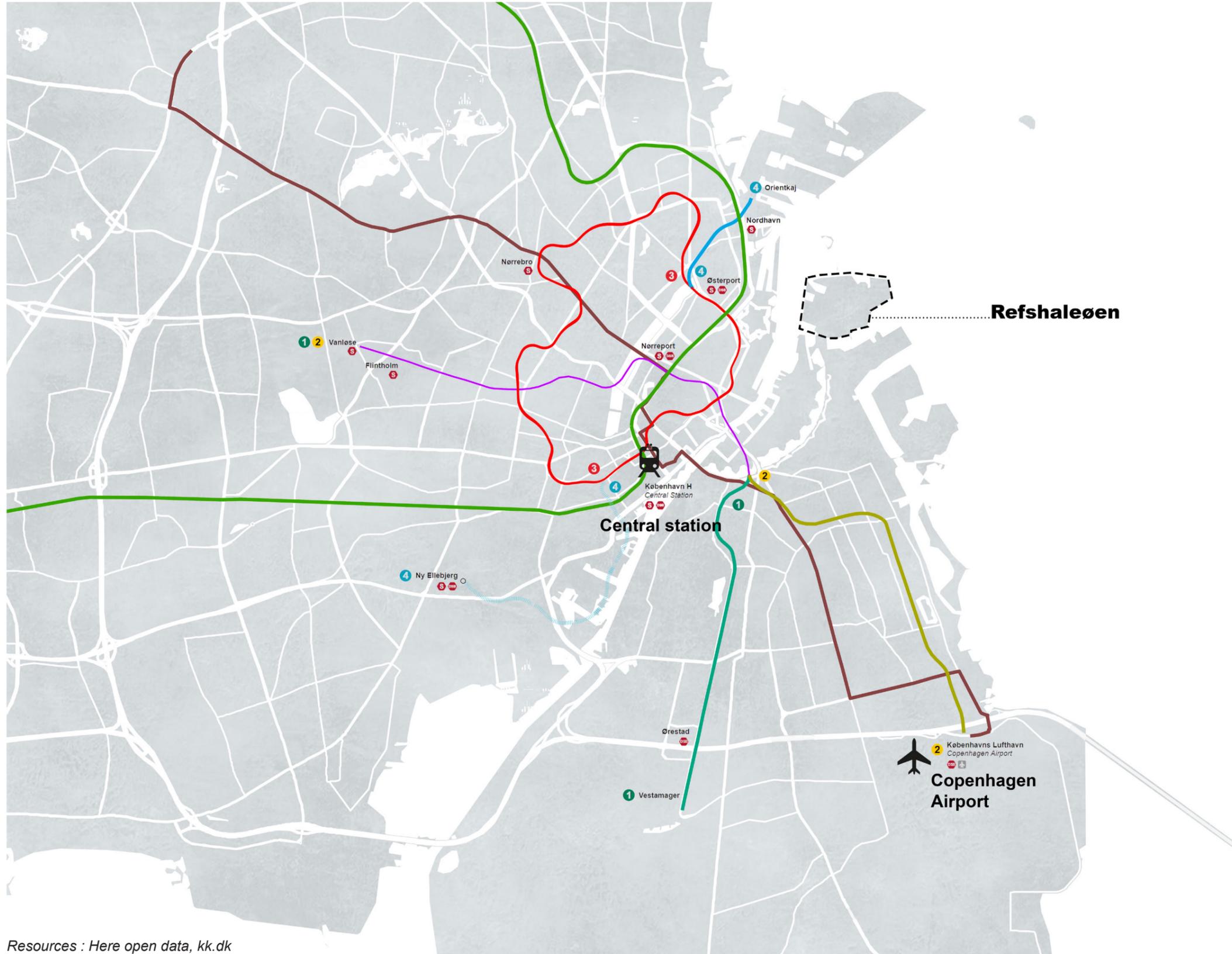
( from The Copenhagen cycling strategy)



1 City Train



2 Metro



- 1 Line 1  
Vanløse - Vestamager
- 2 Line 2  
Vanløse - Københavns Lufthavn
- 3 Line 3  
Circular
- 4 Line 4  
Østerport - Ny Ellebjerg
- S Connection with S-Train
- DSB Connection with regional and national trains
- Airport

**KEY FACTS :**  
**+ THE PRESENT METRO AND TRAIN SYSTEM ARE NOT CONNECTED TO THE REF-SHALEØEN**

**The cityring and the public transportation of the future**

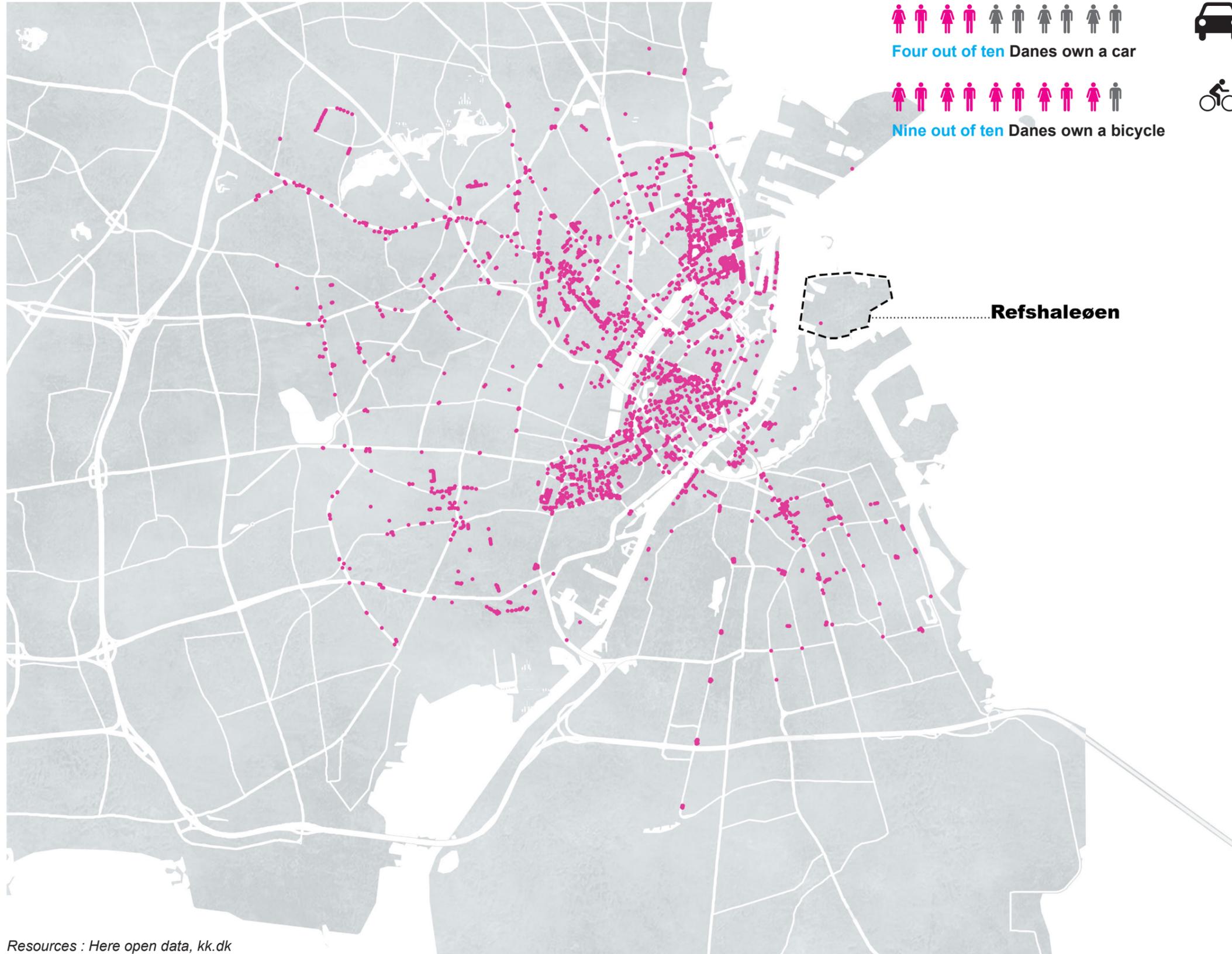
The idea of a transportation ring that runs around the city has changed the way of commuting of Copenhageners totally in a positive way in 2019 when it was operated. Now the local citizen and the visitors will find it more convenient to travel from the suburb neighborhoods to the city center than before. This development also leads to the possibility of new urbanization strategies for the city.

A lot of areas are now connected by the metro system and there will be more in the upcoming years. The urban train and bus systems are also functioning very well in connecting different communes in the region. In 2020, the new metro line of Nordhavn was completed and there is metro Sydhavn which is going to be operated in 2024. With the cityring system, the aim is to increase the number of people using public transport according to the municipality plan 2019.



1 Nørreport - major traffic intersection of city centre

Density of cycling activities



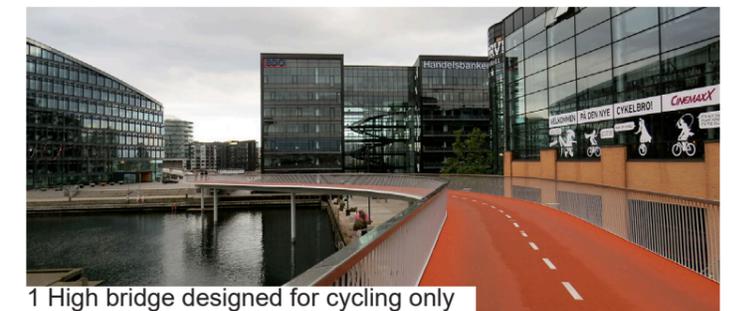
**KEY FACTS :**  
 + THE CYCLING ACTIVITIES ARE MOSTLY CONCENTRATED IN THE CITY CENTRE AND NEARBY NORTHERN AREAS  
 + IT SHOULD BE INCREASED TO THE EAST (THE REFSHALEØEN) AND THE SOUTH



The city of cyclist

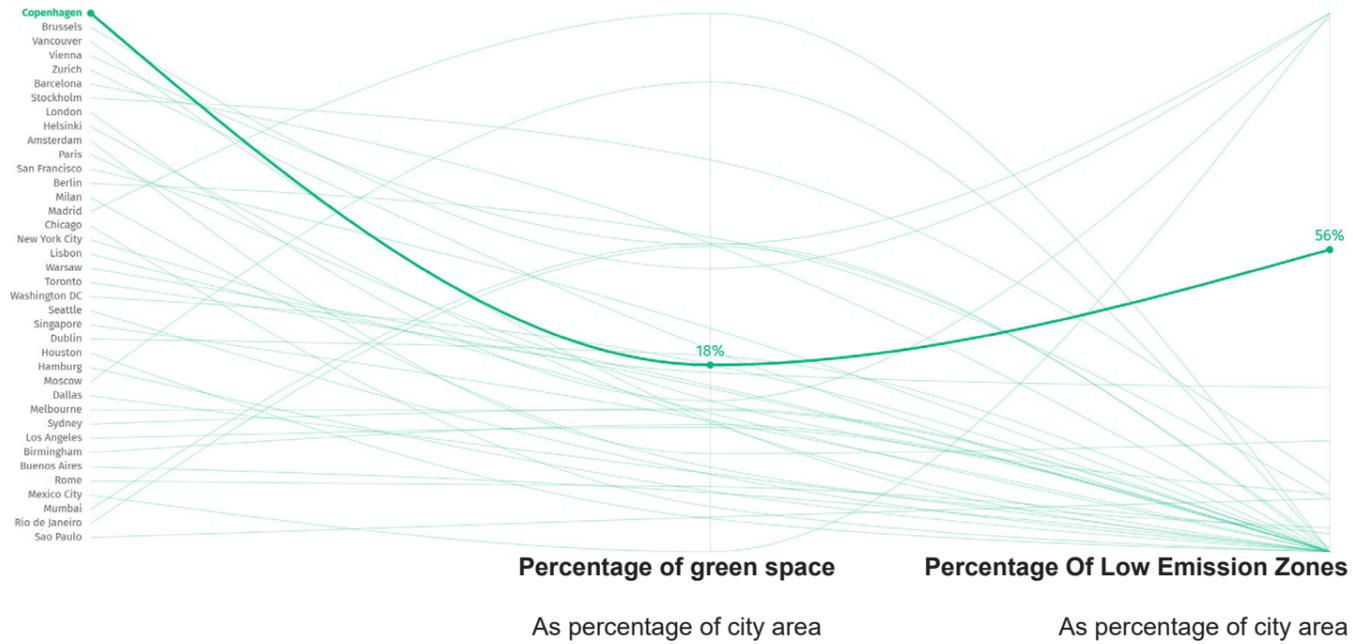
It is Copenhagen's goal to become the world's best bicycle city and for half of commuters to cycle to their place of work or education. That means that whereas today we see three cyclists, in the future we will see four. It will take an extensive effort to reach that goal, which is why bicycles must be incorporated into all planning and all solutions in the city.

Along with Amsterdam, Copenhagen is very famous for the fact that most of the citizens is using bikes as the major mean of transport. Many infrastructures reserved partly or entirely for bikes were built and have been built. Also, the system of bikes for rent and its facilities have been installed in many places in the city. This tendency will not stop here instead, it will be developed more in the future with many incomings projects.

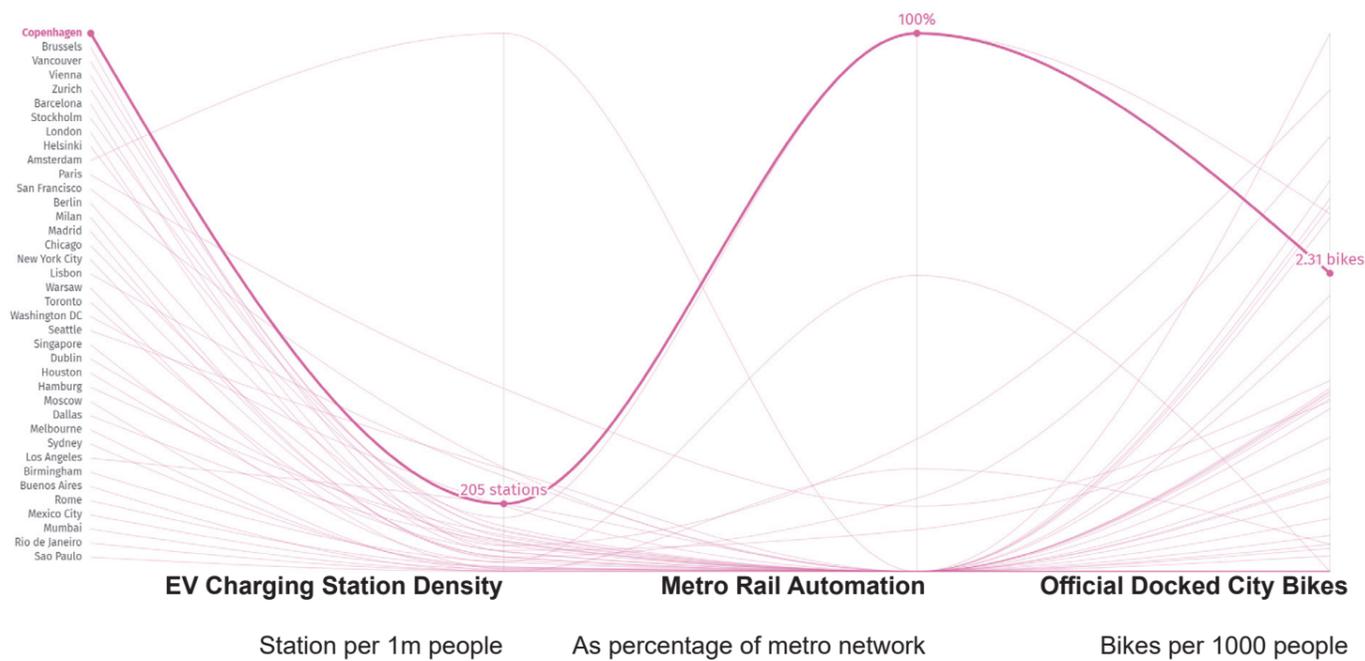
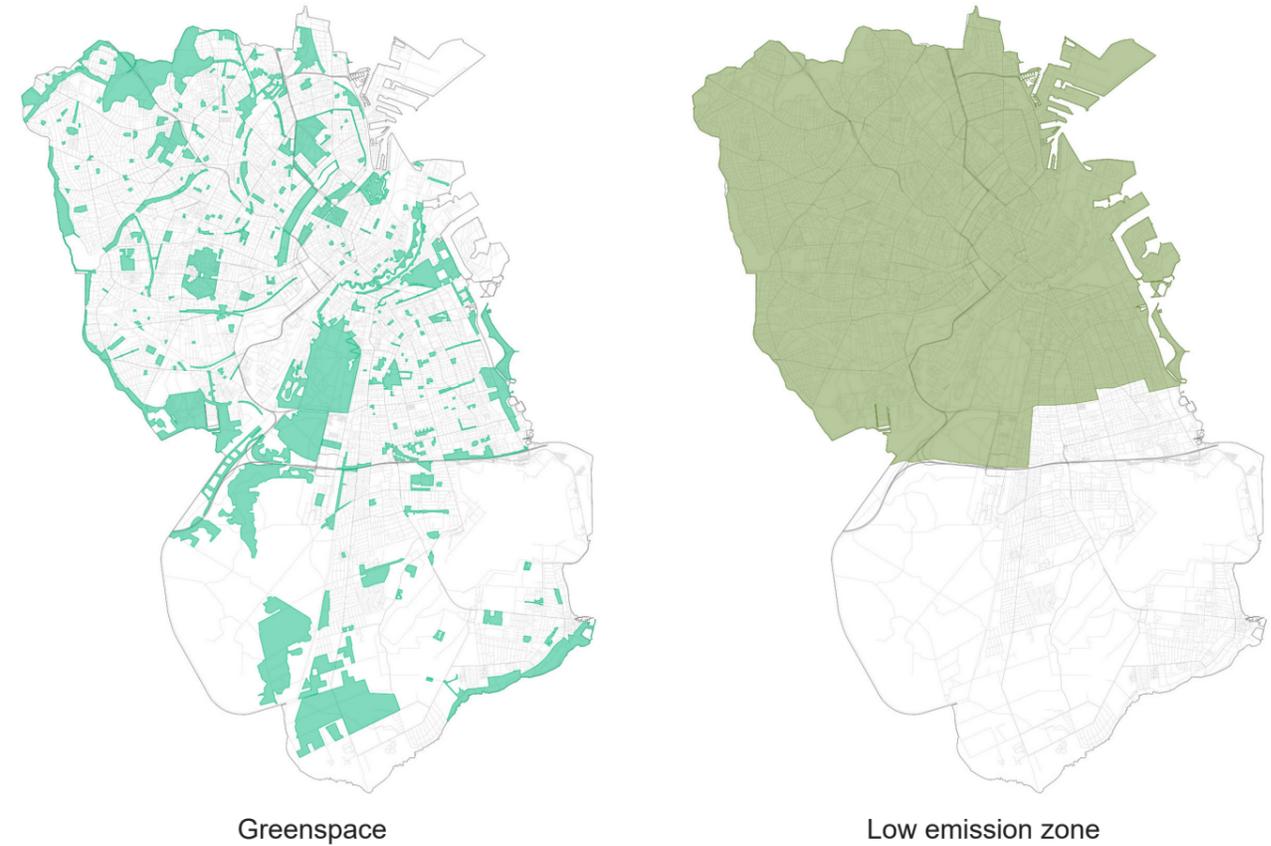


Resources : Here open data, kk.dk

## 2.1 Copenhagen - Urban facts



## Sustainability



**KEY FACTS :**  
**+ THE DENSITY OF GREEN AREAS IS VERY HIGH IN COPENHAGEN**  
**+ LOW EMISSION ZONE LOCATED IN MOSTLY CITY CENTRE AND THE NORTHERN PARTS**

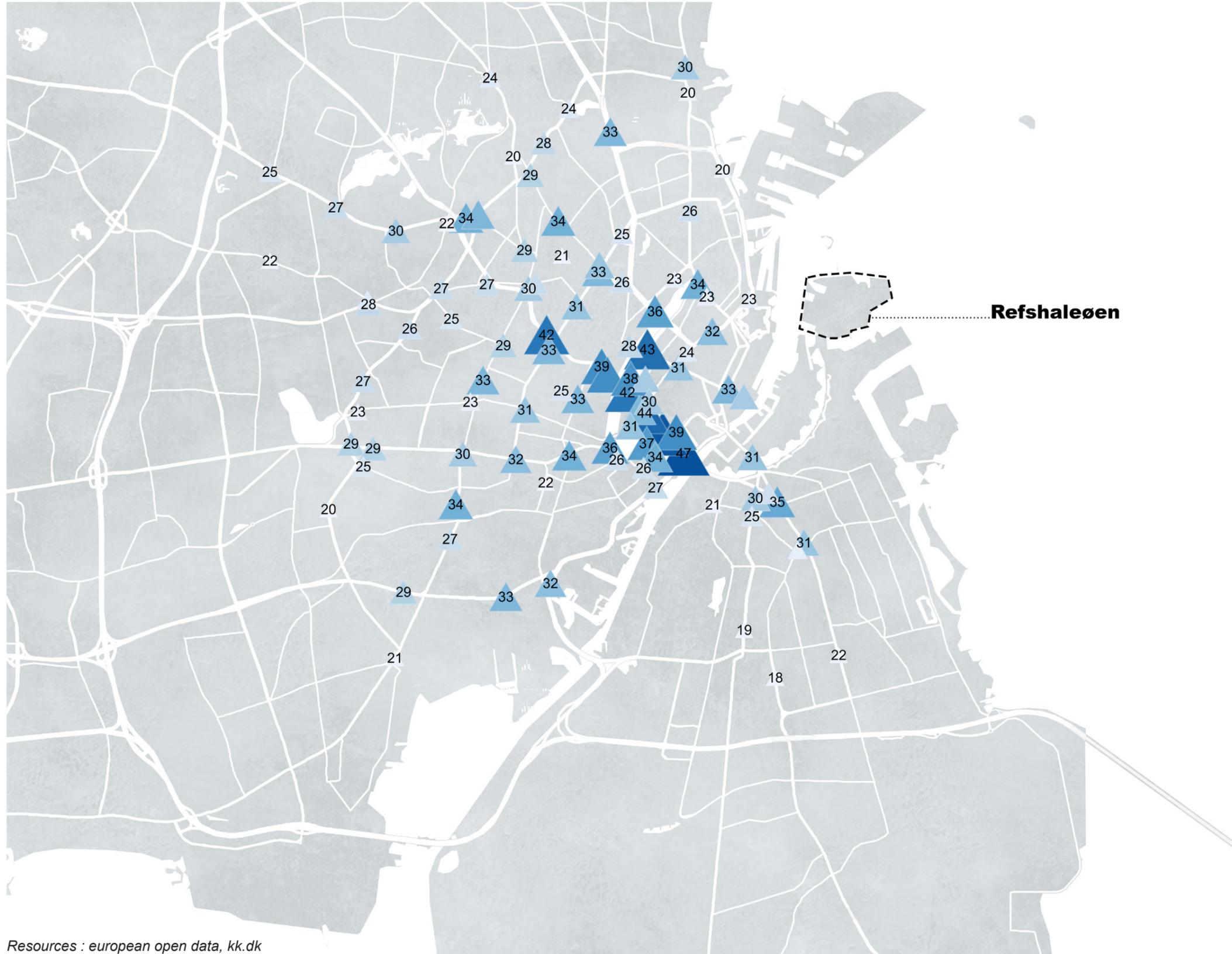
### A green capital - A carbon-neutral city

One of the most ambitious visions of the city of Copenhagen is that in 2025, Copenhagen will be the first carbon-neutral city in the world. Obviously, there are still many discussions, decisions, efforts and works that need to be made but this claim shows a very dedicated development strategy from the authority.

As a harbor city, the blue and green structure is the most important part of the city's landscape playing a crucial role in not only providing a distinct lifestyle but also being an irreplaceable part of climate change adaptation. Thus, many projects and policies were carried out in order to promote this tendency, providing more green spaces and waterfront facilities to ensure the easy access for the people.



Annual CO2 emission in CPH (megatons)



**KEY FACTS :**  
**+ WITH THE HIGH DENSITY OF VEHICLES AND ACTIVITIES IN THE CITY CENTRE, IT IS OBVIOUS THAT THIS AREA HAS HIGHEST CO2 EMISSION**

The goals of the City of Copenhagen are:

- <<→ That Copenhagen will CO2 neutral by 2025.
- That new recreational areas and open spaces for new construction contribute to making the city more green to the benefit of the citizens' quality of life, biodiversity and to adapt the city to the climate of the future.
- That the quality of the city's existing recreational areas is improved to the benefit of the citizens' quality of life, the biodiversity and to adapt the city to the climate of the future.
- That car traffic by 2025 at a maximum makes up 25% of all distances covered in Copenhagen. In addition to this, the various distances covered are divided so that at least 25% is by foot, 25% by bike and 25% by collective transport by 2025.
- That comfort, passability and security for pedestrians is improved so that the average number of daily trips by foot per Copenhagener in Copenhagen is increased by 20% compared to 2017.
- That no road users will be killed or seriously injured in traffic.
- That the air quality in Copenhagen is improved so that it lives up to the guidelines of the World Health Organisation WHO for good air quality.
- To remove or minimise the effects of polluted soil for the health of the citizens, the groundwater and the environment in general.
- That noise pollution of existing and new housing is reduced.>>

(according to Municipality Plan 2019)



1 Wind Turbine (Offshore wind farm)

## 2.2 Municipality Plan

### What is Municipality Plan ?

Copenhagen has become a paragon of urban planning and urban design over the last 7 decades. There are so many urban strategies and projects were carried out to bring that reputation to the city and the most important, turned the city to be one the most liveable and sustainable place in the world. Behind that successful development, the municipality plan plays a crucial role to define the **strategies, policies** and **frameworks** for local planning.

Municipal plans were introduced by the Law on Municipal Planning (adopted in 1975, in force on 1 February 1977) to replace the disposition plans of the past. It was made an obligation by law that the new municipalities which emerged after the 1970 municipal reform should have such an overall plan drawn up, which would then be the basis for drawing up the local plans introduced by the same law.

Basically, **The municipality plan of Copenhagen** is the set of documents that contain the overall plan for the physical development of the city which came from many researches, assesments, consultations from the authorities, citizens and third party stakeholders. This plan will be published for roughly every 4 year, the latest document is from 2019 and at this moment, the city council is working on the new plan for 2023. Municipal plans were to be valid for 12 years at a time and then subject to scrutiny for possible revision.

Furthermore, according to the Planning Act, Copenhagen's Citizens' Representation must adopt and publish a **planning strategy** every 4 years. The municipal plan strategy is the Citizen Representation's assessment of the city's development and contains a long-term strategy for the development of Copenhagen in the years up to 2031 according to the document published in 2018. This strategy also serves as a background or a context for the final municipality plan.

### Contents

The municipality plan was to be a comprehensive framework plan for land use in a given municipality and to provide information on the intended actions within,

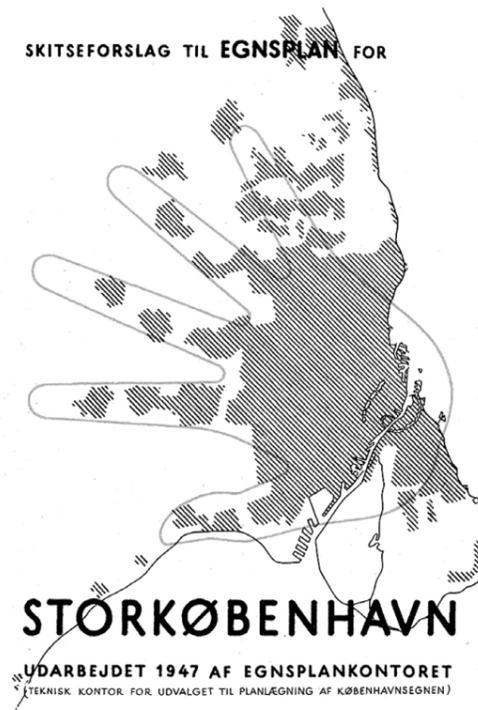
among other things:

- + The distribution of land by main features (residential areas, business areas, industrial areas, green areas, technical installations, holiday homes and so on);
- + The intended service of the population with public institutions (crèches, kindergartens, after-school centres, schools, nursing homes, libraries, sports and sports facilities and so on);
- + The operation of shops (groceries, selection goods), the main features of road networks and paths,
- + The location, design and materials of the building;
- + Preservation of buildings and landscape features,
- + Ensuring free space;
- + The location of common facilities and their operating areas.

In addition, the municipality plan could contain information on the conditions for its content:

- + The legal basis and the municipal council's casework,
- + The previous urban planning work,
- + Population projections by age group,
- + Planning (regional plan, country planning directives, planned highways),
- + Other settlement regulating conditions (airfield noise zones and more),
- + Conservations and building lines under the nature conservation act,
- + Peace forest areas,
- + Redevelopment and urban renewal areas under the redevelopment act, later the urban renewal act,
- + Occupational space and commuting,
- + Information on the volume of trade turnover by sub-area;
- + The economic situation of the municipality (investment opportunities).

The municipal plans were characterised by the fact that the unequal sub-areas (districts or urban areas in municipalities with several urban formations) each received their own special treatment.



This picture is the very first modern urban planning vision as know as "The five finger plan" that was carried out by the collaboration between the city and the urban planners Steen Eiler Rasmussen and Christian Erhardt "Peter" Bredsdorff, developed in 1947 through Urban Planning Laboratory, is an urban development plan that focuses on both metropolitan train lines and the green spaces in between. As you can see from the graphic, the idea is that the train lines (s-tog) spread like fingers on a hand from the "palm" of central Copenhagen. At the time of it's inception, the Five Finger Plan did not go into Amager, which did not have the infrastructure to support its inclusion. Now, Amager is a much more developed area of Copenhagen and is considered to be the "extra finger."

### Preparation of Municipality Plans

From the first municipality plans were published and since then with all significant adjustments to the municipal plan - there are many efforts have been done to ensure the comprehensivity of the

plans in order to support the process of urban planning. This should be achieved by the greatest possible transparency of the planning work and also by encouraging the active participation of the population.

When the Municipal Planning Act was adopted, it was decided that the municipal council should endeavour to involve the municipality's citizens in their design prior to the preparation of the municipal plan. The public should be involved as far as possible in the work on the design of our surroundings. Municipal plans may contain outline proposals on how an area may be used or a planned project should be carried out in concrete terms. As part of this activity, citizens' meetings were also to be held and given the opportunity for the public to discuss opportunities and proposals themselves in working groups and to express themselves on the municipal council's proposals and to make their own proposals for the design of the municipal plan, including for issues which may have escaped the attention of the municipal council.



The above image show an urban workshop that was carried out in Nordhavn which is a great area in term of urban development, The knowledge exchange is the main aim of this activity which includes the citizen, authorities and the organizations.

## 2.2 Municipality Plan

### Copenhagen Municipality Plan 2019

<<The municipal plan is the overall plan for the city's physical development. Copenhagen Municipality Plan 2019 was adopted on 27 February 2020 and is announced on 20 April 2020.

The document indicates a very clear system of "work-to-do" in the upcoming 12 years. There are 3 major pillars which are : a political main structure, guidelines and framework of the local development plan.

The political main structure shows the general strategies for city planning and some regulations regarding the landuse. Furthermore, it also includes some policies for the housing, entertainment facility and landscape or mobility infrastructure.

The second pillar provides the administrative base for the landuse, the preservation and renovation directive of many cultural heritages.

The final pillar, the framework is created to clarify the scope of work for every certain area that are taken into consideration in the scope of Kommune Plan 2019. It also gives information about the local plans or updated version of present ones which is a very useful document when we have to design a building in Denmark.

Generally, the city of Copenhagen want to emphasize on these aspects when the Kommune plan 2019 was published :

- + Urban development framework
- + Urban life between public and private spaces
- + Business
- + Mobility
- + Energy and environment
- + Entertainment and natural elements>>

(Resources (information) : <https://kp19.kk.dk/sites/default/files/2021-03/Kommuneplan%2019%20Engelsk%2003.pdf>)

**Kommune Plan 05**

**Kommune Plan 09**

**Kommune Plan 11**

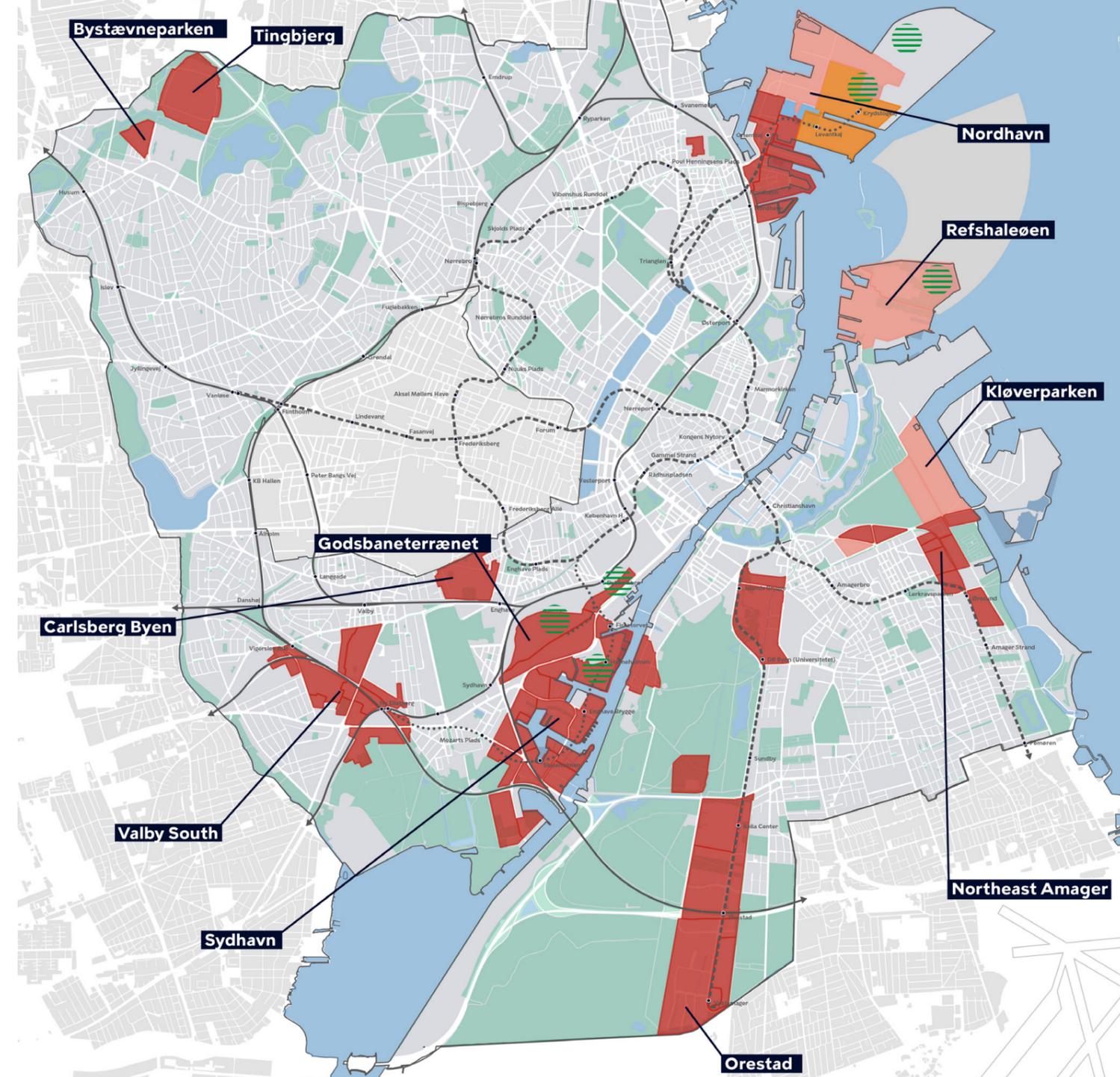
**Kommune Plan 15**

**Kommune Plan 19**

**World city with responsibility**

**KEY FACTS :**  
**+ THE REFSHALEØEN WILL BE DEVELOPED AT THE EARLIEST FROM 2031**  
**+ IT IS ALSO CONSIDERED AS A POTENTIAL AREA FOR NEW RECREATIONAL AREA**

Resources : [kk.dk](http://kk.dk), [wikipedia.org](http://wikipedia.org)



### An overview of Copenhagen plan 2019

#### Order of urban development in Copenhagen

- 1st part of the plan period (developed at the earliest from 2019)
- 2nd part of the plan period (developed at the earliest from 2025)
- Perspective area (developed at the earliest from 2031)
- Potential areas for new large and mid-sized recreational areas

#### Public transport

- S-train
- - - - Existing metro
- · · · · Planned metro

Resources (maps, figures) : <https://kp19.kk.dk/sites/default/files/2021-03/Kommuneplan%2019%20Engelsk%2003.pdf>

#### Need for 60.000 new homes and new business square meters

	Residential (m <sup>2</sup> )	Business (m <sup>2</sup> )
Need towards 2031	4,200,000	2,400,000

Of this 75 % is expected to be established in urban development areas and 25 % in the existing city

#### Spaciousness in urban development areas

Area	Residential (m <sup>2</sup> )	Business (m <sup>2</sup> )
Orestad	830,000	760,000
Nordhavn	920,000	750,000
Sydhavn	390,000	340,000
Valby South	540,000	290,000
Carlsberg Byen	240,000	150,000
Northeast Amager	390,000	150,000
Godtbaneterrænet and Bådehavnsgade	820,000	330,000
Bystævneparken and Tingbjerg	190,000	0
Other areas	80,000	30,000
<b>Total space</b>	<b>4,400,000</b>	<b>2,800,000</b>

Estimated spaciousness (calculated primo 2019)

## 2.2 Municipality Plan

### Lynetteholmen and future mobility

With the agreement in principle between the state and Copenhagen Municipality about Lynetteholmen the first steps have been taken a holistic and long-term plan for Copenhagen's development. Lynetteholmen constructed as a new islet by filling an area in the Sound in extension of Refshaleøen and Lynetten.

Lynetteholmen will help to solve three overall challenges for Copenhagen. Climate change is involved to challenge Copenhagen's coastline. Warmer and generally wetter weather as well as sea level rises mean that Copenhagen in the future will be in higher risk of being flooded. There is in this connection need to ensure Copenhagen against storm surge from the north, which Lynetteholmen contributes to. With continued population growth Copenhagen will be missing in the long term areas for urban development.

Lynetteholmens area of more than 2 million. m<sup>2</sup> will therefore be included as an important contribution to the opportunity to continue to build new homes for those many new Copenhageners and thereby keep house prices down. The congestion problems in Copenhagen increases as we become more numerous in Copenhagen and in the metropolitan area. That is therefore necessary with investments in new infrastructure. The income from the urban development of Lynetteholmen will could help fund metro service of the area and the establishment of an Eastern Ring Road, then the thoroughfare traffic can be diverted inner city districts and to a greater extent settled in tunnel instead of at street level.

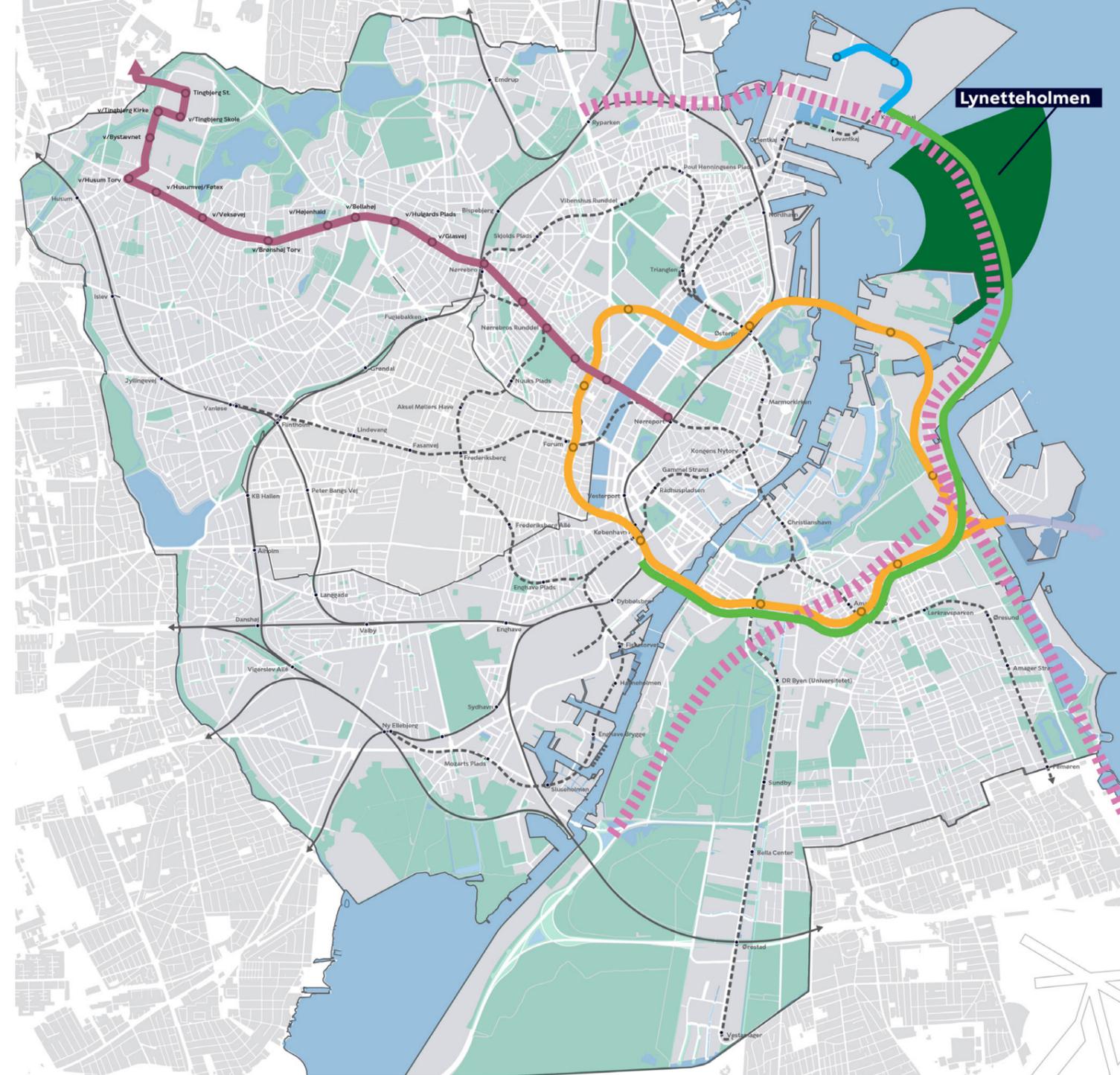
### The vision for Lynetteholmen

Lynetteholmen must be sustainable district with mixed housing and professions based on high standards of sustainable construction. That is the intention to create a district that builds on on Copenhagen's uniqueness with mixed features, green parks and not at least surrounded by water. The development of the new district must therefore also happen with a focus on cycling and with public transport based on metro service to the center of Copenhagen. All residents of Ly-

netteholmen will have close access to the coast-line, which must be established with different qualities, so the residents and all Copenhageners ensure access to new recreational areas. The area will eventually be able to accommodate ca. 2.5-3 million floor meters residential and commercial construction. This means that Lynetteholmen will be able to house around 35,000 residents and a similar number of jobs. 25% of the new ones the dwellings are expected to become public.

### A thorough preparation

It requires a thorough preparation to establish projects of that magnitude as Lynetteholmen, more metro and an Eastern Ring Road is. Therefore must in the coming years a series of studies and analyzes, which illuminates the economics of the projects and impact on the environment, before a final decision can be made about the projects. These analyzes must not least illuminate the impact of residents and users in the areas affected by the major projects and assign long-term sustainable solutions, then the qualities of the areas can be continued. The feasibility studies concerning Eastern Ring road and metro service as well financial analysis of the establishment of Lynetteholmen, Østlig Ringvej and metro expected to be completed in mid-2020. The EIA study regarding construction of Lynetteholmen (filling and operation of land reception) is expected completed in the autumn of 2020. Thereafter, the Construction Act will have to be adopted for Lynetteholmen, after which earth filling can be started. Subsequently, EIA studies will of Østlig Ringvej and metro service could be started. These will subsequently should be adopted by the Construction Act. Overall, this is expected to take two to three years to complete. The parent infrastructure (Østlig Ringvej and metro connection) is assessed to be able to constructed with opening around 2035.



#### Proposals for future infrastructure in Copenhagen

- Light rail from Gladsaxe Trafikplads to Nørreport st.
- Eastern Ring Road
- Metro Havneringen
- Lynetteholmen
- Nordhavnsmetro
- Øresund Metro

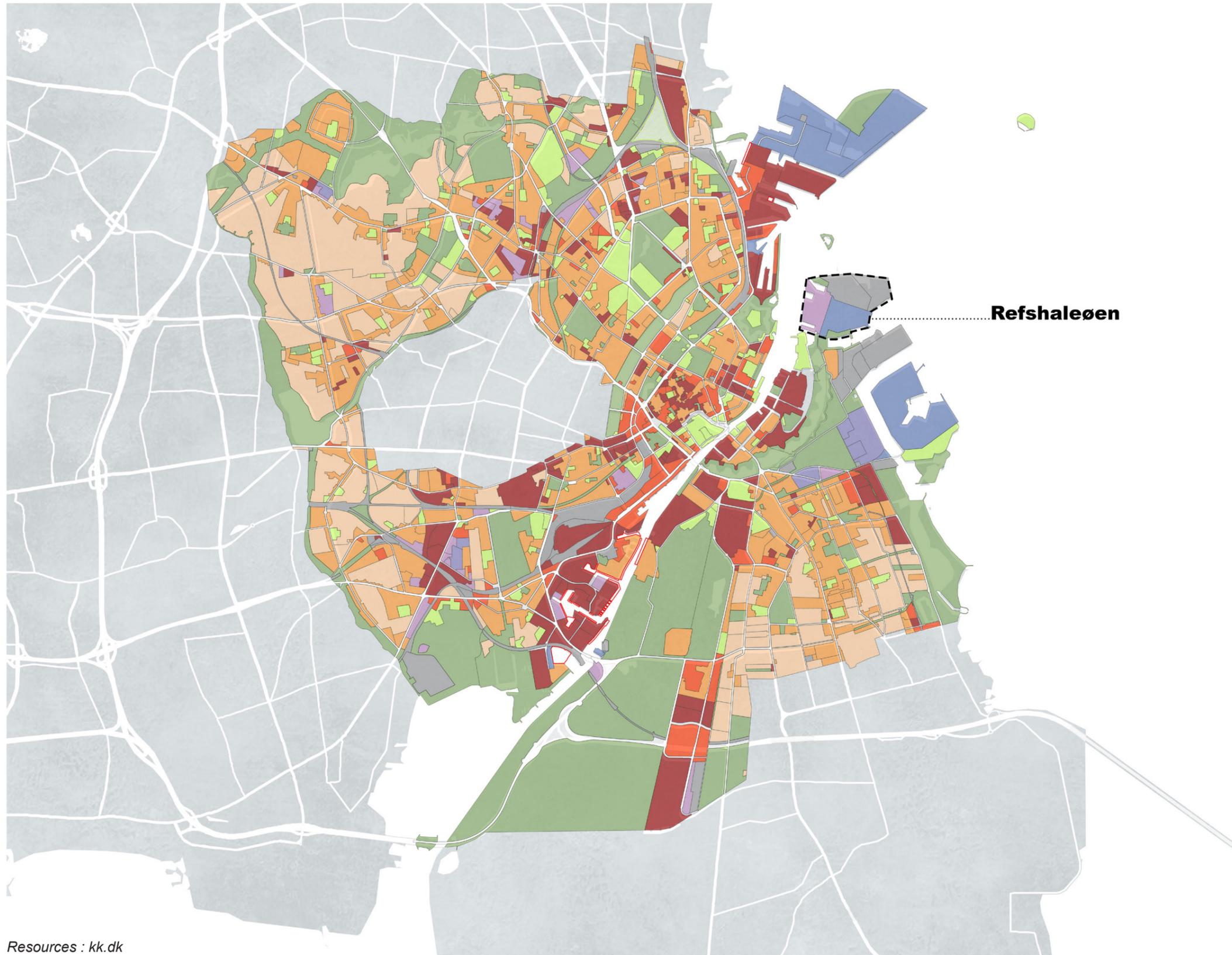
#### Public transport

- S-train
- Existing metro

### Vision for Copenhagen's future mobility

A number of Copenhagen's challenges require long-term solutions. Some of them lie outside the municipal's plan period, applicable to 2031. On the map above it appears key proposals for new infrastructure or expansion of the city for a period up to 2070. Common to all of them is that there is still outstanding studies or funding before they can be realized.

Landuse



- Housing (low density)
- Housing (high density)
- Housing and service industries
- Service profession
- Mixed professions
- Industry
- Port purposes
- Technical facilities
- Technical facilities (roads, etc.)
- Institutions
- Leisure purposes
- Houseboats
- National Planning Directive

**KEY FACTS :**  
**+ THE REFSHALEØEN WILL BE DEVELOPED AT THE EARLIEST FROM 2031**  
**+ IT IS ALSO CONSIDERED AS A POTENTIAL AREA FOR NEW RECREATIONAL AREA**

**Refshaleøen as a perspective area**

Refshaleøen has been developing since the 1990s from being a closed industrial area to be an open area in Copenhagen with lots of opportunities. Refshaleøen is, especially in the summer, has become a popular excursion destination for Copenhageners and the city's guests attractions such as the Copenhagen Museum Contemporary, the food market Reffen and the large climbing hall Blocs & Walls. Refshaleøen is maintained in the Municipal Plan 2019 as an area of perspective in the order plan for the development of the city. That means an urban development first can take place after 2031 and that in the area will continue to be good location opportunities for creative professions, temporary initiatives, festivals and events. In connection with the development of Lynetteholmen and the planning of new infrastructure, Refshaleøen must be considered as coherent with it surrounding town.

# 3

# Refshaleøen

The site area

## Overview



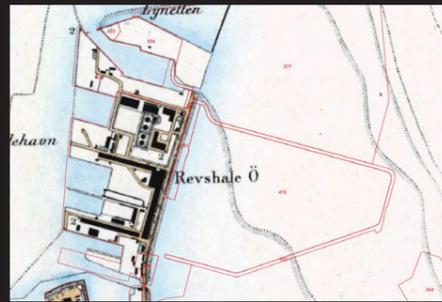
**Refshaleøen** is geographically a separate island and in its history, it is used to be the site of industrial activities for more than a hundred years, especially the shipyard factory of Burmeister & Wain (closed in 1996) which is a symbol of the development of Copenhagen in the last century. It had been developed and expanded for many centuries and now become an immense area with several historical buildings and cultural values.

In recent years, the former industrial district has become one of Copenhagen's hippest areas and a hub for creativity, alternative urban development, festivals and great foods of very different kinds. Easily reached by bike, bus or even harbour bus, the island is an integral part of the city but with its very own identity.

### 3.1 Refshaleøen

#### 1624

Beside St. Ann's Fortress (Kastellet), the area used to be a military guard point in order to protect the entrance to the city harbor. For that reason, there were not so many buildings on the island during this time.

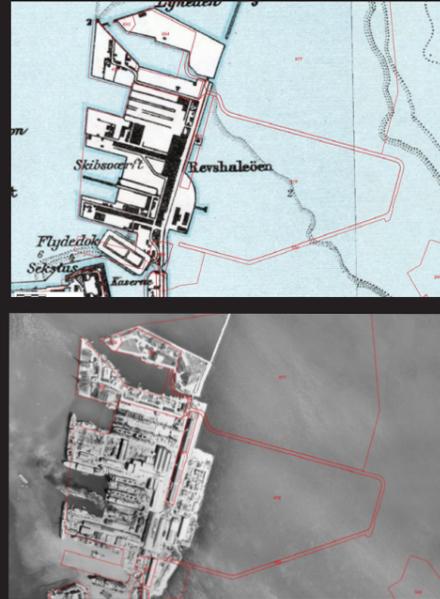


#### 1842-1899

From 1870 to 1880, the size of the area was enlarged significantly and the waterways for the harbor were dug to be deeper. Lynetten is a small peninsula to the north and on Refshaleøen there is only land west of the original Refshalevej.

#### 1901-1971

Land reclamation was carried out until the 1920s on the south-easternmost side of the original Refshalevej.



### History

#### 1945-1975

Refshaleøen seen from east to west. The landfall to the west is almost completed. In the background is the construction dock with cranes and storage areas north of these. In the foreground is Section Workshop 1 and storage space south of it. At the bottom right of the picture is the old welding hall, today used by the Royal Theater. To the right of the image is the not yet filled area, which is designated as the Triangle area in the documents.



#### 2015

Today, Refshaleøen is managed by many companies and organizations (real estate and property). The area now is having a variety of functions and activities. With the food market "the REFFEN" on the west side, several sports and recreational facilities on the east, and mostly the technical buildings on the north side. The southside where the main access is located is next to the residential and private ship's dock area.



1624

1900

2000

2021

#### 1871

Burmeister & Wain established a shipyard on the island. At its height, the shipyard employed 8,000 people, and so appears as an icon of Danish industrial history.



#### 2012

Refshaleøen has been developed with land reclamation on the entire current east side of the original Refshalevej (and also Lynetten). Furthermore, the area between Søndre Hoved and Midtermolen was filled in in 1985, except for the old southern dry dock.





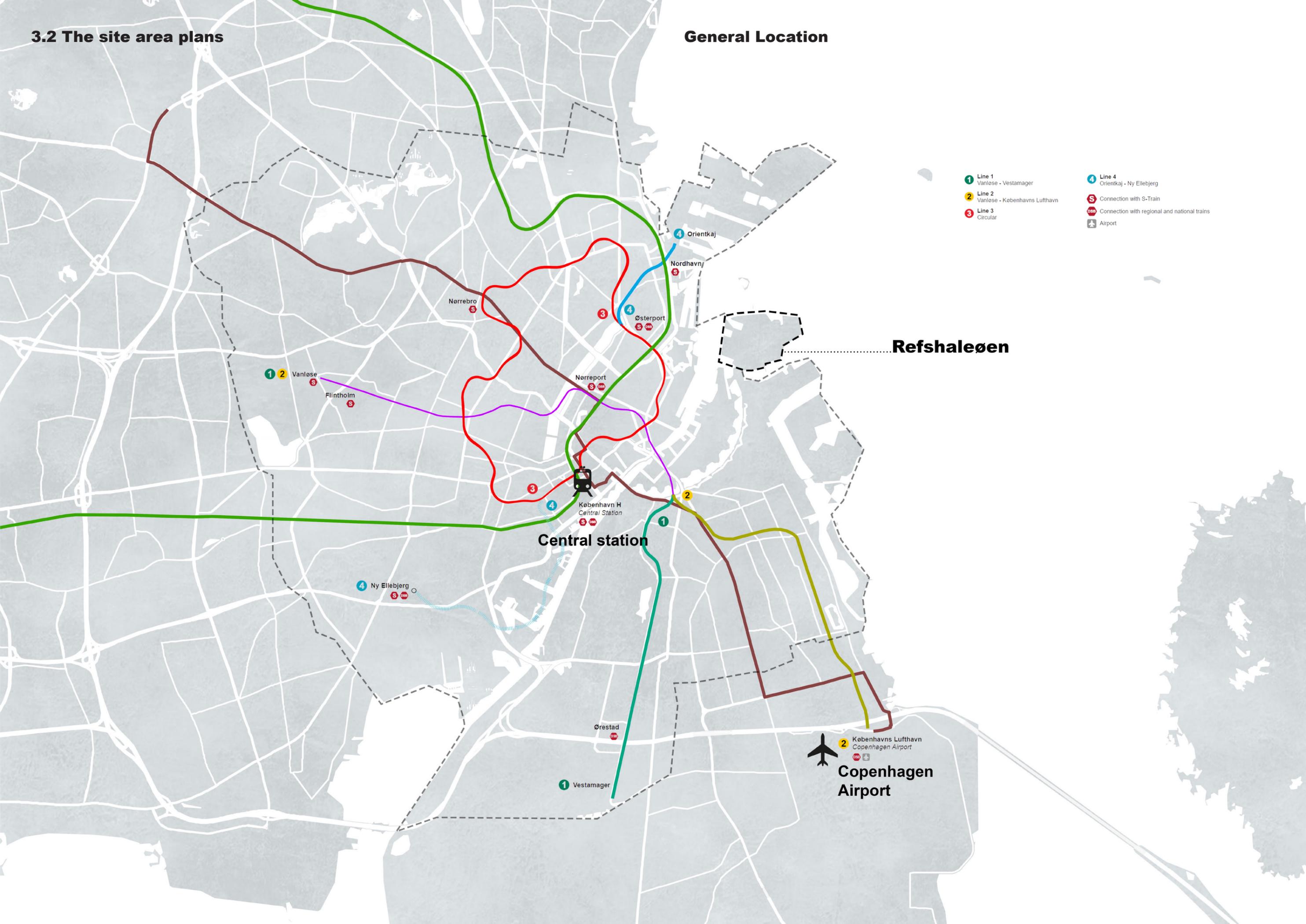
**PAST**



**NOW**

### 3.2 The site area plans

### General Location



Refshaleøen

Central station

Copenhagen Airport

### 3.2 The site area plans

### Mobility

Present Accessibilities

Metro Havneringen (Future)

Eastern ringroad (Future)

Metro Nordhavn (Future)

Lynetteholmen area (Future)

REFSHALEØEN

To central station 

Metro Havneringen

**M** Future metro station

Lynetteholmen

Eastern ringroad

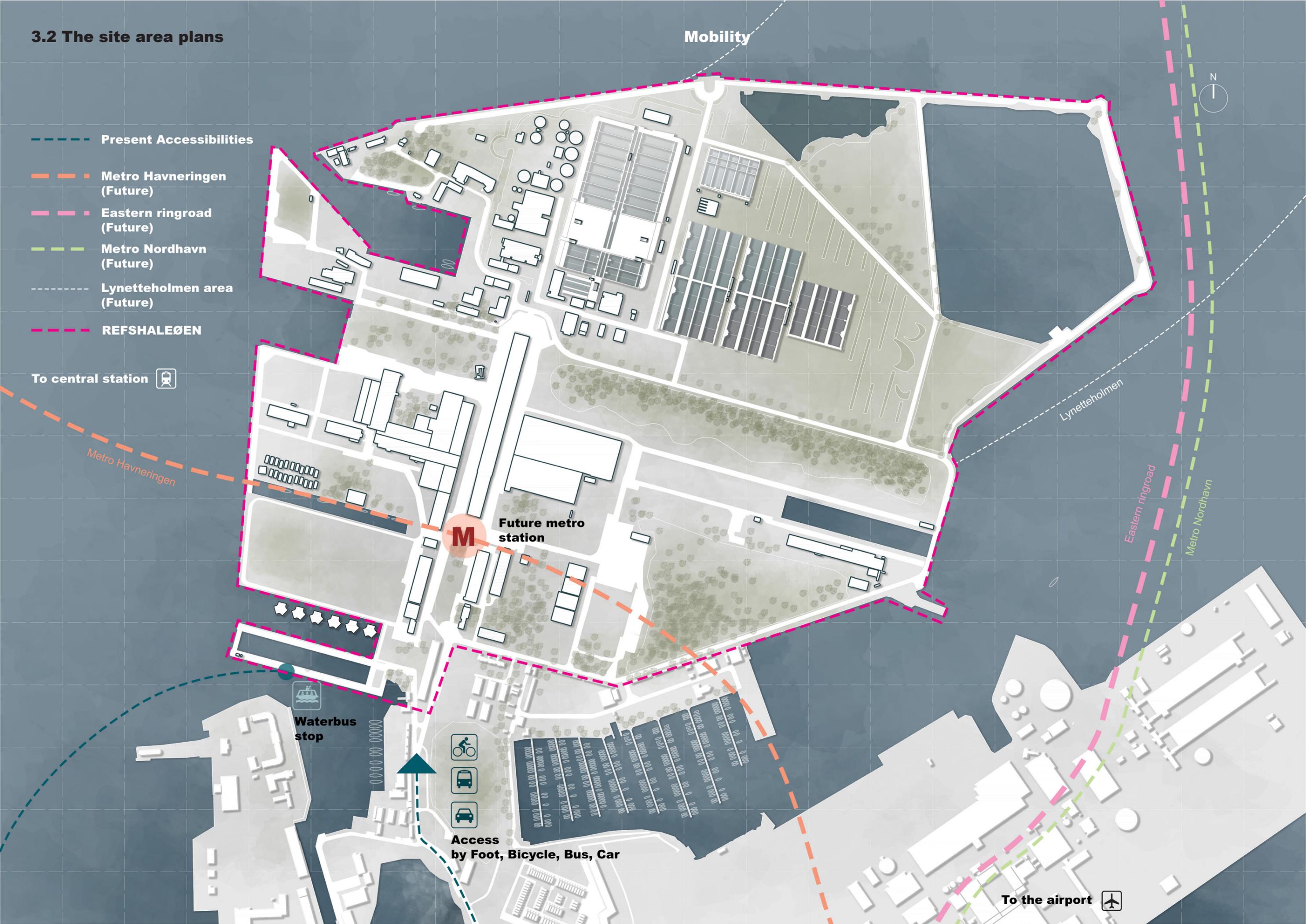
Metro Nordhavn

Waterbus stop 



Access by Foot, Bicycle, Bus, Car

To the airport 



### 3.2 The site area plans

### Landuses



#### 3 – R19.O.1.72



Area : 2,25 ha  
Landuses: leisures  
Max building ratio : non  
Max building height : non  
Free area for house : non  
Free area for business : non

Note:

#### 1 – R19.E.1.1



Area : 25 ha  
Landuses: mixed uses  
Max building ratio : 110%  
Max building height : 20m  
Free area for house : non  
Free area for business : 15%

Note:

#### 4 – R19.T.1.4



Area : 28 ha  
Landuses: technical  
Max building ratio : 110%  
Max building height : 24m  
Free area for house : non  
Free area for business : non

Note:

#### 5 – R19.T.1.5



Area : 21 ha  
Landuses: technical  
Max building ratio : non  
Max building height : non  
Free area for house : non  
Free area for business : non

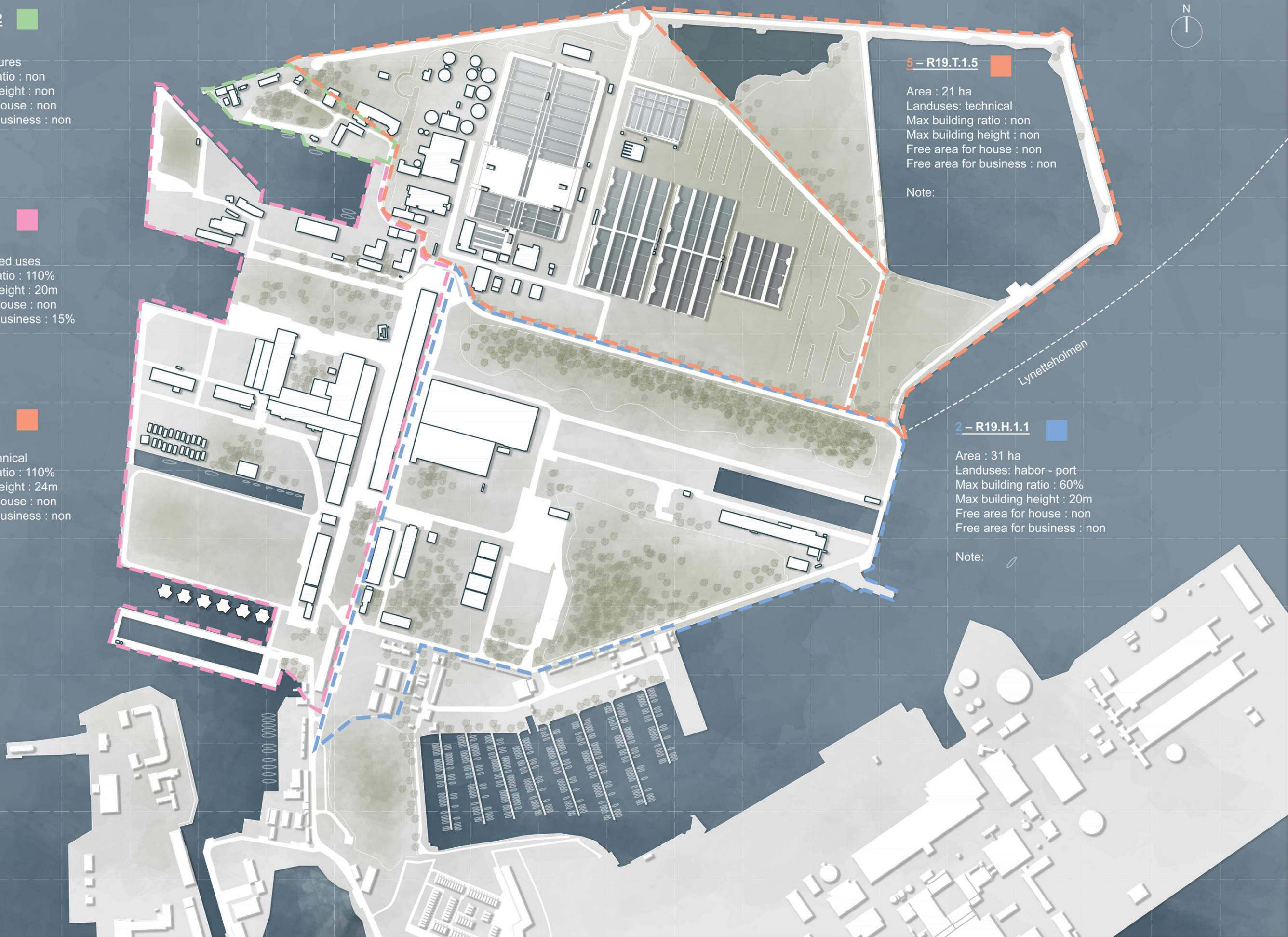
Note:

#### 2 – R19.H.1.1



Area : 31 ha  
Landuses: harbor - port  
Max building ratio : 60%  
Max building height : 20m  
Free area for house : non  
Free area for business : non

Note:

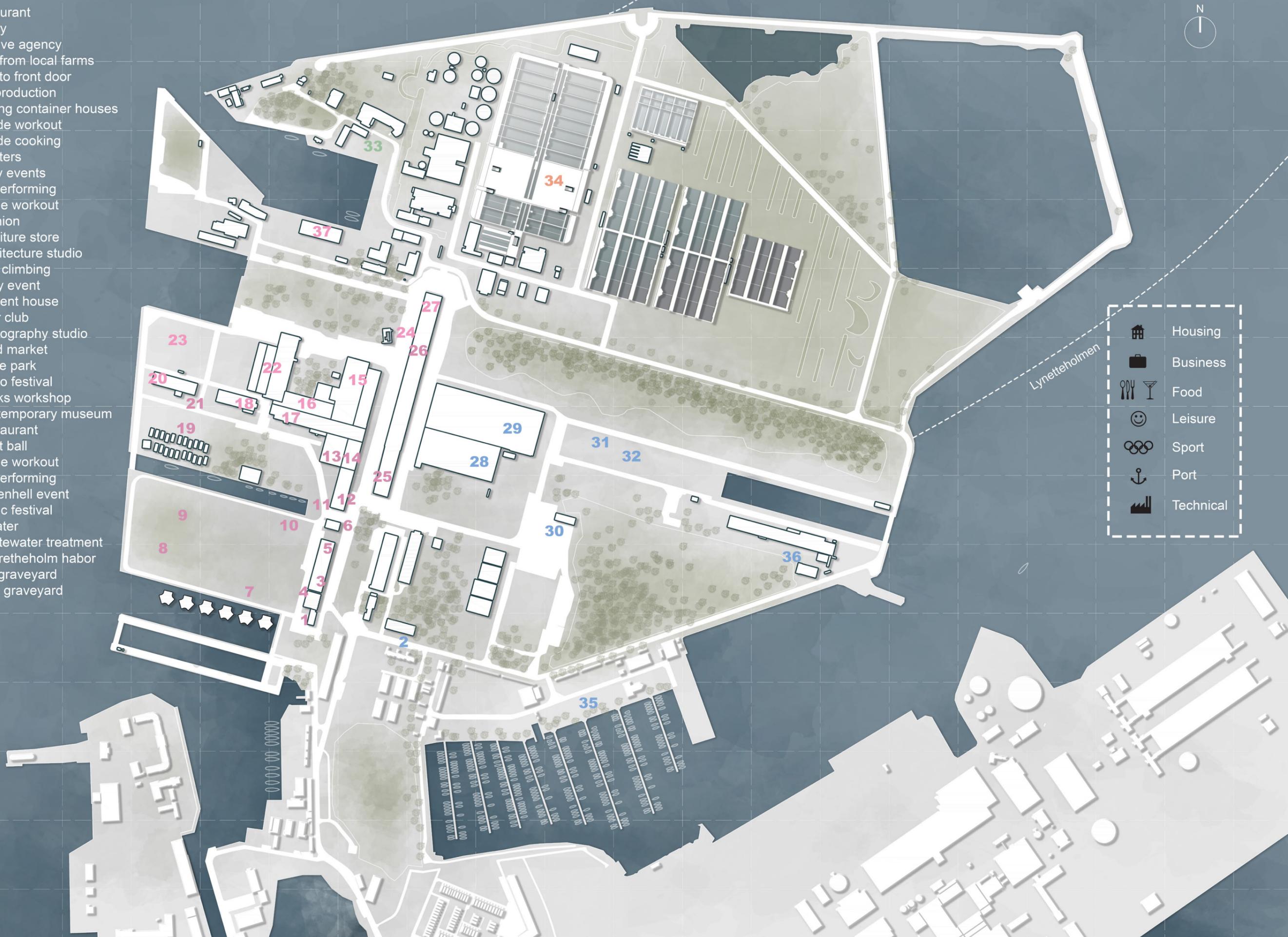


### 3.2 The site area plans

### Program

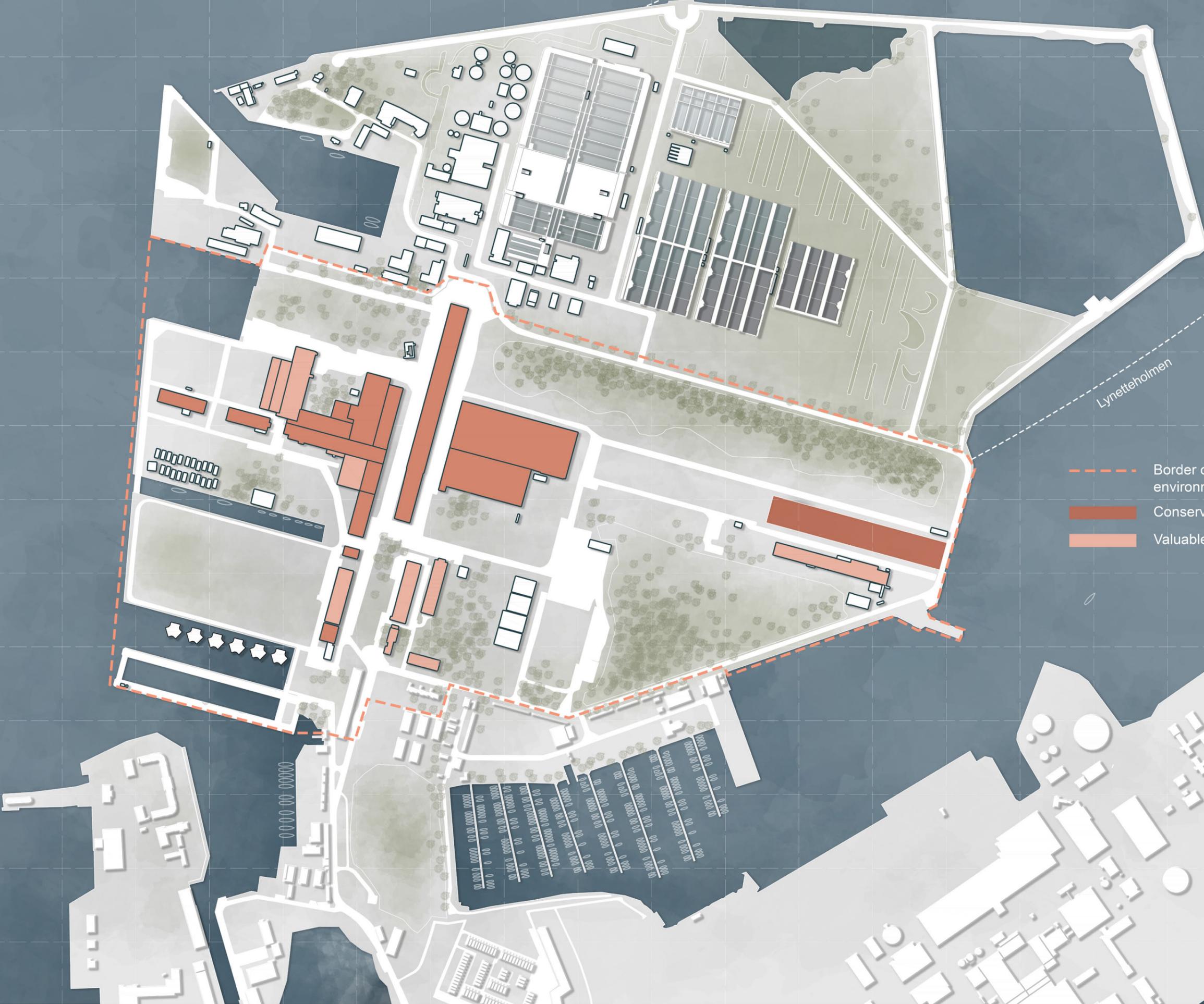
-  1. Restaurant
-  2. Bakery
-  3. Creative agency
-  4. Food from local farms
-  5. Food to front door
-  6. Film production
-  7. Floating container houses
-  8. Outside workout
-  9. Outside cooking
-  10. Shelters
-  11. Party events
-  12. Art performing
-  13. Inside workout
-  14. Fashion
-  15. Furniture store
-  16. Architecture studio
-  17. Wall climbing
-  18. Party event
-  19. Student house
-  20. Beer club
-  21. Photography studio
-  22. Food market
-  23. Skate park
-  24. Photo festival
-  25. Drinks workshop
-  26. Contemporary museum
-  27. Restaurant
-  28. Paint ball
-  29. Inside workout
-  30. Art performing
-  31. Copenhell event
-  32. Music festival
-  33. Theater
-  34. Wastewater treatment
-  35. Magretheholm habor
-  36. Car graveyard
-  37. Boat graveyard

-  Housing
-  Business
-  Food
-  Leisure
-  Sport
-  Port
-  Technical



3.2 The site area plans

Cultural Heritages



-  Border of valuable cultural environment
-  Conservation values areas
-  Valuable built-up areas

## 4.1 The Facts

### Why is regeneration important?

**7.900.000.000**

Current population of the earth

**9.700.000.000**

World population by 2064

**68%**

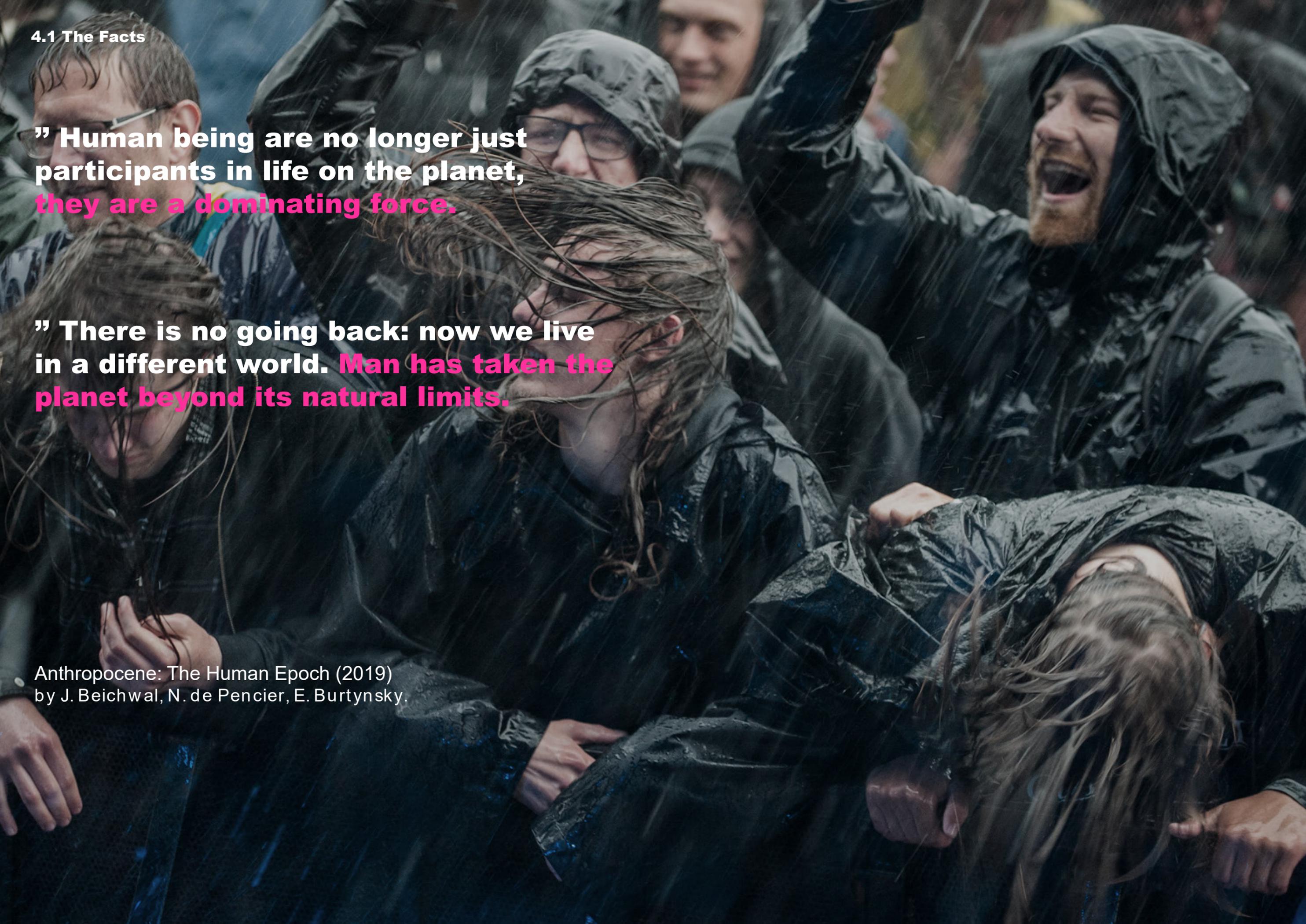
World population living in megalopolies  
by 2050 (currently: 55%; in 1950: 29%)

#### 4.1 The Facts

**” Human being are no longer just participants in life on the planet, they are a dominating force.**

**” There is no going back: now we live in a different world. Man has taken the planet beyond its natural limits.**

Anthropocene: The Human Epoch (2019)  
by J. Beichwal, N. de Pencier, E. Burtynsky.



## 4.1 The Facts

# 2.01 billion tons

**Of solid waste produced every year by world  
Population** (in 2050: 3.7 billion tons)

# 34.000

**Equivalent plastic bottle in oceans every minute**

# 34%

**Share of high-income countries production over the world  
Total production of solid waste**

# 4%

**Share of low-income countries recycled waste**

**What can an architect do?**



## 4.2 The Reasons

# Bioclimatic Design Approach & Urban Metabolism

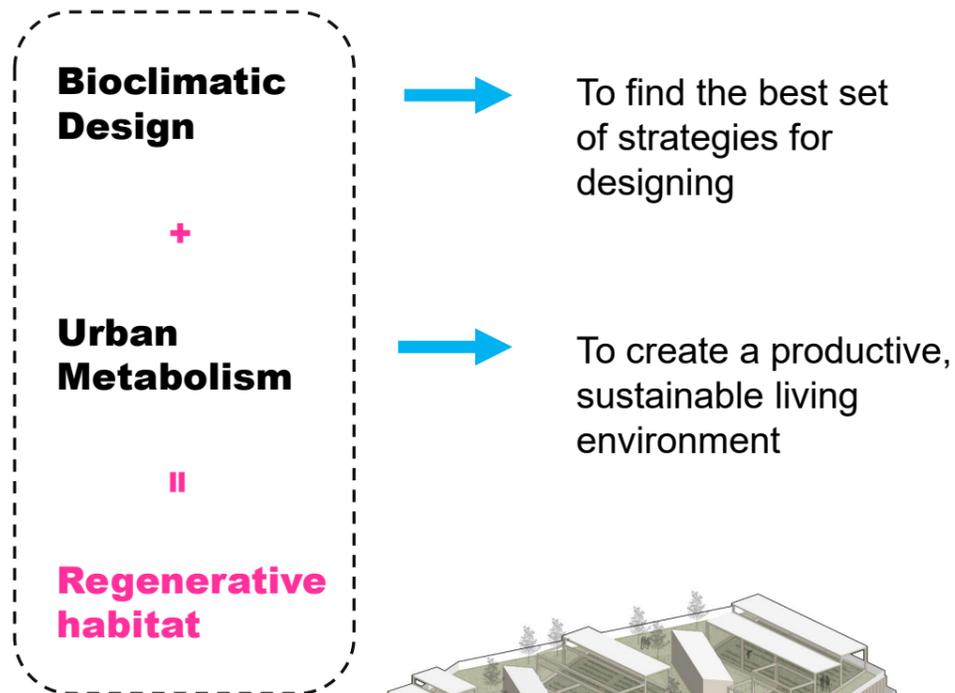
Architecture can have a **direct impact** on minimizing/optimizing matter and **energy flows in urban context**. The design of buildings, infrastructures and urban green areas should aim at the construction and management of a **“carbon neutral” anthropized environment** (European Commission, 2014).

Climate change is real and we can not ignore the fact that the health of the planet and our living condition are at stake. As many facts mentioned and could be witnessed from everywhere in the world, we are able to aware that we are on an unsustainable path.

We as architects, designers, city planners, ... should take our responsibility more than ever to propose designs that adapt and mitigate this problem. For that reason, we believe that integrating the bioclimatic design approach and urban metabolism could be

a great solution for this. With the help of many climate data sources and tools, we can have an accurate assessment of bioclimatic condition of the site to propose a suitable set of strategies for designing in the next phase.

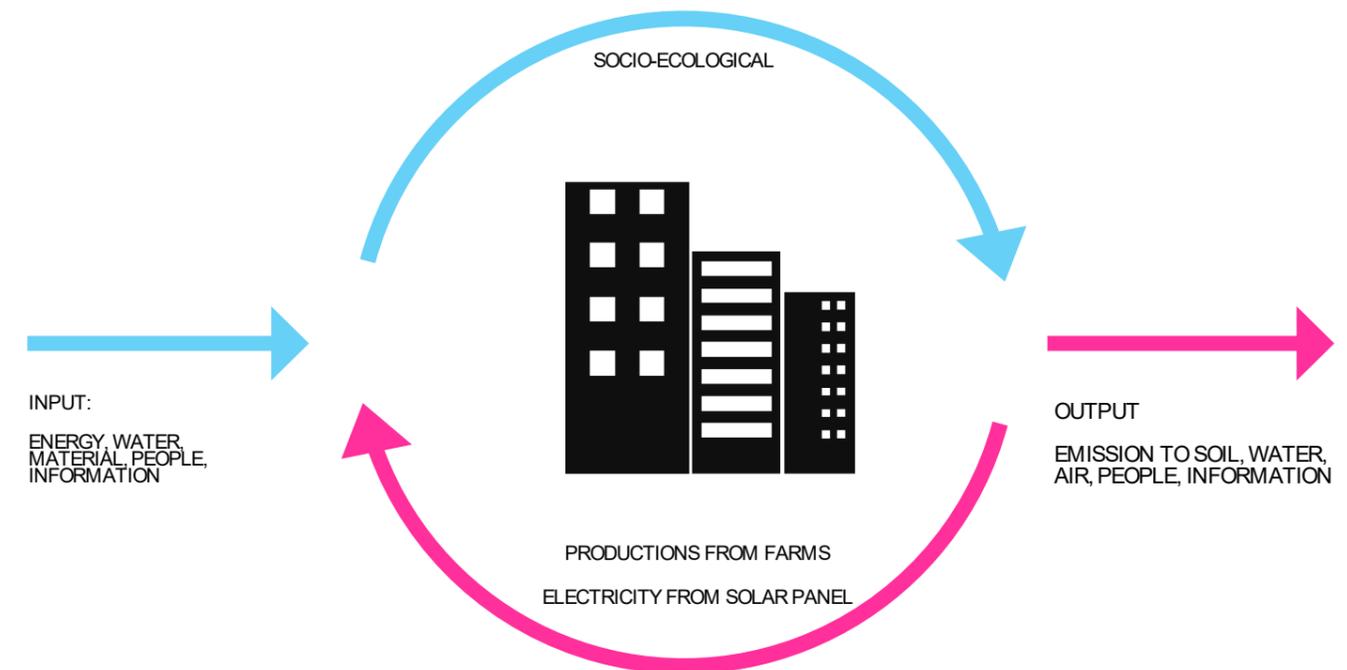
Probably that is not enough to be sustainable if we only design several energy efficient buildings and put them on a site. In fact, we have to have a life circle thinking about the whole habitat in order to limit our ecological footprint so that is why urban metabolism is the second pillar in this thesis. By making a program of how energy, water, food and waste are stored and recycled, we hope our proposal will draw an inspirative and lively future of the Refshaleøen.



## METABOLISM AS A MODEL | Material Flow Analysis (MFA)



**Linear Metabolism**



**Circle Metabolism**

# 5

# The Project

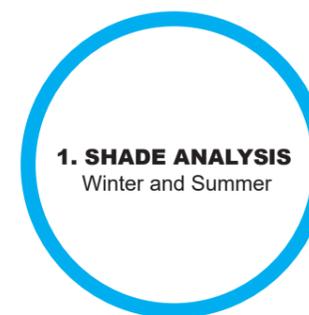
Bioclimatic design approach

## Overview

### Abstract

In order to create a holistic and sustainable design, it is highly important to carry out the climatic analysis from the early phase of the project. The analysis which is taken into account the impact of the crucial environmental factors such as wind and sun. For that reason, the climatic data are essential to find out the most efficient, comfortable and liveable areas of the project site so we can have a logical prediction of where to place the buildings and other structures or facilities.

In this project, we aim to use the microclimate matrix to evaluate the thermal comfort condition of the area of Refshaleøen so at the end of the simulation, we can determine the suitable passive strategies for the site.



## 5.1 Climate Consultant

### Why ?

When we are talking about the urban landscapes or the spaces between the buildings, we are considering them as the essential or inseparable parts of the architectural experiences. Sadly, in many cities or peri-urban and sub-urban areas around the world there are problems not only with aesthetics but also with inadequate environmental quality. The environmental characteristics, different from the aesthetic ones, along with them could be becoming an overall tool or a set of rules for integrating the landscape and the architectural ideas of the building in order to give the spaces its identity and value that they deserve.

This crucial relationship in the process of architectural design requires a project tool to define the climatic characteristics and evaluate the comfort level of the area. For that reason and based on the knowledges that I obtained in Politecnico di Torino, the site microclimate matrix could be able to serve those purposes with the help of climate consultant and other open data sources.

### The method

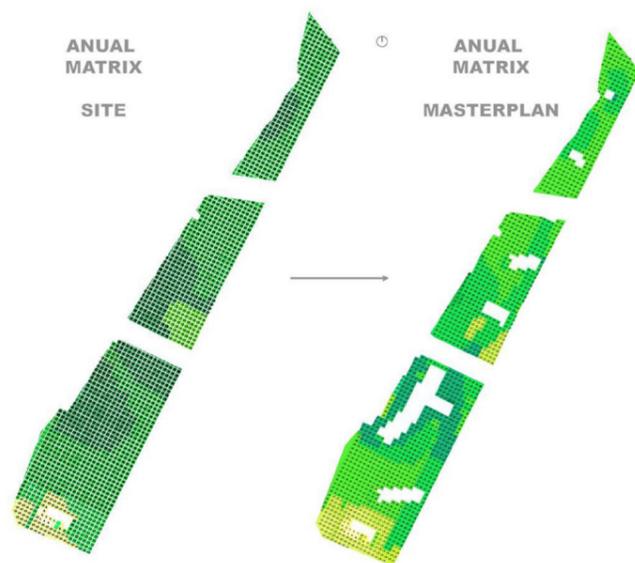
In the first step, We use climate consultant as the primary tool to analyze the large amount of climatic datas. The software are able to translate those many rows, columns and numbers into more simple graphs, charts or graphics. it uses annual 8760 EPW formate climate data that is made available at no cost on European open data sources. the purpose is not simply to demonstrate climate data but also to make this information to be understandable and easier for analyzing or extracting information.

After several analysis with the software, we can obtain the main information for the next step in which, we use the datas of solar profile and wind rose chart as the inputs for microclimate matrix. Firstly, we have to create the 2d shadow footprint for day and noon of summer solstice and winter solstice then they will be overlapped with the 2d footprint of wind calm zone (winter and summer) in order to create some maps in which we have to divide them into a grid of 10x10m to assign the values.

The choices of scoring are different between the building types, activities or climate types so in this thesis and especially for the case study of Copenhagen, we did the evaluation for Skin Loaded building with the temperate humid climate for building localisations, on the other hand, with the outdoor localisations, we did assign the values for both the low metabolic rate activities (west side) and the high metabolic rate activities (east side) because of the different land uses for each side.

### The outcomes

At the end of the process, we achieved the results for seasonal score (summer and winter) and the annual score for both building and outdoor localisations. From these, we aim to propose a set of strategies for doing the masterplan and potentially for building design.



References: The project that me and my groupmates completed in AY 19/20 under the teaching of professor Mario Grosso, the area is on Corso Principe Oddone in Torino, Italy.

## Data summary

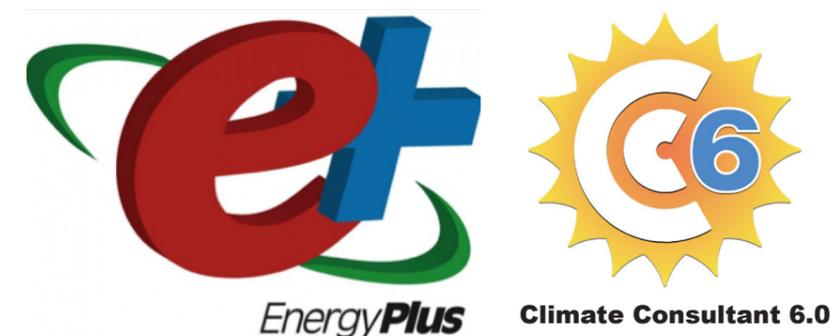
WEATHER DATA SUMMARY													LOCATION: COPENHAGEN, -, DNK	
													Latitude/Longitude: 55.63° North, 12.67° East, Time Zone from Greenwich 1	
													Data Source: IVEC Data 061800 WMO Station Number, Elevation 5 m	
MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		
Global Horiz Radiation (Avg Hourly)	62	115	188	249	307	324	313	289	203	144	71	52	Wh/sq.m	
Direct Normal Radiation (Avg Hourly)	80	140	163	180	225	189	186	203	121	112	65	67	Wh/sq.m	
Diffuse Radiation (Avg Hourly)	47	76	116	152	166	195	189	165	142	103	56	41	Wh/sq.m	
Global Horiz Radiation (Max Hourly)	197	351	598	682	799	823	827	760	608	462	244	142	Wh/sq.m	
Direct Normal Radiation (Max Hourly)	518	756	851	842	833	768	793	784	755	661	433	407	Wh/sq.m	
Diffuse Radiation (Max Hourly)	114	193	330	402	418	454	420	381	330	242	133	90	Wh/sq.m	
Global Horiz Radiation (Avg Daily Total)	465	1060	2203	3467	4934	5557	5200	4284	2549	1452	578	361	Wh/sq.m	
Direct Normal Radiation (Avg Daily Total)	591	1270	1916	2494	3605	3240	3104	3041	1533	1129	521	461	Wh/sq.m	
Diffuse Radiation (Avg Daily Total)	351	705	1357	2131	2679	3355	3134	2424	1776	1041	455	285	Wh/sq.m	
Global Horiz Illumination (Avg Hourly)	6822	12577	20457	27278	33647	35633	34508	31874	22386	15738	7863	5728	lux	
Direct Normal Illumination (Avg Hourly)	5637	11623	15196	17291	21792	18271	17832	19063	11275	9801	4873	4321	lux	
Dry Bulb Temperature (Avg Monthly)	1	0	2	6	11	14	16	16	12	9	5	1	degrees C	
Dew Point Temperature (Avg Monthly)	0	-1	-1	1	6	8	10	13	8	5	2	0	degrees C	
Relative Humidity (Avg Monthly)	83	87	72	74	71	67	68	79	79	77	82	84	percent	
Wind Direction (Monthly Mode)	230	300	240	240	260	290	290	280	260	250	270	240	degrees	
Wind Speed (Avg Monthly)	8	5	7	5	5	4	5	4	5	7	6	6	m/s	
Ground Temperature (Avg Monthly of 3 Depths)	5	3	2	2	4	7	10	12	13	13	11	8	degrees C	

### Data summary for Copenhagen (taken from energyplus.com)

"Climate Consultant is a simple to use, graphic-based computer program that helps architects, builders, contractor, homeowners, and students understand their local climate."

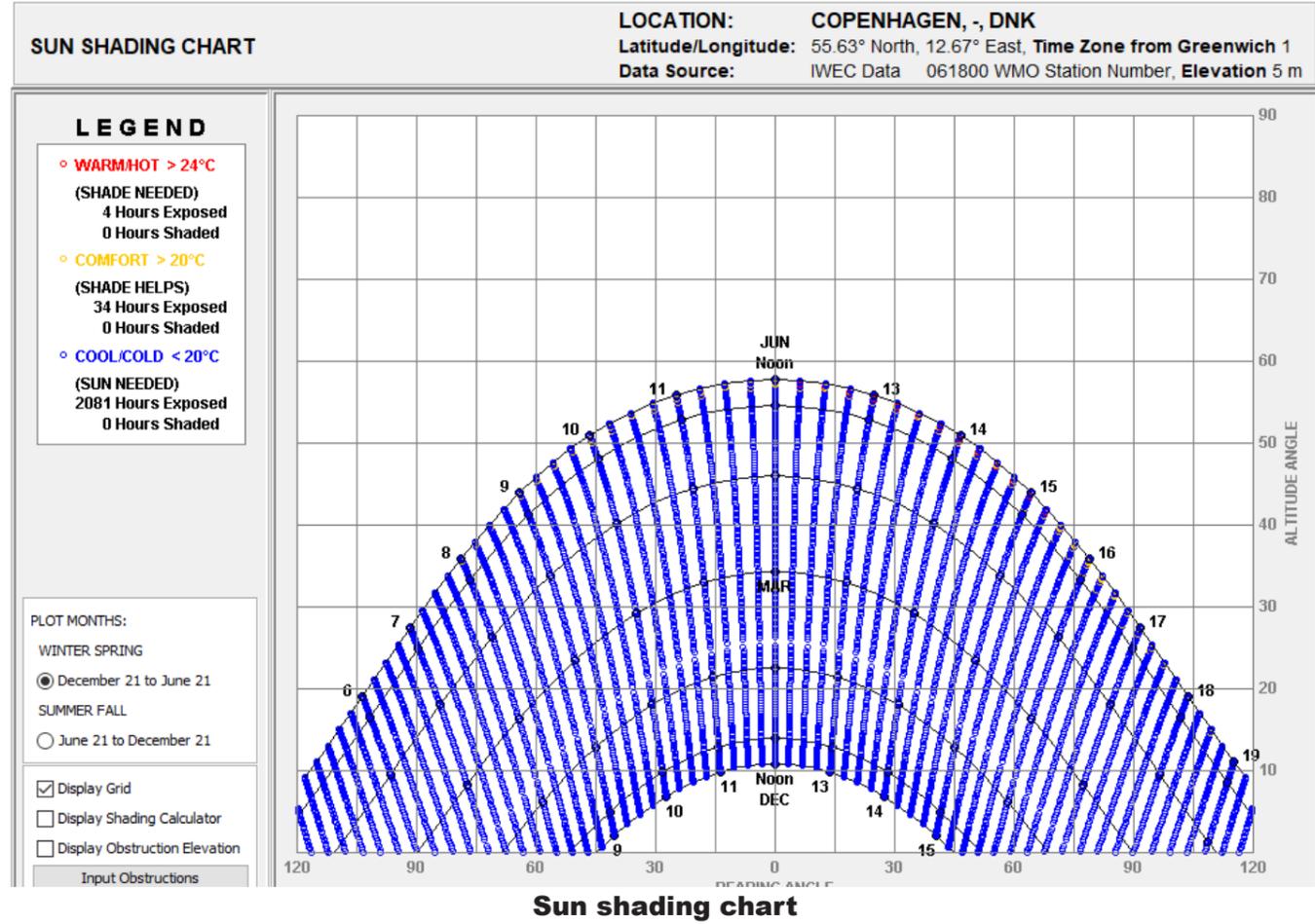
The aim of the software is to create more sustainable building regarding energy uses, Climate consultant can provide us several graphs such as :

- + Temperature Range
- + Monthly Diurnal Averages
- + Radiation Range
- + Illumination Range
- + Sky cover Range
- + Wind Velocity Range
- + Ground Temperature
- + Dry Bulb x Relative Humidity
- + Dry Bulb x Dreu Point
- + **Sun Shading Chart**
- + **Sun Chart**
- + Time Table Plot
- + 3D Charts
- + **Psychrometric Chart**
- + **Design Guidelines**
- + **Wind Wheel**

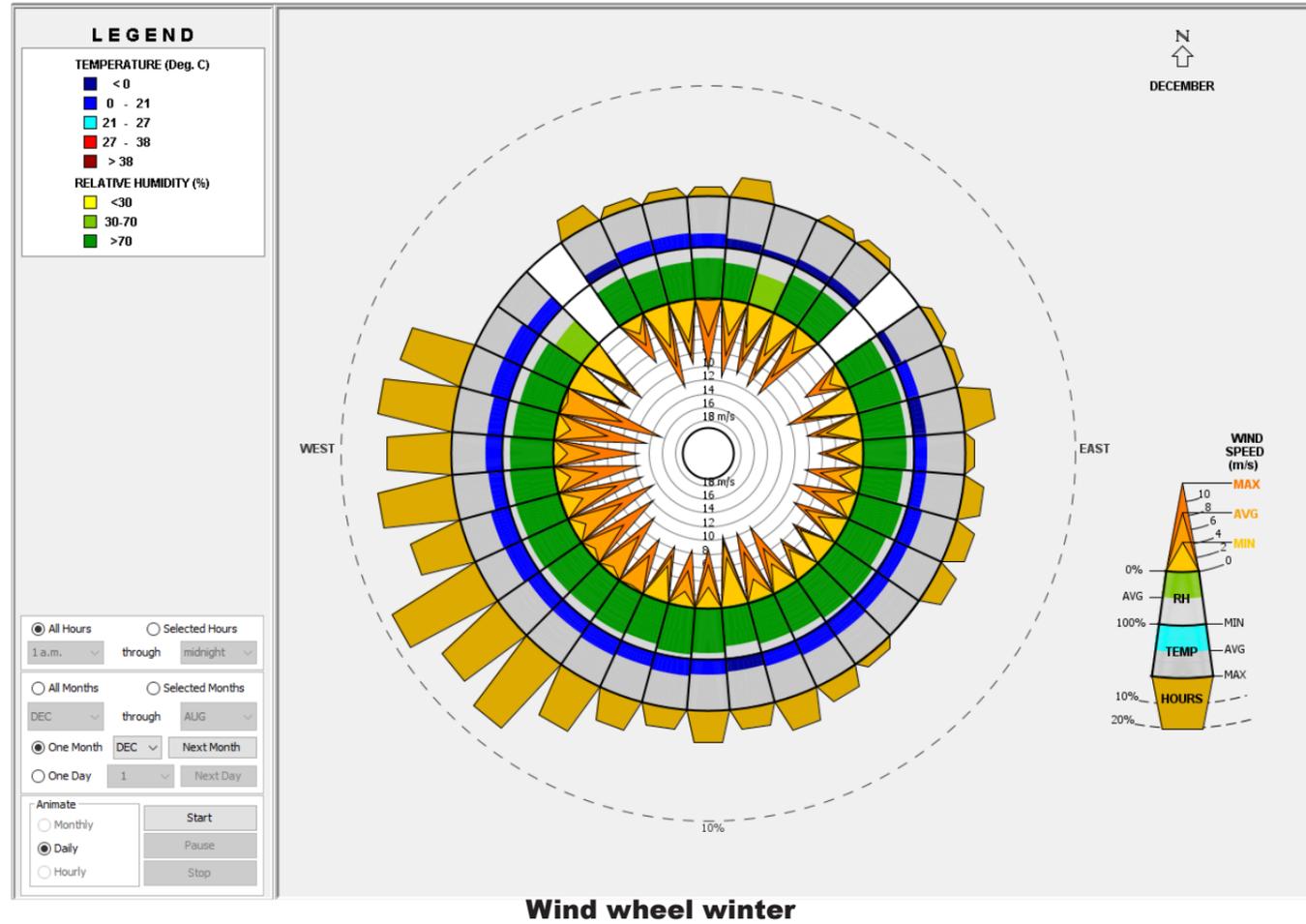
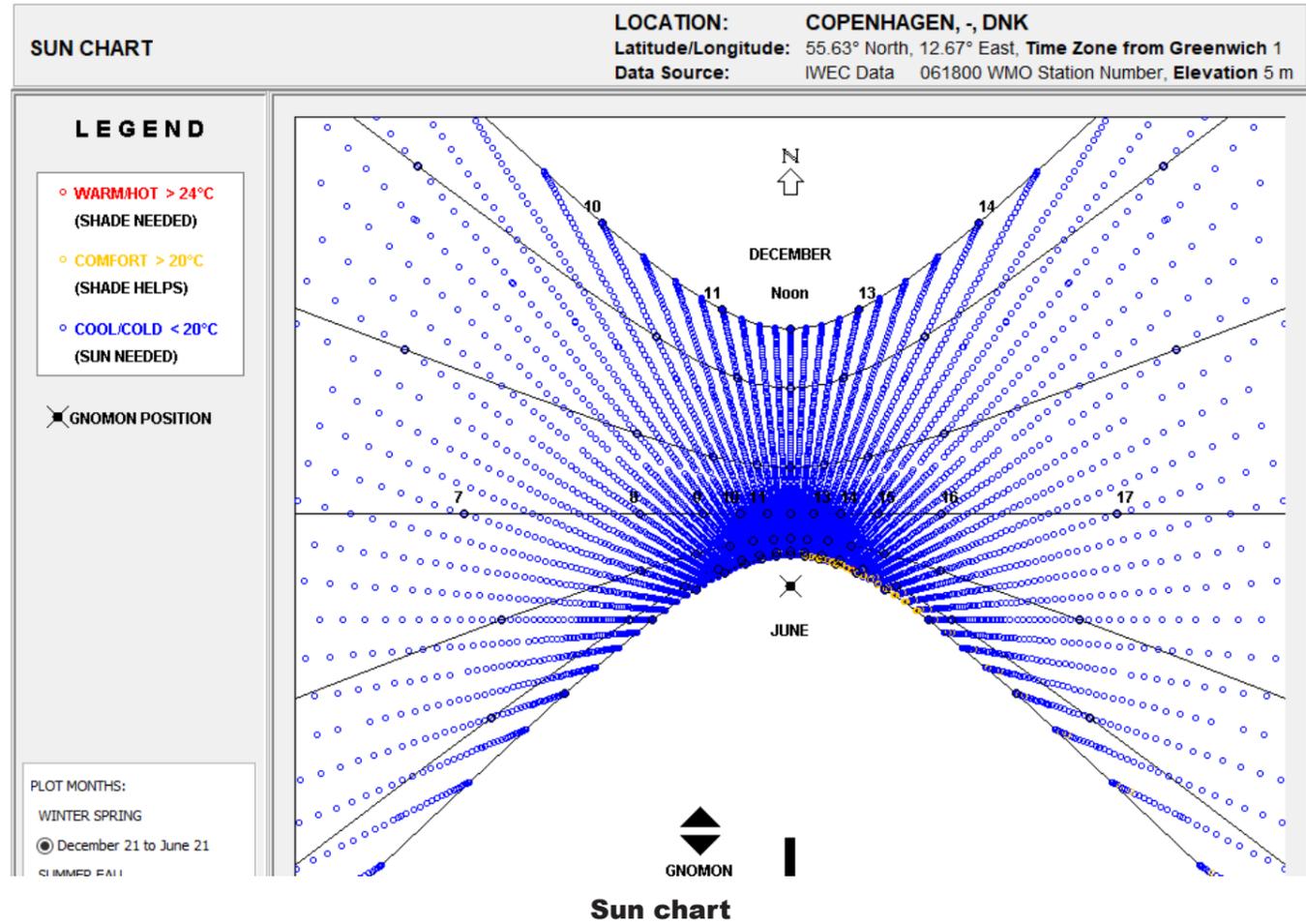
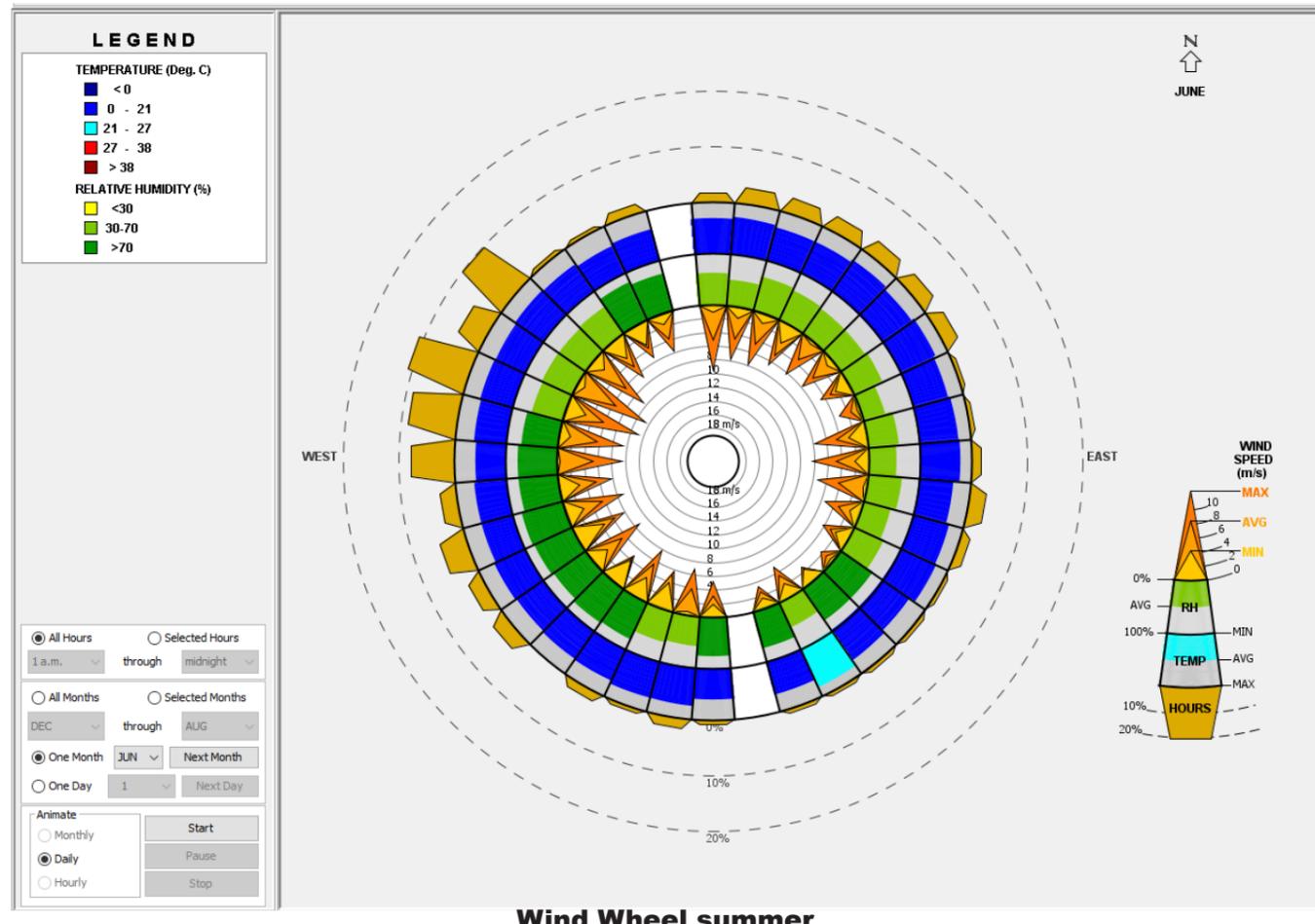


Resources: Climate data that is made available at no cost on European open datasources. The IVEC data is obtained from EnergyPlus weather site, managed by US government and they are available for some locations. The commercial tools allow producing upgraded data from existing meteorological stations and interpolation algorithms (e.g. Meteonorm). In this thesis, the EPW files are all produced via the Meteonorm tool.

# 5.1 Climate Consultant

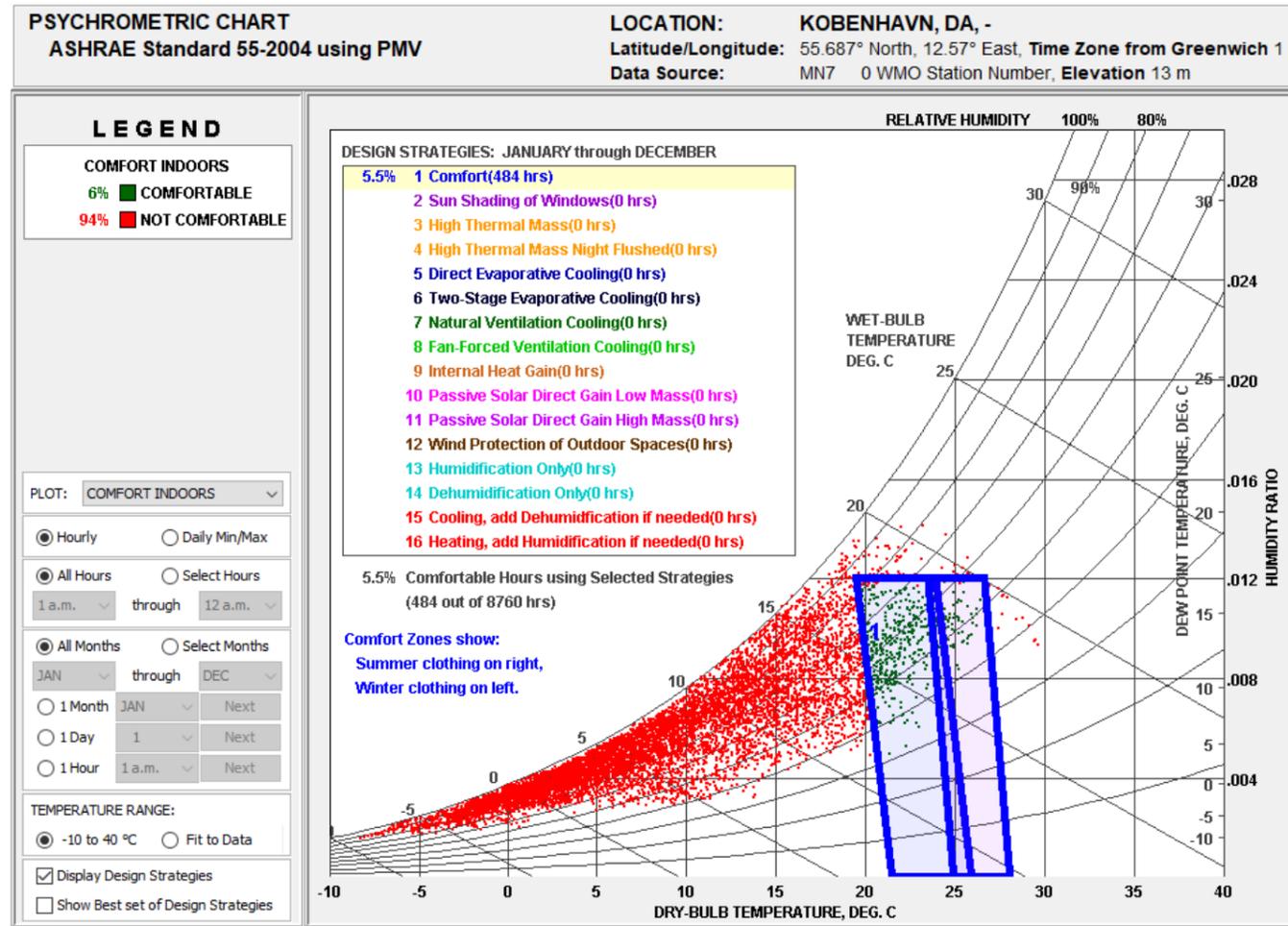


# Sun & wind data



## 5.2 The Psychrometric chart

### Present (No strategies applied)



#### Parameters:

- + **Dry-bulb temperature:** The temperature of dry air
- + **Wet-bulb temperature:** Temperature which is measured by wrapping a wet cloth on thermometer
- + **Humidity ratio:** Hr = gm of water/gm of dry air
- + **Relative humidity:** The amount of air in form of percentage
- + **Dew point temperature:** It is temperature of saturated air

#### Others:

- + **Specific volume:** It is the volume per gram of dry air (m<sup>3</sup>/g)
- + **Enthalpy:** It is the amount of heat present per gram of air (J/g)

#### The present thermal comfort situation:

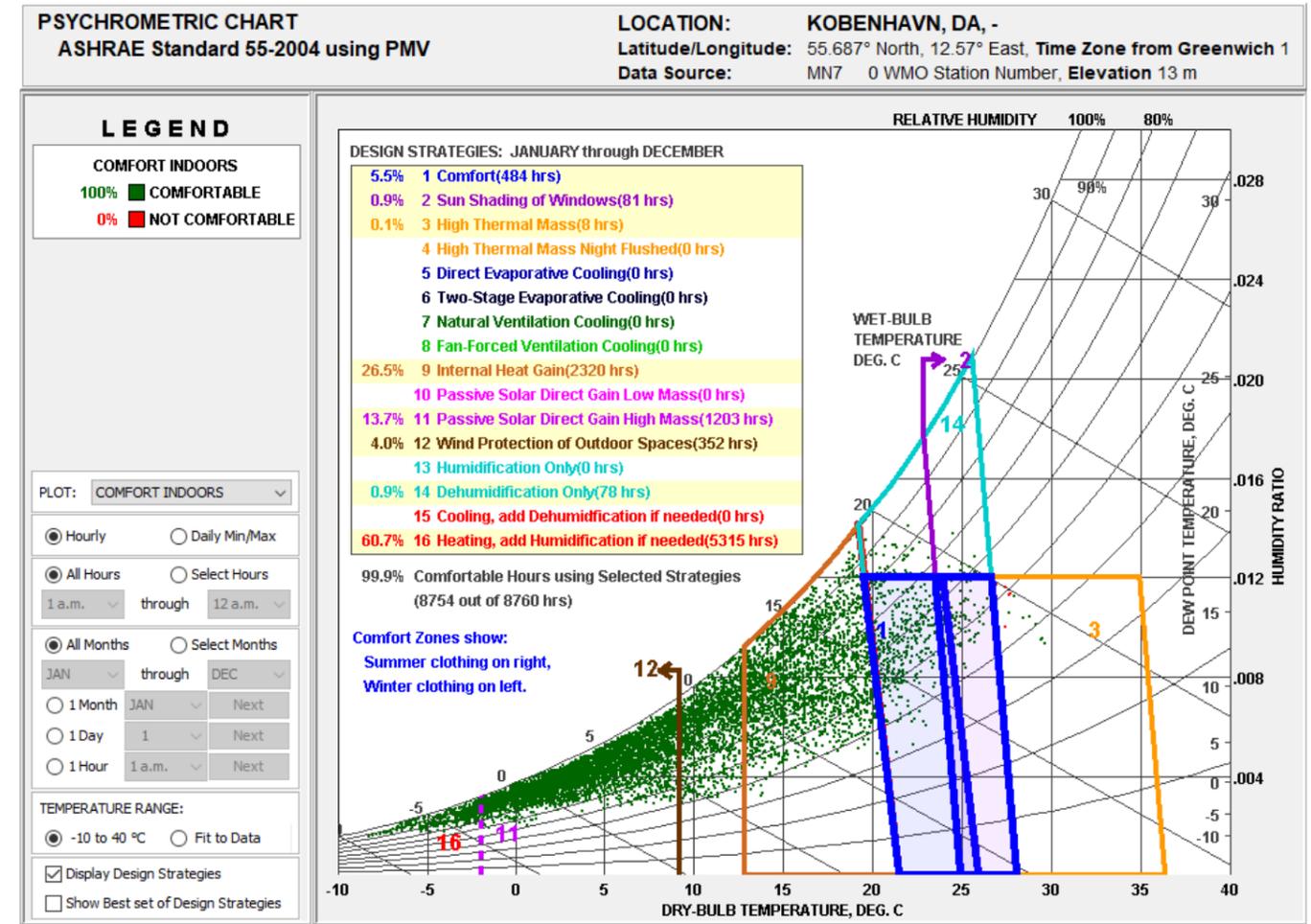
The above graph illustrate the analyses plot external conditions environmentally, showing general comfort zones with the "ASHRAE STANDARD 55" applied, providing a climate early-design analysis. It is noticeable that in every hour during the year without any strategies applied and there are only 5.5 percent of the hour are comfortable.

It can be clearly seen that the weather of the city is pretty cool and has very high humidity. The oceanic flow of northern air causes the climate to have cool summers and cool but not so cold winters. For that reason, in general, the most dominant strategy need to be adopted will potentially be about the heating.

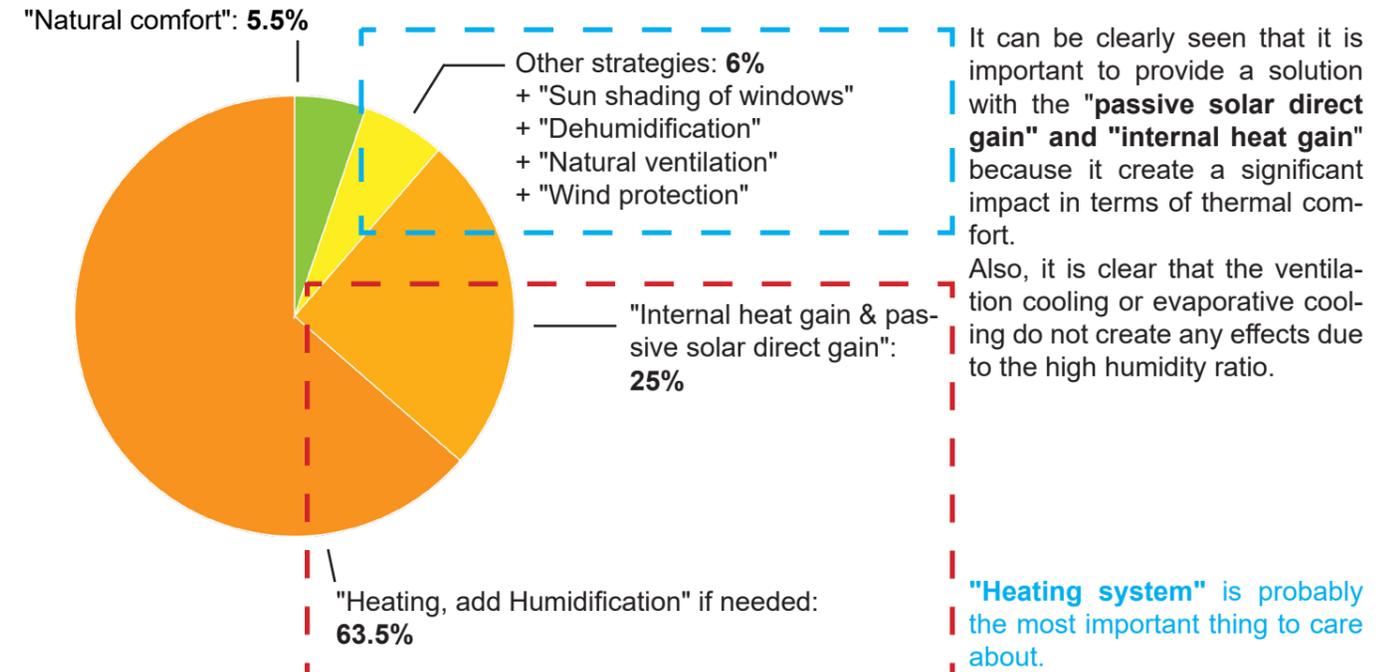
In addition, the length of the day varies greatly between summer and winter, so this fact also leads to the need to devise different strategies to orient buildings to maximize solar gain in winter but also to avoid overheating in summer.

## Present

### Present (Strategies applied)

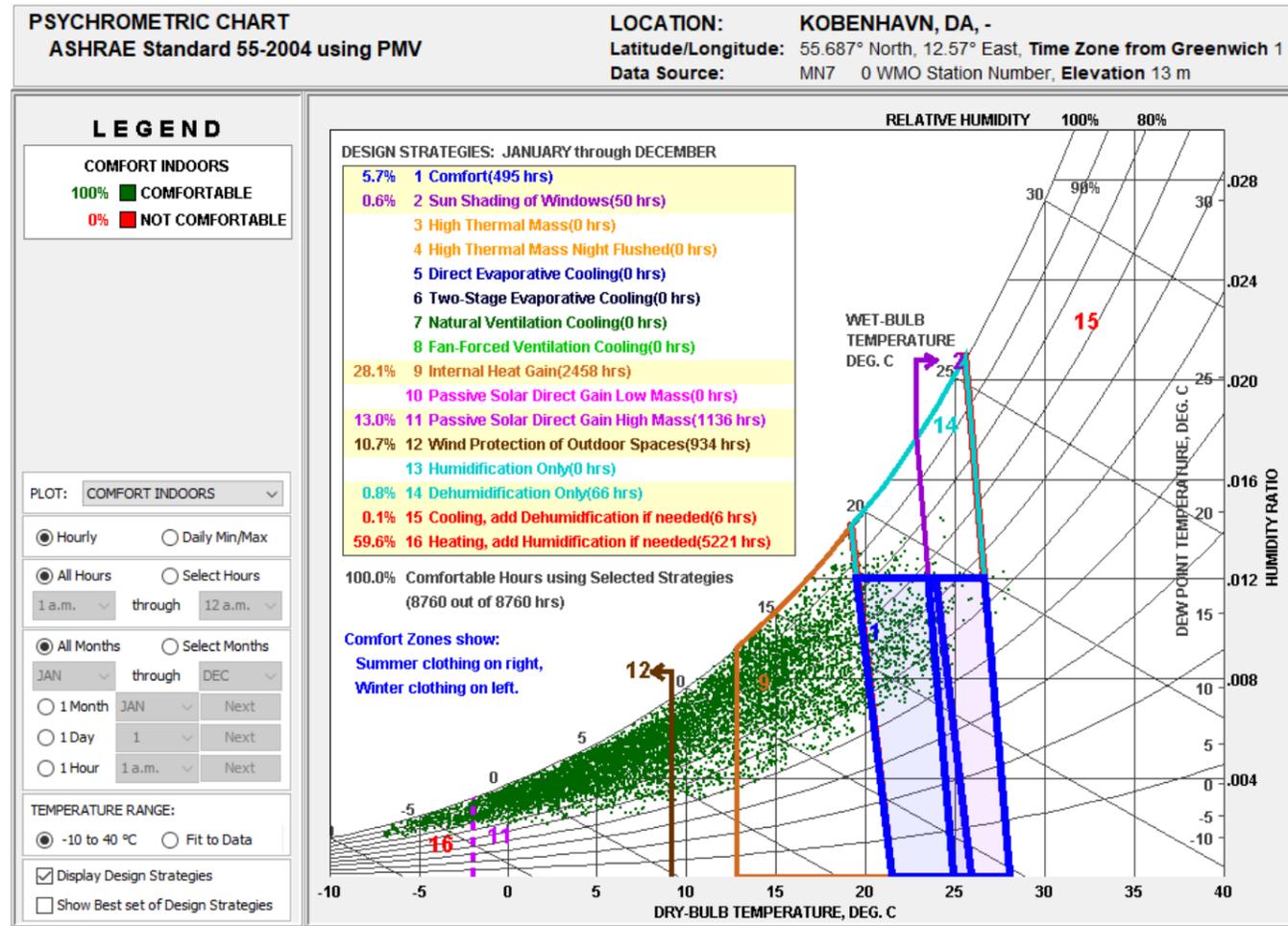


#### Strategies contribution (percentage of hour):



## 5.2 The Psychrometric chart

### 2030 (strategies applied)



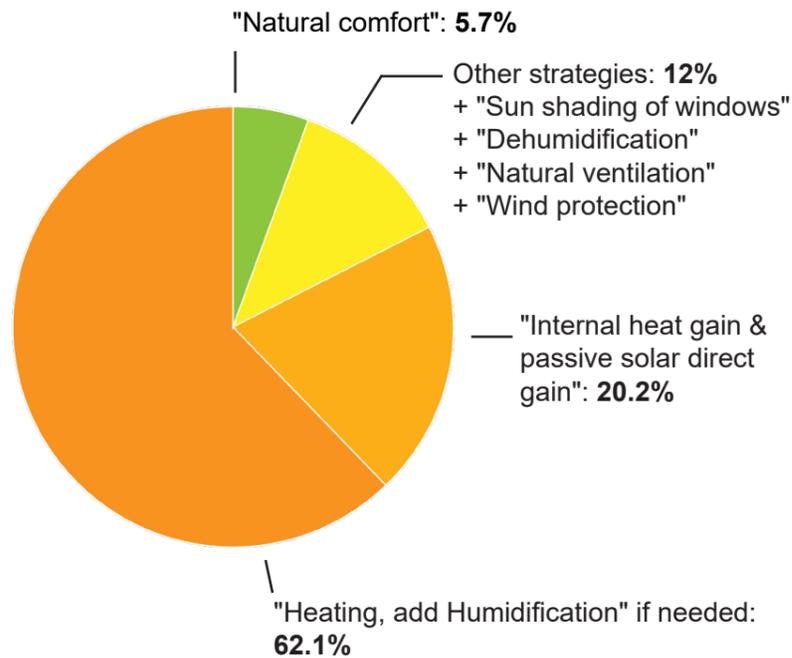
### The thermal comfort in the future:

This analysis about the psychrometric chart will not only stop at investigate the current climate condition but also taking into account the future scenarios, specifically in 2030 and in 2100.

Thank to the support from professor Giacomo Chiesa, the future scenarios of 2030 & 2100 were generated based on the theory that the world is more divided into independent nations and regional economies under the continuous growing and high emission rates.

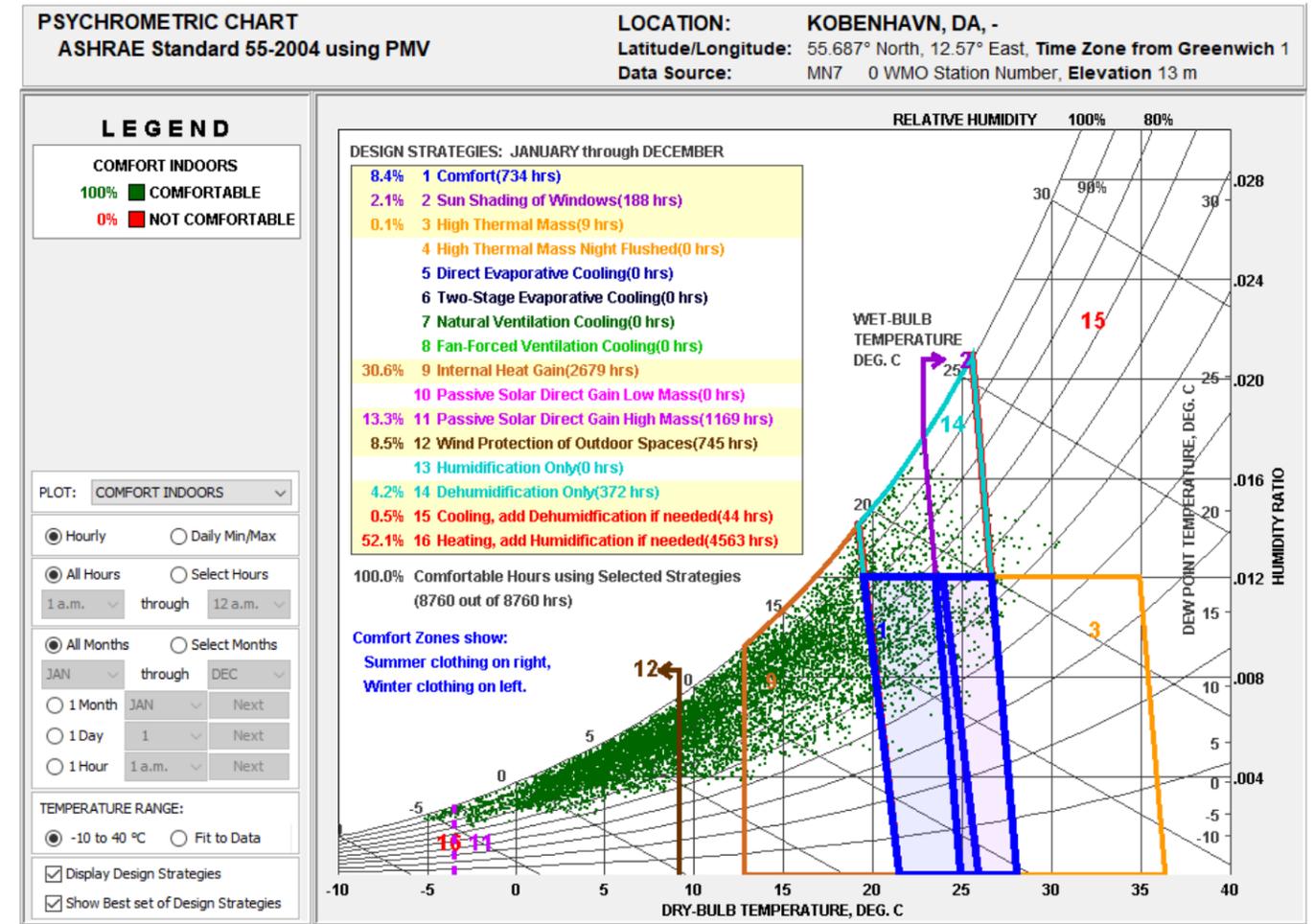
It can be clearly seen that the temperature is getting warmer as a result of that theory but in the other hand, it is creating more hours of natural comfort due to the fact that the climate of Copenhagen is temperate and quite cool in the summer and cold in the winter. In order to evaluate the

### Strategies contribution (2030):



## Future scenarios

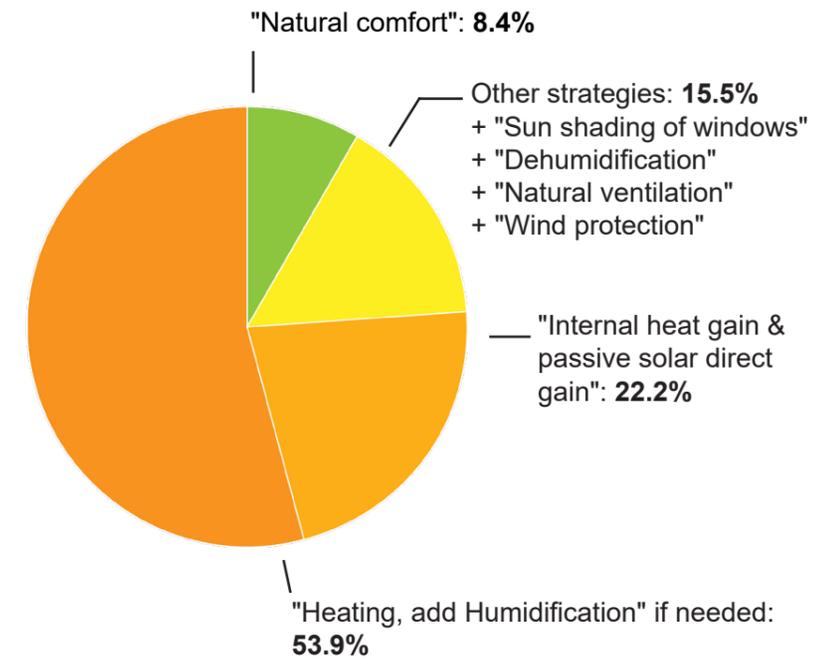
### 2100 (Strategies applied)



affects of this tendency, we would have to look more carefully about the changing of the shares of the strategies, also the increasing of humidity, how these strategies are manipulating back and forth the hotter temperature and higher humidity.

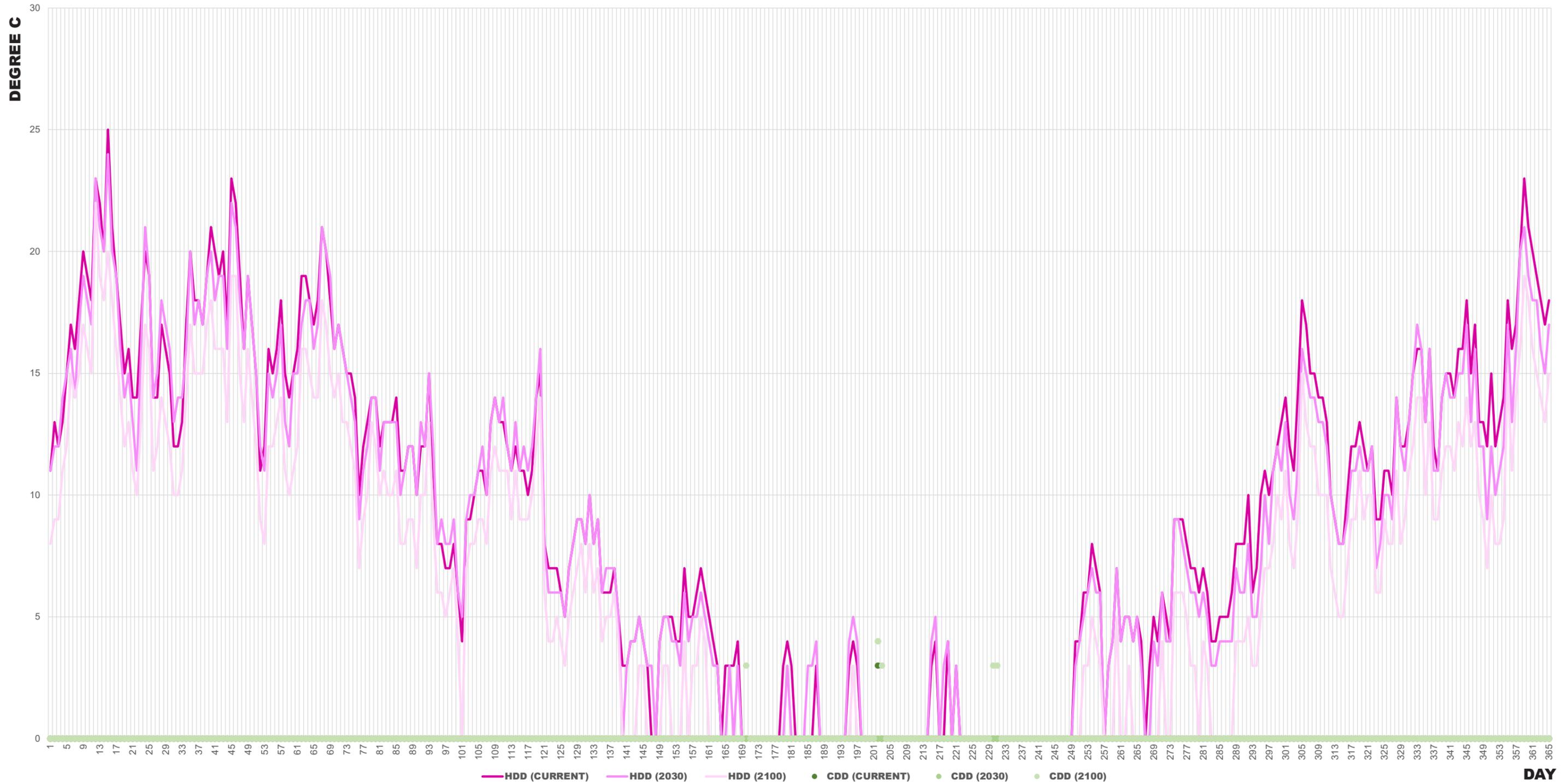
In the next page, we want to use the line graphs instead of piecharts in order to illustrate the trends of these strategies, how are they going to be in the future. By doing that, we can somehow predict not only the most important strategies at this moment but also to find more sustainable solutions for long-term vision.

### Strategies contribution (2100):



## 5.2 The Psychrometric chart

## Heating & Cooling degree days



**<<Heating Degree Days (HDD) index:** the severity of the cold in a specific time period taking into consideration outdoor temperature and average room temperature. The calculation of HDD relies on the base temperature, defined as the lowest daily mean air temperature not leading to indoor heating. In general climatological approach, the base temperature is set to a constant value of 15°C in the HDD calculation.>>

**<<Cooling degree days (CDD) index:** the severity of the heat in a specific time period taking into consideration outdoor temperature and average room temperature. The calculation of CDD relies on the base temperature, defined as the highest daily mean air temperature not leading to indoor cooling. In general climatological approach, the base temperature is set to a constant value of 24°C in the CDD calculation.>>

If  $T_m \leq 15^\circ\text{C}$  Then  $[\text{HDD} = \sum_i(18^\circ\text{C} - T_m^i)]$  Else  $[\text{HDD} = 0]$

where  $T_m^i$  is the mean air temperature of day  $i$ .

If  $T_m \geq 24^\circ\text{C}$  Then  $[\text{CDD} = \sum_i(T_m^i - 21^\circ\text{C})]$  Else  $[\text{CDD} = 0]$

where  $T_m^i$  is the mean air temperature of day  $i$ .

Resources : [https://ec.europa.eu/eurostat/cache/metadata/en/nrg\\_chdd\\_esms.htm](https://ec.europa.eu/eurostat/cache/metadata/en/nrg_chdd_esms.htm)

### **FACTS:**

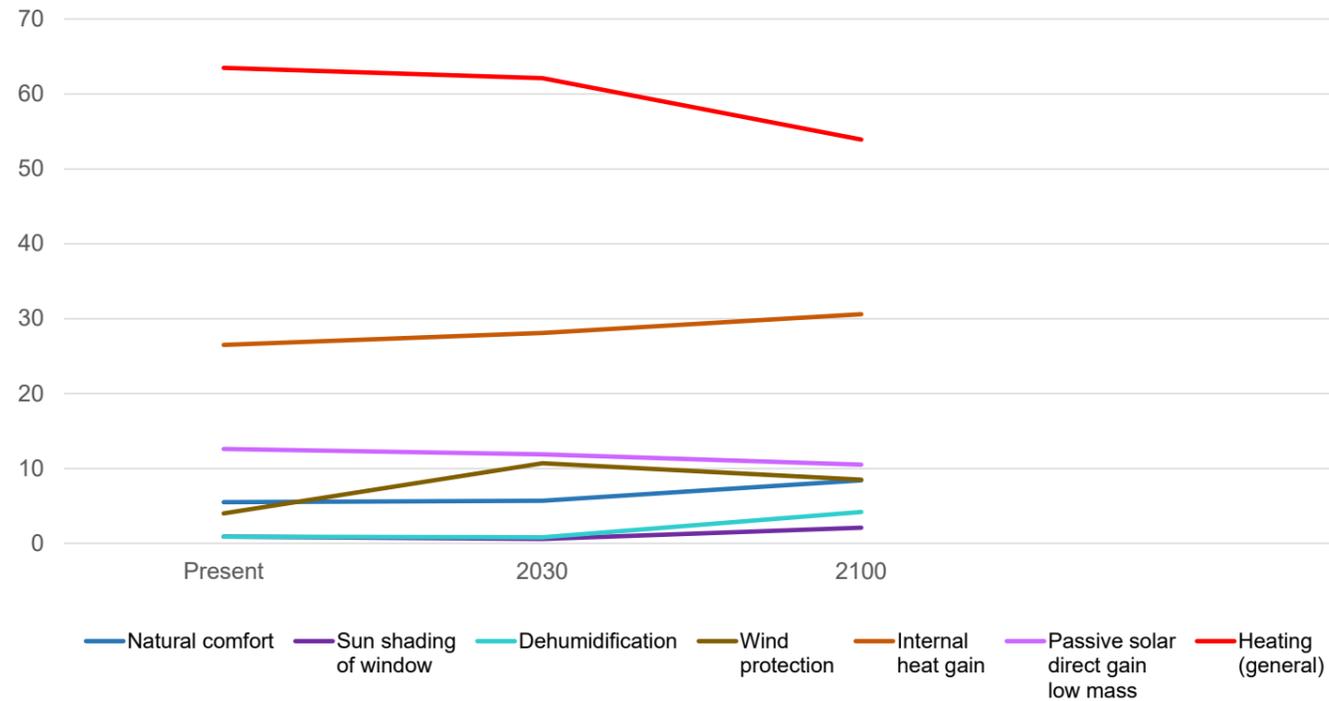
**+ GENERALLY, THE NEED FOR HEATING IS THE MAJORITY DURING THE YEAR, ESPECIALLY FROM OCTOBER TO APRIL**

**+ THE NEEDS FOR HEATING WILL DECREASE IN THE FUTURE**

**+ THERE WILL BE MORE COOLING DEGREE DAYS BUT THE AMOUNT IS STILL QUITE SMALL BUT THIS FACT LEADS TO THE NECESSITY OF COOLING STRATEGIES IN ORDER TO COPE WITH THE FUTURE**

## 5.2 The Psychrometric chart

### Strategies tendency



### The trend:

The chart above is intended to illustrate the reality if the importance of a particular strategy is increasing or decreasing in the future. Although the heating strategy group still generates the main percentage of comfort hours however, it is decreasing significantly. This issue is very reasonable due to the fact that the earth is getting warmer, this phenomenon also causes more natural comfort by raising the temperature in the cold season.

In the design guidelines issued by climate consultant 6.0 it is suggested that window shading is not necessary for the current climate conditions in Copenhagen but according to the chart this solution will still have a significantly positive impact in the future for thermal comfort and should be taken into account because this outcome may change for buildings with a high internal gain and consistent glazed surfaces, the possibility to have discomfort hours may happen so it requires more detailed analyses about the appropriate strategies. The same idea can be applied to wind and dehumidification strategies. Wind and humidity in the city are respectively high and they will get higher and higher in the upcoming years, for that reason those sets of strategies are important in the long term vision.

### KEY FACTS :

**+ THE WEATHER IS GOING TO BE WARMER AND THE NATURAL COMFORT HOURS WILL BE EXPANDED BUT GLOBALLY, IT IS DEFINITELY NOT A POSITIVE THING.**

**+ THE HEATING STRATEGIES ARE STILL IMPORTANT IN THE FUTURE BUT FOR THE LONG-TERM VISION, WIND PROTECTION, DEHUMIDIFICATION AND SUN SHADING ARE ALSO CONSIDERABLE.**

## Define main strategies

### Design guidelines

Assuming only the Design Strategies that were selected on the Psychrometric Chart, 100.0% of the hours will be Comfortable. This list of Residential Design guidelines applies specifically to this particular climate, starting with the most important first. Click on a Guideline to see a sketch of how this Design Guideline shapes building design (see Help).

19	For passive solar heating face most of the glass area south to maximize winter sun exposure, but design overhangs to fully shade in summer
20	Provide double pane high performance glazing (Low-E) on west, north, and east, but clear on south for maximum passive solar gain
3	Lower the indoor comfort temperature at night to reduce heating energy consumption (lower thermostat heating setback) (see comfort low criteria)
1	Tiles or slate (even on wood floors) or a stone-faced fireplace provides enough surface mass to store winter daytime solar gain and summer nighttime 'coolth'
11	Heat gain from lights, people, and equipment greatly reduces heating needs so keep home tight, well insulated (to lower Balance Point temperature)
15	High Efficiency furnace (at least Energy Star) should prove cost effective
18	Keep the building small (right-sized) because excessive floor area wastes heating and cooling energy
13	Steep pitched roof, with a vented attic over a well insulated ceiling, works well in cold climates (sheds rain and snow, and helps prevent ice dams)
4	Extra insulation (super insulation) might prove cost effective, and will increase occupant comfort by keeping indoor temperatures more uniform
67	Traditional passive homes in cold clear climates had snug floorplan with central heat source, south facing windows, and roof pitched for wind protection
2	If a basement is used it must be at least 18 inches below frost line and insulated on the exterior (foam) or on the interior (fiberglass in furred wall)
63	Traditional passive homes in cool overcast climates used low mass tightly sealed, well insulated construction to provide rapid heat buildup in morning
8	Sunny wind-protected outdoor spaces can extend living areas in cool weather (seasonal sun rooms, enclosed patios, courtyards, or verandahs)
31	Organize floorplan so winter sun penetrates into daytime use spaces with specific functions that coincide with solar orientation
23	Small well-insulated skylights (less than 3% of floor area in clear climates, 5% in overcast) reduce daytime lighting energy and cooling loads
16	Trees (neither conifer or deciduous) should not be planted in front of passive solar windows, but are OK beyond 45 degrees from each corner
28	Windows can be unshaded and face in any direction because any passive solar gain is a benefit, and there is little danger of overheating
12	Insulating blinds, heavy draperies, or operable window shutters will help reduce winter night time heat losses
14	Locate garages or storage areas on the side of the building facing the coldest wind to help insulate
22	Super tight buildings need a fan powered HRV or ERV (Heat or Energy Recovery Ventilator) to ensure indoor air quality while conserving energy

### Choosing strategies:

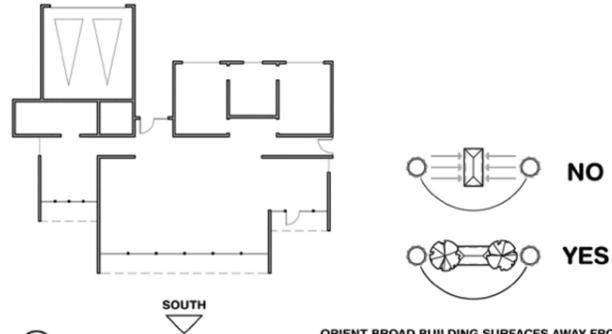
After providing the psychrometric chart, Climate consultant software also gave us a set of strategies based on the theory that 100% of the hours will be comfortable (all the strategies are applied). It is obviously not mandatory to follow strictly these guidelines but they are rather a reference source that we can use to build our own set of strategies. Beside some of the solutions that are more about the architecture, there are several strategies emphasized on mechanical technical works i.e. number 3, 15, 22. Due to the scope of this thesis, we only aim to focus on the architectural strategies.

### KEY FACTS :

#### THE APPLICABLE GUIDELINES COULD BE:

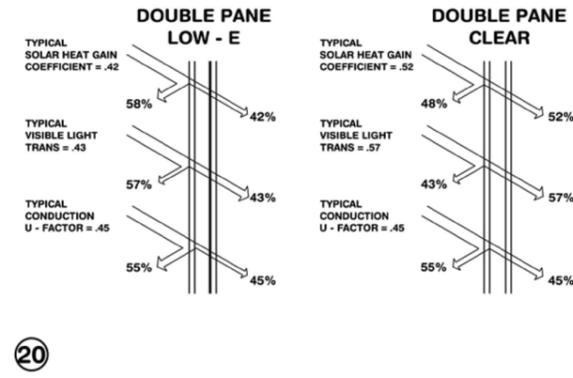
- + 19 - ABOUT THE ORIENTATION
- + 20 - LOW E GLASS
- + 1 - INTERNAL HEAT GAIN
- + 13 - ROOF SHAPE
- + 67 - PASSIVE HOME IN COLD CLEAR CLIMATE
- + 63 - PASSIVE HOME IN COOL OVERCAST CLIMATE
- + 8 - WIND PROTECTION
- + 31 - FLOOR PLAN
- + 23 - SKYLIGHT
- + 16 - TREE ARRANGEMENT
- + 28 - WINDOWS DIRECTION

## 5.2 The Psychrometric chart



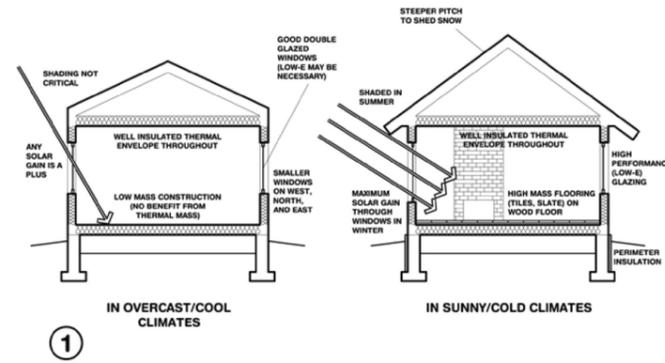
ORIENT BROAD BUILDING SURFACES AWAY FROM THE HOT WESTERN SUN. ONLY NORTHERN AND SOUTHERN EXPOSURES ARE EASILY SHADED

For passive solar heating face most of the glass area south to maximize winter sun exposure, but design overhangs to fully shade in summer

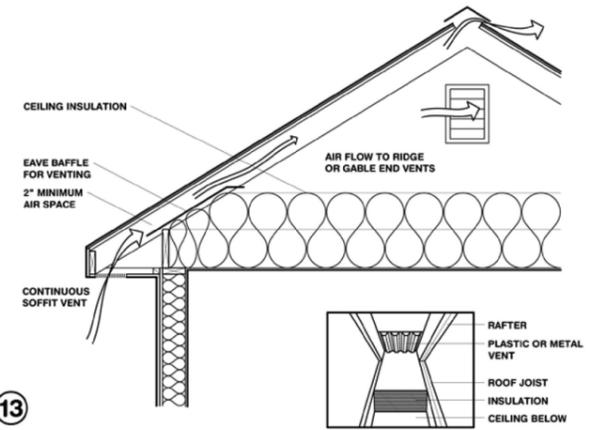


Provide double pane high performance glazing (Low-E) on west, north, and east, but clear on south for maximum passive solar gain

## The Design Guidelines



1 Tiles or slate (even on wood floors) or a stone-faced fireplace provides enough surface mass to store winter daytime solar gain and summer nighttime 'coolth'

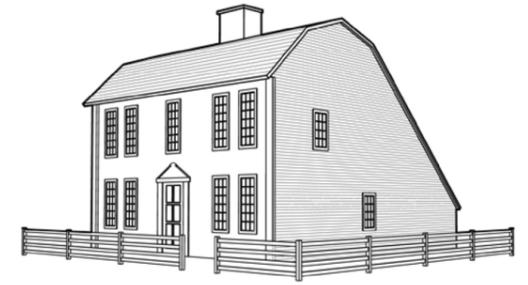


13 Steep pitched roof, with a vented attic over a well insulated ceiling, works well in cold climates (sheds rain and snow, and helps prevent ice dams)

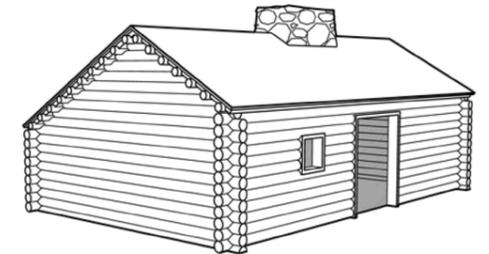
### The strategies:

This is a set of filtered strategies recommended by Climate Consultants for a given area of Copenhagen based on climate data. Obviously these are not some kind of "design bible" that we will strictly adhere to, but we do consider them more like guidelines or references by which we want to guide our design.

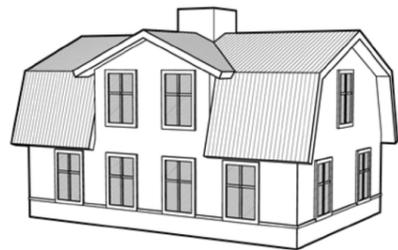
# MASTER PLAN + BUILDING DESIGN STRATEGIES



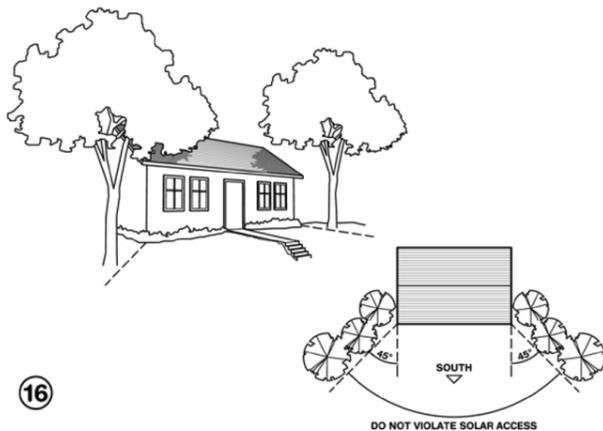
67 Traditional passive homes in cold clear climates had snug floorplan with central heat source, south facing windows, and roof pitched for wind protection



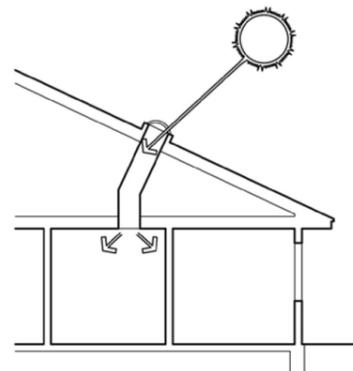
63 Traditional passive homes in cool overcast climates used low mass tightly sealed, well insulated construction to provide rapid heat buildup in morning



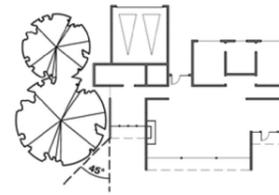
28 Windows can be unshaded and face in any direction because any passive solar gain is a benefit, and there is little danger of overheating



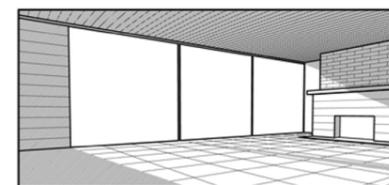
16 Trees (neither conifer or deciduous) should not be planted in front of passive solar windows, but are OK beyond 45 degrees from each corner



23 Small well-insulated skylights (less than 3% of floor area in clear climates, 5% in overcast) reduce daytime lighting energy and cooling loads



31 Organize floorplan so winter sun penetrates into daytime use spaces with specific functions that coincide with solar orientation



8 Sunny wind-protected outdoor spaces can extend living areas in cool weather (seasonal sun rooms, enclosed patios, courtyards, or verandahs)

# 5.3

# The Matrix

### Overview

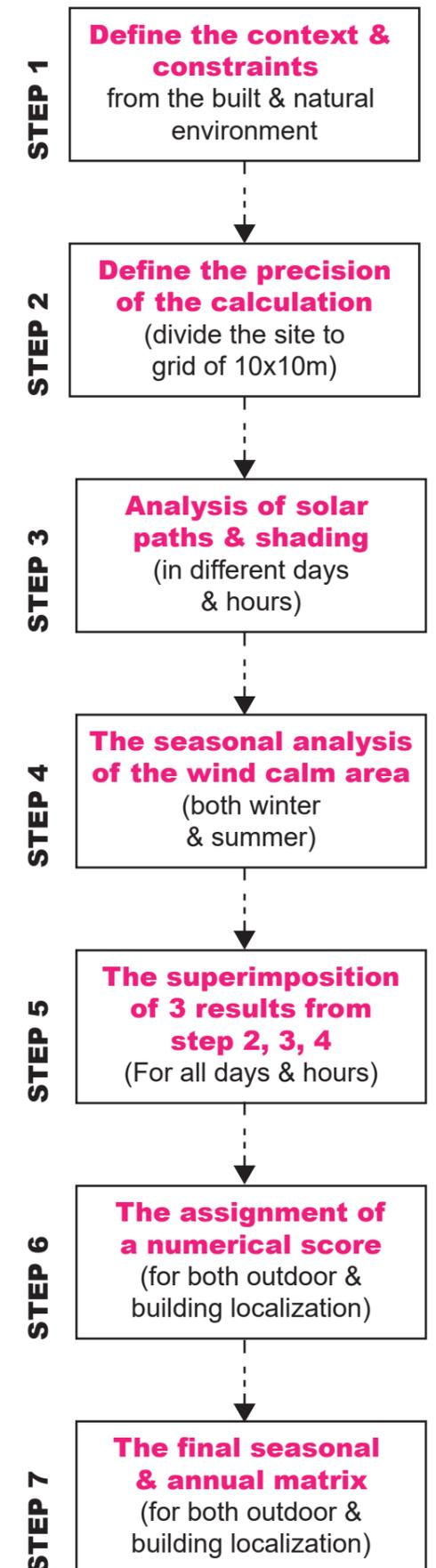
In the next step, with all the data collected from climatic consultant, we performed several calculations in order to have the microclimatic matrix for the winter and the summer then the annual matrix for the building localizations and outdoor localizations as well.

Microclimatic matrix is a very useful and interesting tool that I had a chance to experience and adapt to my first project in Politecnico Di Torino, under the supervisor of professor Mario Grosso. This method was firstly introduced by Two American scholar (Brown and Dekay, 2001) and adapted from professor Mario Grosso (Grosso,2011). There are two main information that we need to take into consideration, they are sun height and direction in winter solstice and summer solstice in order to obtain the shadow footprint on the ground and the prevailing wind direction in summer and winter to get the wind calm zone footprint. The matrix allow the designer to locate correctly the different functions (both outdoor activities and building) on the site based on the analysis about the footprint of shadow and wind calm area on a virtual plane placed at the height of the ground. It is also advisable to proceed with analysis on planes verticals on the facade but in this scale of this thesis, only the horizontal plane matrix analysis is carried out to simplify the process. The choice of scoring is also varied between the building and local climate type and also the intensity of the activities.

### The Site

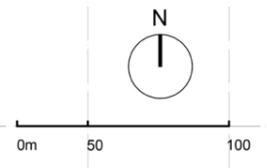
According to municipal plan 2019 and present situation, the area could be divided into 2 parts in which the western side will be used for mixed-use purposes with housing, office and commercial purposes, on the other hand, the eastern side will be the harbour, port and other sports activities or public gatherings. For that reason, after having the shadow and wind data of the site, in order to evaluate the area by scoring each 10x10m grid, we used 2 different grade scales for 2 mentioned parts based on their functions. The western side will be considered as Low Metabolic Rate area and the other side will be High Metabolic Rate.

During the summer, the day in Copenhagen is quite long but the solar altitude is high so the shadow will not have that long lengths and the area will not be affected by surrounding high buildings such as the industrial area in the south-east and the Copenhill which will create a big shadow shape on the site in the winter.



### 5.3 The Matrix

### The Site



#### WESTERN SIDE

Mixed-use purposes with  
commercials, housings,  
offices....

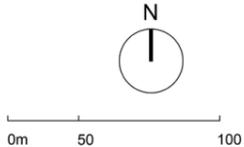
#### EASTERN SIDE

Harbour, port, sport, gymnastics,  
workout activities....



5.3 The Matrix

Summer Shadow - Day

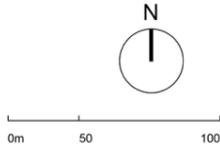


21 JUNE 2022 - 08:00

AZIMUTH : 85.90  
ALTITUDE : 25.99  
SHADOW LENGTH (1M) : 2.05

5.3 The Matrix

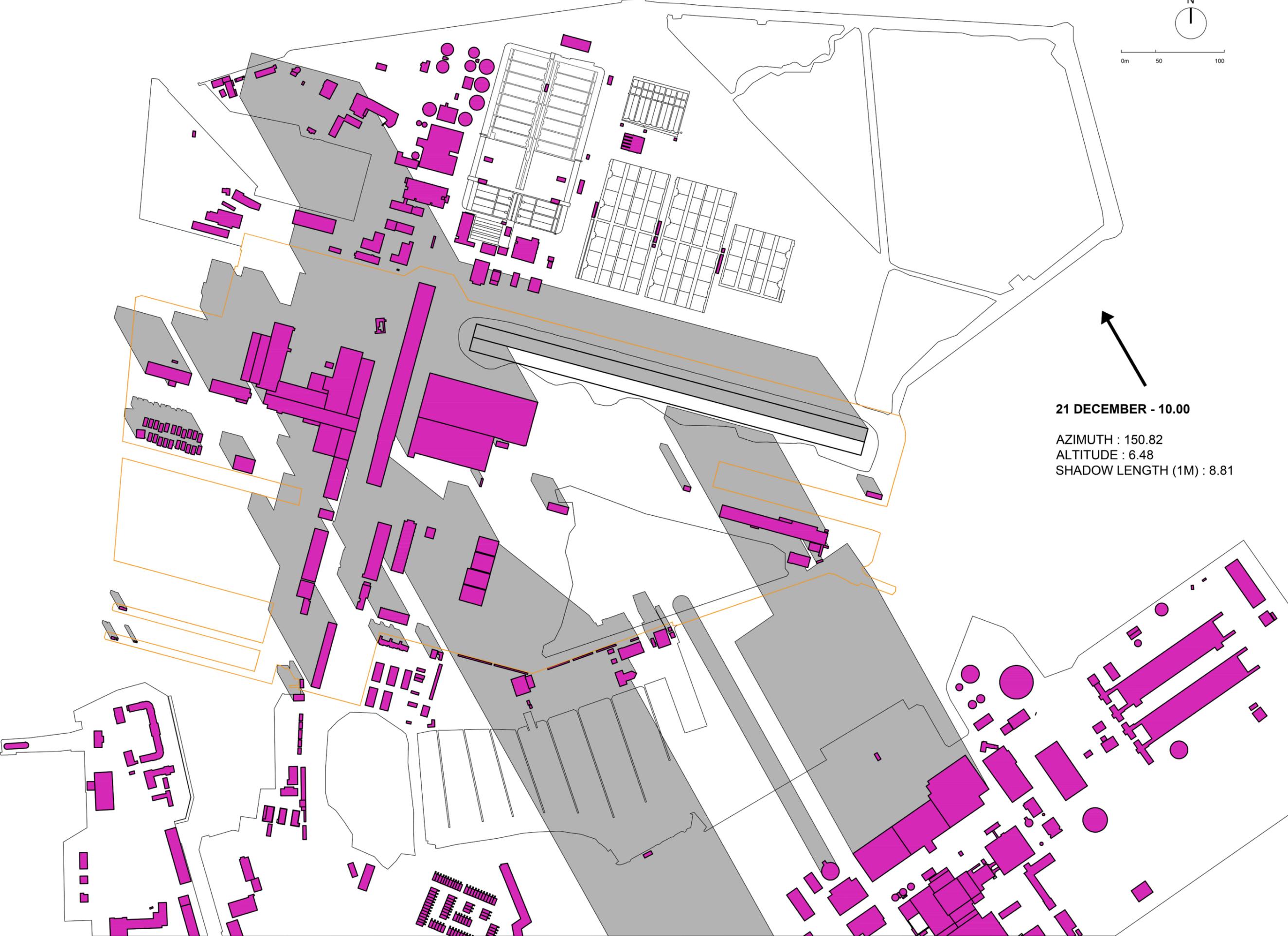
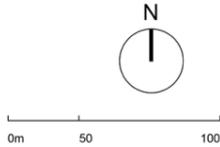
Summer Shadow - Noon



21 JUNE 2022 - 16:00  
AZIMUTH : 241.27  
ALTITUDE : 45.40  
SHADOW LENGTH (1M) : 0.99

5.3 The Matrix

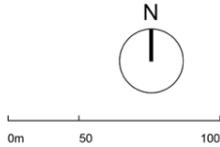
Winter Shadow - Day



**21 DECEMBER - 10.00**  
AZIMUTH : 150.82  
ALTITUDE : 6.48  
SHADOW LENGTH (1M) : 8.81

5.3 The Matrix

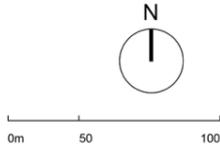
Winter Shadow - Noon



**21 DECEMBER - 14.00**  
AZIMUTH : 205.83  
ALTITUDE : 7.45  
SHADOW LENGTH (1M) : 7.65

5.3 The Matrix

Summer Wind



SUMMER  
WIND DIRECTION : 290 degree

5.3 The Matrix

Winter Wind



### 5.3 The Matrix

ACTIVITIES		PERIOD	INTERRELATION BETWEEN MICROCLIMATE MATRIX & THERMAL COMFORT			
			BEST	GOOD	BAD	WORST
LOW METABOLIC RATE	RESTING, SLOW WALKING	WINTER	SUN + LEE	SUN + WIND	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + LEE	SHADE + WIND	SUN + WIND	SUN + LEE
MEDIUM METABOLIC RATE	FAST WALKING, SLOW RUNNING	WINTER	SUN + WIND	SUN + LEE	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE
HIGH METABOLIC RATE	FAST RUNNING, GYMNASTICS	WINTER	SUN + WIND	SUN + LEE	SHADE + WIND	SHADE + LEE
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE

WESTERN SITE      EASTERN SITE

#### Outdoor Localizations

As it was mentioned before, in this analysis, we are going to do the microclimate matrix for both outdoor and building localization. After finalizing calculations and create the drawings of Sun + Wind shadows, we had to move on with overlapping those drawings to identify the comfort conditions for each square of the grid and assign the appropriate values according to the type of the activities. We learned that the site will have "low metabolic rate" on the western side and "high metabolic rate" on the eastern side so the grade system will be different for both of them.

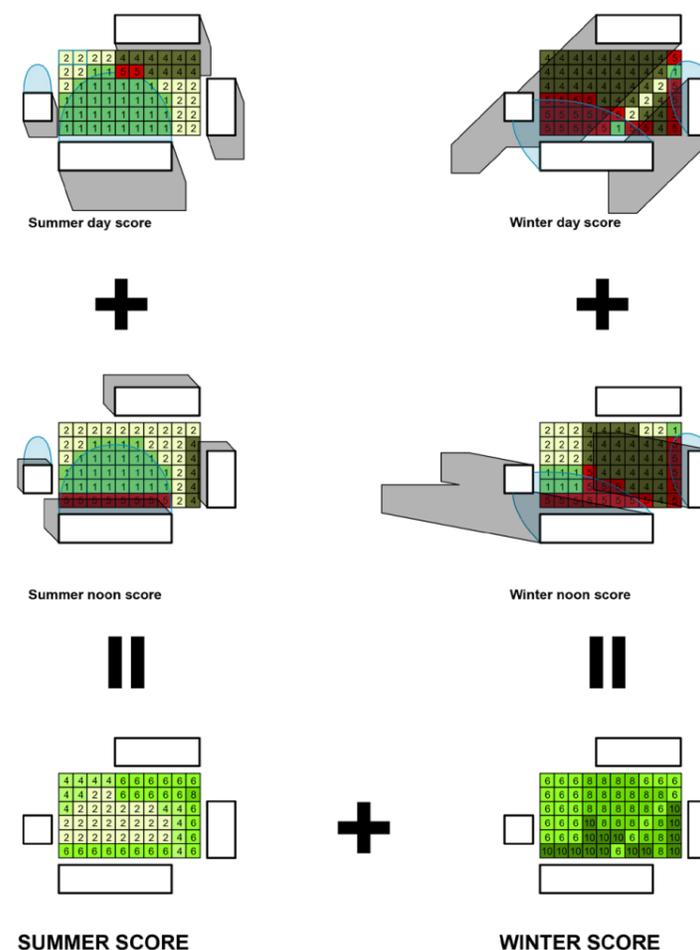
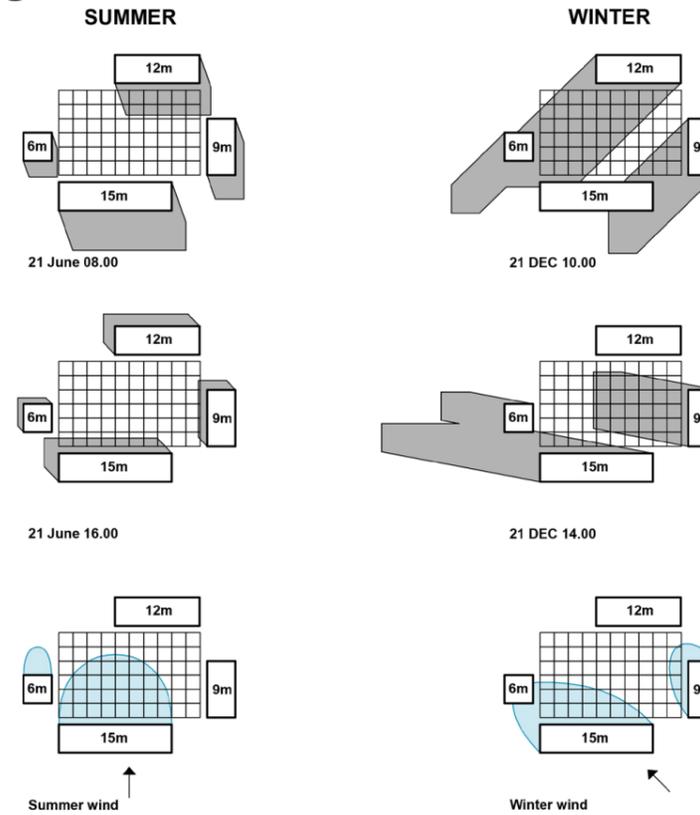
#### Building Localizations

For the building, things are a bit different. Firstly we have to find the climate type of the area, then identify the type of the building (in this case, we consider all the buildings are potential "skin-loaded buildings"). Finally, after having the grade systems, we applied them to the defined comfort condition drawings and create the seasonal comfort score for winter and summer then combine them again to have the annual score.

SKIN LOADED BUILDING/ TEMPERATE HUMID	SUMMER	WINTER
SUN+LEE	1	5
SUN+WIND	4	4
SHADE+LEE	2	2
SHADE+WIND	5	1

Resouces: Giacomo Chiesa, Mario Grosso, «Accessibilita e qualita ambientale del paesaggio urbano. Lamatrice microclimatica di sito come strumento di progetto», RI - VISTA, n°.1 : 78 - 91.

### Assign Values



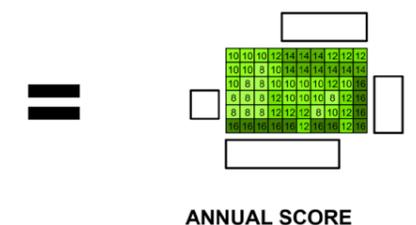
### Footprint tracking for Sun + Wind

#### Define comfort condition

- SUN + WIND
- SUN + LEE
- SHADE + WIND
- SHADE + LEE

+ Assign value (In this example, we was assigning the values for Outdoor Localizations with Low Metabolic Rate)

- 2 SUN + WIND
- 1 SUN + LEE
- 5 SHADE + WIND
- 2 SHADE + LEE



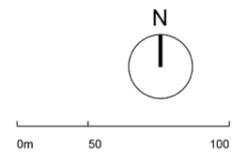
### 5.3 The Matrix

### Outdoor Localisations

### Assign Values - Summer Day

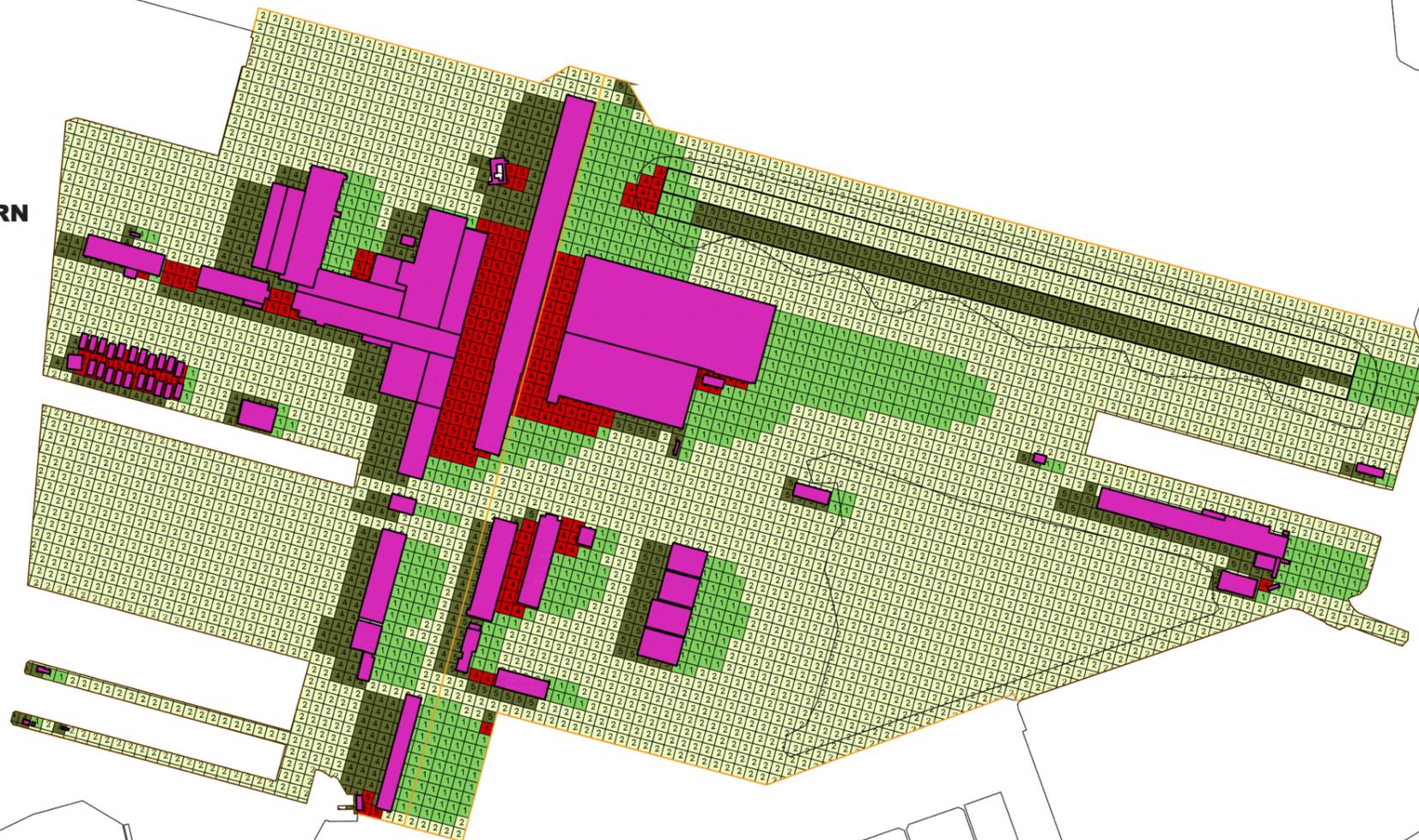
ACTIVITIES		PERIOD	INTERRELATION BETWEEN MICROCLIMATE MATRIX & THERMAL COMFORT			
			BEST	GOOD	BAD	WORST
LOW METABOLIC RATE	RESTING, SLOW WALKING	WINTER	SUN + LEE	SUN + WIND	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + LEE	SHADE + WIND	SUN + WIND	SUN + LEE
MEDIUM METABOLIC RATE	FAST WALKING, SLOW RUNNING	WINTER	SUN + WIND	SUN + LEE	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE
HIGH METABOLIC RATE	FAST RUNNING, GYMNASTICS	WINTER	SUN + WIND	SUN + LEE	SHADE + WIND	SHADE + LEE
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE

BEST	GOOD	BAD	WORST
5	4	2	1



WESTERN SITE

EASTERN SITE



SCORE (WEST)

- 2 SUN + WIND
- 1 SUN + LEE
- 2 SHADE + WIND
- 1 SHADE + LEE

SCORE (EAST)

- 2 SUN + WIND
- 1 SUN + LEE
- 2 SHADE + WIND
- 1 SHADE + LEE

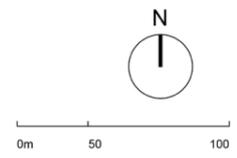
### 5.3 The Matrix

### Outdoor Localisations

### Assign Values - Summer Noon

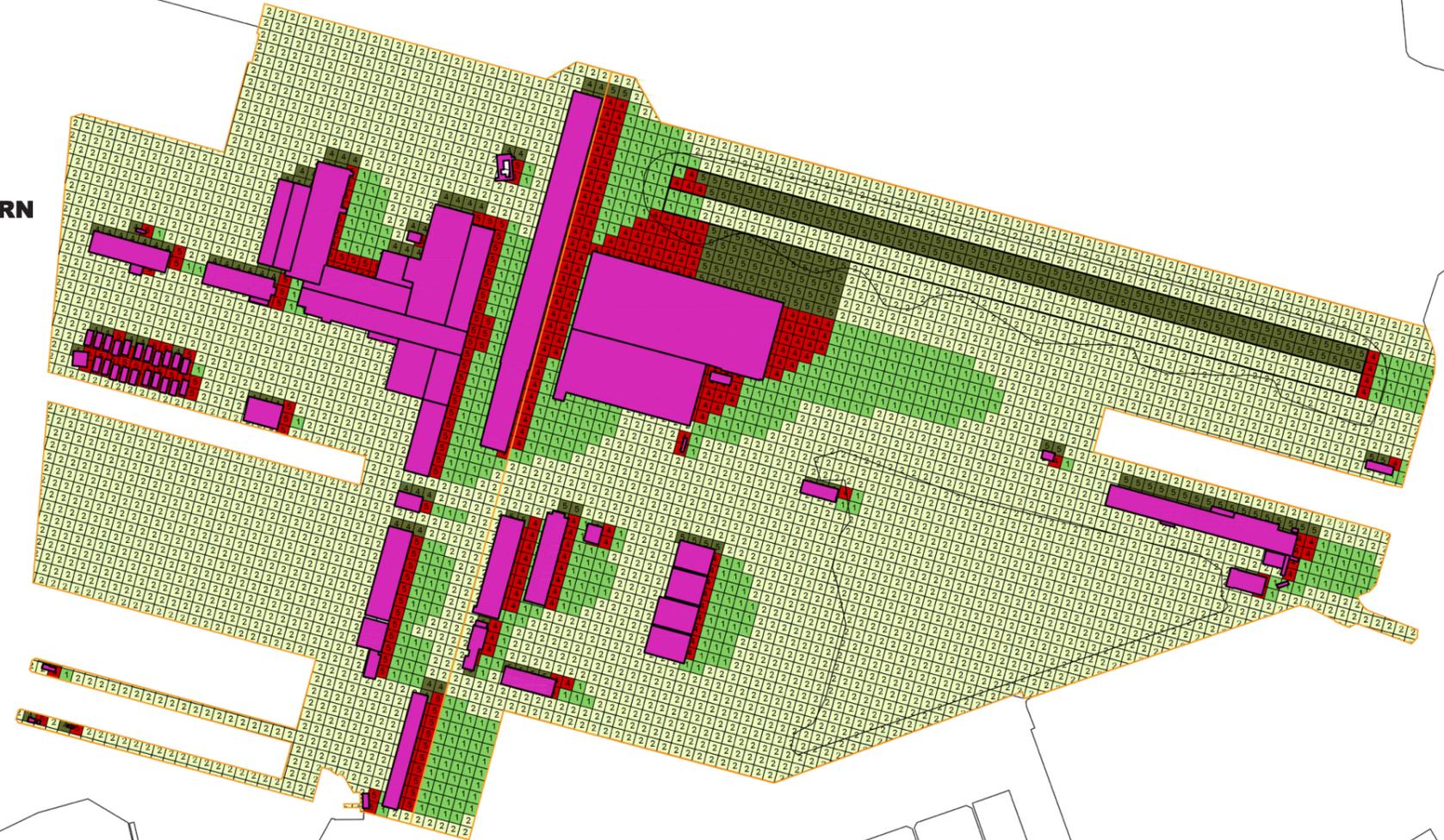
ACTIVITIES		PERIOD	INTERRELATION BETWEEN MICROCLIMATE MATRIX & THERMAL COMFORT			
			BEST	GOOD	BAD	WORST
LOW METABOLIC RATE	RESTING, SLOW WALKING	WINTER	SUN + LEE	SUN + WIND	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + LEE	SHADE + WIND	SUN + WIND	SUN + LEE
MEDIUM METABOLIC RATE	FAST WALKING, SLOW RUNNING	WINTER	SUN + WIND	SUN + LEE	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE
HIGH METABOLIC RATE	FAST RUNNING, GYMNASTICS	WINTER	SUN + WIND	SUN + LEE	SHADE + WIND	SHADE + LEE
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE

BEST	GOOD	BAD	WORST
5	4	2	1



WESTERN SITE

EASTERN SITE



SCORE (WEST)

- 2 SUN + WIND
- 1 SUN + LEE
- 2 SHADE + WIND
- 1 SHADE + LEE

SCORE (EAST)

- 2 SUN + WIND
- 1 SUN + LEE
- 2 SHADE + WIND
- 1 SHADE + LEE

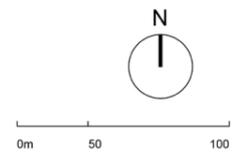
### 5.3 The Matrix

### Outdoor Localisations

### Assign Values - Winter Day

ACTIVITIES		PERIOD	INTERRELATION BETWEEN MICROCLIMATE MATRIX & THERMAL COMFORT			
			BEST	GOOD	BAD	WORST
LOW METABOLIC RATE	RESTING, SLOW WALKING	WINTER	SUN + LEE	SUN + WIND	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + LEE	SHADE + WIND	SUN + WIND	SUN + LEE
MEDIUM METABOLIC RATE	FAST WALKING, SLOW RUNNING	WINTER	SUN + WIND	SUN + LEE	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE
HIGH METABOLIC RATE	FAST RUNNING, GYMNASTICS	WINTER	SUN + WIND	SUN + LEE	SHADE + WIND	SHADE + LEE
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE

BEST	GOOD	BAD	WORST
5	4	2	1



WESTERN SITE EASTERN SITE



SCORE (WEST)

- 4 SUN + WIND
- 5 SUN + LEE
- 4 SHADE + WIND
- 2 SHADE + LEE

SCORE (EAST)

- 5 SUN + WIND
- 4 SUN + LEE
- 2 SHADE + WIND
- 1 SHADE + LEE

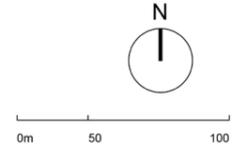
### 5.3 The Matrix

### Outdoor Localisations

### Assign Values - Winter Noon

ACTIVITIES		PERIOD	INTERRELATION BETWEEN MICROCLIMATE MATRIX & THERMAL COMFORT			
			BEST	GOOD	BAD	WORST
LOW METABOLIC RATE	RESTING, SLOW WALKING	WINTER	SUN + LEE	SUN + WIND	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + LEE	SHADE + WIND	SUN + WIND	SUN + LEE
MEDIUM METABOLIC RATE	FAST WALKING, SLOW RUNNING	WINTER	SUN + WIND	SUN + LEE	SHADE + LEE	SHADE + WIND
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE
HIGH METABOLIC RATE	FAST RUNNING, GYMNASTICS	WINTER	SUN + WIND	SUN + LEE	SHADE + WIND	SHADE + LEE
		SUMMER	SHADE + WIND	SHADE + LEE	SUN + WIND	SUN + LEE

BEST	GOOD	BAD	WORST
5	4	2	1



WESTERN SITE

EASTERN SITE



#### SCORE (WEST)

- 4 SUN + WIND
- 5 SUN + LEE
- SHADE + WIND
- SHADE + LEE

#### SCORE (EAST)

- 5 SUN + WIND
- 4 SUN + LEE
- SHADE + WIND
- SHADE + LEE

### 5.3 The Matrix

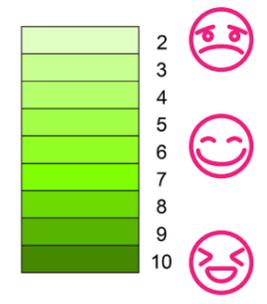
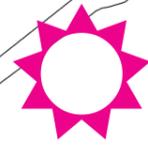
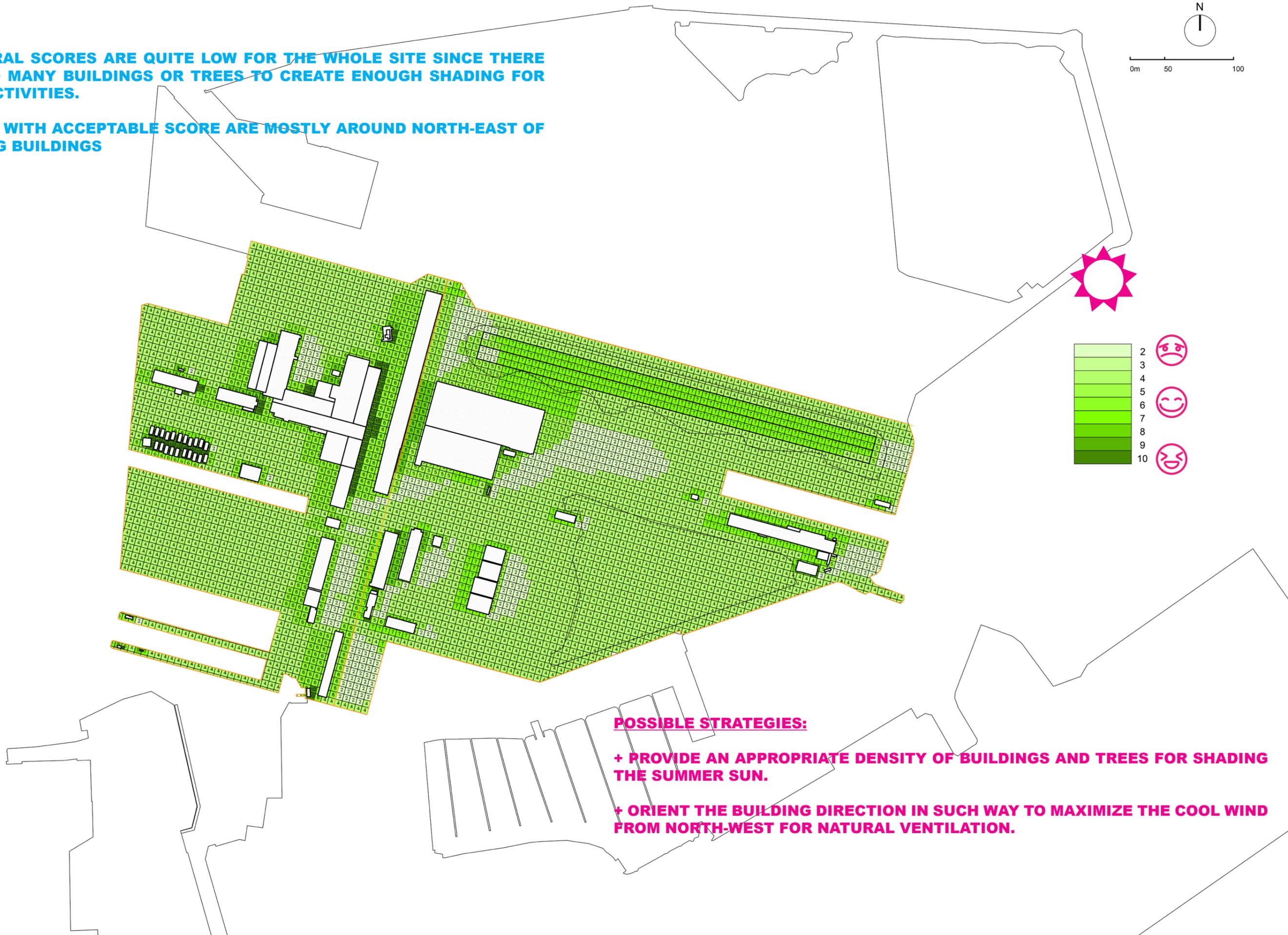
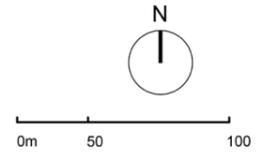
### Outdoor Localisations

### Summer Seasonal Score

#### KEY FACTS :

+ THE GENERAL SCORES ARE QUITE LOW FOR THE WHOLE SITE SINCE THERE ARE NOT SO MANY BUILDINGS OR TREES TO CREATE ENOUGH SHADING FOR OUT DOOR ACTIVITIES.

+ THE AREAS WITH ACCEPTABLE SCORE ARE MOSTLY AROUND NORTH-EAST OF THE EXISTING BUILDINGS



#### POSSIBLE STRATEGIES:

+ PROVIDE AN APPROPRIATE DENSITY OF BUILDINGS AND TREES FOR SHADING THE SUMMER SUN.

+ ORIENT THE BUILDING DIRECTION IN SUCH WAY TO MAXIMIZE THE COOL WIND FROM NORTH-WEST FOR NATURAL VENTILATION.

### 5.3 The Matrix

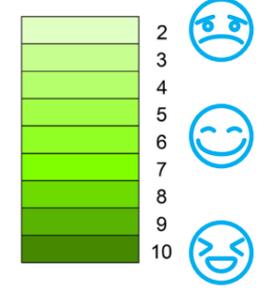
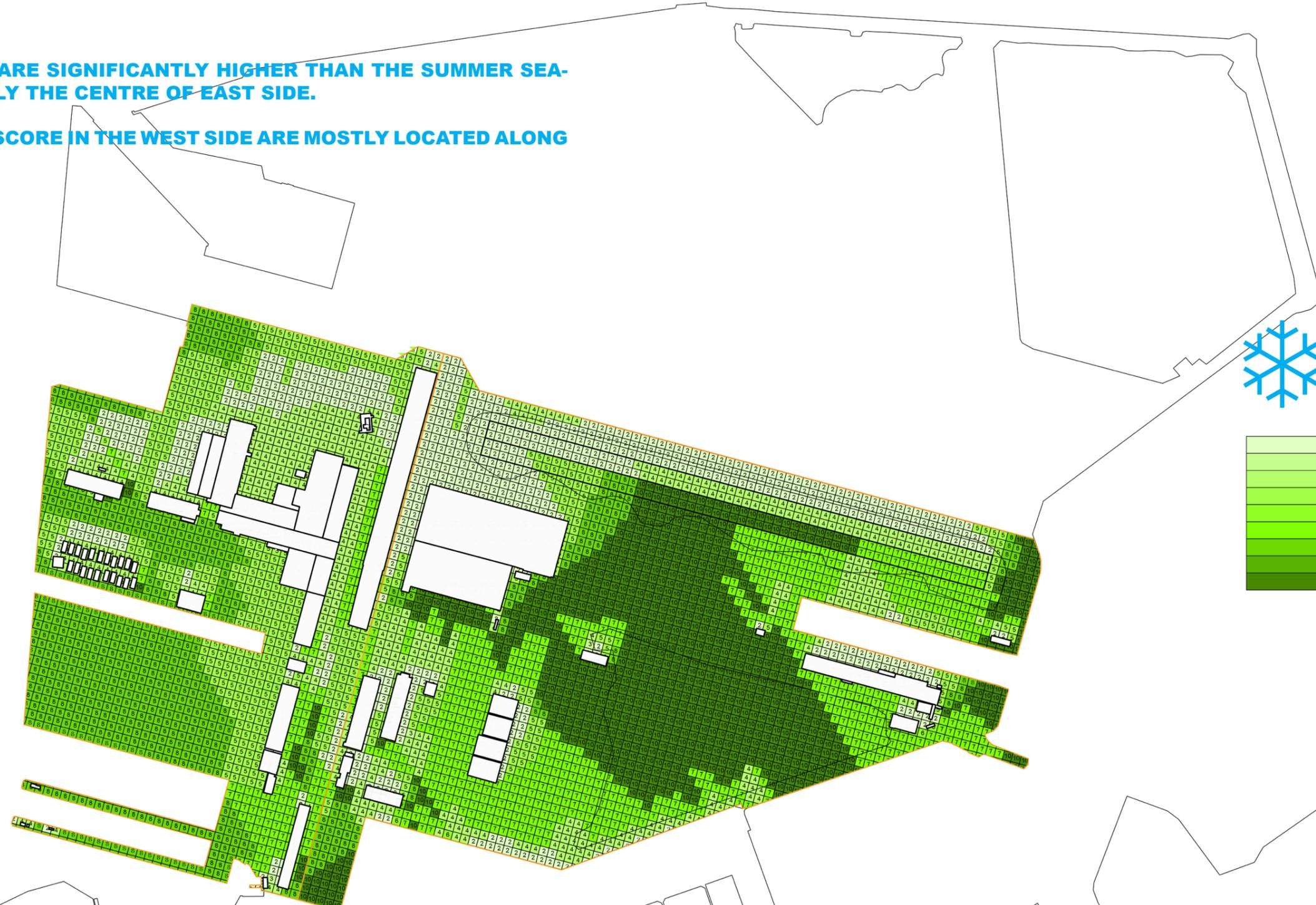
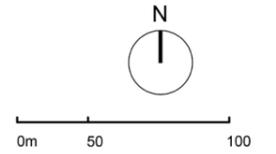
### Outdoor Localisations

### Winter Seasonal Score

#### KEY FACTS :

+ THE GENERAL SCORES ARE SIGNIFICANTLY HIGHER THAN THE SUMMER SEASONAL SCORE, ESPECIALLY THE CENTRE OF EAST SIDE.

+ THE AREAS WITH GOOD SCORE IN THE WEST SIDE ARE MOSTLY LOCATED ALONG THE WATER SURFACE.



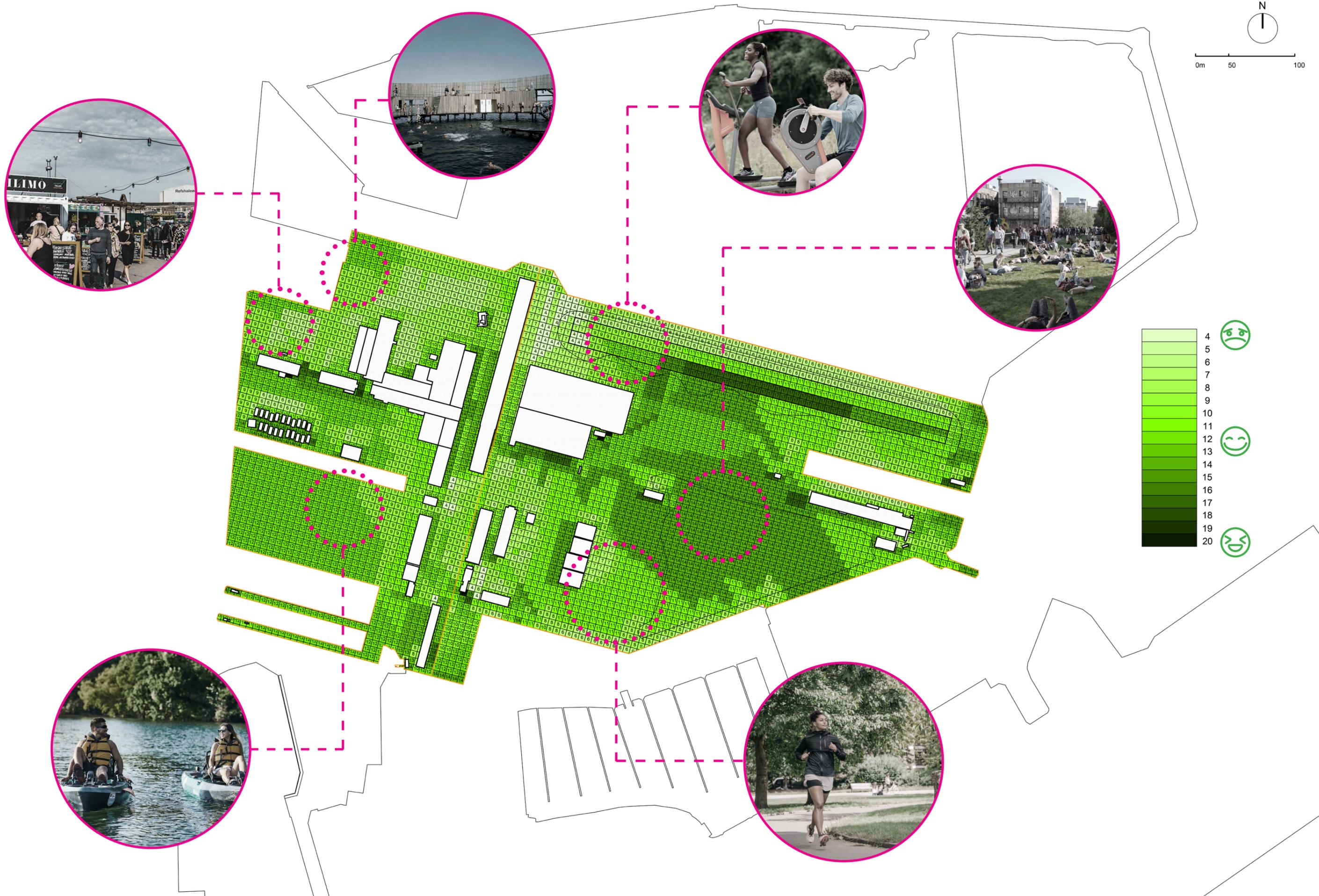
#### POSSIBLE STRATEGIES:

+ ARRANGE THE BUILDING IN ORDER TO MAXIMIZE THE SUN LIGHT FOR BOTH SIDES BUT PROVIDE VEGETATIONS IN THE WEST SIDE TO REDUCE THE AFFECTS OF THE HARSH WIND.

### 5.3 The Matrix

### Outdoor Localisations

### Annual Score

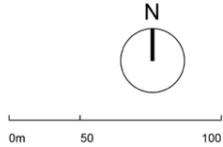


5.3 The Matrix

Building Localisations

Assign Values - Summer Day

SKIN LOADED BUILDING/ TEMPERATE HUMID	SUMMER	WINTER
SUN+LEE	1	5
SUN+WIND	4	4
SHADE+LEE	2	2
SHADE+WIND	5	1



SCORE (WEST+EAST)

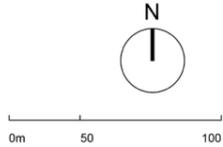
- SUN + WIND
- SUN + LEE
- SHADE + WIND
- SHADE + LEE

5.3 The Matrix

Building Localisations

Assign Values - Summer Noon

SKIN LOADED BUILDING/ TEMPERATE HUMID	SUMMER	WINTER
SUN+LEE	1	5
SUN+WIND	4	4
SHADE+LEE	2	2
SHADE+WIND	5	1



SCORE (WEST+EAST)

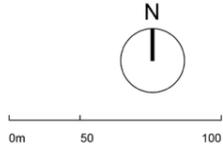
- SUN + WIND
- SUN + LEE
- SHADE + WIND
- SHADE + LEE

5.3 The Matrix

Building Localisations

Assign Values - Winter Day

SKIN LOADED BUILDING/ TEMPERATE HUMID	SUMMER	WINTER
SUN+LEE	1	5
SUN+WIND	4	4
SHADE+LEE	2	2
SHADE+WIND	5	1



SCORE (WEST+EAST)

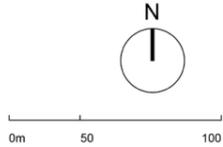
- SUN + WIND
- SUN + LEE
- SHADE + WIND
- SHADE + LEE

5.3 The Matrix

Building Localisations

Assign Values - Winter Noon

SKIN LOADED BUILDING/ TEMPERATE HUMID	SUMMER	WINTER
SUN+LEE	1	5
SUN+WIND	4	4
SHADE+LEE	2	2
SHADE+WIND	5	1



SCORE (WEST+EAST)

- SUN + WIND
- SUN + LEE
- SHADE + WIND
- SHADE + LEE

### 5.3 The Matrix

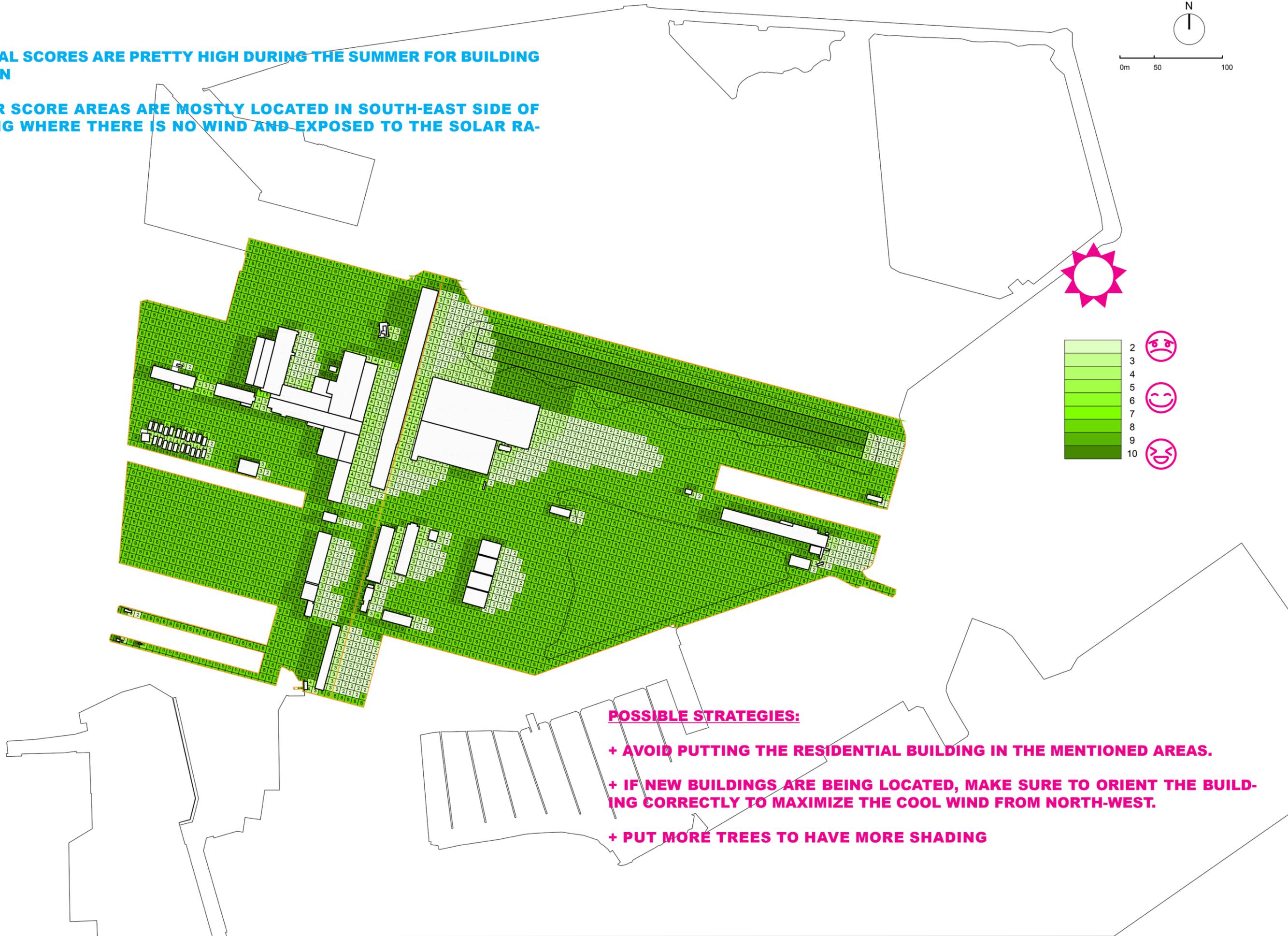
### Building Localisations

### Summer Seasonal Score

#### KEY FACTS :

+ THE GENERAL SCORES ARE PRETTY HIGH DURING THE SUMMER FOR BUILDING LOCALISATION

+ THE LOWER SCORE AREAS ARE MOSTLY LOCATED IN SOUTH-EAST SIDE OF THE BUILDING WHERE THERE IS NO WIND AND EXPOSED TO THE SOLAR RADIATION



#### POSSIBLE STRATEGIES:

+ AVOID PUTTING THE RESIDENTIAL BUILDING IN THE MENTIONED AREAS.

+ IF NEW BUILDINGS ARE BEING LOCATED, MAKE SURE TO ORIENT THE BUILDING CORRECTLY TO MAXIMIZE THE COOL WIND FROM NORTH-WEST.

+ PUT MORE TREES TO HAVE MORE SHADING

### 5.3 The Matrix

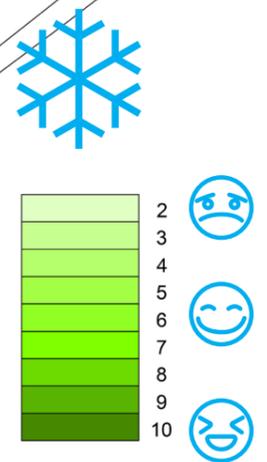
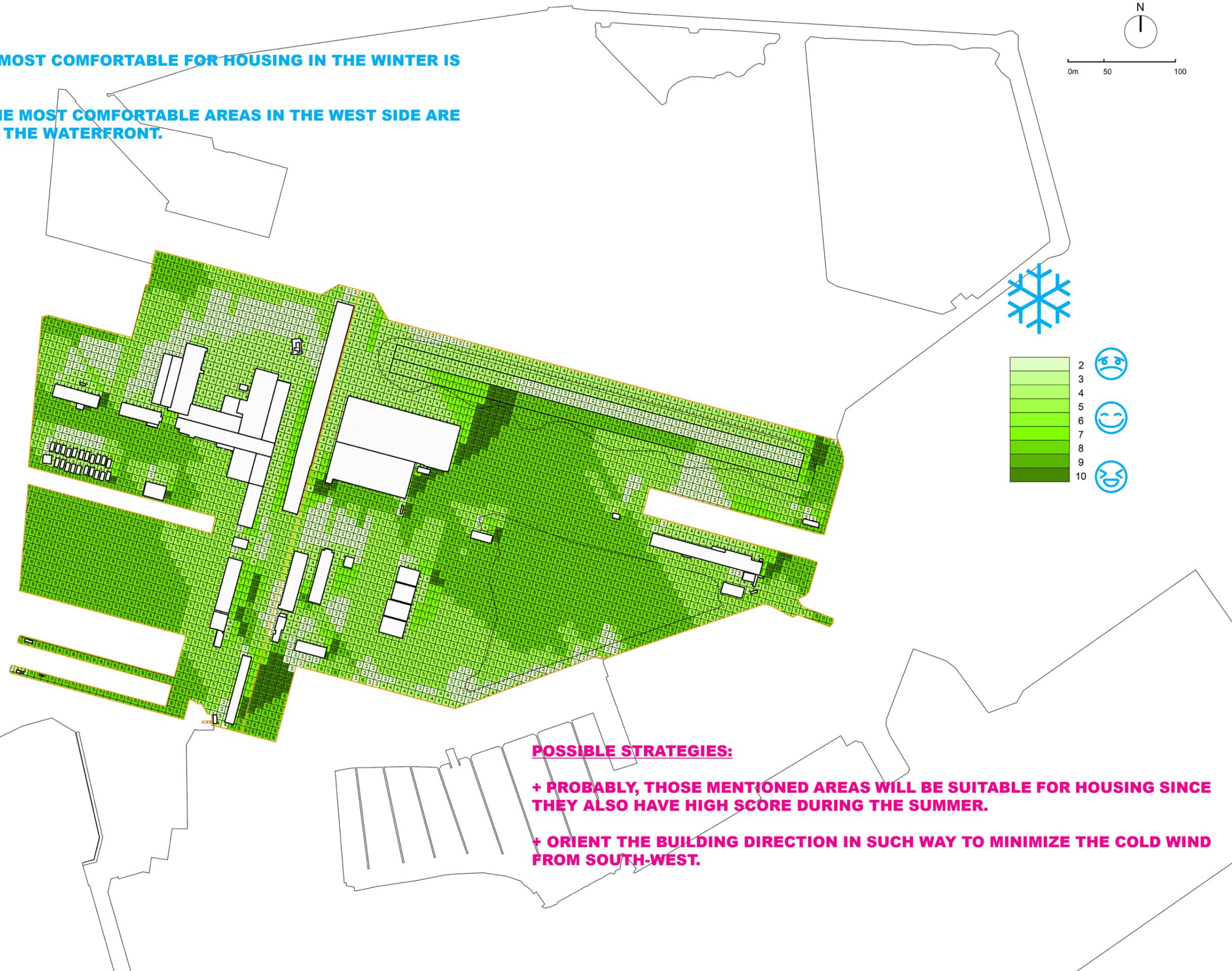
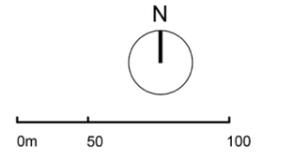
### Building Localisations

### Winter Seasonal Score

#### KEY FACTS :

+ IN THE EAST SIDE, THE MOST COMFORTABLE FOR HOUSING IN THE WINTER IS IN THE CENTER.

+ IN THE OTHER HAND, THE MOST COMFORTABLE AREAS IN THE WEST SIDE ARE MOSTLY LOCATED ALONG THE WATERFRONT.



#### POSSIBLE STRATEGIES:

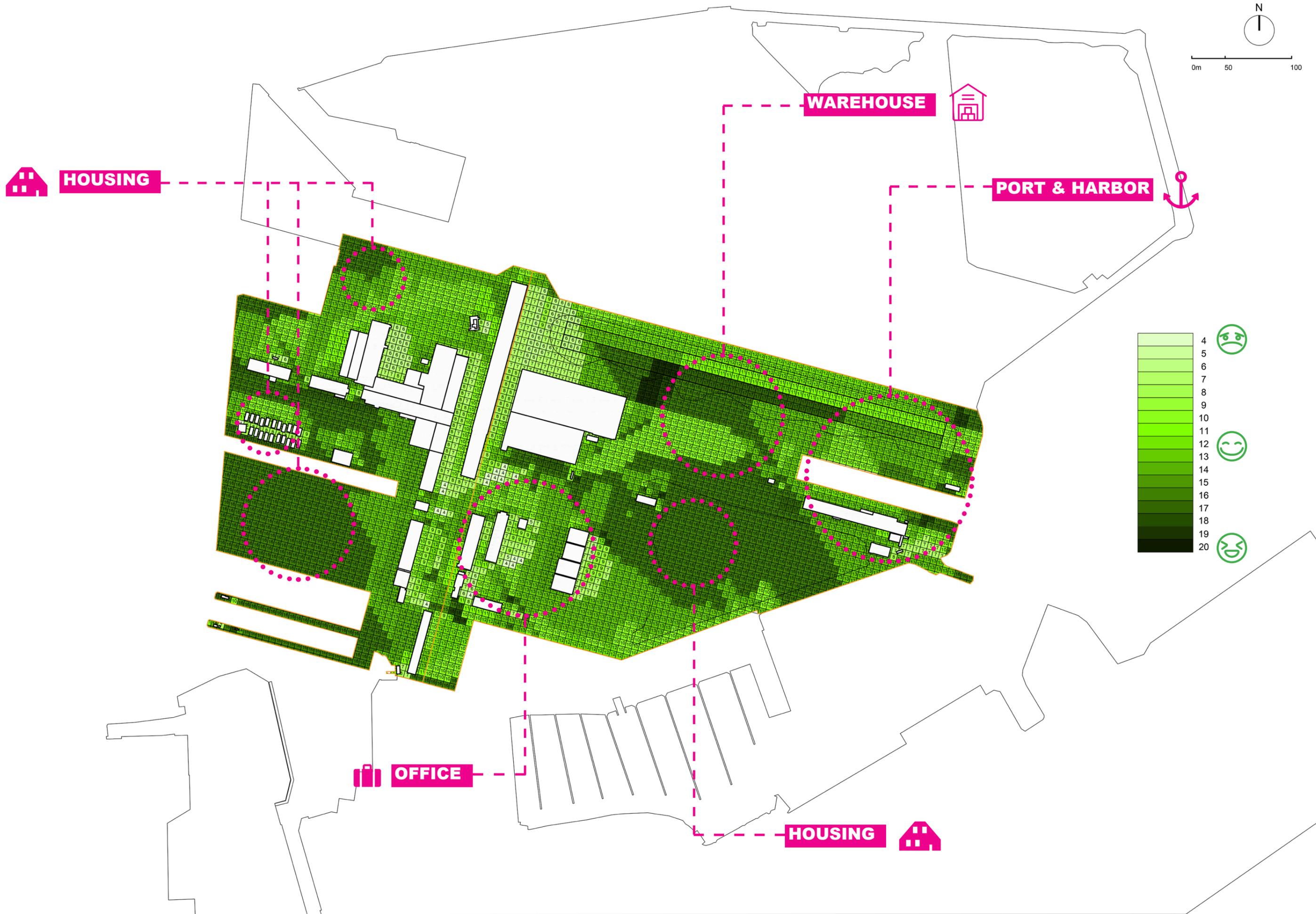
+ PROBABLY, THOSE MENTIONED AREAS WILL BE SUITABLE FOR HOUSING SINCE THEY ALSO HAVE HIGH SCORE DURING THE SUMMER.

+ ORIENT THE BUILDING DIRECTION IN SUCH WAY TO MINIMIZE THE COLD WIND FROM SOUTH-WEST.

### 5.3 The Matrix

### Building Localisations

### Annual Score



Foundation



**URBAN METABOLISM**

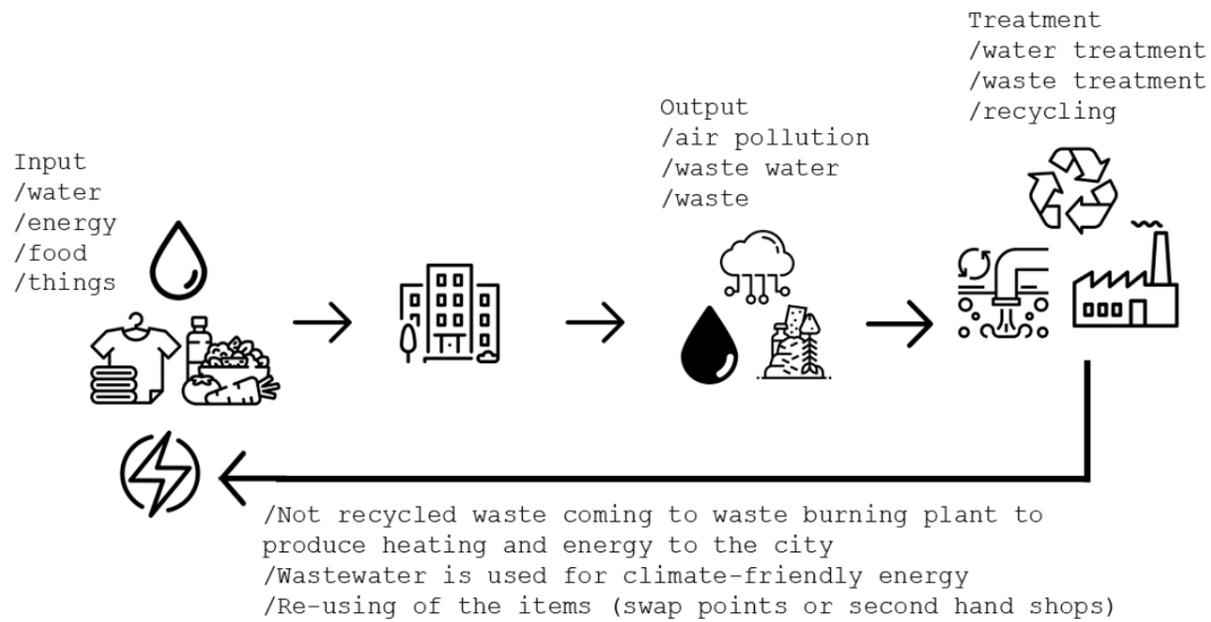
**6**

# The Project

Urban metabolism

## 6.1 Learning from Copenhagen

### Metabolism of Copenhagen



ARC, Copenhill / Amager Bakke, Copenhagen, Denmark

ARC is waste-to-energy plant. Its able to receive 400 000 tones of waste per year and provides district heating for 160 000 homes and energy for 62 500 homes. More over the technology allows to separate the valuable materials like metal from the trash.

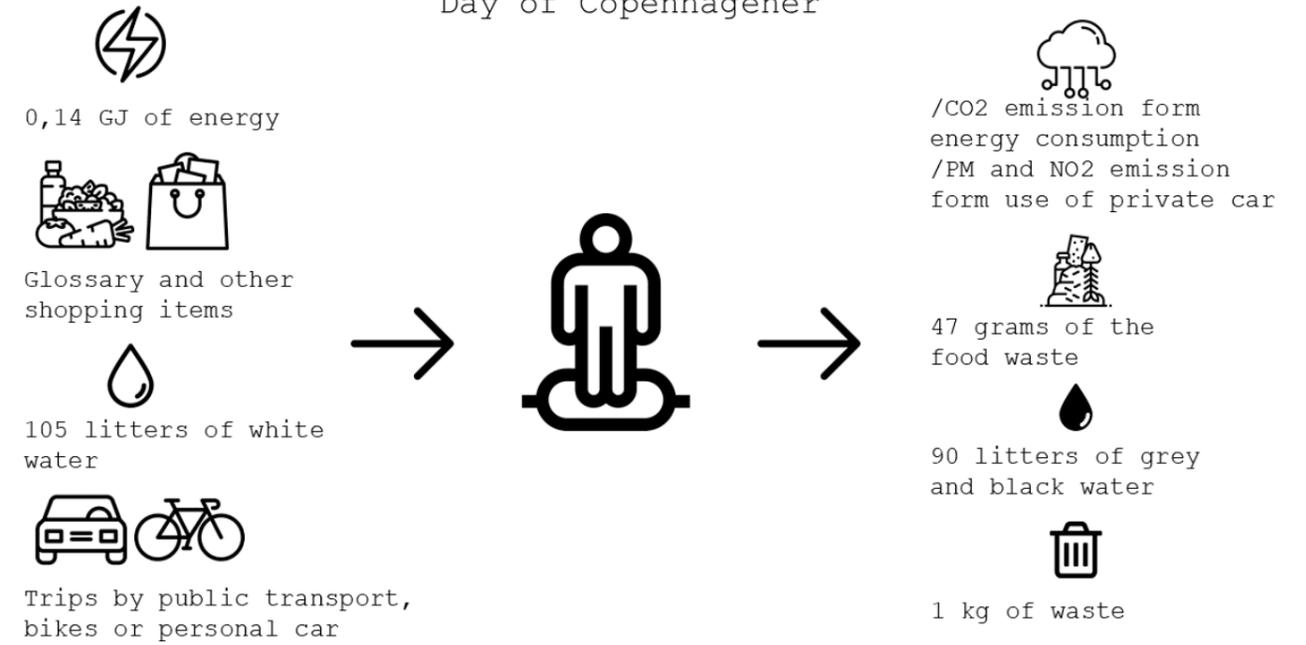
Urban metabolism can be demonstrated as a model to facilitate the description and analysis of the complex socio-technical and socio-ecological processes by which promotes the flow of different factors such as energy, materials, energy and human activities and information to shape a closed circle of habitat. We are facing with many negative changes of the world that require us to be adaptive and find solutions to mitigate this consequences. As the cities consume a massive amount of resources while generating a large output of waste and pollution, an urban metabolism model could be a great idea to achieve sustainable goals.

Copenhagen is one of the most sustainable cities in Europe and even so it still has a goal to reduce environmental impact. The above references is a research to explore the secret of the metabolism model of the city.

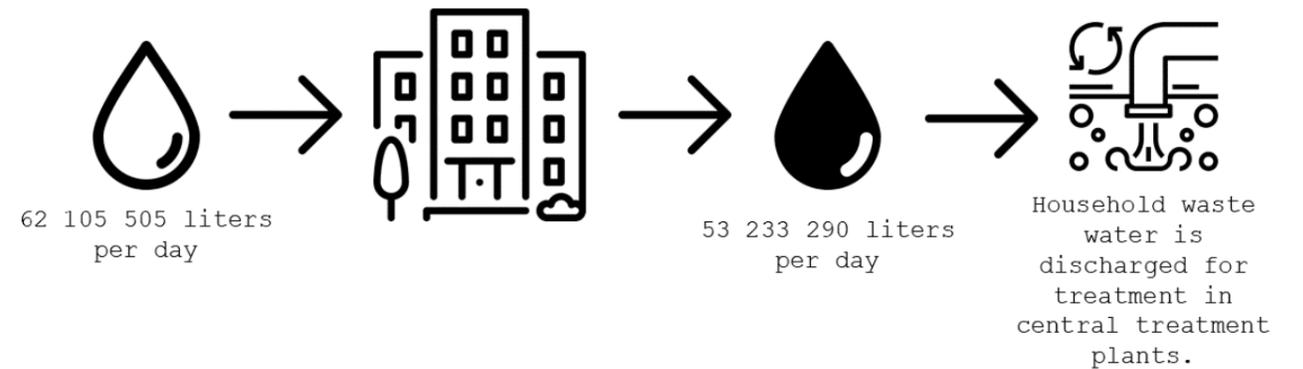
Resources (graphics, illustrations) : <https://medium.com/@valeriyacherekaeva/today-sustainability-and-green-way-of-living-become-an-important-part-of-urban-development-5330a06eea0f>

## A role model

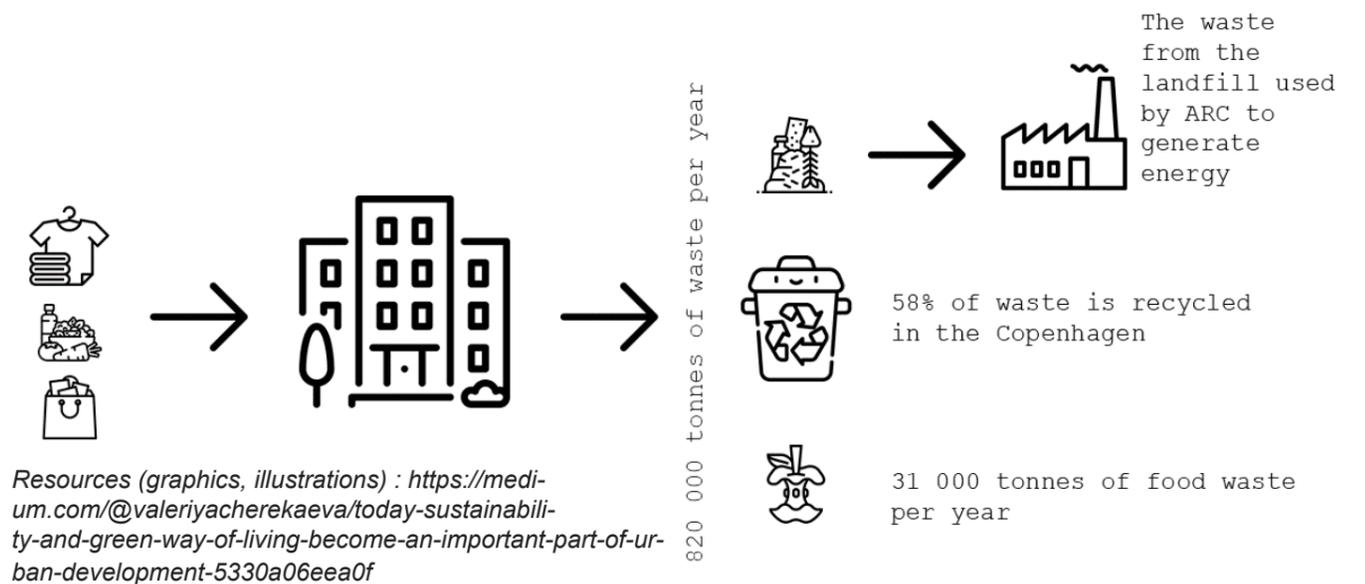
### Day of Copenhagener



### Water metabolism

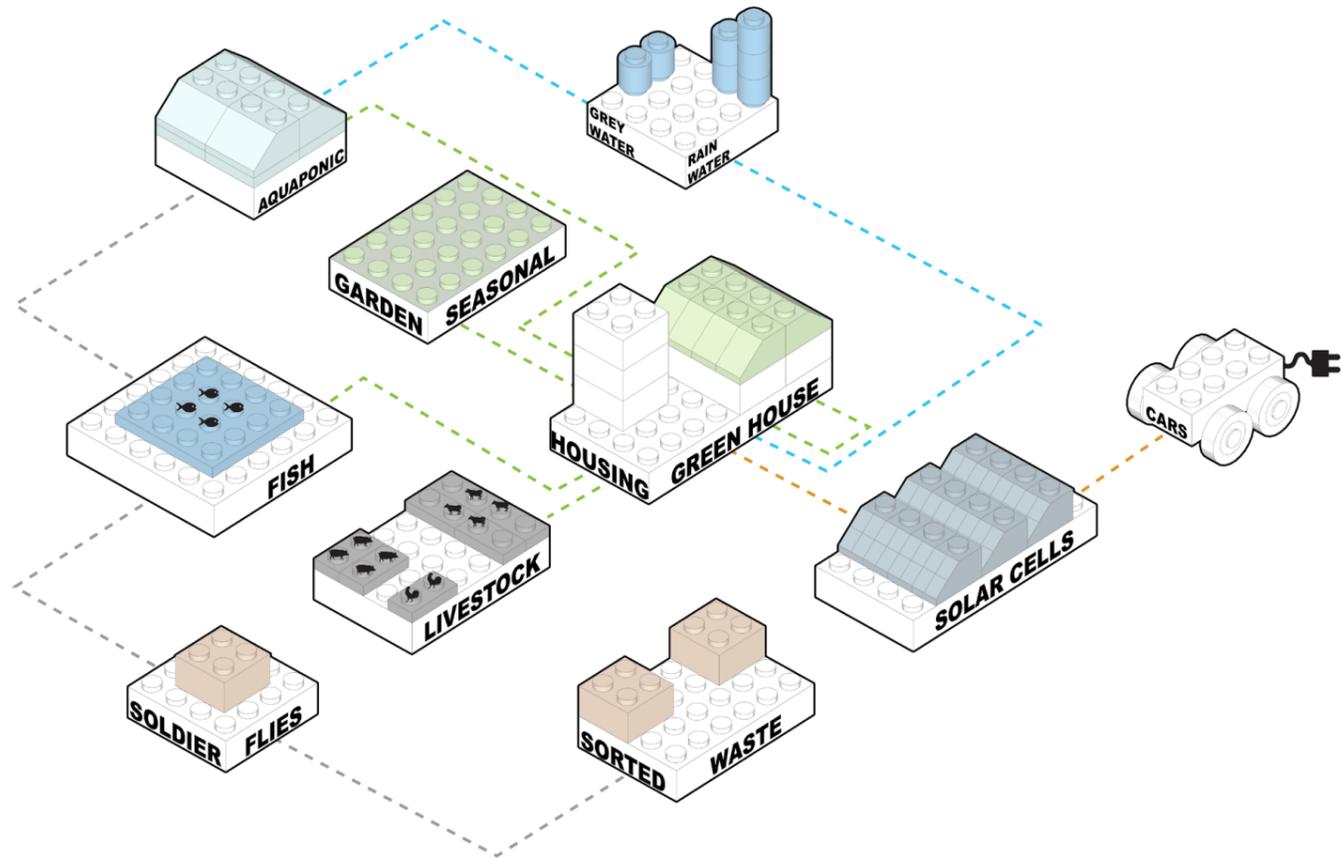


### Waste metabolism



## 6.2 The system

### Metabolism model of Refshaløen



As what is mentioned before, one of the main purposes of this project is to integrate the development of Refshaløen into the urbanization of Copenhagen. For years, the city of Copenhagen has been a model of urban metabolism with various of buildings, infrastructures and facilities were built in order to serve that purpose. Because of that fact we aim to build a separated system of metabolism for the area. By doing that, we believe that a closed-eco system can be promoted and plays an crucial role to create a greener and more sustainable inhabitat. Basically, There are 4 layers that we proposed to be the core of the system, they are **waste, water, food and energy**. All of those layers contain several elements that will be linked in many useful ways to close the loop to create circular metabolisms where resources are recycled and almost no waste is produced. The first layer that could be mentioned is the waste specifically the daily wastes from the housing

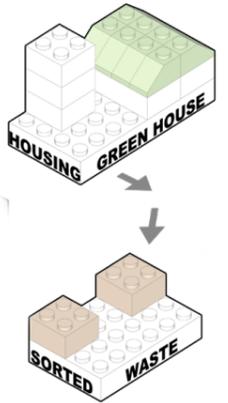
or other types of building. The second layer is the water circle, the domestic waste water along with collected rainwater can be use or reuse for multi-purposes for example watering the plants in the seasonal garden or if it is clean enough, it could be used by animals in livestock. The third layer is the food which is inspired by the Danish living style "farm to table" which is manifested in the way the people use the foods come directly from a specific farm without going through a store, market, or distributor along the way. The final layer is the energy in which we emphasized using the solar panel to gain the electricity during the day which could be a potential source of energy for the vehicles or activities that require extra electricity.

## 6.2 The system - The Layers

### Waste

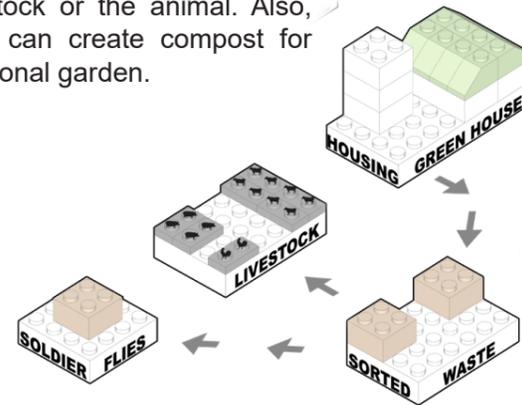
#### Phase 1:

Domestic waste from apartments or other buildings will be sorted for different purposes.



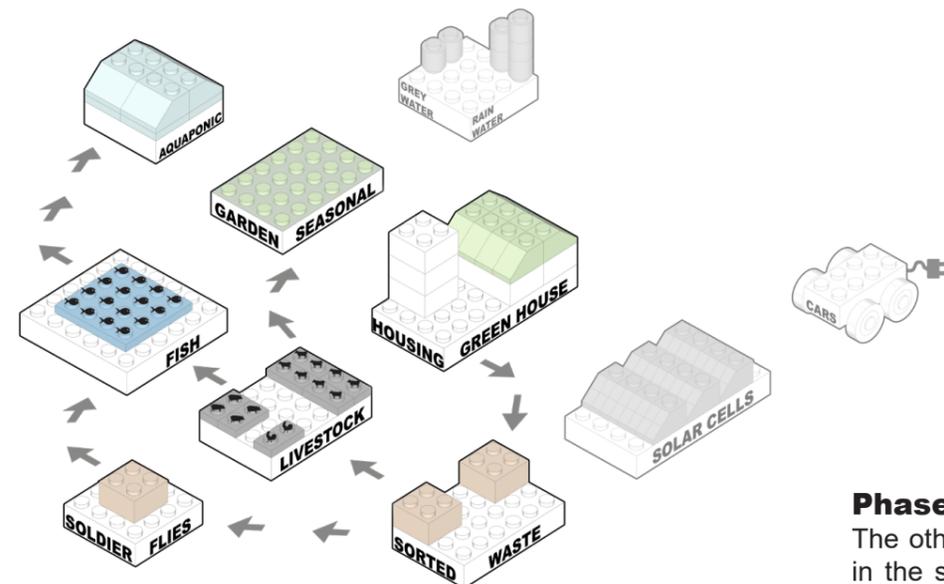
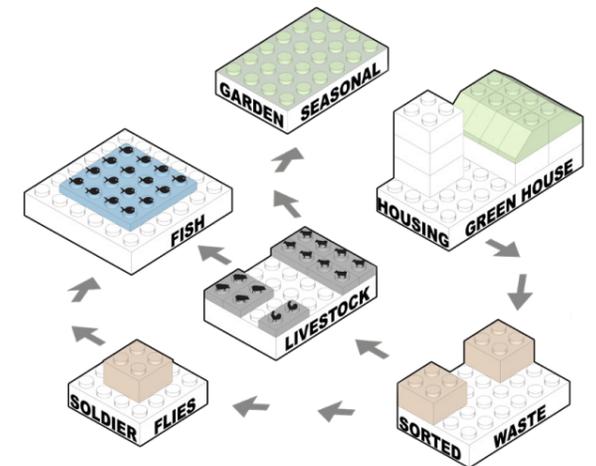
#### Phase 2:

Leftover food or organic waste can be reused for feeding the livestock or the animal. Also, they can create compost for seasonal garden.



#### Phase 3:

The main source of fish can be soldier flies, the manure that is taken from livestock will be used to fertilize the plants in the seasonal garden.



#### Phase 4:

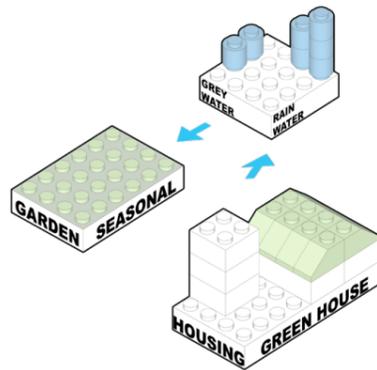
The other way to fertilize the plants in the season garden is to use the fish feces in the aquaponic system

## 6.2 The system - The Layers

### Water

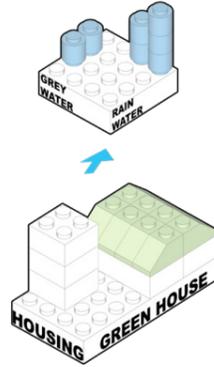
#### Phase 2:

To watering the season garden, the "grey" water can be used.



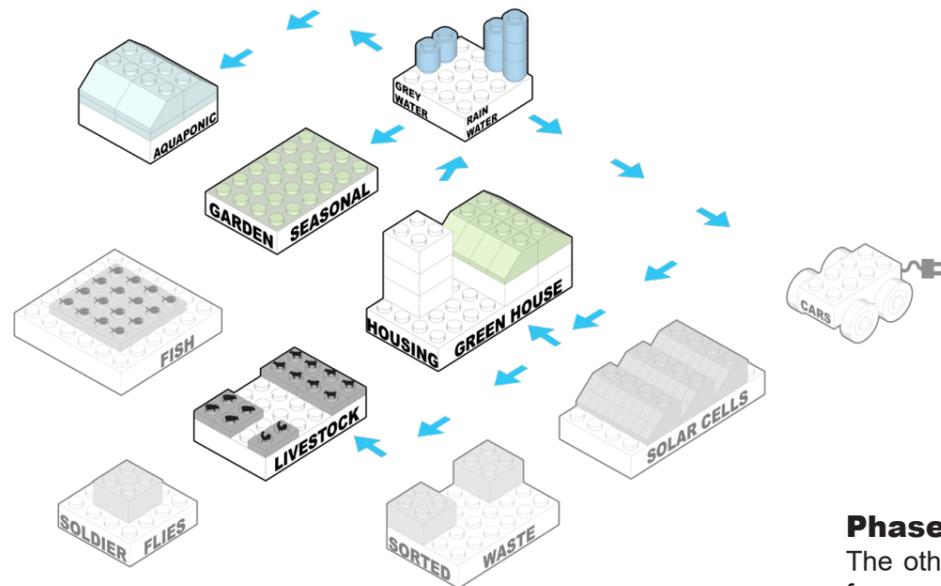
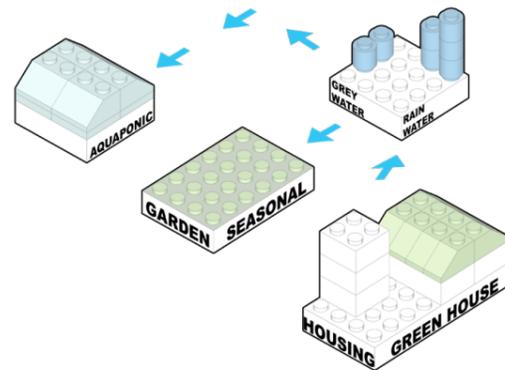
#### Phase 1:

The domestic waste water will be divided into clean and grey water and then be stored. Furthermore, the rainwater also can be collected and kept in reservoirs, storages or tanks.



#### Phase 3:

The stored rain water will be used for the aquaponics.



#### Phase 4:

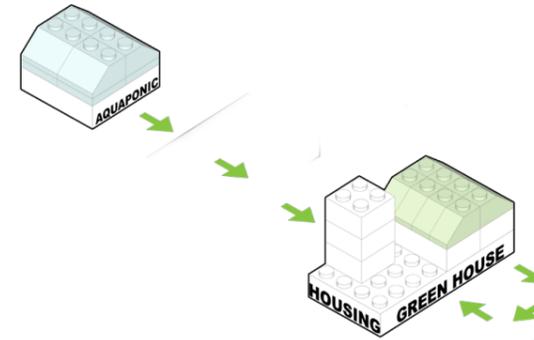
The other "grey" water will be used for greenhouse & livestocks

## 6.2 The system - The Layers

### Food

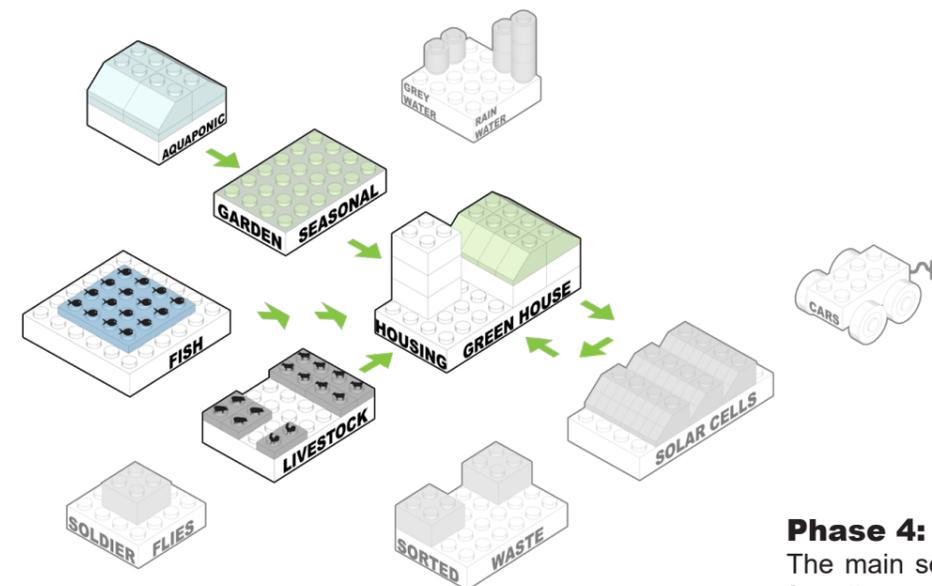
#### Phase 2:

Vegetables and food will be produced by Aquaponic.



#### Phase 3:

To maximize the possibility of homemade food throughout the year, the seasonal garden was installed.

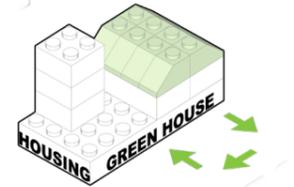


#### Phase 4:

The main source of protein will be taken from livestocks or fish.

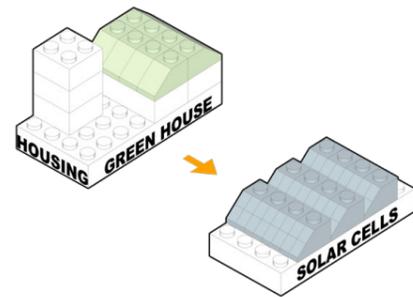
#### Phase 1:

The greenhouse on top of the building can be used to grow fresh vegetables.

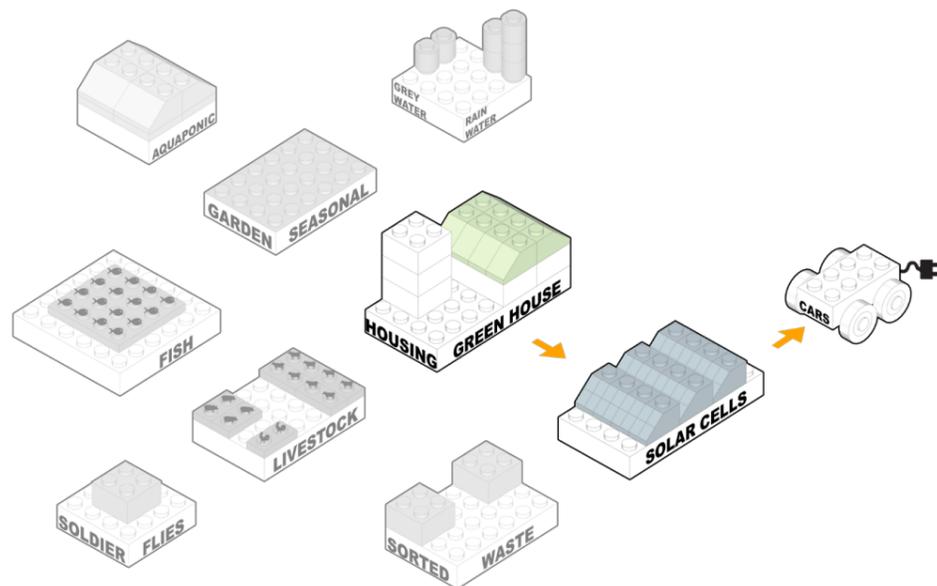


## 6.2 The system - The Layers

### Energy

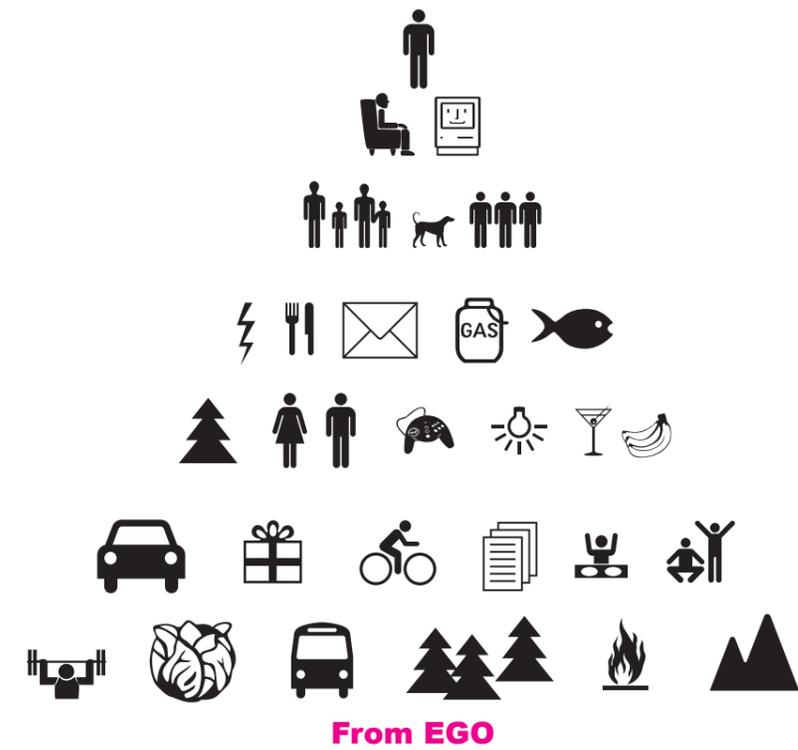


**Phase 1:**  
The energy from solar radiation will be obtained and stored for residential uses and sent to a smart grid to be stored for other uses.



**Phase 2:**  
The smart grid deliver energy to residential (when there is a need) and to the charging spots for certain vehicles or activities.

## 6.2 The system - the motto

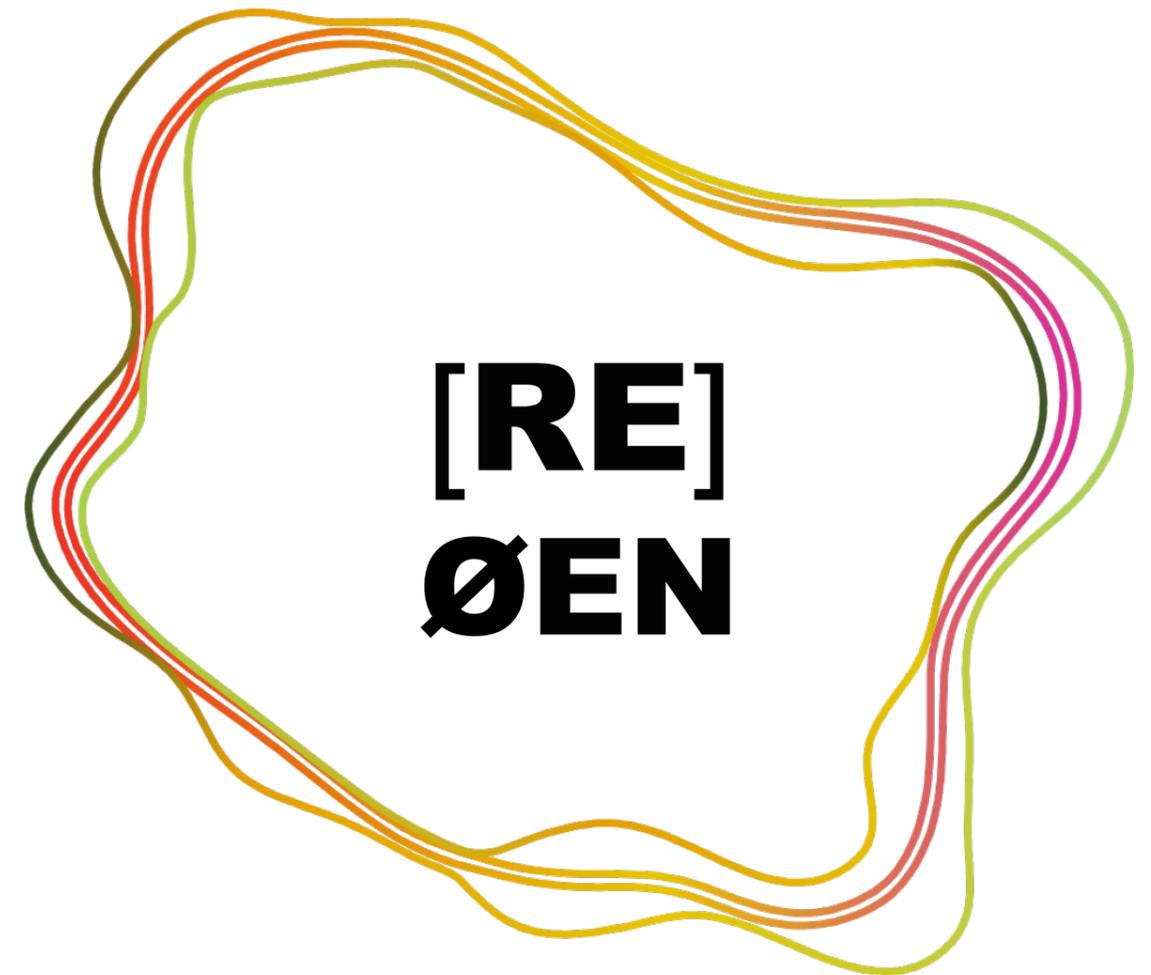


From EGO



To ECO

We need to change our way of life  
Ego = To rule over  
Eco = To be equal and respect



# 7

## The Project

Design implementation

# MEANING

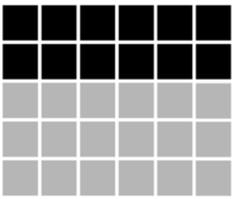
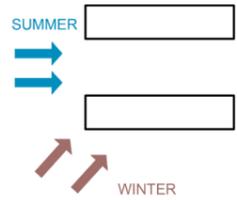
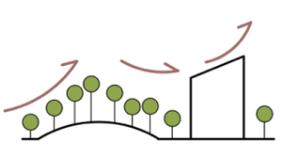
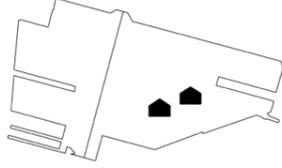
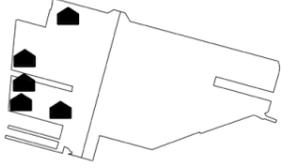
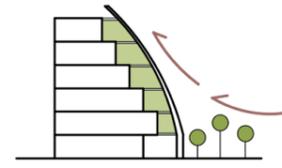
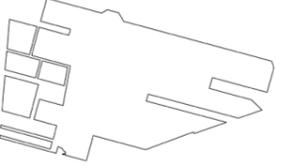
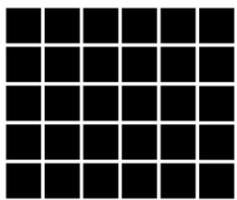
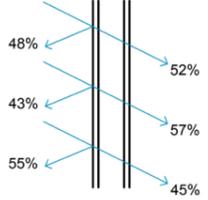
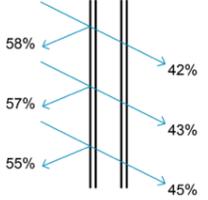
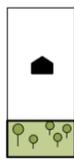
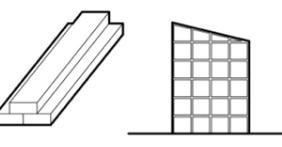
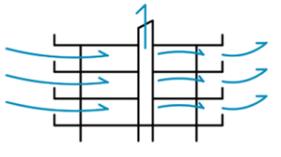
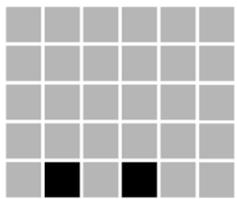
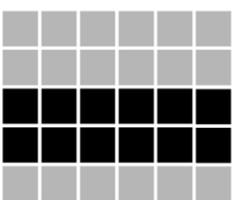
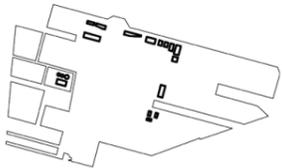
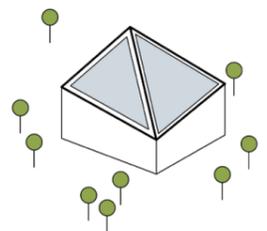
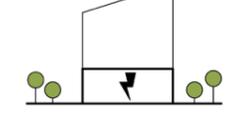
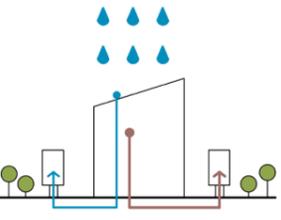
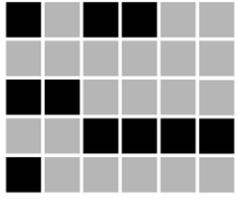
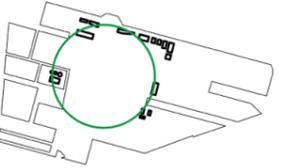
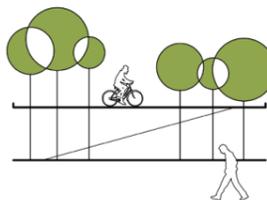
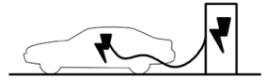
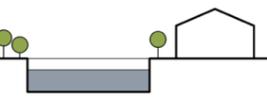
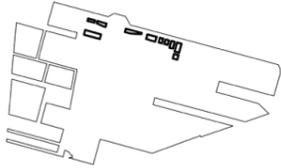
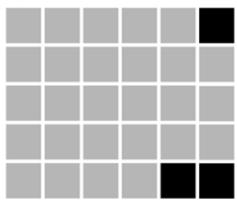
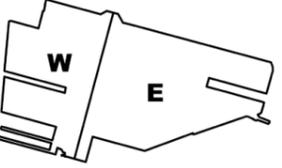
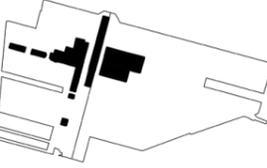
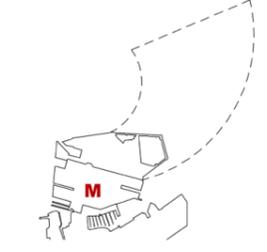
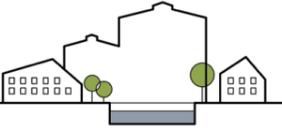
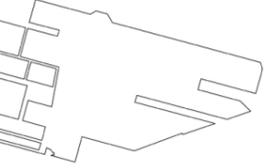
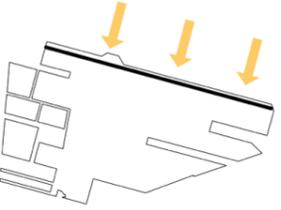
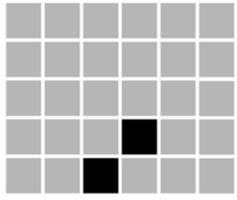
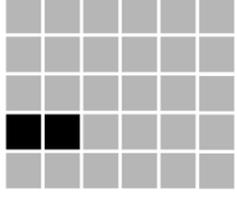
[RE] = Refshaleøen

= Regenerate

= Recreational

ØEN = The Island



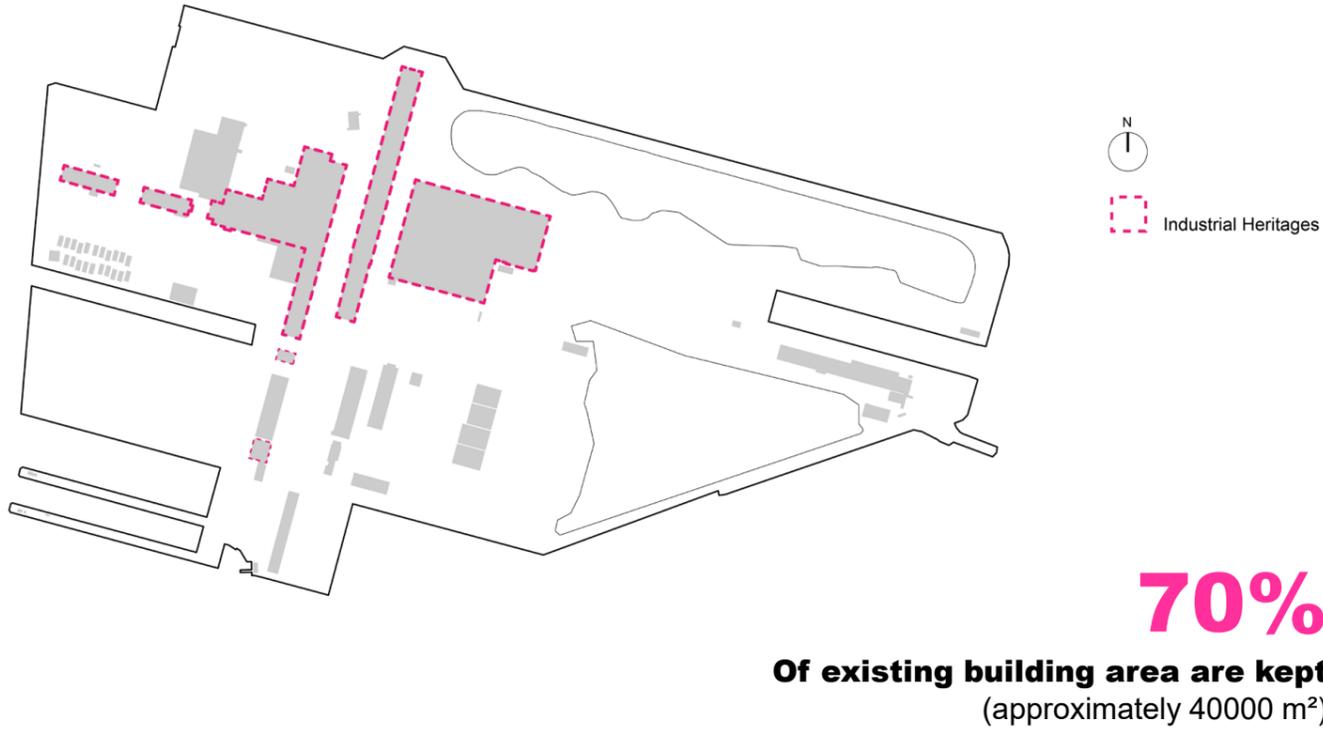
<h3>CLIMATIC DESIGN APPROACH</h3> 	 <p>Orient the building longitudinal side to the south to prevent harsh wind, maximize cool wind flows to outdoor spaces and building ventilation.</p>	 <p>Using the trees or elevated ground with trees to prevent the harsh wind coming to the buildings or outdoor common spaces i.e the south-east area of the site.</p>	 <p>In the east side, the living areas will be located in the center part, surrounded by an adequate amount of parks, office buildings, sport facilities, warehouses.</p>	 <p>In the west side, the living areas will be located along the waterfront.</p>	 <p>provide the trees to prevent cold wind in west side, if it is not enough, other passive design strategies will be applied.</p>	 <p>Open the canals towards the center of the site to use the waterfront to cool down the temperature and wind for thermal comfort.</p>	<h3>DESIGN MANUAL</h3> 
	 <p>Arrange clear glass on the south facade to maximize the solar gain in winter.</p>	 <p>Low-E glass on the west, east and north facades to avoid overheating in the summer.</p>	 <p>Steep pitched roof, with a vented attic over a well insulated ceiling, works well in Nordic areas (shed rain and snow, prevent ice dams)</p>	 <p>The winter gardens will be arranged in the south side to maximize the solar gains in the winter, they are also be able to be opened in the summer.</p>	 <p>The structures and materials will aim to use timber, prefabricated components, tightly sealed and well insulated for internal heat gain.</p>	 <p>The buildings will aim to promote both the stack and cross ventilation with the helps from interior shafts, side corridors.</p>	<h3>STEP 1</h3> 
<h3>URBAN METABOLISM</h3> 	 <p>Spent a certain amount of area for metabolism facilities, arrange them close to residential building to increase the effectiveness.</p>	 <p>The farming facilities will be arranged inside the residential or maybe just next to them.</p>	 <p>Most of the apartment will have the possibility to access to winter garden facing the south side or maybe on the roof top.</p>	 <p>The roofs with different angles of slope to maximize the solar radiation gain of photovoltaic panels.</p>	 <p>The obtained energy will be stored in the solar cells arranged inside the local buildings and be ready for charging when it is required.</p>	 <p>The rainwater is also being collected along with waste water for watering the plants in the farming facilities or aquaponic.</p>	<h3>STEP 2</h3> 
	 <p>Create "a green belt" connecting all the metabolism facilities but at the same time, orienting the natural landscape of the site.</p>	 <p>The green belt serves as a transportation path way by bike and cargo bike elevated 5m from the ground with several slopes &amp; elevator to access.</p>	 <p>The natural landscape and farms will be blended to create a feeling of "green for all" to raise the awareness of cultivation and environment.</p>	 <p>The electric vehicles will be promoted with the support of charging facility and energy storage around the site.</p>	 <p>The aquaponic will be located close to the waterfront.</p>	 <p>Garbage collector and treatment and live stocks will be located in the northern part of the site to avoid the bad smells going to the living area.</p>	<h3>STEP 3</h3> 
<h3>KOMMUNE PLAN 19</h3>	 <p>The site is divided into East side (harbor, office, recreational, outdoor) and West side (living, business) with different regulations.</p>	 <p>It is very important to identify the industrial and culture heritage of the site and find a good solution to preserve them.</p>	 <p>Taking into consideration the future extension of the area towards the sea (Lynetteholmen), new metro station will be in the middle of the site.</p>	 <p>Preserve the industrial characters of the area but at the same time, integrate them into new living habitats and landscapes.</p>	 <p>Promote the waterfront "culture" or "life style", bring the water closer to the buildings, arrange more waterfront playful facilities.</p>	 <p>Using a "Wall" as a backbone to not only prevent the noise, dirt from the north but also bring more value to the site landscape.</p>	<h3>STEP 4</h3> 
							<h3>STEP 5</h3> 

In order to illustrate the foundation of the next design step in a logical way and also to summarize all the results that we got from many climatic analysis, urban metabolism studies and the researches from municipality plan 2019 or related official documents, we created a "design manual", which is used as a source of reference that orient the next phase of design process. All the strategies, guidelines are sorted into 3 categories mentioned above. They are ranged from master plan scale to building or detail scale, we also propose a small matrix to

describe which strategies are applied for each specific design step. By doing that, we hope that there will be a strong link between several researches in the previous phase and the next steps of design in which we want to reach to a physical proposal for the development of the area, not only about the planning policy or the feasibility analysis.

## 7.1 Design steps

### STEP 1: PRESERVING

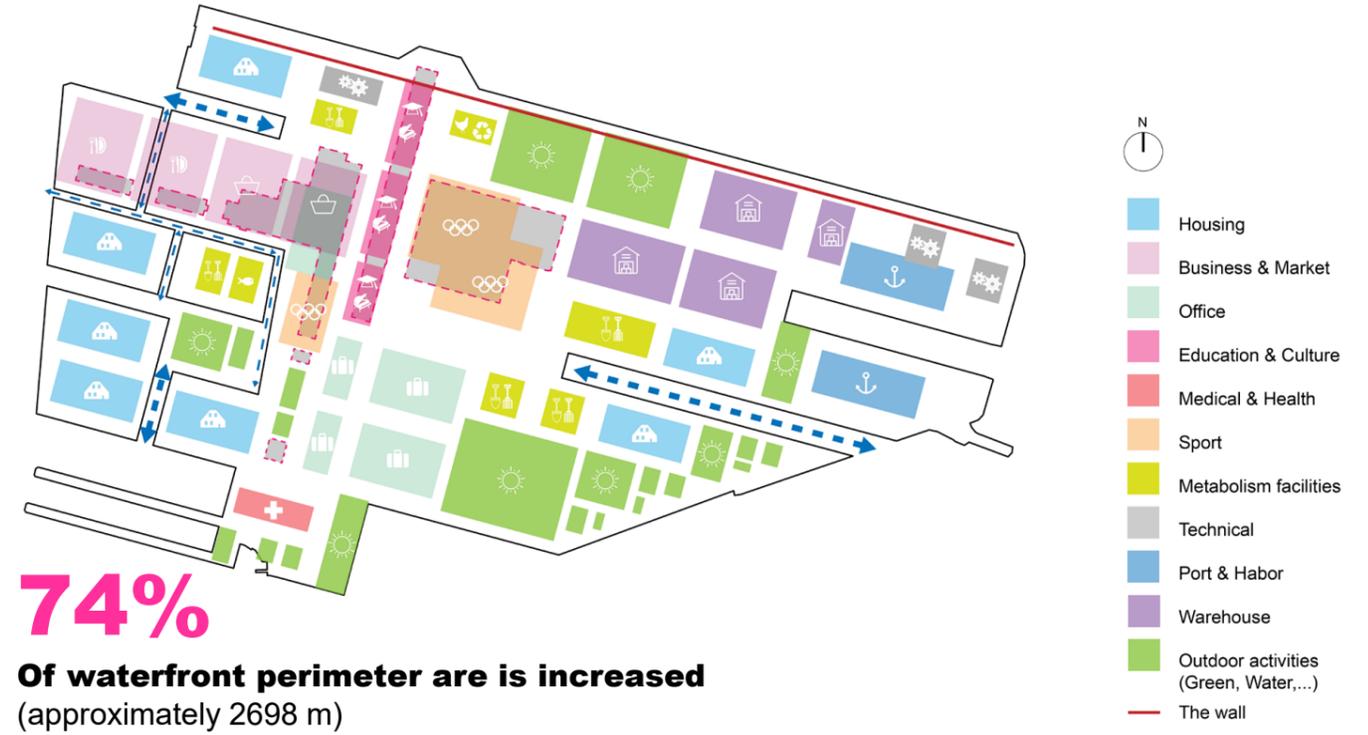


### STEP 2: FUNCTIONING



## Design steps

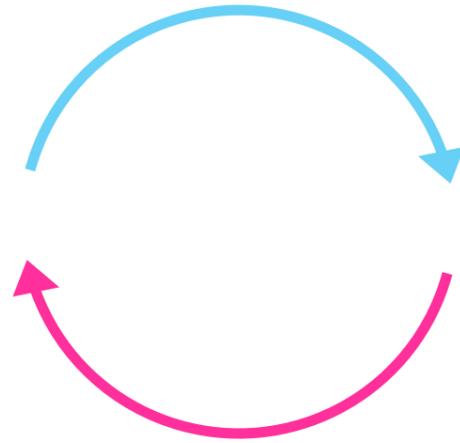
### STEP 3: IDENTITY



### STEP 4: CIRCULATION

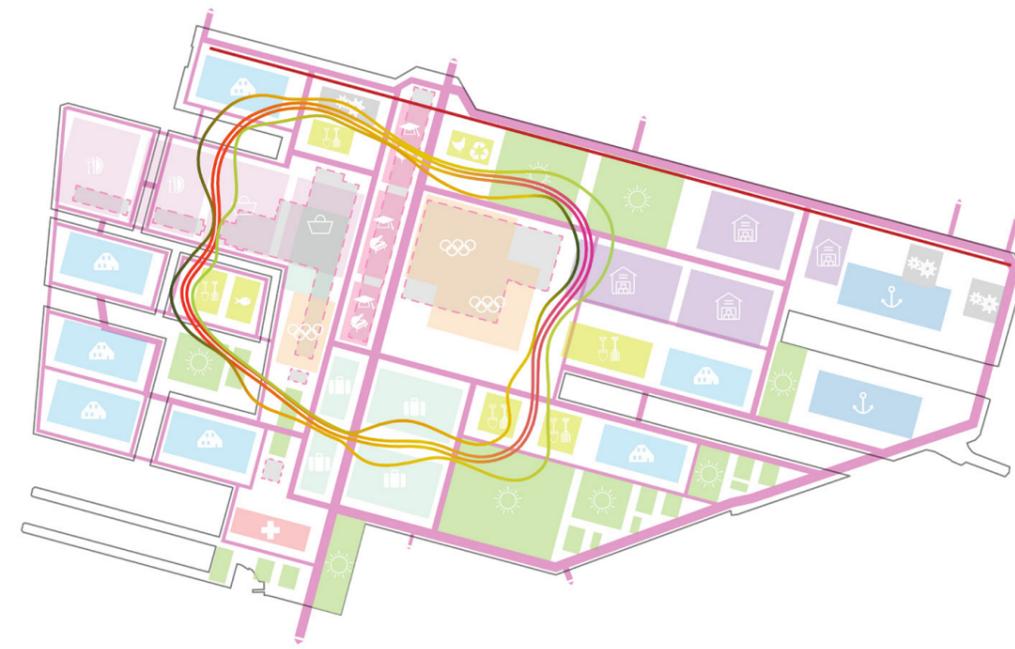


## 7.1 Design steps



## Design steps

### STEP 5: GREEN LOOP



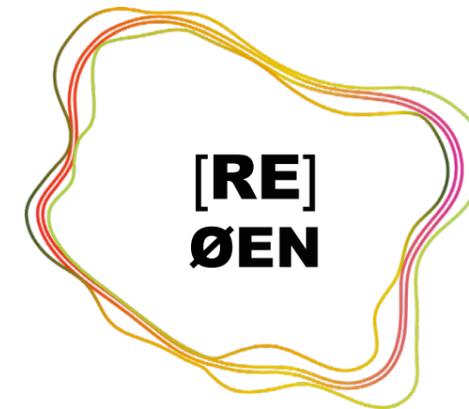
- Housing
- Business & Market
- Office
- Education & Culture
- Medical & Health
- Sport
- Metabolism facilities
- Technical
- Port & Harbor
- Warehouse
- Outdoor activities (Green, Water,...)
- The wall

The iconic shape of the terrain as a defensive territory in the past

The concept of the circle metabolism, the loop

**“The regenerate loop” which not only serve as an orientation for urban landscape but also an physical infrastructure to make urban metabolism facilities operated and circulated inside the area.**

# 7.2 The Masterplan



## Welcome to [RE]ØEN city!

[RE]ØEN is not an utopian destination. It is a real place, coming from the expectations of those who love it and from those who want to promote the idea of sustainable living. It is a realistic proposal on how the island of Refshaleøen could look like in the years to come if it can be developed to its full potential and with the investments it deserves.

We identify our city as a “regenerative city” in which we do not have that much of fossil fuel vehicles. Instead, we use “cooler cars”, bike (normal or electricity) or we just simply “walk”. Furthermore, we also live in smart houses which can gain solar energy and store it, gain the rain water for re-using in our urban agriculture farms. We eat healthier food and we do not have to spend too much money on buying groceries because we produce them by ourself in our seasonal gardens.

[RE]ØEN will be built for people, not for cars. You can come and enjoy our fresh air, try some dishes from food market or enjoy our huge amount of sport activities. It is even better if you decide to live or work here as we have a wide selection of accomodation typologies and offices or businesses. As the post pandemic context left a new norm of “normal”, we fully aware the importance of the “Regenerate” city where it can live by itself and the accessibility to main facilities for all social classes.

So let's have a look to [RE]ØEN, a city with a mix of function, strong identity coming from many years of development and strong base of cultural activities and industrial heritages.

We look forward to showing you around !

## 7.2 Masterplan

### The sense of [RE]ØEN !

The sense of the city, which is one of the most important factor of a city, in my opinion, could only be recognized by the experiencing or consuming. In order to give people the very first impression of a city design proposal, we suppose that the explanation of design process is a strong foundation from which we would be able to summarize all the design strategies and conclude them into several identities that are going to bring the sense of the city to the people. The 3 key points or foundation of masterplan are :

#### 1.Municipality plan 2019 & planning policies:

In this aspect, we was not only looking for the regulation or technical building codes but also we tried to identify which are the most critical social issues and realized what is the characteristic of the area. **The waterfront life, mixed-use development between the richness of industrial-historical heritages and businesses or "from farm to table" thinking** are parts of the important keywords that we obtained and used to build the masterplan.

#### 2.Climatic design approach:

The technical part of this research is as important as the other part of analysis. It is not a linear process but instead, it is a process of going back and forth between different aspect of analyzing in order to find the most appropriate design outputs based on the inputs which are the weather, geographical and environmental data. I would say that the **climatic analysis results** is the base on which all the other design choices were implemented.

#### 3.Urban metabolism & environmental landscape issues:

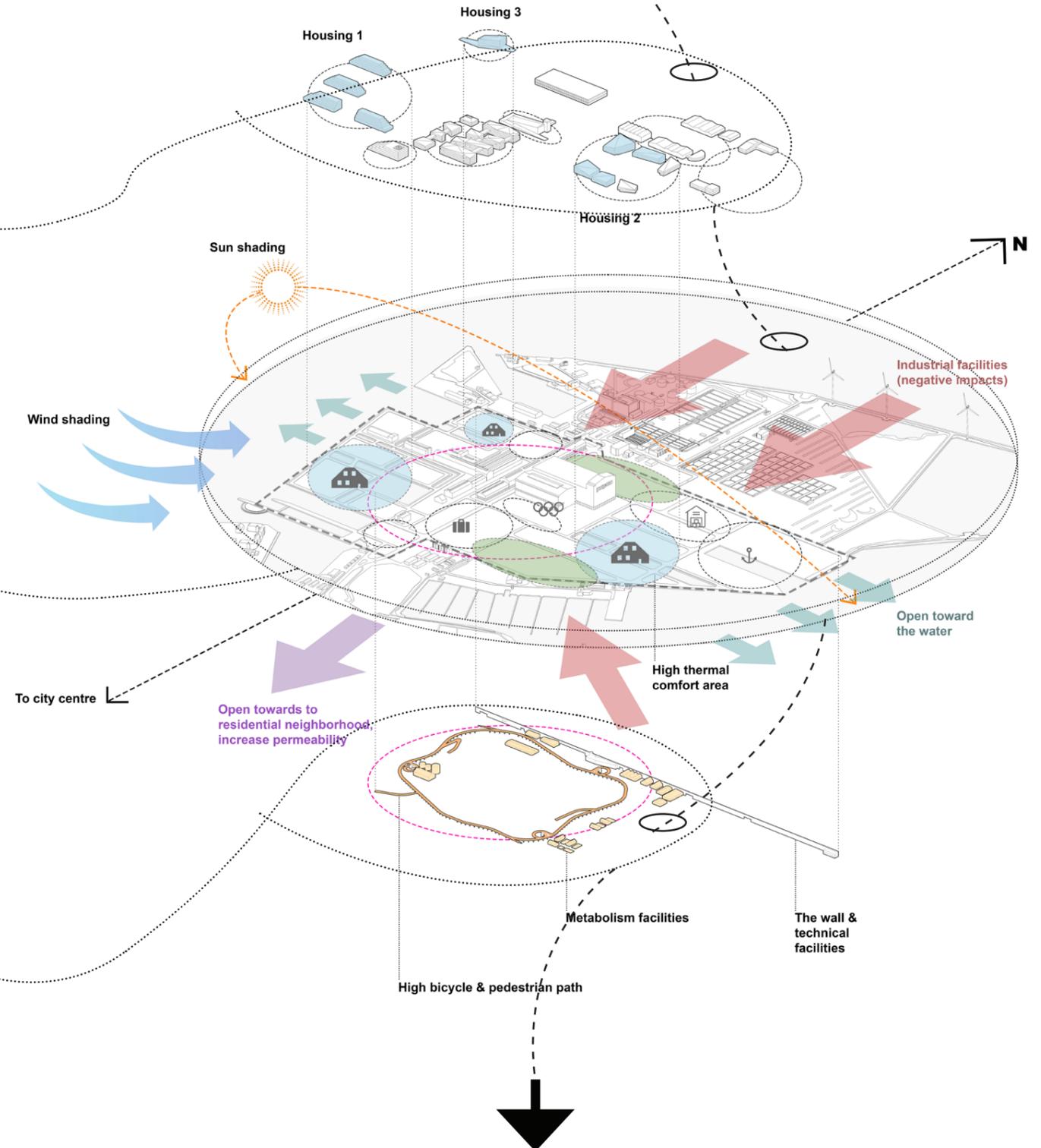
The urban agriculture and the urban green spaces are obviously the aspects that the city of Copenhagen did very well. We also want to continue those positive influences in [RE]ØEN. In order to do so, the system of **urban metabolism** will be generated by a high bicycle and pedestrian path. **"The wall"** will play a role as a solution againts the negative effects from the existing technical facilities in the north, connect the technical buildings in the site and provide a value for natural landscape.

## Design process

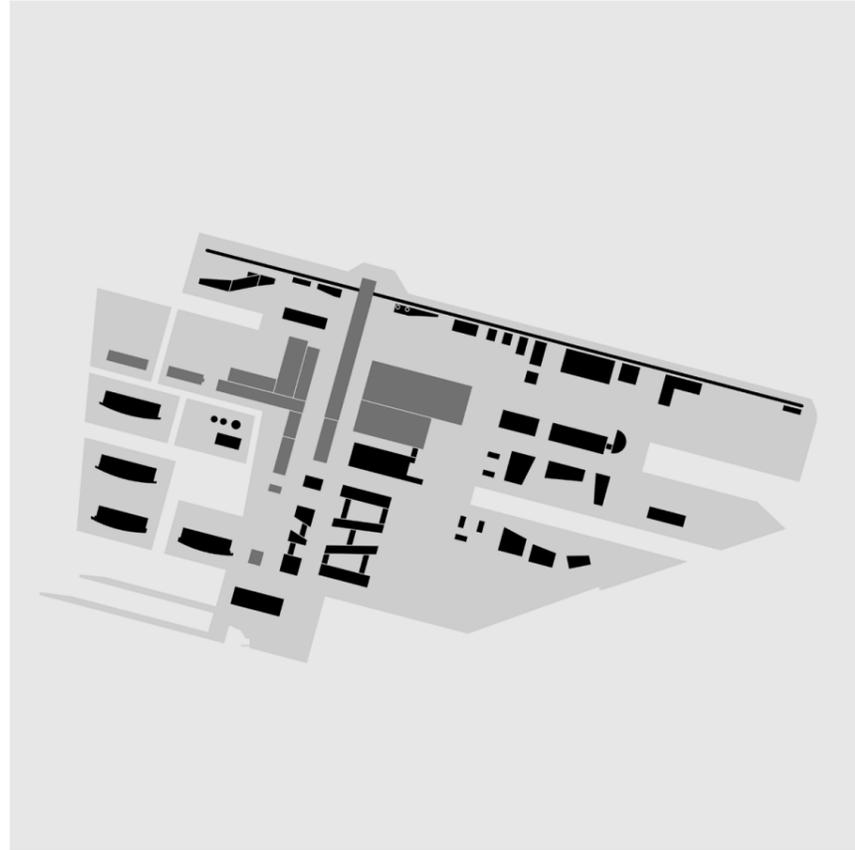
### 1.Municipality plan 2019 & Planning policies

### 2.Climatic design approach

### 3.Urban metabolism & environmental landscape issues

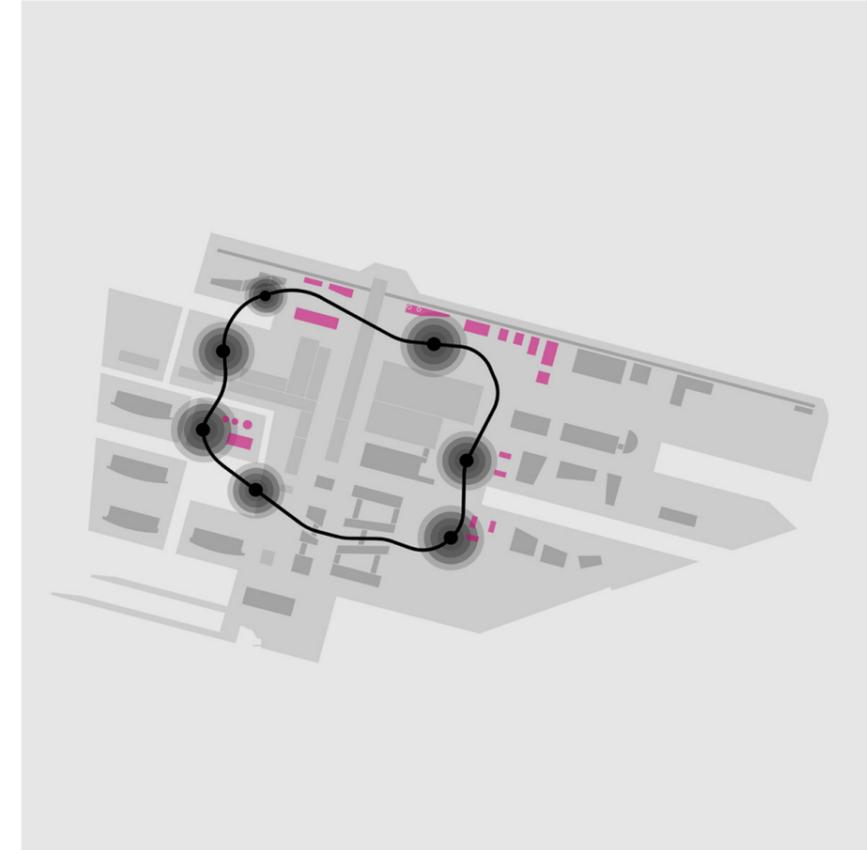


**What are the identities ?**



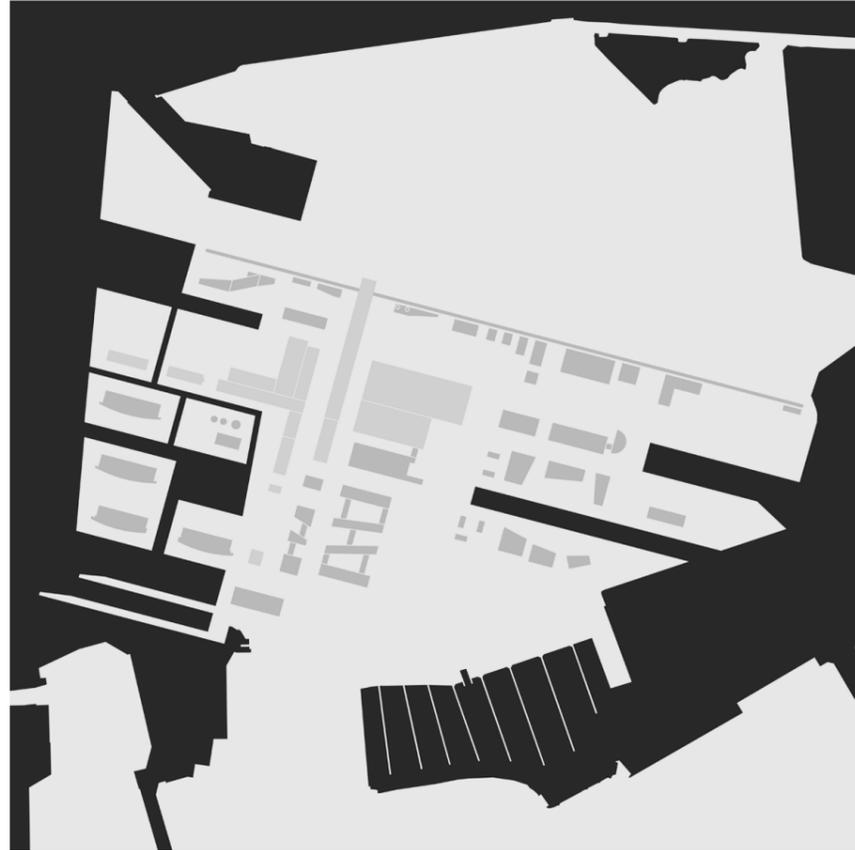
### Neighborhoods and heritages

The site is a mixed-use area which is divided into islets that create distinct identities and neighborhoods. This variation is came from the expectation of maintaining and preserving the strong industrial heritage of Refshaleøen but at the same time, bring new lives, new spiritual values to the area.



### The belt - Urban metabolism

Cycling is the most popular means of transportation in Copenhagen, with the intention of promoting that lifestyle, we propose the “green belt” which is an elevated bicycle bridge that runs in a loop, connecting all urban metabolism facilities and other buildings. This path not only functions as an urban mobility infrastructure, but also orients the natural landscape of the site as well as operates the system of urban metabolism.



### Playful islets

It is very clear that the waterfront activities are immense in Copenhagen and it has been becoming an identical feature of the city. The relationship between the habitat and the waterfront is stated also in "Municipality plan 2019". For that reason, we aim to open more canals which orient closer to the living area, bring the water culture not only for the border of the area but also to the center part. According to the vision of the city council, the area of the east side will be used for harbor, recreational activities so that is why the building density is quite low out there, in contrary with the west side which is mostly used for housing and businesses.



### Common green for all

There is a large variation of green spaces in [RE]ØEN, from inner courtyard vegetations, side walks to the "urban forest" with a lot of fruit trees. We conceive that these green spaces play an crucial role to shape the identity of the site. The idea of common green for all inspired us so much, along with the system of metabolism, we want to provide an equal right to every people, every class, group ages, who is working or living there or just visiting, a right to access to all infrastructure, green-space and recreational activities.

# 7.2 Masterplan

SPORT CENTER

RESIDENCE 3

FOOD MARKET  
SKATE PARK

RESIDENCE 1  
"BOATHOUSE"

THE OFFICE

MEDICAL  
CENTER

BIKE PATH  
PEDESTRIAN PATH

THE WALL

THE HARBOR

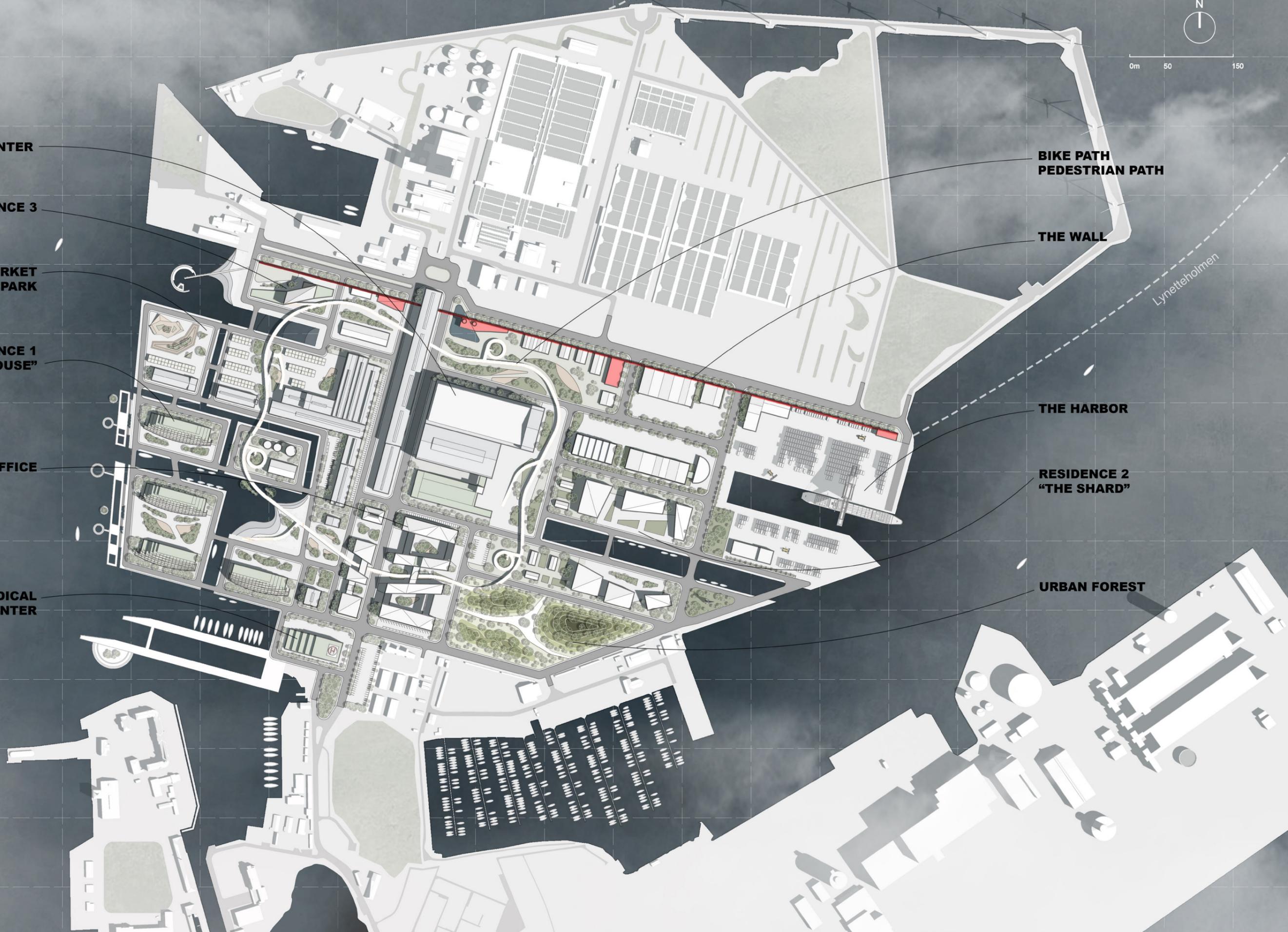
RESIDENCE 2  
"THE SHARD"

URBAN FOREST



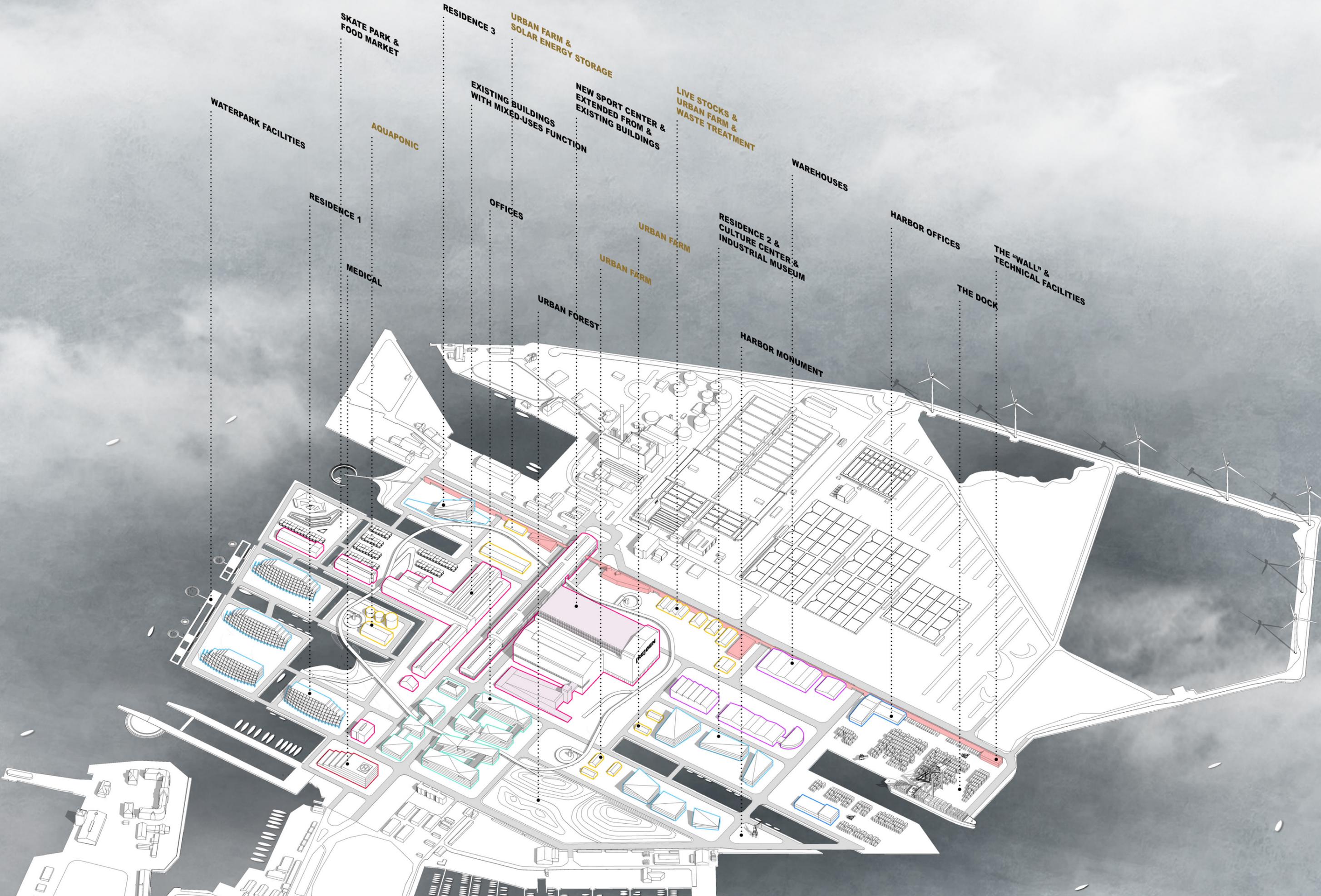
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Lynetteholmen



# 7.2 Masterplan

# Functions



WATERPARK FACILITIES

SKATE PARK & FOOD MARKET

RESIDENCE 1

MEDICAL

AQUAPONIC

RESIDENCE 3

URBAN FARM & SOLAR ENERGY STORAGE

EXISTING BUILDINGS WITH MIXED-USES FUNCTION

OFFICES

URBAN FOREST

NEW SPORT CENTER & EXTENDED FROM & EXISTING BUILDINGS

URBAN FARM

URBAN FARM

LIVE STOCKS & URBAN FARM & WASTE TREATMENT

WAREHOUSES

RESIDENCE 2 & CULTURE CENTER & INDUSTRIAL MUSEUM

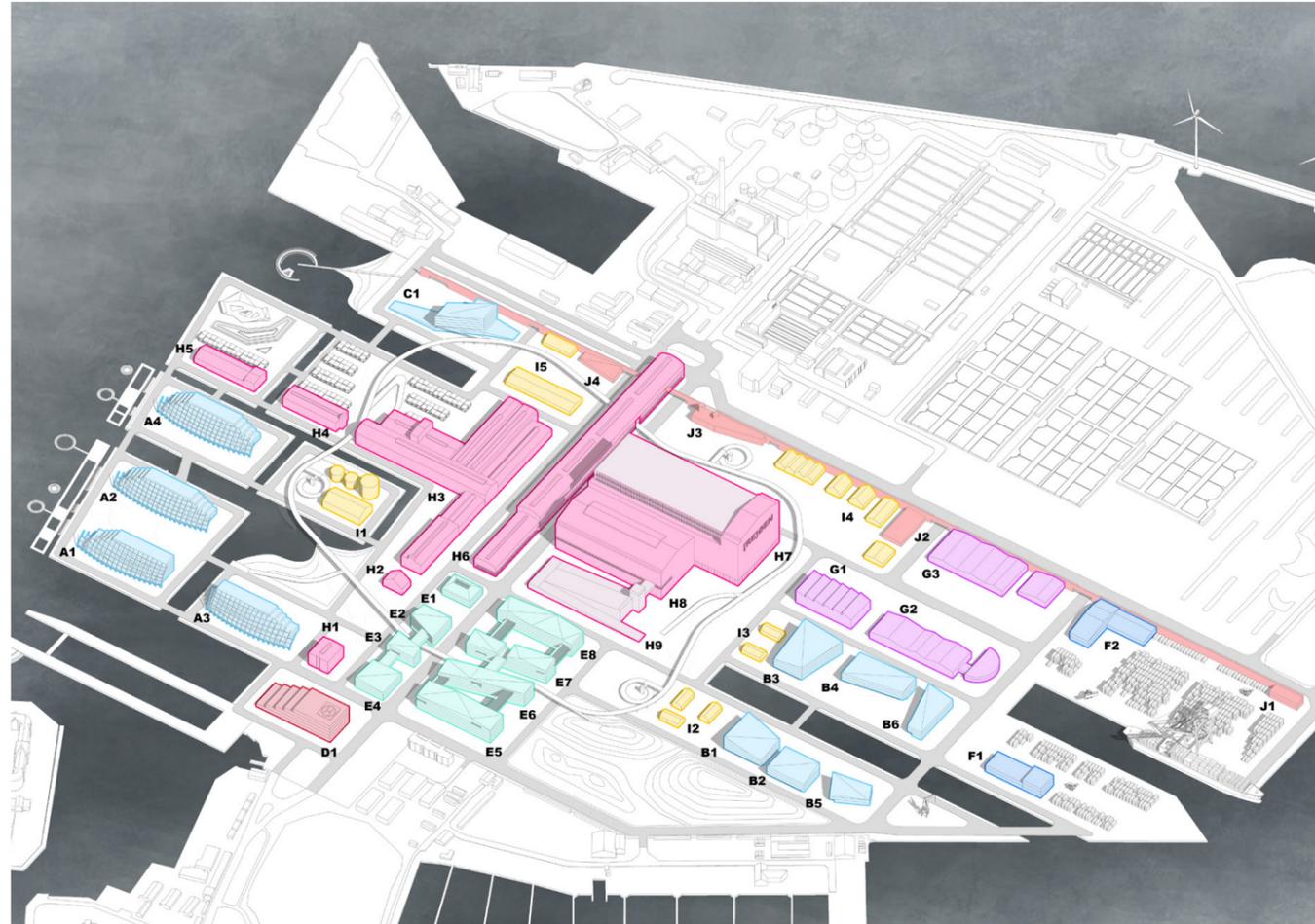
HARBOR MONUMENT

HARBOR OFFICES

THE DOCK

THE "WALL" & TECHNICAL FACILITIES

## 7.2 Masterplan



### Programme

One key piece of information we were looking for when we research urban planning 2019 is about the area's building regulations regarding building rates, maximum building heights, land plots,... Because of the differences in terms of land uses between the east and the west, the building ratio and maximum height are very clearly varied. Along with the intention to integrate those information with the other design strategies (climatic design and urban metabolism), we had to carefully consider and look closer to each segment of the site in order to propose an optimized programme for the area.

<span style="color: lightblue;">■</span> A,B,C: Residential	<span style="color: purple;">■</span> G: Warehouses, logistics,...
<span style="color: pink;">■</span> D: Medical	<span style="color: lightpink;">■</span> H: Existing buildings - mixed-use
<span style="color: lightgreen;">■</span> E: Offices, businesses,...	<span style="color: lightpurple;">■</span> H: Extensions - sport, workout,...
<span style="color: blue;">■</span> F: Harbor facilities,...	<span style="color: yellow;">■</span> I: Metabolism facilities,...
	<span style="color: red;">■</span> J: Technical facilities,...

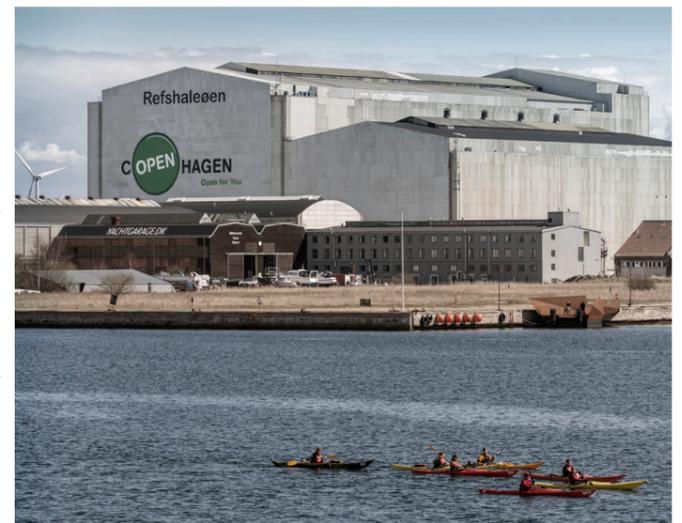
## Area table

PLOT	BUILDING FLOOR RATIO (%)	BUILDING HEIGHT (MAXIMUM IN METER)	PLOT AREA (m²)	TOTAL FLOOR AREA (m²)	BUILDING CODE	PROGRAMS	DIMENSIONS			BUILDING FLOOR RATIO (%)
							FLOOR	BUILDING HEIGHT (m)	FLOOR AREA (m²)	
WEST SIDE	110%	20	195428	214978.8	A1	Residential, commercial, sport	6	20	10375	
					A2	Residential, commercial, sport	6	20	10063	
					A3	Residential, commercial, sport	6	20	10375	
					A4	Residential, commercial, sport	6	20	10063	
					C1	Residential, commercial, sport	6	20	3500	
					D1	Medical	5	15	10000	
					E1	Office, Business, Station	3	10	2000	
					E2	Office, Business	4	12	3000	
					E3	Office, Business	4	12	1800	
					E4	Office, Business	3	10	2700	
					H1	Culture, Heritage	5	15	2575	
					H2	Culture, Heritage	3	14	1080	
					H3	Business, Office, Culture	5	22	75000	
					H4	Business, Service, Entertainment	5	15	5335	
					H5	Business, Service, Entertainment	4	12	4800	
					H6	Business, Office, Culture, Education	5	21	40180	
I1	Metabolism: Aquaponic	1	13	1100						
I5	Metabolism: Urban farm, Solar cells	1	7	1700						
J4	Technical facilities	1	7	500						
TOTAL									196146	100.37%
EAST SIDE	60%	20	292783	175669.8	B1	Residential, commercial, sport	4	16	5600	
					B2	Residential, commercial, sport	4	16	4400	
					B3	Residential, commercial, sport	6	20	10500	
					B4	Residential, commercial, sport	4	16	6000	
					B5	Culture, Sport	3	10	3000	
					B6	Culture, Recreational activities	3	10	1000	
					E5	Office, Business	5	15	8000	
					E6	Office, Business	5	15	6000	
					E7	Office, Business	5	15	6000	
					E8	Office, Business	5	15	8000	
					F1	Harbor facilities	3	10	3600	
					F2	Harbor facilities	2	7	3000	
					G1	Warehouse	1	8	1800	
					G2	Warehouse	1	8	3500	
					G3	Warehouse	1	8	3000	
					H7	Existing: Sport, Workout	4	60	42640	
H8	Existing: Sport, Workout	3	40	18000						
H9	Extension: Sport center	3	10	18000						
I2	Metabolism: Urban farm	1	6	600						
I3	Metabolism: Urban farm	1	6	400						
I4	Metabolism: Urban farm, live stocks	1	7	2400						
J1	Technical facilities, solar cells	2	9	600						
J2	Technical facilities, solar cells	1	7	800						
J3	Technical facilities, water treatment, solar cells	1	7	825						
TOTAL									157666	53.85%

### From Area to Volume

We do not want to fill the area with high density of buildings to achieve certain proportions indicated in the urban planning, instead we aim to strike a balance between indoor and outdoor spaces. We aim to ensure the "recreational spirit" of the area, with more outdoor spaces for urban agriculture, food markets, sports and recreational activities, and more space for trees.

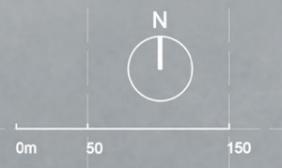
We fully aware the importance of the industrial heritage of the area, so we want to implement the old Burmeister & Wain's factory as the highest landmark of the area (60m) as it has been an important landmark of Copenhagen for several decades which can be observed from many places in the city.





# 7.2 Masterplan

## Permeability - Motor vehicles



SPORT CENTER

RESIDENCE 3

FOOD MARKET  
SKATE PARK

RESIDENCE 1  
"BOATHOUSE"

THE OFFICE

MEDICAL  
CENTER

BIKE PATH &  
PEDESTRIAN PATH

THE WALL

THE HARBOR

RESIDENCE 2  
"THE SHARD"

URBAN FOREST

Lynetteholmen



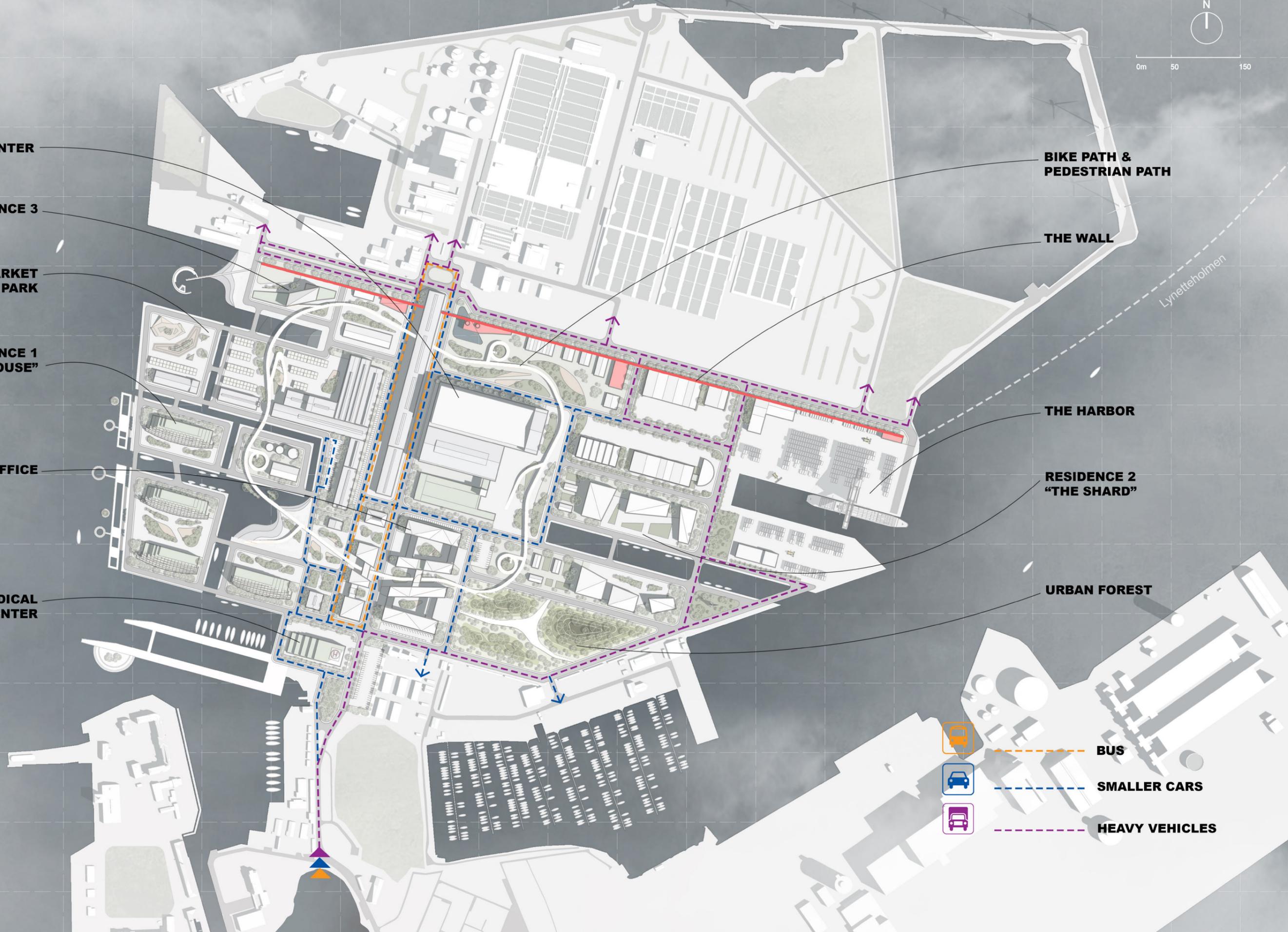
BUS



SMALLER CARS

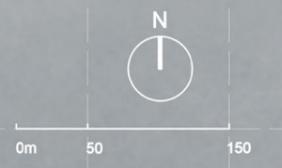


HEAVY VEHICLES



# 7.2 Masterplan

## Permeability - Bicycle & Pedestrian



SPORT CENTER

RESIDENCE 3

FOOD MARKET  
SKATE PARK

RESIDENCE 1  
"BOATHOUSE"

THE OFFICE

MEDICAL  
CENTER

BIKE PATH &  
PEDESTRIAN PATH

THE WALL

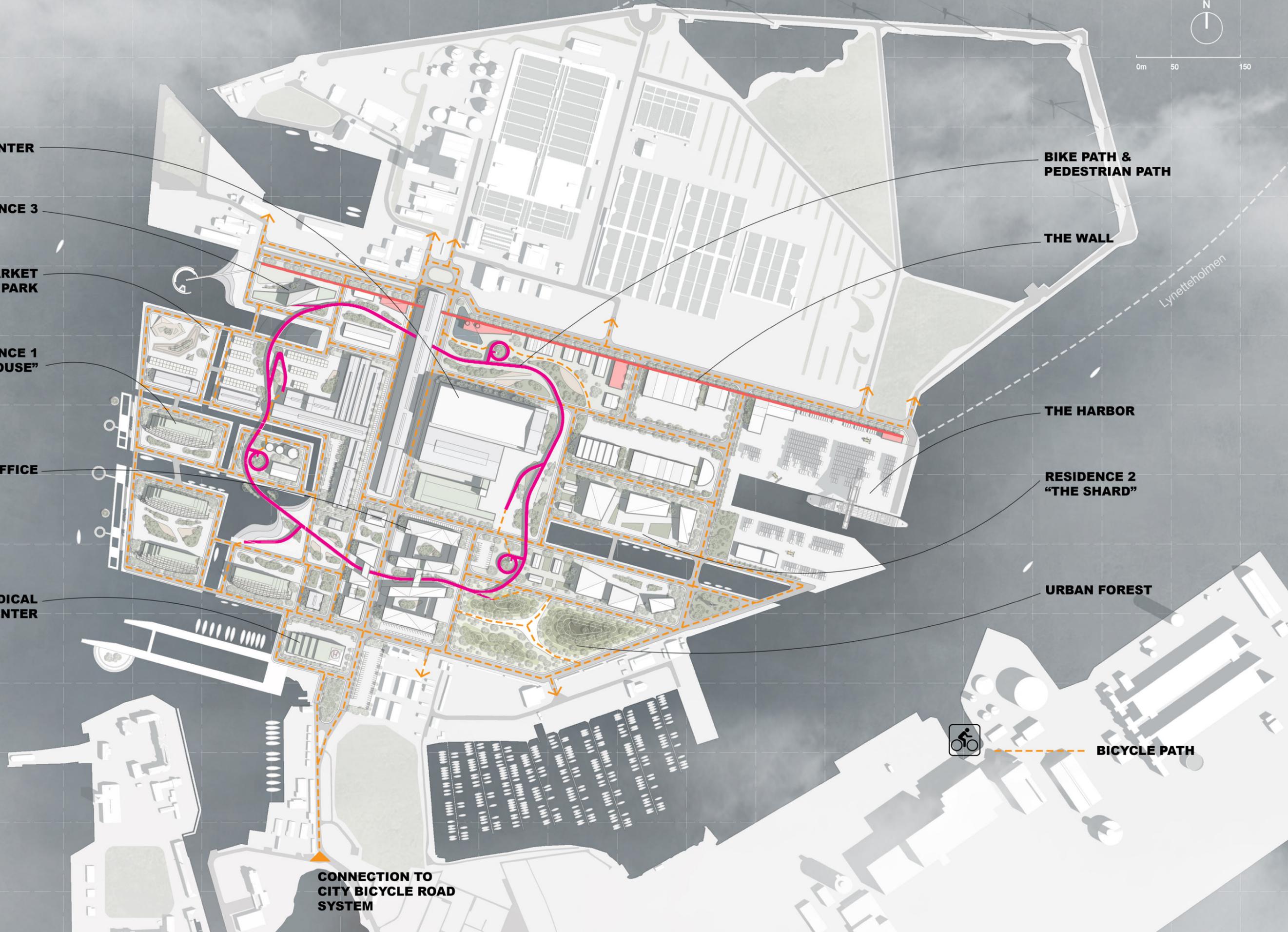
THE HARBOR

RESIDENCE 2  
"THE SHARD"

URBAN FOREST

BICYCLE PATH

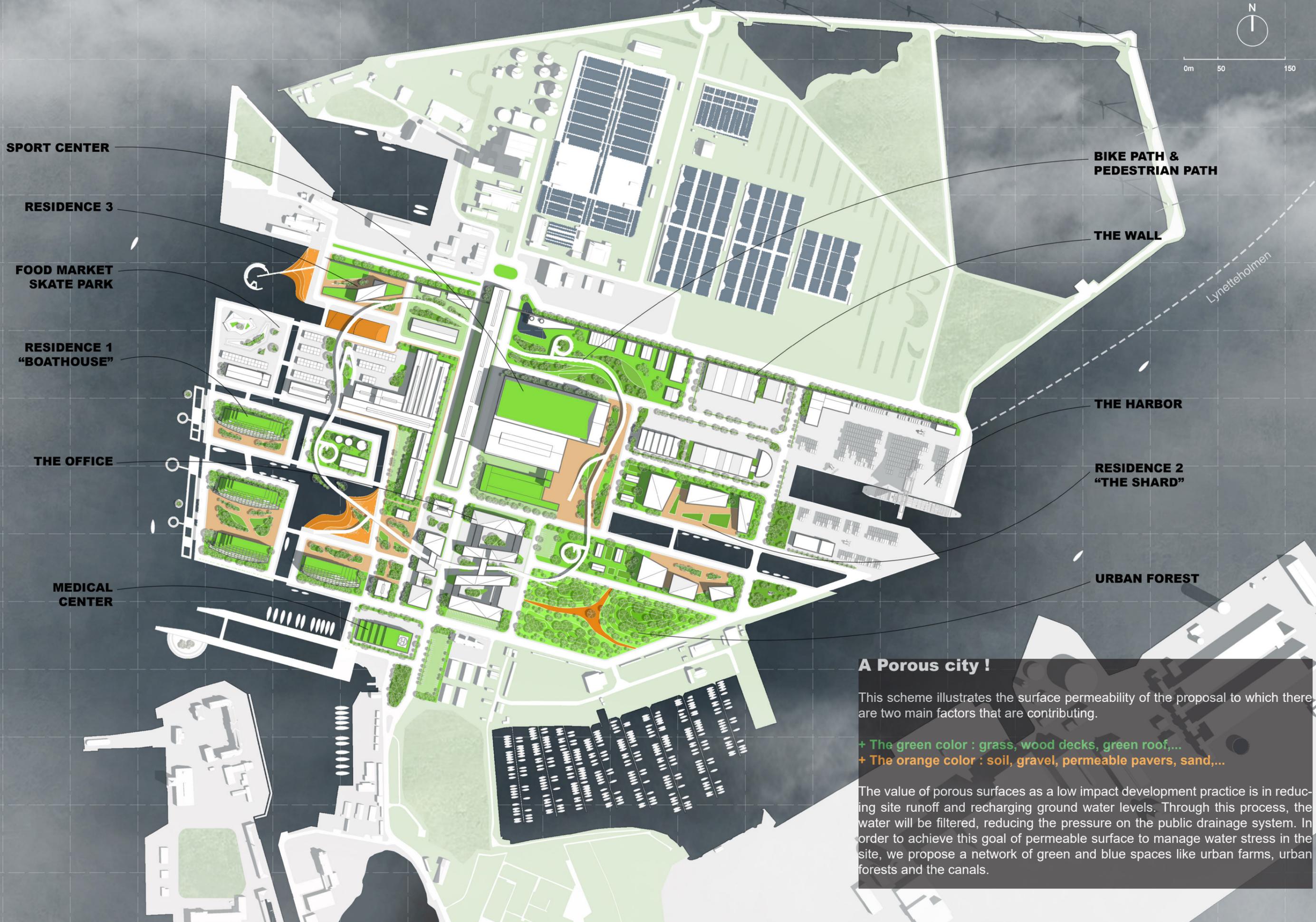
CONNECTION TO  
CITY BICYCLE ROAD  
SYSTEM



Lynetteholmen

## 7.2 Masterplan

## Permeability - Surface



### A Porous city !

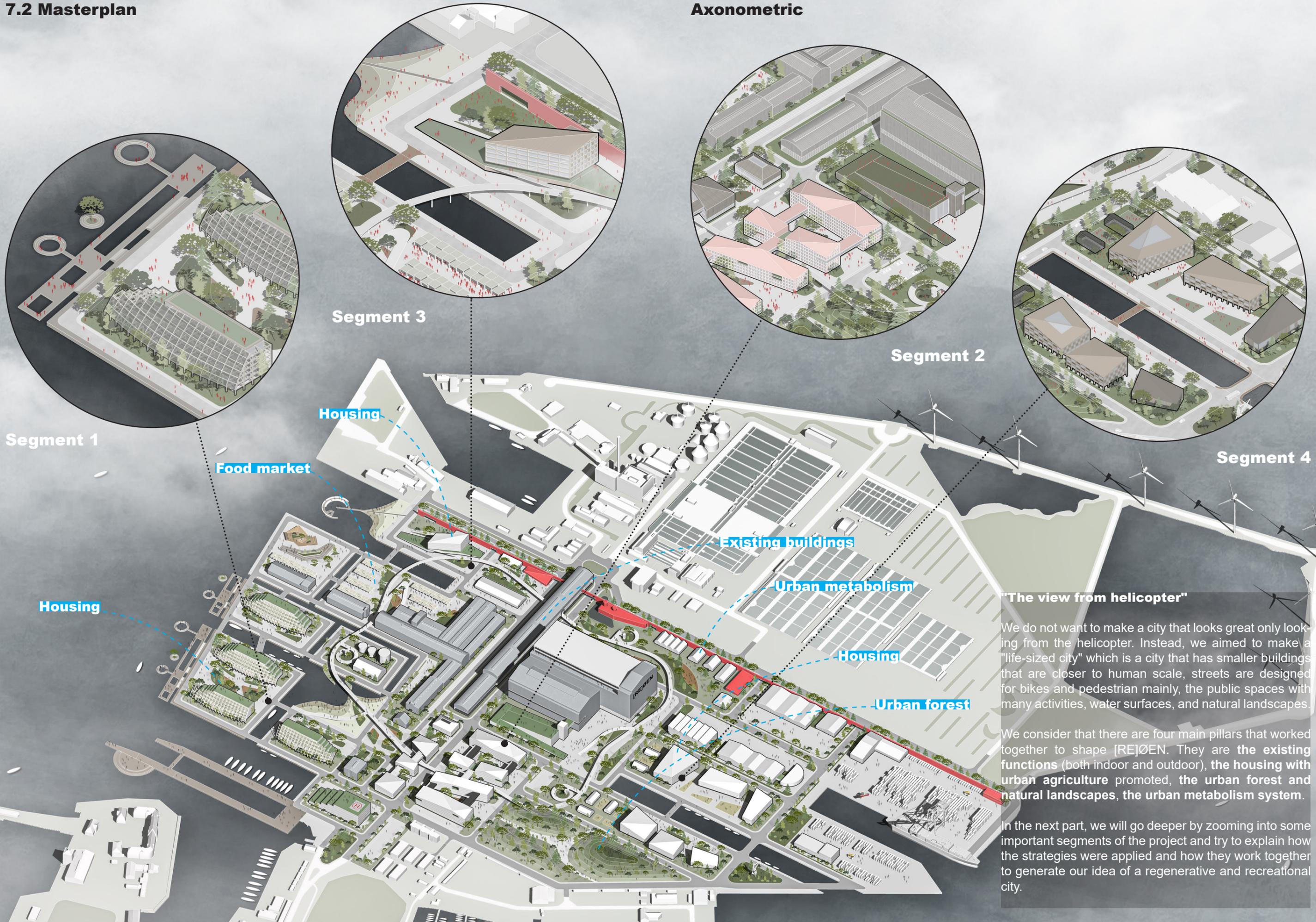
This scheme illustrates the surface permeability of the proposal to which there are two main factors that are contributing.

- + The green color : grass, wood decks, green roof,...
- + The orange color : soil, gravel, permeable pavers, sand,...

The value of porous surfaces as a low impact development practice is in reducing site runoff and recharging ground water levels. Through this process, the water will be filtered, reducing the pressure on the public drainage system. In order to achieve this goal of permeable surface to manage water stress in the site, we propose a network of green and blue spaces like urban farms, urban forests and the canals.

## 7.2 Masterplan

## Axonometric



Segment 1

Segment 3

Segment 2

Segment 4

Housing

Food market

Housing

Existing buildings

Urban metabolism

Housing

Urban forest

### "The view from helicopter"

We do not want to make a city that looks great only looking from the helicopter. Instead, we aimed to make a "life-sized city" which is a city that has smaller buildings that are closer to human scale, streets are designed for bikes and pedestrian mainly, the public spaces with many activities, water surfaces, and natural landscapes.

We consider that there are four main pillars that worked together to shape [RE]ØEN. They are **the existing functions** (both indoor and outdoor), **the housing with urban agriculture** promoted, **the urban forest and natural landscapes**, **the urban metabolism system**.

In the next part, we will go deeper by zooming into some important segments of the project and try to explain how the strategies were applied and how they work together to generate our idea of a regenerative and recreational city.

# 7.3

# Zoom In

## SEGMENT 1

The main part of the segment 1 is the “boathouse residence” which is inspired by the traditional viking’s boathouse, the transparent curved surfaces which are south-faced can help to prevent the harsh-wind but also open the possibility to install the solar films for energy as well as provide a warm atmosphere underneath it for the winter gardens.

## SEGMENT 2

The main part of the segment 2 is “the shard residence” with the farming culture, “the hill” and the harbor area. All of those 3 elements will work together to maintain and promote the recreational, regenerative spirits which its importance is clearly analyzed in the previous part.

## SEGMENT 3

Similar to segment 2, which is aimed to preserve the strong identities of the area, the segment 3 is designed to preserve the food market (the Reffen) which is the most famous food market in Copenhagen at the same time, integrate that culture with the new co-living residence which is spent for youngster or student.

## SEGMENT 4

The existing buildings plays an important role in this segment. In order to continue the interesting diversity of functions in this part, we aim to build several buildings with the mixed-use functions in the southern side.



**[RE]  
ØEN**

# SEGMENT 1

The main part of the segment 1 is the "boathouse residence" which is inspired by the traditional viking's boathouse, the transparent curved surfaces which are south-facing can help to prevent the harsh-wind but also open the possibility to install the solar films for energy as well as provide a warm atmosphere underneath it for the winter gardens.

## Roof garden & solar hot water

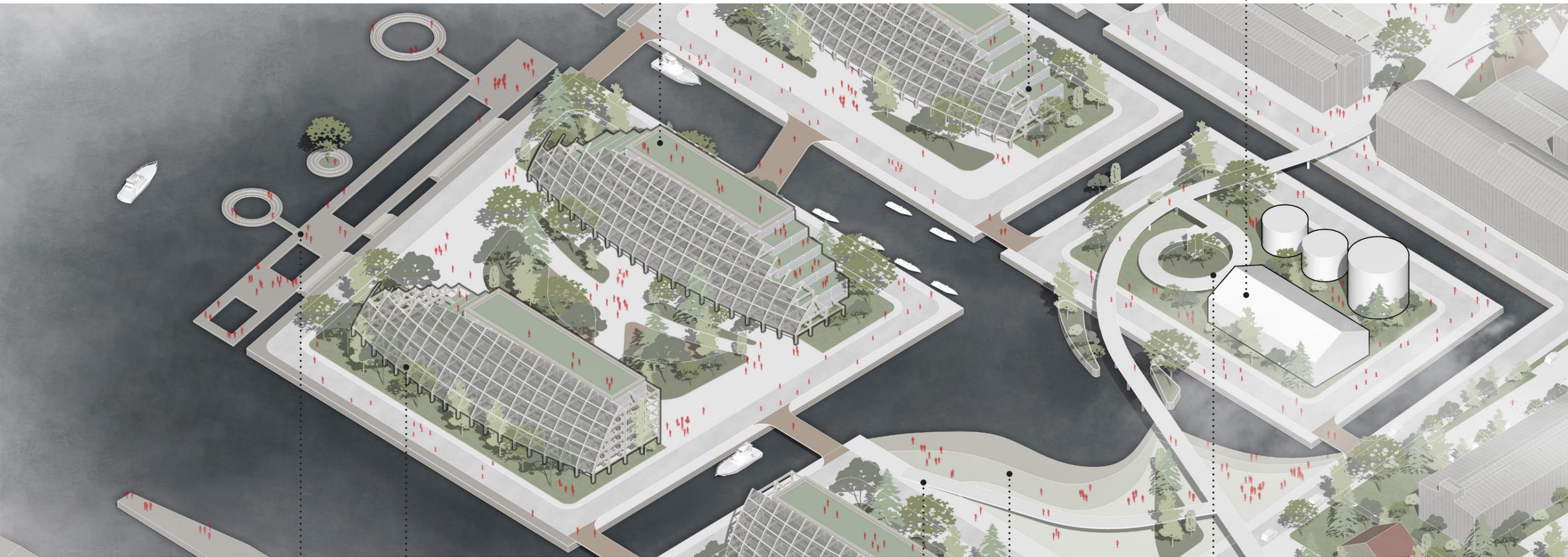
Rooftop vegetation insulates buildings against heat and cold and absorbs storm water. There are tanks arranged on the roof, heated by the sun, provide domestic hot water instead of furnaces.

## Vertical farms

Food grown indoors could reduce fertilizer and freshwater use, shorten transport and recycle gray water otherwise dumped by treatment plants.

## Aquaponic

Clean water from the rain water storage is delivered to aquaponics, which is using high performance technology produces fruits and vegetables.



## Waterpark facilities

Along the west shore of the area, there are some playful facilities installed in order to promote the recreational relationship between the people and the sea as it is a unique culture of Copenhagen

## Solar films

Photovoltaic panels on the south-facing facade of the building generate electricity, while blocking strong winds and creating space for the winter garden below it.

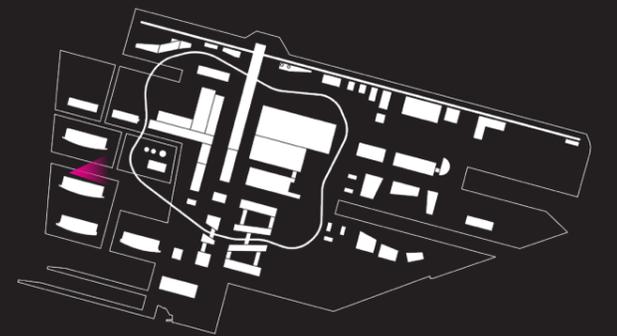
## The beach

## Slope to bicycle path

In order to provide the functional access from the ground level to the high bicycle path, there are several ramps or slopes were created with the maximum slope ratio is 6%.

## Spiral slope & elevator to bicycle path

In some certain areas which are limited in terms of space, the spiral slopes can be used for accessing with the slope ratio is 6% and also, the elevators can be installed near the metabolism facilities for heavy load transportations.



# SEGMENT 2

The main part of the segment 2 is “the shard residence” with the farming culture, “the hill” and the harbor area. All of those 3 elements will work together to maintain and promote the recreational, regenerative spirits which its importance is clearly analyzed in the previous part.

## Outdoor greenhouse

Along with the urban farm, several green house will be arranged for seasonal garden, maximize the possibility of cultivation activities during the year.

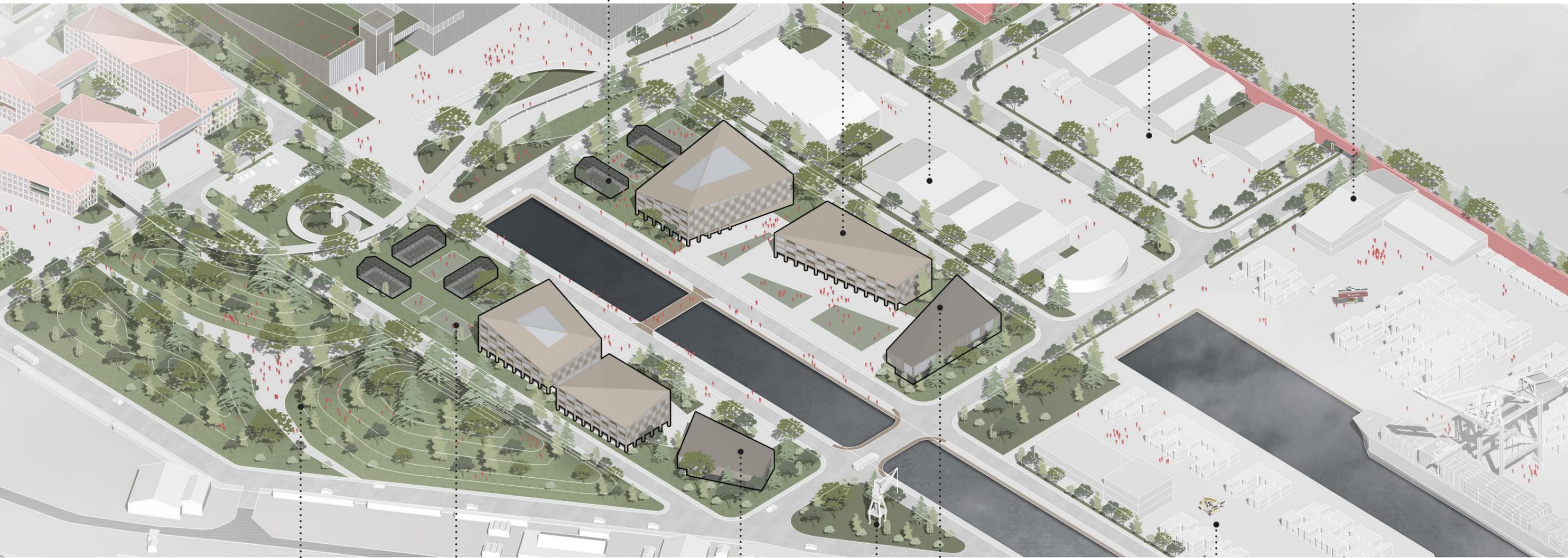
## The house

The apartments are aimed to use the timber structures with a modular plan designed. The south facing windows have bigger capabilities for solar gains in the winter (could be covered partly). The window on the other side will be supported by lamella screens to avoid overheating in the summer. The roofs area designed with different slope angles but mostly are facing the south to maximize the possibility of solar gains for solar panels. In the eastside, the culture centers, sport house will play a role as connecting the people with the industrial identities of the area, maintaining the recreational spirits. Furthermore, those buildings will be a buffer zone between the apartments and the harbor.

## The warehouse

## The warehouse

## The harbor office



## Sport center, culture

## Culture, recreational

## The common green park

The green park will have 3 hills with different heights to distract the cold wind towards the residential areas. Furthermore, it will be the main green space in the whole area with several seasonal fruit trees.

## The farms

The main identity of the segment 2 is about urban agriculture and the green space. With the limitation about the indoor area, we want to propose the urban farm in the outside of the building, close to the high bicycle path and the urban forest.

## The history

The industrial culture is a very strong identity of the area. With the intention to preserve that heritage, we want to keep some of the harbor features as the landmark as well as connecting the old values and the new habitat.

## The harbor

The harbor in the east side of the area is created based on the growing needs of the city with the possibility to extent toward the north-east side, along with the development of the Lynetteholm in the future.



# SEGMENT 3

Similar to segment 2, which is aimed to preserve the strong identities of the area, the segment 3 is designed to preserve the food market (the Reffen) which is the most famous food market in Copenhagen at the same time, integrate that culture with the new co-living residence which is spent for youngster or student.

## The beach

With the same purpose as other waterpark facilities, the beach and its playful facilities will strengthen the relationship between people and the water.

## The co-living house

With the aim of providing different lifestyles, co-living quarters are created for students, commuters or temporary guests. The ground floor of the building will be a sloping roof for easier penetration from the outside and under the sloping roof there will be smart cells to store energy from solar panels.



## The restaurant

### The skate park

As today, the skate park and food market and many other entertainment activities are the places that attract the most visitors. Maintaining these activities will be key to avoiding cultural loss.

## The market, shops and services

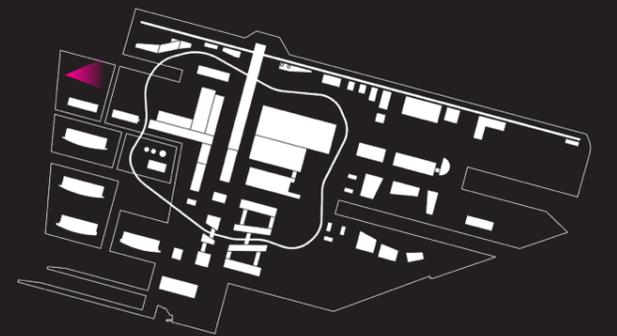
### The food market

Reffen was formerly located near Nyhavn harbour, now located in Refshaleoen. This old value together with the enthusiasm of the new people will help strengthen the food culture of the area as well as secure the market for the urban farm products and promote the idea of "farm to table".

## The seasonal gardens, metabolism facilities

### "The wall"

In order to prevent the negative impact from the technical facilities in the northside, we believe that the wall is not only about the technical purposes (connecting the technical buildings in the area and prevent the noise,..etc..) but also it can give a value for the space and the landscape (strongly inspired by "kilometro ross" by Jean Nouvel)



# SEGMENT 4

The existing buildings plays an important role in this segment. In order to continue the interesting diversity of functions in this part, we aim to build several buildings with the mixed-use functions in the southern side.

## The existing buildings

The existing buildings in the central part of the area are the soul of Refshaløen. There is a lot of business and activity going on there today. The main strategy is to open up the ground floor with more public access and activities, give more possibility for the people to access to those buildings from any direction. The mixed-use functions will be kept and integrated with several other uses such as education, office, services, etc...

## The new attachments

As it is mentioned in previous part, the old B&W boat factory will be the key landmark, our intention is to create a recreational space as well as a view point on very top of it, giving the possibility to have a high view point which is a thing that can not be seen everywhere in Denmark, a very flat country.

## The live stock

The livestock and other sort of technical facilities for urban metabolism will be put in the northern part of the site which is the end side of the dominant wind to mitigate the smells.

## The seasonal garden, Storage

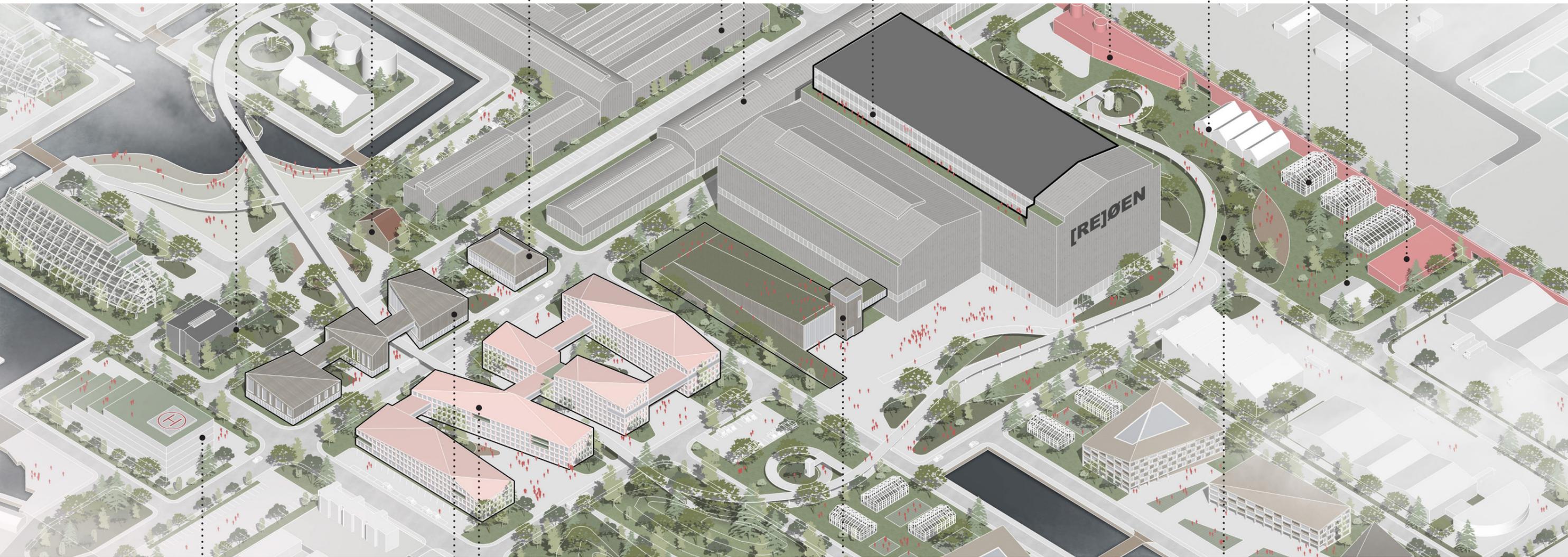
## The solar cells

## The water storage & treatment

## The metro station

## Culture center

## The metro station



## The medical center

With the post pandemic situation and the need to cope with the future amount of population, we identify the need of a healthcare facility is necessary.

## The business

A low rise complex buildings with maximum of 4 floors are created for mixed use functions. This will be the main structure for shops, supermarket, restaurant or coffee shops or events, culture activities.

## The office

The main strategies for the office complex is to create several long building blocks as one of the strategy comes from climatic analysis. Furthermore, we want to create the high bridge connections, giving the possibility to connect the buildings and the chance to enjoy the landscape for the people working on higher floors.

## The auditorium

The biggest attachment to the existing building complex is the auditorium or the sport center. In normal daily use, it can be used for indoor sport activities but in the certain occasion, it can be used as an auditorium for performing or events. The shape of the building is like a hill with the access from the ground to the higher view point toward the canal but also there is a connection to the existing buildings.

## The park

Another green park will be blended with the urban metabolism facilities. We consider this is a way to integrate the recreational activities with the cultivation culture, raising the awareness of the people about one of the most important identity of the site.



## 7.4 Conclusion

### Summary

In the contrary with the expectations of many people, there are still **several disadvantaged areas** in Copenhagen are currently subject to more thorough physical transformations and refurbishments. As it is mentioned in very first part of this thesis, the purpose of this thesis is to **integrate the development of Refshaleøen with the growing of the city of Copenhagen.**

As the title of this thesis, we want to investigate the possibility to apply several urban planning tools into the case study of one of the famous area in Copenhagen, Refshaleøen. In order to better explore the complex interrelation between social and spatial dynamics, the thermal comfort of the urban environment or the sustainable habitat generally, the methodological approach of the thesis was multidisciplinary, involving competencies from urban planning, environmental technology and architecture. The basic concept of the methodology is to adapt a set of strategies obtained from many researches regarding bioclimatic design approach, urban metabolism model and the municipality plan to create a masterplan for the area with the possibility to zoom in some areas and illustrate how particular design strategies were applied .

Firstly, with the help from the municipality of Copenhagen, we have the chance to access to the open data of the city in terms of urban planning, statistic and information. The key piece of information during this step is the **“kommune plan 2019”** which is the latest document summarizing all the regulations, directions or visions of not only the municipality but also the citizen and the stakeholders. Along with the interviews with the managers of the area of Refshaleøen, we tried to exploit the resources as much as possible, from which we are able identify the most critical features of Refshaleøen. Furthermore, the commune plan also gives us not only the technical information regarding the urban planning aspect but also many facts and inspirations from the visions and the needs of the authority and citizen, how did they worked together in a very democratic way to discuss about the solution to make their city better. The more developed Copenhagen are becoming, the more drawbacks that we can observe in Refshaleøen despite the fact that this area has been attracting a lot of people coming from not only Denmark but also the foreigners. For that reason, we created several maps from the city scale to the local area scale to explain how the area is disconnected from the public transportation system for example or how many different functions are being operated every day to create an unique culture characteristic for Refshaleøen. By doing that, we believe that we can have a better understanding about the social aspect of the area and propose the suitable strategies based on that concrete foundation.

Next, with the helpful hands from many source of data, climate tools, we tried to identify the climate type and the geographical parametric of the city and the area. One of the important analysis that we did in this phase is about the **psychrometric chart** which provides a highly detailed information about the comfort hours of the area and how the different strategies can be applied to improve the thermal comfort of the investigated site. Thank to Meteororm tool, we can do a more holistic and comprehensive analysis not only for the present condition but also the future in both near and long term scenarios ( the years of 2030 and 2100). Since the scope of this thesis does not include the detail building design process, such the analysis for example: the impact of the envelope typologies or materials was not carried out but with the suggestion from Climate consultant (ASHRAE Standard 55), we are still able to investigate how particular design strategies may avoid discomfort and try to build a set of possible strategies as a source of references for deeper design implementation. The second and the most important work in this step is to create **the microclimatic matrix** which is a simplified analysis tool in which both the sun shading and wind shading are considered. The scale of the site made the time that I have to spend for the simulation becomes longer than I estimated but the results are greatly practical and useful, which play a crucial role in the decision making process of design the masterplan in the following phases.

The final pillar of the thesis is about the idea of **“Regenerative city”** which is implemented by building up the model of urban metabolism. The important of this idea was clearly illustrated in the previous part but we want to emphasize again that it comes as a results from the analysis about the identities of Copenhagen and the current situation of the area where the such idea of “farm to table”, “urban agriculture” are already existed and still operating effectively. The things that we want to implement is only about proposing the suitable planning for those activities as well as the appropriate infrastructures to exploit its productivity. The system is not a separated element which is going to be attached into the habitat but it is really a part of it and it must be built by the people who are coming to live or work there. “A regen city” is not a bunch of condominiums putting together and filled by the occupation to maximize the profit, it is where the citizen have a chance to contribute, build together and speak for themselves.

**The masterplan** was designed as the conclusion of all those three above tools. The very first decision was made is related to which of existing buildings will be kept based on the industrial heritages map from the commune plan. It is very obvious that we could not

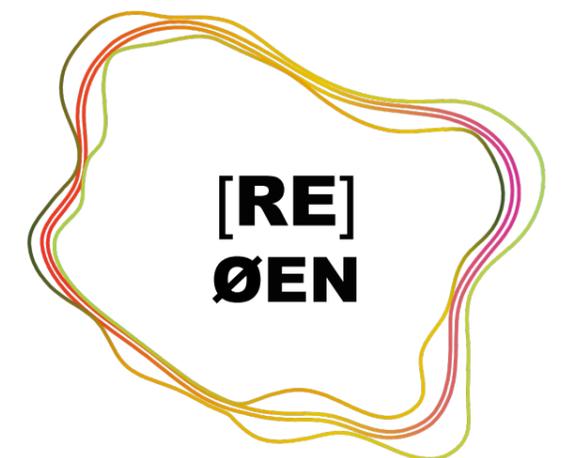
keep all of them but at the same time, destroying all of them to build a total new city is such a cruel way to deny the history of the area. In stead, the old B&W building will still be the landmark of the area as it is today with some slight modifications and attachments, the Reffen food market will still be crowded and will be more lively with new waterpark facilities and new co-living apartment. The other new functions were added based on mostly the requirements from the commune plan and also from the analysis and investigation from our point of view. The urban metabolism with the supportation from the high bicycle path is the **key identity of our proposal** among the other many strategies were applied. All of them were explained in more detail in the zoom in part with several illustrations. The fact that we did not include the detail building design step makes all the building’s facade geometries are for illustration and explanation purposes only, in stead, we want to emphasize about the spaces between the buildings and visualize our visions or imagination about **[Re]øen**.

### The hope

At the end of the thesis, we realized that there are still many aspects of Refshaleøen that we could not reach to due to the scale of this thesis such as the northern technical parts of the area or the southern neighborhood and landscape. Also, going to the detail level of one segment could be an wonderful idea to examine the effectiveness of our proposal and propose more building-related strategies. Despite all that facts, our very initial and basic intention is to research how different urban planning tool, environmental technology knowledges can work together in the design process and from that illustrate a possible future for Refshaleøen and how the area could be if it is sustainably developed.

One of the potential further studies that can be carried out is to experiment back and forth with different scenarios of masterplan to see how the different building shape, height or distribution can have an impact on the matrix results and the thermal comfort performance of the area. The other thing related to the environmental technology is about the trees, all the calculations were made without the consideration of vegetation since the size of the area are immense and we wanted to simplify as much as possible so with a bigger scale study with more man power, this could be a good point to experiment.

At the end, we hope that our work can be an inspiration or a reference for those who are sharing the same concern about the related topic of urban planning as well as who are in love with the area of Refshaleøen.



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European Commission  
2050 Long-term strategy  
[https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2050-long-term-strategy\\_en](https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2050-long-term-strategy_en)

Refshaleøen:  
<https://refshaleoen.dk/>

Statistics Denmark:  
<https://www.dst.dk/>

The Danish National Archives:  
<https://www.sa.dk/>

White Architects  
Research & Development section:  
<https://whitearkitekter.com/research-and-development/>

## 8.2.1 Annexes 1 - Interviews

**Mr. Claus Hovmøller Jensen – Director of urban planning and development of Refshaleøen.**

### 1. What is your vision or expectation for Refshaleøen in the future?

First and the most important is political decision. We will have to have discussions with both politicians and Copenhagen citizen about how to do this, but our own expectation is that the area will be developed into a new city district in Copenhagen with mixed housing and businesses. We also expect that the area can be succeeded to transform from temporary to permanent development, that as I see is one of the keys to secure the right development of Refshaleøen.

### 2. In your opinion, what are the advantages of the area according to Commune Plan 2019?

I think one of the things that is special about Refshaleøen is that we have passed many years of waiting time. We have had ambitions to develop Refshaleøen since 1996, after the closing of the old shipyard. So many years have passed, and a lot of activities have been rolled up from a very grass root level to more organized level today. It means that the identity of the area today is based on 25 years of development. There are some people who have the business from 1996 so the depth of the activities and the creative environment here is huge because it has been built up for many years. When you go to the Refshaleøen you will experience it like a kind of community in which everyone knows each other, and this is a very clear and distinct identity of the place today. That is really something unique in Copenhagen and could be a point of departure for development. It is also the advantage but also a challenge because things will change a lot when a lot of new building will come, some of existing buildings will be expanded or disappeared. So how can you reach that transformation in a way that you can bring forward the existing qualities and help them fitting into a new frame is a challenge and the thing that we are aware of. It is one of the largest challenges but also the advantage I could say because you are not going to build this from nothing, in fact, you have a solid ground to build from.

Another advantage is our physical location, we are the part of Copenhagen harbor. So, we have a lot of space in front of us that can secure the feeling of being on an island. Surrounding Refshaleøen are mostly historical buildings, and you have a lot of space because we are part of the harbor in the western and eastern side. The direction of the Refshaleøen is very attractive, we have a large harbor runs on the western side where you have the sunset, and it is a potential aspect to build a life there. And you are also very close

to city center, it takes only 3 km to go to the center and when the infrastructures are established (metro, buses, trains and bridges for bicycle), the area will be very integrated with the city.

### 3. When I was in the area, I could see that the infrastructures are not so developed and inconvenient, so do you think this is a big challenge and are there any disadvantages that you want to mention?

For me it is yes and no. It could be a disadvantage in term of urban development and something you need to address to fulfil the percent of the area. But for me right now, it is an advantage because if you look also internationally what is the condition needed to build up an area with temporary activities like ours, some few conditions that could be mentioned are close distant to the city center, lower rental level than other parts of the city and the basic and functional infrastructures meaning that it is not only about how to get here but also about the electricity, water and other utilities. Because it is a bit difficult to get here physically so the rent level is a bit lower. So, if it is full of services, infrastructures and utilities, it will not so easy to do what we have been done. I could say we are having a perfect condition but to take the next step, we need to address the issue about how to get here.

One of the largest challenges is that we are surrounded by companies that are making noises and smells. That is makes sense when it was the shipyard but now when we come to city development, those things cost some challenges to overcome somehow.

Also, we are also a part of the front toward the Øresund meaning that the rising sea level also affect us, and it need to be addressed as a challenge.

We are also surrounded by the culture heritages and the technical areas, and its deliveries some challenges to overcome in the future planning process.

### 4. How do you think about Lynettholmen and how can it affect the future of the area?

Lynettholmen project, according to us is not an obstacle or disadvantage, we are sharing the same need in terms of infrastructures. So, the project is something that we are very happy about, it could have very positive effect on our area. The attitude of the citizen about the project is very divided. It will solve different challenges for Copenhagen as I see such as housing for raising population, a solution to secure the city from raising sea level. Furthermore, it also gives the city the opportunity to handle the dirt from building project in the municipal.

## 8.2.1 Annexes 2 - Heating and Cooling degree days

KOBENHAVN		CURRENT			FUTURE (2030)			FUTURE (2100)		
Month	Day	Dry Bulb Temp (degree C)	Heating degree days (HDD)	Cooling degree days (CDD)	Dry Bulb Temp (degree C)	Heating degree days (HDD)	Cooling degree days (CDD)	Dry Bulb Temp (degree C)	Heating degree days (HDD)	Cooling degree days (CDD)
1	1	7	11	0	7	11	0	10	8	0
1	2	5	13	0	6	12	0	9	9	0
1	3	6	12	0	6	12	0	9	9	0
1	4	5	13	0	4	14	0	7	11	0
1	5	3	15	0	3	15	0	6	12	0
1	6	1	17	0	2	16	0	3	15	0
1	7	2	16	0	4	14	0	4	14	0
1	8	0	18	0	1	17	0	3	15	0
1	9	-2	20	0	-1	19	0	1	17	0
1	10	-1	19	0	0	18	0	2	16	0
1	11	0	18	0	1	17	0	3	15	0
1	12	-5	23	0	-5	23	0	-4	22	0
1	13	-4	22	0	-3	21	0	-1	19	0
1	14	-2	20	0	-2	20	0	0	18	0
1	15	-7	25	0	-6	24	0	-2	20	0
1	16	-3	21	0	-2	20	0	0	18	0
1	17	-1	19	0	-1	19	0	2	16	0
1	18	1	17	0	2	16	0	4	14	0
1	19	3	15	0	4	14	0	6	12	0
1	20	2	16	0	3	15	0	5	13	0
1	21	4	14	0	5	13	0	7	11	0
1	22	4	14	0	7	11	0	8	10	0
1	23	1	17	0	2	16	0	5	13	0
1	24	-2	20	0	-3	21	0	1	17	0
1	25	-1	19	0	-1	19	0	2	16	0
1	26	4	14	0	4	14	0	7	11	0
1	27	4	14	0	3	15	0	6	12	0
1	28	1	17	0	0	18	0	4	14	0
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1	30	3	15	0	2	16	0	6	12	0
1	31	6	12	0	5	13	0	8	10	0
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2	2	5	13	0	4	14	0	7	11	0
2	3	1	17	0	2	16	0	4	14	0
2	4	-2	20	0	-2	20	0	1	17	0
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2	6	0	18	0	0	18	0	3	15	0
2	7	1	17	0	1	17	0	3	15	0
2	8	-1	19	0	-1	19	0	1	17	0
2	9	-3	21	0	-2	20	0	0	18	0
2	10	-2	20	0	0	18	0	2	16	0
2	11	-1	19	0	-1	19	0	2	16	0
2	12	-2	20	0	-1	19	0	2	16	0
2	13	1	17	0	2	16	0	5	13	0
2	14	-5	23	0	-4	22	0	-1	19	0
2	15	-4	22	0	-3	21	0	-1	19	0
2	16	-1	19	0	0	18	0	3	15	0
2	17	2	16	0	2	16	0	5	13	0
2	18	-1	19	0	-1	19	0	2	16	0
2	19	1	17	0	1	17	0	4	14	0
2	20	3	15	0	3	15	0	6	12	0
2	21	7	11	0	6	12	0	9	9	0
2	22	6	12	0	7	11	0	10	8	0
2	23	2	16	0	3	15	0	6	12	0
2	24	3	15	0	4	14	0	6	12	0
2	25	2	16	0	3	15	0	5	13	0
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3	2	2	16	0	3	15	0	6	12	0
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3	8	-3	21	0	-3	21	0	0	18	0
3	9	-2	20	0	-2	20	0	1	17	0
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3	16	4	14	0	5	13	0	7	11	0
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3	19	5	13	0	6	12	0	8	10	0
3	20	4	14	0	4	14	0	5	13	0
3	21	4	14	0	4	14	0	6	12	0
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3	25	5	13	0	5	13	0	8	10	0
3	26	4	14	0	5	13	0	7	11	0
3	27	7	11	0	8	10	0	10	8	0
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3	29	6	12	0	6	12	0	9	9	0
3	30	6	12	0	6	12	0	9	9	0
3	31	8	10	0	8	10	0	11	7	0
4	1	6	12	0	5	13	0	8	10	0

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4	4	7	11	0	6	12	0	9	9	0
4	5	10	8	0	10	8	0	12	6	0
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7	4	16	0	0	15	3	0	17	0	0
7	5	16	0	0	15	3	0	17	0	0
7	6	15	3	0	14	4	0	16	0	0

## Heating and Cooling degree days

7	7	17	0	0	16	0	0	18	0	0	
7	8	18	0	0	18	0	0	20	0	0	
7	9	22	0	0	21	0	0	23	0	0	
7	10	20	0	0	19	0	0	21	0	0	
7	11	18	0	0	17	0	0	19	0	0	
7	12	17	0	0	17	0	0	19	0	0	
7	13	18	0	0	17	0	0	20	0	0	
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9	12	11	7	0	12	6	0	14			

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10	11	14	4	0	15	3	0	18	0	0
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11	12	8	10	0	9	9	0	11	7	0
11	13	6	12	0	7	11	0	9	9	0
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11	17	7	11	0	7	11	0	8	10	0
11	18	6	12	0	6	12	0	8	10	0
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11	21	7	11	0	8	10	0	9	9	0
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11	25	6	12	0	6	12	0	10	8	0
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12	27	-2	20	0	0	18	0	2	16	0
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